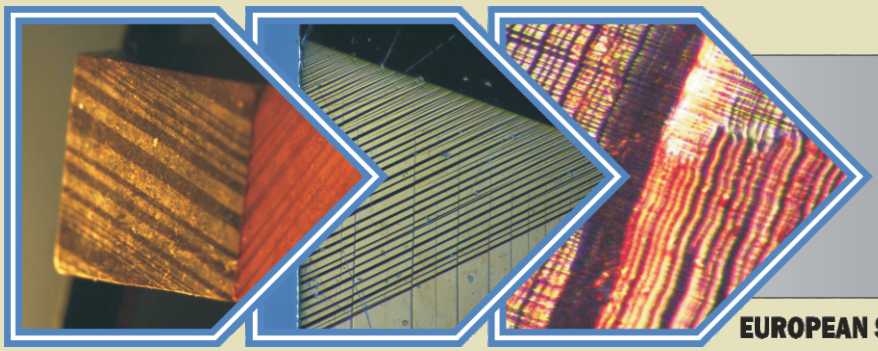


ESOMAT

EUROPEAN SYMPOSIA ON MARTENSITIC TRANSFORMATION

The 8th European Symposium on Martensitic Transformations

Program and Abstract Book

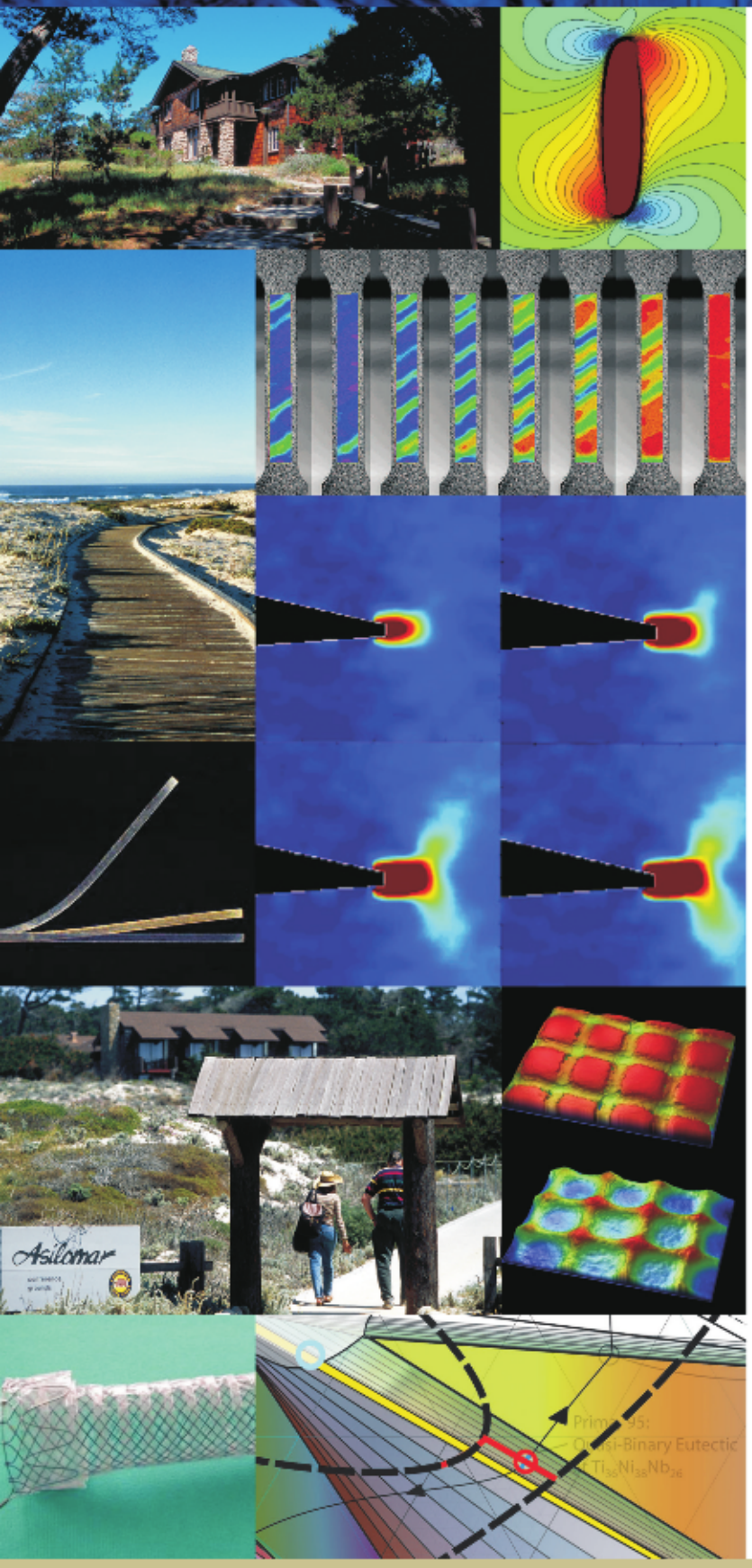
SEPTEMBER 7-11, 2009

MALOSTRANSKY PALACE
PRAGUE, CZECH REPUBLIC

SMST 2010

The International Conference on Shape Memory and Superelastic Technologies

PLAN TODAY.
Register for SMST 2010.



The International Conference on Shape Memory and Superelastic Technologies

May 16-20, 2010
Asilomar Conference Center
Pacific Grove, California USA

This year's focus is on new applications and practical engineering aspects of shape memory and superelastic materials. The conference attracts a diverse group of SMA researchers and practitioners from the engineered-materials community encompassing industry, government and academia.

Features include:

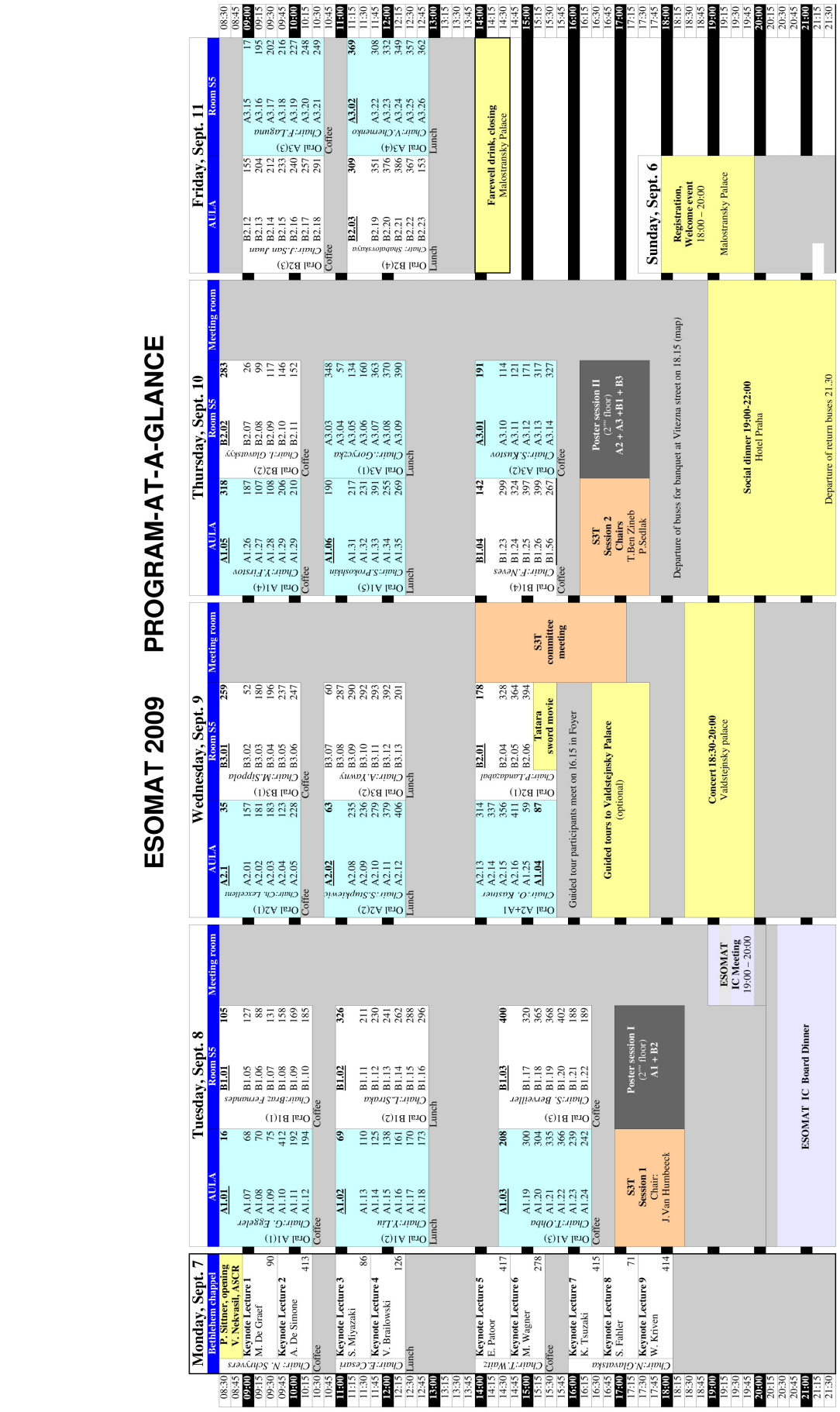
- Oral and Poster Sessions
- Product and Process Exhibition
- Education Short Courses
- Networking Opportunities
- Dynamic Exhibition
- Great location...back in Pacific Grove, California

In addition to the in-depth technical sessions, an educational workshop entitled *Nitinol — Beyond the Fundamentals* will be held on Sunday, May 16th. This workshop serves as an excellent precursor to the conference, particularly for individuals seeking to gain an advanced understanding of this specialty alloy.

If you are involved in the SMA R&D or related industry, don't miss this conference and exposition — the networking opportunities are invaluable. Plan now for SMST 2010. See you at Asilomar!

For more information, visit www.asminternational.org/smst

ESOMAT 2009 Program At A Glance



A.Martensitic and related transformations – principles, simulations, materials

A.1 Background
A.2 Mathematical modelling
A.3 Advanced materials

B.Martensitic and related transformations - applied research and applications

B.1 Engineering materials with MT
B.2 Testing and modelling
B.3 Applications

General conference information

Conference fee – what is included

Keynote lectures and technical meetings
Poster session and S3T session
Esomat community website with proceedings of all Esomat conferences
Proceedings of Esomat 2009
Lunches and coffee breaks
Conference materials
Guided tour of the house of the Senate of the Parliament of the Czech Republic and concert in Wallenstein Garden on Wednesday, September 9
Conference banquet on Thursday, September 10
Welcome event on Sunday, September 6
Farewell drink on Friday, September 11
5 days local transport ticket

Esomat 2009 website

http://esomat.fzu.cz/esomat2009/index.php/esomat/esomat2009

Esomat community website with Esomat proceedings

http://www.esomat.org/

On-site registration

Registration office – room S11 in Malostransky Palace
Sunday, September 6 in Malostransky Palace 18.00 – 20.00
Monday, September 7 in Bethlehem Chapel 8.00 –18.00
Tuesday – Thursday, September 8.00 – 10.00 in registration office

Lunches

Lunches will be served on Monday in Bethlehem Chapel, on Tuesday 13.00 – 14.00 and Wednesday – Friday 12.30 – 13.30 on the 1st floor of the venue

WiFi connection in the Malostransky Palace

Free wifi connection is available on the 1st floor in Malostransky Palace

Policy on Audio and Video recordings

Recording of conference talks and posters without permission of conference organizers is strictly prohibited

Session Chair briefing

Will be organized every morning Tuesday – Thursday 8.00 – 8.20, Friday 8.40 – 9.00 in the Meeting room. Authors may meet session chairs here.

Participants and computer rooms

Participants room S9 and computers with Internet connections are available for participant's convenience.

Participants are kindly requested to wear name badges during all conference and social events.

ESOMAT 2009 Organization

It is our great pleasure to welcome all participants of the **8th European Symposium on Martensitic Transformations** in Prague. We thank all presenters, session chairs and local organizers for their efforts in creating the ESOMAT 2009 conference and proceedings.

P. Šittner, M. Landa, A. Dlouhý, J. Pokluda, M. Karlík

On behalf of the ESOMAT International Committee
and ESOMAT 2009 Organizing Committee

Institute of Physics of the ASCR, Prague, Czech Republic
Institute of Thermomechanics of the ASCR, Prague, Czech Republic
Institute of Physics of Materials, Brno, Czech Republic
Brno University of Technology, Brno, Czech Republic
Czech Technical University in Prague, Prague, Czech Republic

and

Senate of the Parliament of the Czech Republic

ESOMAT 2009 Organization Committee

ESOMAT 2009 CHAIRMEN

PETR ŠITTNER (IP ASCR PRAGUE)
ANTONÍN DLOUHÝ (IPM ASCR BRNO)
JAROSLAV POKLUDA (BUT BRNO)

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S. Ignacová, IP ASCR, Prague
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O. Heczko, IP ASCR, Prague
M. Landa, IT ASCR, Prague
P. Sedlák, IT ASCR, Prague
H. Seiner, IT ASCR, Prague
T. Roubíček, Charles University, Prague
M. Karlík, CTU, Prague

Scope & Scientific programme

While maintaining the traditional scientific topics of the ESOMAT series in focus, in particular the theoretical and experimental research of materials with martensitic transformation (MT), the scientific program of the ESOMAT 2009 conference is organized in groups: A (basic research) and B (applied research) as follows:

A. Martensitic and related transformations – principles, simulations, materials

A.1 Background

basic experimental research, physics and thermodynamics of MT, crystallography and structural analysis, structure and chemistry at atomic resolution.

A.2 Mathematical modelling

mathematical theory of martensitic microstructures, discrete and continuous models of MT at the microscale, constitutive models of polycrystals, multiscale modelling.

A.3 Advanced materials

new phase transforming materials, nanostructured steels based on martensite and bainite, magnetic shape memory alloys magnetocaloric materials utilizing MTs, metamaterials with MTs, martensitic-like transformations in non-metallic materials.

B. Martensitic and related transformations – applied research and applications

B.1 Engineering materials with MT

shape memory alloys, conventional and nonconventional production technologies for SMAs, phase transforming TRIP and TRIP-assisted steels for industrial applications, creep-resistant martensitic steels, SMA composites.

B.2 Testing and modelling

mechanical properties, fracture and fatigue, characterisation of functional properties, modelling and control algorithms, industrial design procedures

B.3 Applications

conventional applications, smart structures and composites, low dimensional structures, microsystems, magnetic shape memory alloys applications, medical device applications, new concepts with traditional materials, concepts for mass production of martensitic and bainitic steels, bio-applications

Social Events

Sunday, September 6
18.00 – 20.00 ..... Welcome event with registration in Malostransky Palace

Monday, September 7
8.30 – 9.00 ..... Conference opening in Bethlehem Chapel

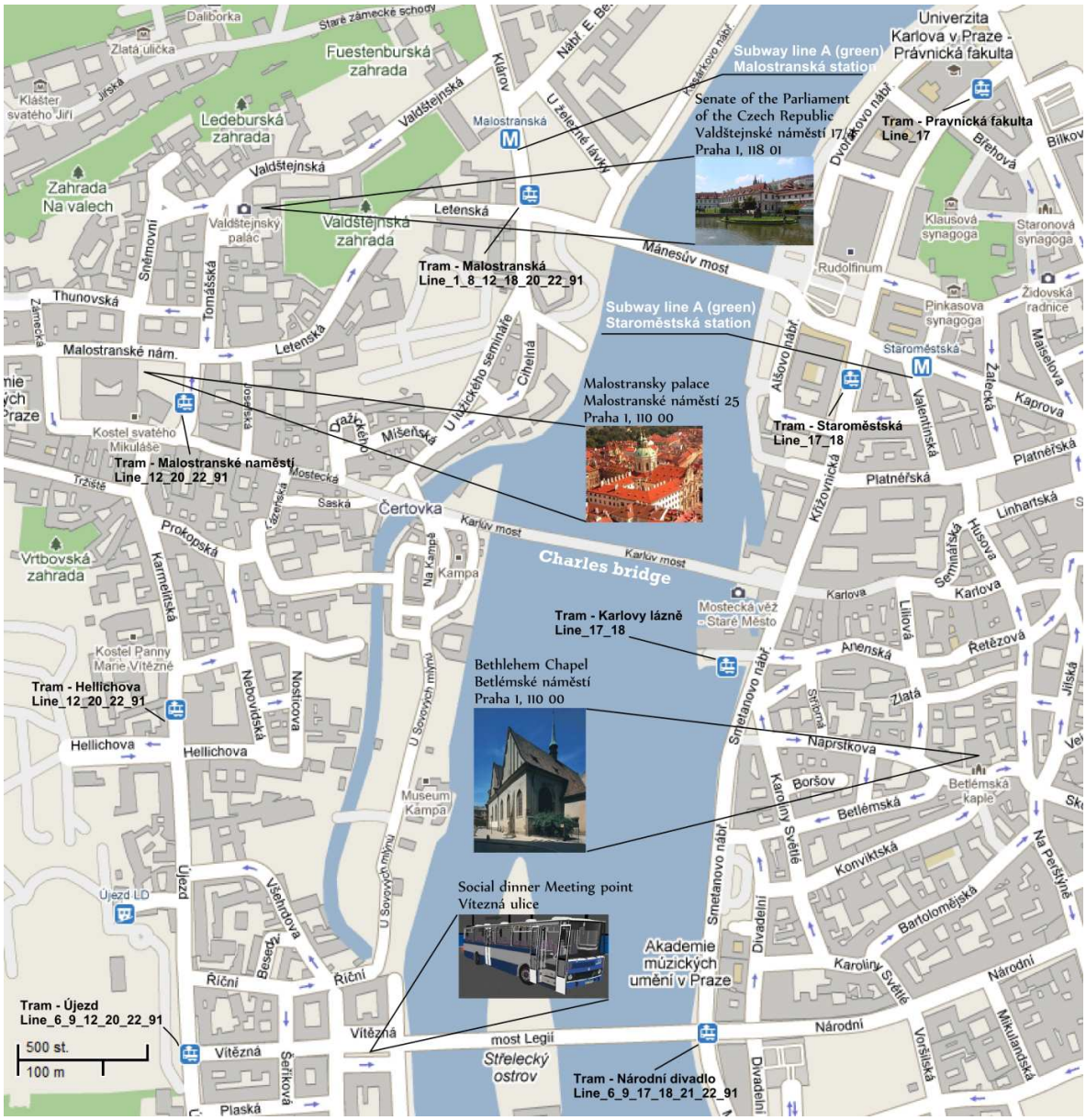
Wednesday, September 9
16.30 – 18.00 ..... Guided tours of the house of the Senate of the Parliament of the Czech Republic in Wallenstein Palace

18.30 – 20.00 ..... Concert in Wallenstein Garden performed by Wihan Quartet

Thursday, September 10
19.00 – 21.30 ..... Conference banquet in hotel Praha

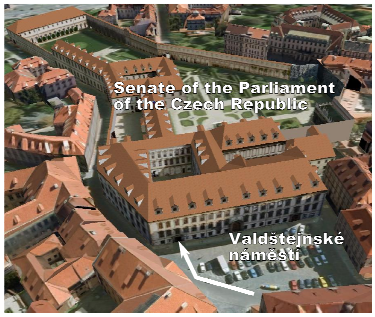
Friday, September 11
14.00 – ..... Farewell drink and conference closing in Malostransky Palace

Map of Prague



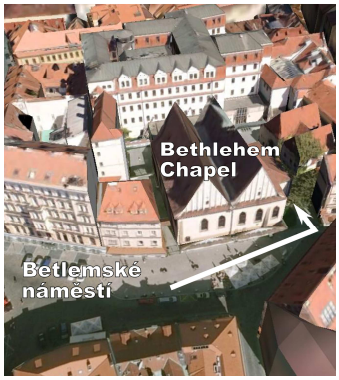
Malostransky palace

Malostranské náměstí 25
Praha 1, 110 00
50°05´18.30´´N
14°24´13.30´´E



Senate of the Parliament of the Czech Republic

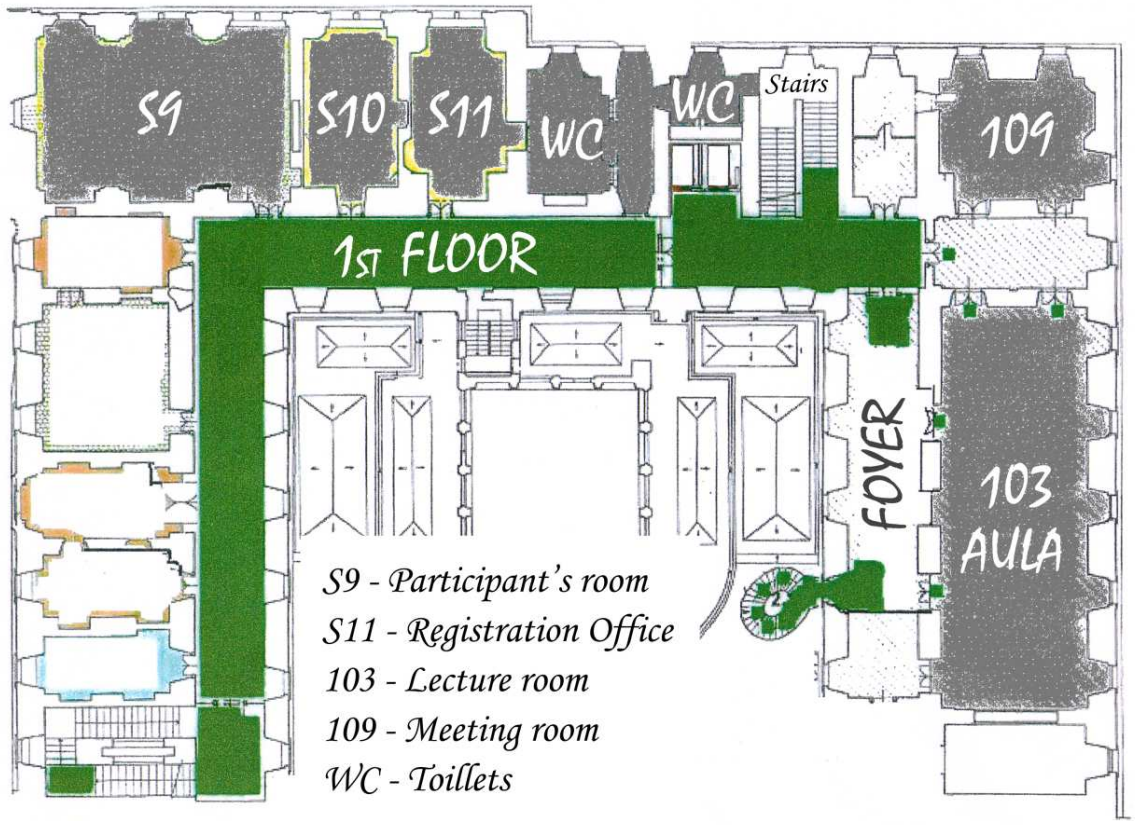
Valdštejnské náměstí 17/4
Praha 1, 118 01
50°05´24.80´´N
14°24´19.33´´E

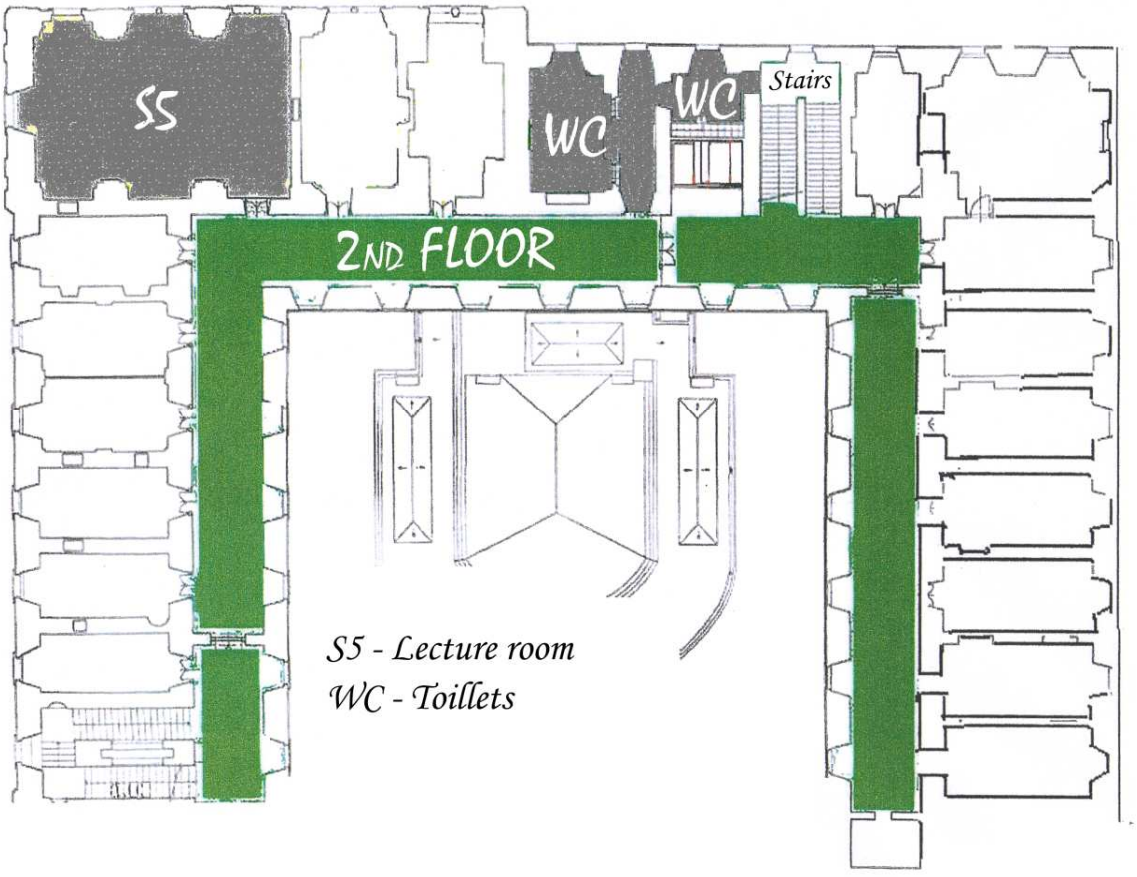


Bethlehem Chapel

Betlémské náměstí
Praha 1, 110 00
50°03´18.90´´N
14°25´03.83´´E

Floor Plan


S9
S10
S11
WC
WC
Stairs
109
1ST FLOOR
FOYER
103
AULA
S9 - Participant's room
S11 - Registration Office
103 - Lecture room
109 - Meeting room
WC - Toillets


S5
WC
WC
Stairs
2ND FLOOR
S5 - Lecture room
WC - Toillets

S3T session

Smart Structural Systems Technologies (S3T) is an ESF EUROCORES programme supporting European research collaboration in the field smart engineering structures

http://www.esf.org/activities/eurocores/programmes/s3t

S3T invited session is a special networking event organized during ESOMAT 2009 with the aim to finally evaluate and conclude a S3T EUROCORES sponsored initiative called ***Roundrobin SMA modeling***. This is a collaboration activity of European research teams working together within the S3T programme. It is aimed at mutual assessment of various models of thermomechanical behaviors of shape memory alloys, particularly to the comparison of their mathematical structure, performance and capability to capture stress-strain-temperature SMA responses. Experimental results measured on thin NiTi wires loaded in tension and combined tension and torsion serve as roundrobin datasets. S3T session is open for Esomat conference participants. Instructions for modelers and experimental datasets are available on the ESOMAT website. Short talks presenting the Roundrobin SMA modeling results will be given by individual modelers during the first session on Tuesday, September 8. Second session on Thursday September 10 will be organized as a roundtable discussion around simulation results/models.

Programme

Tuesday, September 8 Datasets and simulations

Chair: J. Van Humbeeck

17.00	A.Ekers	ESF S3T Eurocores programme remark
17.05	P.Šittner	SMA Roundrobin introduction
17.10	J.Pilch	SMA Roundrobin dataset presentation
17.20	Arnaud Duval	Simulation results
17.30	Boris Piotrowski	Simulation results
17.40	Gerard Rio	Simulation results
17.50	Darren Hartl	Simulation results
18.00	Alessandro Reali	Simulation results
18.10	Miroslav Frost	Simulation results
18.20	Yves Chemisky	Simulation results
18.30	Ell Gibeau	Simulation results

Thursday, September 10 Evaluation

Chairs: T. Ben Zineb, P. Sedlák

16.15 – 17.15	Roundtable evaluation of simulation results


ICOMAT '11
International Conference
on Martensitic Transformations
September 4-9, 2011
Osaka Japan
Chair: Tomoyuki Kakeshita (Organizing Chair)
Minoru Nishida (Executive Chair)
Syuichi Miyazaki (Program Chair)
Contact: icomat@mat.eng.osaka-u.ac.jp

Technical Program

Monday, September 7

Keynote Lectures I	**Bethlehem Chappel**
Session chair **N. Schryvers**	**9.00 – 10.30**

Keynote Lecture 1/p.29 9.00 – 9.45

Recent progress in Lorentz transmission electron microscopy

M. De Graef

Keynote Lecture 2/p.29 9.45 – 10.30

Martensitic-like microstructures in nematic polymers: modeling, analysis, and numerical simulation

A. De Simone

Keynote Lectures II	**Bethlehem Chappel**
Session chair **E. Cesari**	**11.00 – 12.30**

Keynote Lecture 3/p.30 11.00 – 11.45

Development of high temperature Ti-Ta shape memory alloys

S. Miyazaki

Keynote Lecture 4/p.30 11.45 – 12.30

Functional properties of nanocrystalline, submicrocrystalline and polygonized Ti-Ni alloys processed by cold rolling and post-deformation annealing

V. Brailovski

Keynote Lectures III	**Bethlehem Chappel**
Session chair **T. Waitz**	**14.00 – 15.30**

Keynote Lecture 5/p.31 14.00 – 14.45

An overview of different approaches used to model SMAs and SMA structures

E. Patoor

Keynote Lecture 6/p.31 14.45 – 15.30

Elastic anisotropy, micro-/ meso-scale interfaces and macroscopic mechanical properties of NiTi

M. F. Wagner

Keynote Lectures IV	**Bethlehem Chappel**
Session chair **N.Glavatska**	**16.00 – 18.15**

Keynote Lecture 7/p.32 16.00 – 16.45

Tough and smart steels with martensite

K. Tsuzaki

Keynote Lecture 8/p.32 16.45 – 17.30

Epitaxial magnetic shape memory films

S. Fähler

Keynote Lecture 9/p.33 17.30 – 18.15

In situ, high temperature, synchrotron studies of monoclinic to tetragonal phase transformation in HfO2

W. M. Kriven

Tuesday, September 8

Session **A1 - 1** *Room* **Aula**
Session chair **G. Eggeler** **8.30 – 10.30**

A1.01/p.37 Invited Lecture 8.30 – 9.00
The kinetics of austenite to martensite phase transformation in shape memory alloys under a rapid heating pulse
D. Shilo, S. Vollach

A1.07/p.40 9.00 – 9.15
Effect of martensitic transformation on eutectic cell count (ECC), dendrite arm spacing (DAS), grain size (GS) and ultimate tensile strength (UTS) of cryogenically solidified hypoeutectic cast iron
J. Hemanth

A1.08/p.40 9.15 – 9.30
Influence of way of B19'-phase formation on B19' - B2 transition temperatures in TiNi shape memory alloy
N. Resnina, S. Belyaev

A1.09/p.41 9.30 – 9.45
Mechanisms of austenite-martensite transition
V. Paidar

A1.10/p.41 9.45 – 10.00
In-situ synchrotron studies of ceramics to 2000°C in air
W. M. Kriven

A1.11/p.42 10.00 – 10.15
Position of diffuse satellites appearing in Ti-44Ni-6Fe shape memory alloy
M. Todai, S. Majima, T. Fukuda, T. Kakeshita

A1.12/p.42 10.15 – 10.30
Preferential selection of variants in ferromagnetic Fe-Pd alloys under magnetic field
S. Farjami, T. Fukuda, T. Kakeshita

Session **B1 - 1** *Room* **Room S5**
Session chair **Braz Fernandes** **8.30 – 10.30**

B1.01/p.115 Invited Lecture 8.30 – 9.00
Microhardness of binary near-equiatomic Ti-Ni alloys after severe cold rolling and post-deformation annealing
K. Inaekyan, V. Brailovski, S. Prokoshkin, A. Korotitskiy, A. Chernavina

B1.05/p.117 9.00 – 9.15
Influence of minor additions of boron and zirconium on shape memory properties and grain refinement of a Cu-Al-Mn shape memory alloy
V. Sampath, U. Mallik

B1.06/p.117 9.15 – 9.30
Effect of martensite structure in graphitization process in hypereutectoid steel
S. Rounaghi, A. Kiani-Rashid, F. Fazeli

B1.07/p.118 9.30 – 9.45
Comparative study of the structures of Fe-Mn-Si-Cr-Ni shape memory alloys obtained by classical and by powder metallurgy, respectively
L. G. Bujoreanu, S. Stanciu, B. Özkal, R. I. Comăneci, M. Meyer

B1.08/p.118 9.45 – 10.00
Shape memory behaviour of nanostructured Ti-Ni alloy
E. P. Ryklina, S. D. Prokoshkin, A. A. Chernavina

B1.09/p.119 10.00 – 10.15
TEM study of the mechanism of Ni ion release from Nitinol wires with original oxides
D. Schryvers, H. Tian, S. Shabalovskaya, J. Van Humbeeck

B1.10/p.119 10.15 – 10.30
Analysis of twin boundary movement under stress in polycrystalline Ni50Mn29Ga21
C. Hürrich, M. Pötschke, S. Roth, B. Rellinghaus, A. Böhm, L. Schultz

Tuesday, September 8

Session **A1 - 2** *Room* **Aula**
Session chair **Y. Liu** **11.00 – 13.00**

A1.02/p.37 Invited Lecture 11.00 – 11.30
Lattice dynamics in the magnetic superelastic Ni-Mn-In alloy
L. Manosa, A. Planes, X. Moya, D. Gonzalez-Alonso, O. Garlea, T. Lograsso, D. Schlagel, J. Zarestky, S. Aksoy, M. Acet

A1.13/p.43 11.30 – 11.45
A comparative study of martensite crystal lattice in nanostructured, quenched and deformed Ti-Ni shape memory alloys
S. Prokoshkin, A. Korotitskiy, V. Brailovski, K. Inaekyan, S. Dubinskiy

A1.14/p.43 11.45 – 12.00
Structural stabilities, elastic constants, generalized stacking fault energetics, and the martensitic transformation mechanisms for the Ni_{50-x}TiPt_{x}(x=0-30) ternary system: ab initio investigation
N. B. Hatcher, O. Y. Kontsevoi, A. J. Freeman

A1.15/p.44 12.00 – 12.15
Thermal stability of the martensite in Ni-Mn-Ga based FSMA
I. Glavatskyy, N. Glavatska, J. Hoffmann, B. Ouladdiaf, J. Rodriguez-Carvajal

A1.16/p.44 12.15 – 12.30
Phase stability during martensitic transformation in ZrCu intermetallics: crystal and electronic structure aspects
G. S. Firstov, A. N. Timoshevskii, Y. N. Koval, S. A. Kalkuta, J. Van Humbeeck

A1.17/p.45 12.30 – 12.45
Dynamic theory of FCC-BCC (BCT) martensitic transformation in iron based alloys
M. Kashchenko, V. Chashchina

A1.18/p.45 12.45 – 13.00
A new diffraction approach to crystal structure determination of nano-twined martensites
L. Olikhovska, A. Ustinov, N. Glavatska, I. Glavatskyy

Session **B1 - 2** *Room* **Room S5**
Session chair **L. Straka** **11.00 – 13.00**

B1.02/p.115 Invited Lecture 11.00 – 11.30
Shape recovery in high temperature shape memory alloys based on the Ru-Nb and Ru-Ta systems
A. Manzoni, A. Denquin, K. Chastaing, P. Vermaut, R. Portier

B1.11/p.120 11.30 – 11.45
Preparation of textured and coarse grained Ni-Mn-Ga to show MFIS
M. Pötschke, U. Gaitzsch, C. Hürrich, S. Roth, R. Chulist, L. Schultz

B1.12/p.120 11.45 – 12.00
Functional properties of spherical segments made of Ti-Ni alloy with shape memory effect
M. A. Khusainov, A. B. Bondarev, V. A. Andreev, O. V. Letenkov

B1.13/p.121 12.00 – 12.15
Properties of textured polycrystalline Ni50Mn29Ga21 after hot extrusion
A. Böhm, T. Junker, S. Roth, C. Hürrich, R. Chulist, W. Skrotzki, W. Drossel, R. Neugebauer

B1.14/p.121 12.15 – 12.30
Probing the martensitic transformation in low-alloyed TRIP steels at the level of individual grains
E. Jimenez-Melero, N. Van Dijk, L. Zhao, J. Sietsma, S. Van Der Zwaag

B1.15/p.122 12.30 – 12.45
Microstructural investigations of laser welded dissimilar Nickel-Titanium-steel joints
H. Gugel, W. Theisen

B1.16/p.122 12.45 – 13.00
Enhancement of superelasticity in Fe-Ni-Co-Al based alloys by texture control
Y. Tanaka, Y. Sutou, T. Omori, R. Kainuma, K. Ishida

Tuesday, September 8

Session **A1 - 3** *Room* **Aula**
Session chair **T. Ohba** **14.30 – 16.30**

A1.03/p.38 Invited Lecture 14.30 – 15.00
In-situ TEM cooling/heating experiments on deformed NiTi shape memory single crystals
T. Simon, A. Kröger, C. Somsen, A. Dlouhy, G. Eggeler

A1.19/p.46 15.00 – 15.15
Strain glass in ferroelastic systems — premartensitic tweed vs. strain glass
X. Ren, Y. Wang, Y. Zhou, Z. Zhang, K. Otsuka, T. Suzuki

A1.20/p.46 15.15 – 15.30
Charactersitic of burst transformations in pseudoelasticity and shape memory effect-A review
K. Harikrishnan, P. S. Misra, K. Chandra, V. S. Agarwala

A1.21/p.47 15.30 – 15.45
Stress-induced martensitic transformation and martensite deformation with controlled stress-strain dependence
A. Roytburd

A1.22/p.47 15.45 – 16.00
In-situ TEM study of stress-induced transformations in CuAlNi
N. Zarubova, J. Gemperlova, A. Gemperle, Z. Dlabacek

A1.23/p.48 16.00 – 16.15
Non-martensitic needle-like structures on Ni-Ti alloys - occurrence and origin
A. Undisz, M. Rettenmayr, M. Wilke, L. Spieß

A1.24/p.48 16.15 – 16.30
Thermodynamic study and modelling of the temperature memory effects in Cu-Al-Ni shape memory alloys.
J. Rodríguez-Aseguinolaza, I. Ruiz-Larrea, M. Nó, A. López-Echarri, J. San Juan

Session **B1 - 3** *Room* **Room S5**
Session chair **S. Berveiller** **14.30 – 16.30**

B1.03/p.116 Invited Lecture 14.30 – 15.00
Collaborative research center TRIP-matrix-composite
H. Biermann, C. Aneziris, M. Kuna

B1.17/p.123 15.00 – 15.15
Effects of severe plastic deformation and quaternary additions on the shape memory response of NiTiPd high-temperature shape memory alloys
K. C. Atli, I. Karaman, R. D. Noebe, G. S. Bigelow

B1.18/p.123 15.15 – 15.30
Final thermomechanical treatment of thin NiTi filaments for textile applications by electric current
J. Pilch, L. Heller, P. Sittner

B1.19/p.124 15.30 – 15.45
Nonconventional production technologies for NiTi shape memory alloys
F. Neves, F. Braz Fernandes, I. Martins, J. Correia, M. Oliveira, E. Gaffet, M. Lattemann, J. Suffner, H. Hahn, T. Wang

B1.20/p.124 15.45 – 16.00
Influence of Mn doping on the martensitic transformations and magnetic properties of Fe-Pd alloys
J. I. Perez-Landazabal, V. Sanchez-Alarcos, V. Recarte, C. Gomez-Polo

B1.21/p.125 16.00 – 16.15
Deformation microstructure of TRIP/TWIP steels at the early deformation stages
X. Zhang, T. Sawaguchi, F. Yin, X. Zhao, K. Ogawa

B1.22/p.125 16.15 – 16.30
Shape memory behaviour of Ni-rich NiTi(Cu,Pd)Hf high temperature shape memory alloys (HTSMAs)
H. E. Karaca, G. Ded, R. Noebe, A. Hatemi, M. Souri, Y. Chumlyakov

Wednesday, September 9

Session **A2 - 1** *Room* **Aula**
Session chair **Ch. Lexcellent** **8.30 – 10.15**

A2.01/p.77 Invited Lecture 8.30 – 9.00
Nucleation and kinetics of phase boundaries in peridynamics
K. Dayal

A2.03/p.78 9.00 – 9.15
Modeling of non-local interactions on a phase transformation interface
I. Dobovšek

A2.04/p.78 9.15 – 9.30
Numerical study of the martensite formation in nanostructured niti shape memory alloys
W. Pranger, T. Antretter, T. Waitz, F. D. Fischer

A2.05/p.79 9.30 – 9.45
MD studies on the effect of the transformation dynamics on martensitic microstructure.
O. Kastner, G. Ackland

A2.06/p.79 9.45 – 10.00
Ab initio search for the NiTi ground state with shape-memory ability
D. Holec, M. Friak, J. Neugebauer

A2.07/p.80 10.00 – 10.15
On dissipation, interfacial energy and size effects in shape memory alloys
S. Stupkiewicz, H. Petryk

Session **B3 - 1** *Room* **Room S5**
Session chair **M. Sippola** **8.30 – 10.15**

B3.01/p.177 Invited Lecture 8.30 – 9.00
Application of nanostructural nickel titanium implants with shape memory effect to modern dental practice
V. S. Afonina, N. I. Borisenko, R. M. Gizatullin, D. V. Gunderov, V. S. Kalashnikov, V. V. Koledov, E. P. Krasnoperov, V. G. Shavrov, V. I. Suslov, N. A. Yusov

B3.02/p.177 9.00 – 9.15
Fastening of shape memory hook arrays
D. Vokoun, D. Majtás, M. Frost, P. Sedlák, P. Sittner

B3.03/p.178 9.15 – 9.30
Magnetic-field-induced reorientation in single crystalline Ni-Mn-Ga foil actuators
F. Khelfaoui, Y. Srinivas Reddy, M. Kohl, A. Mecklenburg, R. Schneider

B3.04/p.178 9.30 – 9.45
Study of microstructures on cross section of JAPANESE SWORD
M. Yaso, T. Takaiwa, Y. Minagi, K. Kubota, S. Morito, T. Ohba, A. Das

B3.05/p.179 9.45 – 10.00
A new control strategy for shape memory alloys actuators
P. Gedouin, C. Join, E. Delaleau, J. Bourgeot, S. Arbab Chirani, S. Calloch

B3.06/p.179 10.00 – 10.15
Analysis of Niobium precipitates effect on the thermo-mechanical behavior of a NiTiNb shape memory alloy and modeling
B. Piotrowski, T. Ben Zineb, E. Patoor, A. Eberhardt

Wednesday, September 9

Session **A2 - 2** *Room* **Aula**
Session chair **S. Stupkiewicz** **10.45 – 12.30**

A2.02/p.77 Invited Lecture 10.45 – 11.15
First principles calculations of energy barriers in martensitic phase transformation of NiTi
H. Sehitoglu

A2.08/p.80 11.15 – 11.30
Martensite microstructure. Formation principles and scaling phenomena
L. Alexander

A2.09/p.81 11.30 – 11.45
Energy bounds for polycrystalline shape-memory alloys
M. Peigney

A2.10/p.81 11.45 – 12.00
First principles investigation of Fe-Pd magnetic shape memory alloys
M. E. Gruner, P. Entel

A2.11/p.82 12.00 – 12.15
FEM modelling of elastically strained interfacial microstructures in Cu-Al-Ni single crystals
O. Glatz, H. Seiner, M. Landa

A2.12/p.82 12.15 – 12.30
On the numerical simulation of material inhomogeneities due to martensitic phase transformations in poly-crystals
P. Junker, K. Hackl

Session **B3 - 2** *Room* **Room S5**
Session chair **A. Yawny** **10.45 – 12.30**

B3.07/p.180 10.45 – 11.00
The SMA properties in civil engineering applications. The SMARTeR project: Use of SMA in damping of stayed cables for bridges
V. Torra, A. Isalgue, G. Carreras, F. Lovey, H. Soul, P. Terriault, B. Zapico

B3.08/p.180 11.00 – 11.15
Martensitic transformation and shape memory effect in NiTiCu alloy on submicron scale
P. Lega, K. Victor, K. Dmitry, S. Vladimir, I. Vladimir, I. Artem, P. Nikita, T. Ilya

B3.09/p.181 11.15 – 11.30
Electrochemical parameters and biocompatibility of bare Nitinol surfaces
S. A. Shabalovskaya, G. Rondelli, M. Rettenmayr

B3.10/p.181 11.30 – 11.45
Development of standardised and integrated shape memory components in “one-module”-design
S. Langbein

B3.11/p.182 11.45 – 12.00
Phase transformations in NiTi endodontic files and fatigue resistance
S. V. Correia, M. T. Nogueira, R. J. Cordeiro Silva, L. Pires Lopes, F. M. Braz Fernandes

B3.12/p.182 12.00 – 12.15
Modelling and testing of a load limiting sandwich structure
M. K. Sippola, T. Lindroos

B3.13/p.183 12.15 – 12.30
Martensitic transformation and its effect on the interfacial debonding in single Ni-Ti fibre/ epoxy composite
Y. Payandeh, F. Meraghni, E. Patoor, A. Eberhardt

Wednesday, September 9

Session **A2 - 3** *Room* **Aula**
Session chair **O. Kastner** **14.00 – 15.30**

A2.13/p.83 14.00 – 14.15
Numerical study of mean-field approach capabilities for shape memory alloys matrix composites description
Y. Chemisky, B. Piotrowski, T. Ben-Zineb, E. Patoor

A2.14/p.83 14.15 – 14.30
Computations of geometrically linear and nonlinear Ginzburg-Landau models for martensitic pattern formation
B. K. Muite, U. Salman

A2.15/p.84 14.30 – 14.45
Enhanced micromechanical modelling of martensitic phase-transitions considering plastic deformations
T. Bartel, A. Menzel, B. Svendsen

A2.16/p.84 14.45 – 15.00
Martensitic transformations with a classical isotropic two body potential: Intrinsic hysteresis and superelasticity
M. F. Laguna, E. A. Jagla

A1.25/p.49 15.00 – 15.15
Transmission electron microscopy study of low-hysteresis shape memory alloys
R. Delville, R. D. James, A. Finel, U. Salman, D. Schryvers

A1.04/p.38 Invited Lecture 15.15 – 15.45
Domain boundary engineering in alloys and oxides
E. K. Salje

Session **B2 - 1** *Room* **Room S5**
Session chair **P. Landazabal** **14.00 – 15.15**

B2.01/p.147 Invited Lecture 14.00 – 14.30
Thermomechanical cyclic behavior modeling of SMA materials and structures
S. Arbab Chirani, L. Saint-Sulpice, S. Calloch

B2.04/p.148 14.30 – 14.45
Structural and textural evolution during cold work in Ti-Rich Ni-Ti shape memory alloy
A. D. Paula, F. M. Braz Fernandes

B2.05/p.149 14.45 – 15.00
Two-way shape memory effect and magnetic field induced strain in Ni-Fe-Ga-Co single crystals
F. Masdeu, J. Pons, E. Cesari, S. Kustov, Y. I. Chumlyakov

B2.06/p.149 15.00 – 15.15
Thermo-mechanical properties of shape memory alloys at nano-scale
J. San Juan, M. No, C. Schuh

Thursday, September 10

Session **A1 - 4** *Room* **Aula**
Session chair **Y. Firstov** **8.30 – 10.15**

A1.05/p.39 Invited Lecture 8.30 – 9.00
Mystery of martensitic crystal structure on the example of Ni-Mn-Ga
N. Glavatska, L. Olikhovska, I. Glavatskyy

A1.26/p.49 9.00 – 9.15
Isotropic phase transformation in anisotropic stainless steel 301LN sheets
A. M. Beese, D. Mohr, P. Santacreu

A1.27/p.50 9.15 – 9.30
Effect of carbon and cold rolling on the latent heat upon $\epsilon \rightarrow \gamma$ transformation in metastable Fe-Mn alloys
M. Murasov, L. Duprez, B. Verlinden, J. Van Humbeeck

A1.28/p.50 9.30 – 9.45
Structural analysis of a new precipitate phase in high-temperature Ni30Pt20Ti50 shape memory alloys
L. Kovarik, F. Yang, A. Garg, R. D. Noebe, D. Diercks, M. J. Kaufman, M. J. Mills

A1.29/p.51 9.45 – 10.00
In-situ TEM straining investigations on stress induced R-phase transformation in Ni48Ti50Fe2 single crystals
C. Somsen, T. Simon, A. Kröger, A. Dlouhy, G. Eggeler

A1.30/p.51 10.00 – 10.15
3D FIB/SEM study of Ni4Ti3 precipitates in Ni-Ti alloys with different thermal-mechanical histories
S. Cao, M. Nishida, C. Somsen, D. Schryvers, G. Eggeler

Session **B2 - 2** *Room* **Room S5**
Session chair **I. Glavatskyy** **8.30 – 10.15**

B2.02/p.147 Invited Lecture 8.30 – 9.00
Numerical simulation of nitinol peripheral stents: from lasercutting to deployment in a patient specific anatomy
M. Conti, F. Auricchio, M. De Beule, B. Verhegghe

B2.07/p.150 9.00 – 9.15
NiTi thermal sprayed coatings characterization
N. Cinca, A. Isalgue, J. Fernandez, J. Guilemany

B2.08/p.150 9.15 – 9.30
Combinatorial development of quaternary Ti-Ni-Cu-Pd shape memory alloys
R. Zarnetta, S. Thienhaus, A. Savan, M. L. Young, R. Takahashi, I. Takeuchi, A. Ludwig

B2.09/p.151 9.30 – 9.45
Influence of pre-strain and carbon content on delayed cracking phenomenon in unstable austenitic steels
S. Berveiller, M. Kemdehoundja, E. Patoor, D. Bouscaud, M. R. Berrahmoune

B2.10/p.151 9.45 – 10.00
Deformation behavior at rolling and tension under current in TiNi alloy
V. Stolyarov

B2.11/p.152 10.00 – 10.15
Nonlocal modelling of superelastic behavior of shape memory alloys
A. Duval, M. Haboussi, T. B. Zineb

Thursday, September 10

Session **A1 - 5** *Room* **Aula**
Session chair **S. Prokoshkin** **10.45 – 12.30**

A1.06/p.39 Invited Lecture 10.45 – 11.15
Observations of decomposition of martensite during heat treatment of steels using atom probe tomography
E. Pereloma, S. P. Ringer, I. B. Timokhina, P. D. Hodgson

A1.31/p.52 11.15 – 11.30
Aging effect on martensitic transformation at cryogenic temperatures in Cu-Al-Mn alloy
S. Ii, K. Tsuchiya, T. Koyano

A1.32/p.52 11.30 – 11.45
Role of Si on the shape memory property of Fe-Mn-Si-C based alloys
M. Koyama, T. Sawaguchi, M. Murakami, K. Tsuzaki

A1.33/p.53 11.45 – 12.00
R-phase stabilization in ultra-fine grain NiTi wires after mechanical cycling
A. Condó, J. Olbricht, C. Somsen, G. Eggeler, A. Dlouhý

A1.34/p.53 12.00 – 12.15
High field magnetisation study of the isothermal martensitic transformation kinetics in maraging steel
N. Van Dijk, D. San Martin, E. Jiménez-Melero, E. Kampert, U. Zeitler, S. Van Der Zwaag

A1.35/p.54 12.15 – 12.30
Characteristic Feature Found in Typical TATARA Product, Japanese Sword
A. K. Das, T. Ohba, S. Morito, G. Takami, T. Fujikawa, M. Yaso

Session **A3 - 1** *Room* **Room S5**
Session chair **T. Goryczka** **10.45 – 12.30**

A3.03/p.92 10.45 – 11.00
Experimental evaluation of the rheological properties of veriflex® shape memory polymer
J. Klesa, V. Placet, E. Foltete, M. Collet

A3.04/p.92 11.00 – 11.15
Characteristics of superelasticity in ferromagnetic <001>-single crystals of a CoNiGa alloy during compressive deformation
I. V. Kireeva, Z. V. Pobedennaya, Y. I. Chumlyakov, I. V. Kretinina, E. Cesari, J. Pons, I. Karaman

A3.05/p.93 11.15 – 11.30
Structural, magnetic and phase transformation properties of ferromagnetic shape memory Fe-Pd-X thin films
S. Hamann, S. Thienhaus, A. Savan, A. Ludwig

A3.06/p.93 11.30 – 11.45
Martensitic transformation in Cu-Al-Mn alloy melt-spun ribbons
L. E. Kozlova, V. V. Kokorin, S. M. Konoplyuk, A. O. Perekos, V. M. Nadutov

A3.07/p.94 11.45 – 12.00
Mechanical properties of high alloyed cast and rolled CrMnNi TRIP Steels with varying Ni contents
A. Jahn, A. Kovalev, A. Weiß, P. R. Scheller, S. Wolf, L. Krüger, S. Martin, U. Martin

A3.08/p.94 12.00 – 12.15
Stress-induced magnetization and magnetoelastic coupling in ferromagnetic martensites
M. L. Corró Moyá, S. Kustov, E. Cesari, J. Dutkiewicz

A3.09/p.95 12.15 – 12.30
From superplastic to springlike behavior and beyond by tailored martensite twin structures in low twinning stress Ni-Mn-Ga alloys
L. Straka, N. Lanska, K. Ullakko, A. Sozinov

Thursday, September 10

Session **B1 - 4** *Room* **Aula**
Session chair **F. Neves** **14.00 – 15.45**

B1.04/p.116 Invited Lecture 14.00 – 14.30
Deformation twinning-induced grain boundary engineering and microstructural refinement in martensitically transforming materials
I. Karaman, B. Kockar, Z. Luo, Y. I. Chumlyakov, I. V. Kireeva

B1.23/p.126 14.30 – 14.45
Gradient ageing of functionally graded NiTi
Y. Liu, A. King, H. Yang, T. Nam

B1.24/p.126 14.45 – 15.00
Role of severe plastic deformation on cyclic reversibility of Ti50Ni30Pd20 high temperature shape memory alloy
B. Kockar, I. Karaman

B1.25/p.127 15.00 – 15.15
Investigations on martensite formation in CrMnNi-TRIP steels
S. Martin, S. Wolf, U. Martin, L. Krüger, A. Jahn

B1.26/p.127 15.15 – 15.30
Low cycle fatigue behavior and microstructure of a high alloyed metastable austenitic cast TRIP-steel
A. Glage, A. Weidner, T. Richter, P. Trubitz, H. Biermann

B1.56/p.128 15.30 – 15.45
Interaction of creep with the martensitic transformation in TiPdNi High Temperature Shape Memory Alloys
D. C. Lagoudas, P. K. Kumar

Session **A3 - 2** *Room* **Room S5**
Session chair **S. Kustov** **14.00 – 15.45**

A3.01/p.91 Invited Lecture 14.00 – 14.30
Rearrangement of crystallographic domains driven by magnetic field in Fe3Pt and CoO and new phase appearance in Ni2MnGa
T. Kakeshita, T. Terai, M. Yamamoto, T. Fukuda

A3.10/p.95 14.30 – 14.45
Three-dimensional Monte Carlo model for study of magnetocaloric properties of Heusler Ni-Mn-Ga alloys
V. Buchelnikov, V. Sokolovskiy, S. Taskaev, P. Entel

A3.11/p.96 14.45 – 15.00
Straining martensitic Fe70Pd30 films along the bain path by coherent epitaxial growth
J. Buschbeck, I. Opahle, M. Richter, G. Jakob, L. Schultz, S. Fahler

A3.12/p.96 15.00 – 15.15
Acoustic emission experiments with magnetic field in Ni_2MnGa magnetic shape memory alloys
A. Planes, B. Ludwig, C. Strothkaemper, U. Klemradt, X. Moya, L. Mañosa, E. Vives

A3.13/p.97 15.15 – 15.30
Shape memory and superelasticity in BCC metal nanowires
S. Li, X. Ding, T. Suzuki, J. Sun, X. Ren

A3.14/p.97 15.30 – 15.45
Structural and magnetic properties of Ni-Mn-Ga films sputter-deposited on cube-textured polycrystalline substrate
V. A. Chernenko, P. Bassani, R. Lopez Anton, S. Besseghini, J. M. Barandiaran, A. Tuissi, I. Orue, P. Lazpita, M. Ohtsuka

Friday, September 11

Session **B2 - 3** *Room* **Aula**
Session chair **J. San Juan** **9.00 – 10.45**

B2.12/p.152 9.00 – 9.15
Phase transformation fronts propagation during the stress induced martensitic transformation at impact strain rates in NiTi shape memory alloy wires
J. Zurbitu, G. Castillo, L. Aretxabaleta, J. Aurrekoetxea

B2.13/p.153 9.15 – 9.30
Finite – element model for simulations of fully coupled thermomechanical processes in shape memory alloys
F. Richter, O. Kastner, G. Eggeler

B2.14/p.153 9.30 – 9.45
Strain mapping of crack extension in pseudoelastic NiTi shape memory alloys
M. L. Young, S. Gollerthan, J. Frenzel, W. W. Schmahl, A. Baruj, G. Eggeler

B2.15/p.154 9.45 – 10.00
Strain mapping at propagating interfaces in pseudoelastic NiTi
A. Schaefer, M. F. Wagner

B2.16/p.154 10.00 – 10.15
TEM investigation of the microstructural evolution during nanoindentation of NiTi
J. Pfetzing, M. F. Wagner, T. Simon, A. Schaefer, C. Somsen, G. Eggeler

B2.17/p.155 10.15 – 10.30
Study of nanostructured NiTi shape memory alloy's structure and functional properties
V. Afonina, R. Gizatullin, D. Gunderov, V. S. Kalashnikov, V. Koledov, V. Shavrov, V. V. Istomin-Kastrovsky

B2.18/p.155 10.30 – 10.45
Coupling between experiment and numerical simulation of shape memory alloy multicrystal
T. Merzouki, C. Collard, N. Bourgeois, T. Ben Zineb, F. Meraghni

Session **A3 - 3** *Room* **Room S5**
Session chair **F. Laguna** **9.00 – 10.45**

A3.15/p.98 9.00 – 9.15
High-temperature superelasticity in ferromagnetic single crystals with thermoelastic martensitic transformation
Y. I. Chumlyakov, I. V. Kireeva, E. Y. Panchenko, H. J. Maier, I. Karaman, E. E. Timofeeva, Z. V. Pobedennaya, V. A. Kirillov

A3.16/p.98 9.15 – 9.30
Temperature-stress phase diagram and the properties of Ti48.5Ni51.5 strain glass
Y. Wang, X. Ren, K. Otsuka, A. Saxena

A3.17/p.99 9.30 – 9.45
Peculiarities of structure and thermomechanical strengthening of martensitic structural steels microalloyed by nitrogen
V. Prokoshkina, L. Kaputkina, M. Medvedev

A3.18/p.99 9.45 – 10.00
Characterization of new ferromagnetic Fe-Co-Zn-Ga alloys by ab initio investigations
A. Dannenberg, M. E. Gruner, M. Wuttig, P. Entel

A3.19/p.100 10.00 – 10.15
TEM, XRD and DSC analysis of a HPT deformed NiTiHf shape memory alloy
G. Steiner, T. Waitz, H. Karnthaler

A3.20/p.100 10.15 – 10.30
Influence of the valence electron density (e/a) on the magnetic properties and martensitic transition temperatures of Ni-Mn-X (X=Ga, In, Sn, Sb)
M. Siewert, M. E. Gruner, P. Entel

A3.21/p.101 10.30 – 10.45
Inverse transition from low temperature paramagnetism to high temperature ferromagnetism in Co-doped NiMnGa alloys
S. Fabbrici, F. Albertini, A. Paoluzi, F. Bolzoni, R. Cabassi, M. Solzi, L. Righi, G. Calestani, J. Kamarad, Z. Arnold, M. Souckova

Friday, September 11

Session **B2 - 4** *Room* **Aula**
Session chair **S. Shabalovskaya** **11.15 – 13.00**

B2.03/p.148 Invited Lecture 11.15 – 11.45
From the thermal and kinematical full-field measurements to the analysis of deformation mechanisms of NiTi SMAs
P. Schlosser, D. Favier, H. Louche, L. Orgéas, Y. Liu

B2.19/p.156 11.45 – 12.00
Relation between crystal quality and fatigue life of a Cu-Al-Be single crystal shape memory alloy under repeated bending.
N. Siredey-Schwaller, A. Eberhardt, E. Patoor, P. Bastie

B2.20/p.156 12.00 – 12.15
Microstructure and functional superelasticity property changes in thin NiTi wires heat treated by electric current
M. Benoît, J. Pilch, P. Šittner, V. Gärtnerová, R. Delville, D. Schryvers, C. Curfs

B2.21/p.157 12.15 – 12.30
Strain recovery at fast heating of a pre-tensioned shape memory alloy specimen
A. E. Volkov, N. A. Volkova, S. A. Marchenko

B2.22/p.157 12.30 – 12.45
Two-dimensional thermomechanical model for combined loading of NiTi wire structures
M. Frost

B2.23/p.158 12.45 – 13.00
Martensitic phase transformations in NiTi. Lagrangian dynamics simulations
O. Shchyglo

Session **A3 - 4** *Room* **Room S5**
Session chair **V. Chernenko** **11.15 – 13.00**

A3.02/p.91 Invited Lecture 11.15 – 11.45
Magnetic after-effect and isothermal martensitic transformation in metamagnetic shape memory alloys
S. Kustov, M. Corró, E. Cesari

A3.22/p.101 11.45 – 12.00
Determining the liquidus and ordering temperatures of the ternary Ni-Mn-Ga and quaternary Ni-Mn-Ga-Fe/Cu alloys
I. Aaltio, O. Söderberg, M. Friman, I. Glavatskyy, Y. Ge, N. Glavatska, S. Hannula

A3.23/p.102 12.00 – 12.15
Grain size dependence of martensitic phase transformation in Ni -Mn-Ga
N. Scheerbaum, J. Liu, S. Weiß, O. Gutfleisch, L. Schultz

A3.24/p.102 12.15 – 12.30
First principles determination of phase transitions in magnetic shape memory alloys
T. Hickel, J. Neugebauer

A3.25/p.103 12.30 – 12.45
In-situ TEM straining of tetragonal martensite of Ni-Mn-Ga alloy
Y. Ge, N. Zárubová, Z. Dlabáček, I. Aaltio, O. Söderberg, S. Hannula

A3.26/p.103 12.45 – 13.00
Magnetically induced martensite transition in freestanding epitaxial Ni-Mn-Ga films
O. Heczko, M. Thomas, S. Kaufmann, L. Schultz, S. Faehler

Abstract Book

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Keynote Lectures

Keynote Lecture 1 | Paper ID – 01002 Keynote Lecture | Monday, Sept. 7, 9.00 - 9.45

Recent progress in Lorentz transmission electron microscopy

M. De Graef[1]

[1] *Department of Materials Science and Engineering, Carnegie Mellon University, Pittsburgh, USA*

Abstract. Along with ordered domains and structural (martensitic) variants, magnetic domains play an important role in the behavior of multiferroic materials. In this plenary talk, we will review recent progress in the characterization, by means of Lorenz transmission electron microscopy (LTEM), of magnetic domain configurations, in particular the measurement of the domain wall thickness. We will introduce the concept of the magnetic phase shift of the electron wave, which contains all information about the magnetic state of the material. Then we will employ the Transport-of-Intensity Equation formalism to extract the phase shift from a through-focus series of images; when combined with time reversal symmetry, this allows for the quantitative extraction of the magnetic phase shift. We will give examples of domain wall configurations in Ni-Mn-Ga and Fe-Pd alloy systems, in particular the interaction between magnetic domain walls and anti-phase boundaries. When combined with spherical-aberration correction, LTEM has the potential to analyze domain walls with a sub-nanometer resolution; we will discuss the principles of aberration correction in the context of LTEM, and present examples of phase reconstructions in standard and corrected instruments. We will conclude this presentation with a brief look at the future of multiferroic materials characterization, including the tomographic reconstruction of the magnetic vector potential.

Remarks:

Keynote Lecture 2 Keynote Lecture | Monday, Sept. 7, 9.45 - 10.30

Martensitic-like microstructures in nematic polymers: modeling, analysis, and numerical simulation

A. De Simone[1]

[1] *Scuola Internazionale Superiore di Studi Avanzati, via Beirut 2-4, I-34014 Trieste, Italy*

Abstract. The deep understanding gleaned from the study of martensitic transformations in metals has often provided the tools for the accurate prediction of the mechanical response of other materials. Liquid crystal polymers and, in particular, nematic elastomers provide an example in this direction. Similarities in physical behavior (e.g., soft elasticity, which is the analogue of superelasticity or stripe-domain instability, which is the analogue of mechanical twinning) have inspired the use of similar thermodynamic models and mathematical techniques based on the minimization of multi-well free-energies. In this talk, we will review the recent progress on the modelling of martensitic-like microstructures in nematic elastomers, which has led to accurate coarse-grained models for the effective mechanical response. Highlights on current research on the dynamic accessibility of energy minimizing microstructures will also be presented, with the aim of showing that nematic elastomers provide an extremely valuable model system to sharpen our understanding of martensitic microstructures.

Remarks:

Keynote Lecture 3 | Paper ID – 01003 Keynote Lecture | Monday, Sept. 7, 11.00 - 11.45

Development of high temperature Ti-Ta shape memory alloys

S. Miyazaki[1], H. Kim[1], P. J. Buenconsejo[1]

[1] *Institute of Materials Science, University of Tsukuba, Tsukuba, Japan*

Abstract. Recent development of Ti-Ta and Ti-Ta-Al high temperature shape memory alloys was reviewed. The effect of Ta content on shape memory behavior of Ti-Ta alloys was first described. Shape memory effect was confirmed in Ti-(30-40)Ta alloys. The Ms temperature decreased by 30K per 1at.% Ta. The amount of omega phase formed during aging decreased with increasing Ta so that stable high temperature shape memory effect was confirmed for Ti-32Ta (Ms=440K) during thermal cycling between 173K and 513K. Secondly, the effect of ternary alloying elements (X = V, Cr, Fe, Zr, Hf, Mo, Sn, Al) on the shape memory behavior of Ti-30Ta-X alloys was described. Among the alloying elements, Sn and Al were effective to suppress the effect of aging on the shape memory behavior, since they strongly suppress the formation of omega phase induced due to aging during thermal cycling. For this reason the Ti-30Ta-1Al and Ti-30Ta-1Sn alloys exhibited stable high temperature shape memory effect during thermal cycling. It is suggested that Ti-Ta based alloys are attractive candidates for the development of novel high temperature shape memory alloys.

Remarks:

Keynote Lecture 4 | Paper ID – 01001 Keynote Lecture | Monday, Sept. 7, 11.45 - 12.30

Functional properties of nanocrystalline, submicrocrystalline and polygonized Ti-Ni alloys processed by cold rolling and post-deformation annealing

V. Brailovski[1], S. Prokoshkin[2], K. Inaekyan[3], V. Demers[4]

[1] *Ecole de Technologie Superieure, Montreal, Canada*
[2] *Moscow Institute of Steel and Alloys, Moscow, Russian Federation*
[3] *Ecole de Technologie Superieure, Montreal, Russia*
[4] *Pratt & Whitney, Longueuil, Quebec, Canada*

Abstract. The thermomechanical processing consisting in cold rolling (e=0.3-2.0) and post-deformation annealing (200-700oC, 1h) was applied to the binary Ti-Ni alloys to produce nanocrystalline structure (NS) or polygonized dislocation substructure (PDS), or their mixture. The evolution of the material structure and properties was studied using TEM, X-ray, microhardness, calorimetry and tensile testing techniques. Recovery stress and strain of the 50.26at% Ni alloy and superelastic strain of the Ti-50.6at% Ni alloy were measured under static and fatigue (run-out at N=20000 cycle) conditions. It was found that higher true yield stress of NS alloys increases not only the recovery stress potential, but being combined with a relatively low transformation yield stress; it increases the completely recoverable strain. NS alloys generate recovery stresses twice as high as PDS alloys (1200 MPa), and 10% higher completely recoverable strains (up to 6% in tension), and demonstrate higher cyclic stability of functional properties. This improvement comes however with the cost of lower fatigue damage tolerance of NS alloys aggravated by the presence of microcracks caused by cold working. Binary Ti-Ni alloys processed by annealing of an intermediately cold-worked (e=0.75...1) alloy and containing mixed nanocrystalline structure and polygonized dislocation substructure allow a high fatigue life combined with relatively high and cyclically stable functional properties.

Remarks:

Keynote Lecture 5 Keynote Lecture | Monday, Sept. 7, 14.00 - 14.45

An overview of different approaches used to model SMAs and SMA structures

E. Patoor[1]

[1] *Arts et Métiers ParisTech - Laboratoire de Physique et de Mécanique des Matériaux , rue Augustin Fresnel - Metz Technopôle 57078 Metz, France*

Abstract. The development of smart materials and intelligent systems opens new opportunities to design more efficient and better integrated devices. Vibration control in aerospace and civil engineering, wing morphing, biomedical implants and microrobotics are few examples to illustrate the importance of this class of materials in current technological and social issues. Shape memory alloys (SMA) belong to this class of materials. These alloys exhibit a non linear behaviour, strongly dependant on microstructural features and mechanical and thermal fields strongly interact, so their integration into applications is not straightforward. Experimental characterisation and modeling of SMA behavior are key issues. A very short illustration of the current state of the art in SMA modeling will be given and three main topics will be developed in this talk. The application of the framework of classical thermodynamics to SMA including the question of the choice of internal variables will be discussed. Main features in scale transition approaches and phenomenological modeling will be presented. The energy minimization scheme and its application to phase field modeling will be considered. This presentation also includes several new results obtained within the MAFESMA project supported by the European Science Foundation Eurococores programme Smart Structural Systems Technologies (S3T) and by the French National Agency for Research (ANR).

Remarks:

Keynote Lecture 6 Keynote Lecture | Monday, Sept. 7, 14.45 - 15.30

Elastic anisotropy, micro-/ meso-scale interfaces and macroscopic mechanical properties of NiTi

M. F. Wagner[1]

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Abstract. The mechanical behaviour of NiTi shape memory alloys has been studied for decades and by now all fundamental properties are well understood – or are they? In this contribution, several recent advances in the general field of mechanical properties are reviewed. Novel experimental and theoretical results offering new - and sometimes surprising - insights are presented. The different investigations discussed here range across all relevant length scales: On the atomistic length scale, ab initio calculations allow a detailed analysis of the relative stability as well as a calculation of the elastic constants of NiTi martensites. By fully considering elastic anisotropy, compatibility stresses at twin boundaries are assessed for the first time, and micro-mechanical models demonstrate the importance of inelastic deformation processes (e.g., de-twinning, reorientation) during multi-axial loading. On a coarser scale, strains and volume fraction distributions at meso-scale phase interfaces during localized deformation of tensile specimens are characterized by in-situ diffraction methods, surface strain mapping techniques, and thermal imaging. Combining the resulting data, a detailed picture of the local thermo-mechanical behaviour of NiTi emerges. Potential future directions of research are pointed out, and it is emphasized that research into the mechanical behaviour of NiTi is technologically relevant, scientifically rich and, above all, far from finished.

Remarks:

Keynote Lecture 7 Keynote Lecture | Monday, Sept. 7, 16.00 - 16.45

Tough and smart steels with martensite

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Abstract. Toughness of steels decreases sharply as the yield strength increases. Thus, there has been strong demand for enhanced toughness in ultra-high strength steels with a yield strength of more than 1400MPa. This presentation introduces our recent studies on enhanced toughness through thermo-mechanical processing. Warm deformation of tempered martensite, tempforming, can create an ultrafine fibrous grain structure with a strong <110>//RD deformation texture. The 0.4C-2Si-1Cr-1Mo steel with this structure exhibited a yield strength of 1800MPa at ambient temperature along with very high impact energy of 220J. In addition, the steel revealed inverse temperature dependence in the temperature range from 330K to 210K, where a decrease in impact energy by the so-called ductile to brittle transition is usually observed in the conventional quenched and tempered martensitic steels.
Shape memory effect (SME) of steels has been studied intensively in the last 30 years, but its applications have been limited. Since their SME property is not excellent like that of NiTi alloys, a new application field must be found. This talk introduces a new application of SME steels in Japan as smart structural parts. The 28Mn-6Si-5Cr steel with fcc to hcp martensitic transformation has recently been applied to the joint plates for crane rails of factories, where the available foothold is narrow and welding work is difficult. A large recovery strain is not required and two percent is sufficient for tight joining, although formability and machinability are demanded.
This presentation also covers recent developments of other high strength steels and SME steels, where steels have become tough and smart with martensite.

Remarks:

Keynote Lecture 8 Keynote Lecture | Monday, Sept. 7, 16.45 - 17.30

Epitaxial magnetic shape memory films

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Abstract. The high strain of close to 10% reachable in Magnetic Shape Memory (MSM) alloys makes this class of materials of particular interest for the use in microactuators based on thin films. After a short introduction on the different actuation mechanism in bulk single crystals, the different behaviour of thin films made of Ni-Mn-Ga and Fe-Pd is analyzed. In particular the advantages of a well oriented, epitaxial growth are used. This allows for a comparison of magnetic and martensitic properties with first principle calculations as well as continuum models. In thin films the epitaxial interface to substrates with different lattice constants is used to stabilize intermediate states during the martensitic transition. The martensitic instability allows covering almost the complete Bain transformation path from an fcc to a bcc structure up to relatively thick films (50 nm). Hence one can use bulk probes for the analysis of these frozen, intermediate martensitic states. In thicker films the influence of an interface to a rigid substrate on the martensitic transition is examined with different in-situ methods. Since the epitaxial interface can be used as reference frame, these films are used for experimental confirmation of the WLR theory and the concept of adaptive martensite, not accessible in bulk. In contrast to bulk, free standing films dicussed finally allow a completely new thermal actuation mechanism, which requires neither training nor an external magnetic field.

Remarks:

Keynote Lecture 9 Keynote Lecture | Monday, Sept. 7, 17.30 - 18.15

In situ, high temperature, synchrotron studies of monoclinic to tetragonal phase transformation in HfO2

W. M. Kriven[1], R. Haggerty[2], P. Sarin[2], Z. Apostolov[2]

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[2] *Illinois at Urbana-Champaign, USA*

Abstract. The transformations of hafnia (HfO2) are described analogous to the transformations in zirconia (ZrO2) because of the similar crystal structures, although the phase transformations in hafnia occur at higher temperatures. In this study, the monoclinic to tetragonal transformation in HfO2 (∼1800°C, compared to 950°C in ZrO2) was studied in situ, in air, by high temperature X-ray diffraction using synchrotron radiation. In the past, high temperature studies have been conducted in an inert atmosphere which results in structural modifications caused by the formation of oxygen vacancies. In order to utilize the material in air it must be studied in a similar atmosphere. A quadrupole lamp furnace (QLF) was used, in conjunction with three state of the art X-ray detectors, to study HfO2 in situ at the transformation temperature in air. Results will be presented to show the complex thermal expansion as it relates to the crystal structure of monoclinic HfO2, the hysteresis of the transformation and the high temperature structure as studied for the first time in air. The use of reflection geometry diffraction on highly absorbing samples, as well as pair distribution function analysis will be discussed.

Remarks:

A. Principles, Simulations, Materials
A.1 Background

A1.01 Invited Oral Presentation | Tuesday, Sept. 8, 8.30 - 9.00

The kinetics of austenite to martensite phase transformation in shape memory alloys under a rapid heating pulse

D. Shilo[1], S. Vollach[1]

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Abstract. Shape Memory Alloy (SMA) actuators are very promising due to their large strains but are considered to be very slow due to their cooling rate. In this presentation we explore the capabilities of a fast one-directional actuation mode based on one-occasional rapid Joule heating of SMA elements. For this purpose a unique experimental system has been developed which applies a high-voltage electric pulse to a detwined NiTi wire and measures the resulted displacement due to the martensite to austenite phase transformation. The electric pulse is tuned to produce variable temperature jump of up to 160 ˚ C within a risetime of few microseconds. The response of the SMA under different dead-weight loads allows studying the kinetics of temperature induced austenitic transformation. In particular, dynamic stress-strain curves are extracted and the nucleation time is investigated. Further analysis reveals a relation between the thermodynamic driving force and the austenite volume fraction which resembles the Koistinen-Marburger kinetic law for martensitic transformations in steels. A comparison of actuation performances demonstrates that our actuation experiments are significantly advantageous over other fast actuation methods in almost every actuation aspect reviewed. This demonstrates the great potential of SMA for applications that require high speeds and large displacements one-occasional actuation.

Remarks:

A1.02 Invited Oral Presentation | Tuesday, Sept. 8, 11.00 - 11.30

Lattice dynamics in the magnetic superelastic Ni-Mn-In alloy

L. Manosa[1], A. Planes[1], X. Moya[1], D. Gonzalez-Alonso[1], O. Garlea[2], T. Lograsso[2], D. Schlagel[2], J. Zarestky[2], S. Aksoy[3], M. Acet[3]

[1] *Universitat de Barcelona, Spain*
[2] *Ames Laboratory, USA*
[3] *Universitaet Duisburg-Essen, Germany*

Abstract. We report on neutron scattering an ultrasonic measurements on the magnetic superelastic Ni-Mn-In shape memory alloy. Measurements have been conducted on the cubic phase of two single crystals with compositions close to the Ni50Mn34In16.. Data for the low-lying phonon dispersion curves and for the elastic constants are reported within a broad temperature range and under applied field. Results are compared to the values predicted from ab-initio calculations.

Remarks:

A1.03 | Paper ID – 02030 Invited Oral Presentation | Tuesday, Sept. 8, 14.30 - 15.00

In-situ TEM cooling/heating experiments on deformed NiTi shape memory single crystals

T. Simon[1], A. Kröger[1], C. Somsen[1], A. Dlouhy[2], G. Eggeler[1]

[1] *Ruhr-University Bochum, Institute for Materials, Bochum, Germany*
[2] *Institue of Physics of Materials, ASCR, Brno, Czech Republic*

Abstract. In the present study we report about the influence of dislocations on martensitic transformations in NiTi single crystals. Microstructural investigations are performed on Ni50.4Ti49.6 (at.%) single crystals using in-situ cooling and heating transmission electron microscopy (TEM). Solution heat-treated Ni50.4Ti49.6 single crystals were oriented by electron backscatter diffraction (EBSD) and compressed in [111]B2-direction to different strain levels. DSC measurements on undeformed and deformed material states reveal a two step transformation from B2 to R-phase and then from R-phase to B19´ confirmed by TEM. The analysis of the dislocation structure of a 3.3% compressed single crystal shows that mainly screw dislocations with [001] type burgers vectors are present. During cooling, the martensitic R-phase grows homogeneously. On further cooling in some regions a burst like growth of B19'-neddles can be observed in addition to B19'-regions that nucleate and grow promoted by the stress-fields of dislocations. Dislocation analysis after back transformation suggests that dislocations form as a result of the martensitic transformation.

Remarks:

A1.04 Invited Oral Presentation | Wednesday, Sept. 9, 15.15 - 15.45

Domain boundary engineering in alloys and oxides

E. K. Salje[1]

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Abstract. Domain boundaries, rather than domains, can carry information and act as memory devices. While domains are bulk objects; their large response to changing external fields is related to their change in volume which implies the movement of domain boundaries. In many cases, the design of 'optimal' domain structures corresponds to 'optimal' domain boundaries with parameters such as the domain boundary mobility, pinning properties and the formation of specific boundaries such as curved boundaries or needle domains. This argument is enhanced further: domain boundaries themselves can host properties which are absent in the bulk, they can be multiferroic, super- or semi-conductors while the matrix shows none of these properties. It is argued that multiferroic walls can be described formally as chiral whereby the chirality relates to state-vectors such as polarization and magnetic moment and their (non-linear) coupling. Chirality massively changes the surface energy and the macroscopic response of domain walls. Such walls can be generated reliably in certain oxide materails, it is now discussed whether a similar effect can be seen in alloys.

Remarks:

A1.05 Invited Oral Presentation | Thursday, Sept. 10, 8.30 - 9.00

Mystery of martensitic crystal structure on the example of Ni-Mn-Ga

N. Glavatska[1], L. Olikhovska[1], I. Glavatskyy[1]

[1] *Institute for Metal Physics, Kiev, Ukraine*

Abstract. Despite the fact that Heusler martensites are intensively investigated over decades, there still exist a set of "mysteries" in the identification of modulated martensitic crystal structures by means of diffraction. In example, for Ni-Mn-Ga martensites, some of such "mysteries", like: existence of unidentifiable reflections, change of the peak profiles, intensity rise and new "satellites" appearance during cooling, together with inconsistence of the diffraction patterns simulated after determined lattice parameters to the experimental patterns are vide spread problems. In addition, martensites of very close chemical compositions often show different types of the crystal lattice, e.g. – tetragonal, orthorhombic and "monoclinic". At the same time, on the basis of HRTEM, SEM and optical microscopy studies, it is established, that 5R and 7R martensites possess a nano- and micro- twinning hierarchical morphology. However, microtwinned nature of those martensites had never been taken into account during the crystal structure analysis in the X-ray and neutron diffraction studies. Thus, in the given work, on the basis of collected experimental data array from series of neutron and X-ray diffraction studies, on one hand, and mathematical simulation on the other - we show, that taking into account the nano- and micro- scale twinning allows solving the above mentioned "mysteries" and correct identification of the crystal structure of martensite.

Remarks:

A1.06 | Paper ID – 02027 Invited Oral Presentation | Thursday, Sept. 10, 10.45 - 11.15

Observations of decomposition of martensite during heat treatment of steels using atom probe tomography

E. Pereloma[1], S. P. Ringer[2], I. B. Timokhina[3], P. D. Hodgson[3]

[1] *School of Mechanical, Materials and Mechatronic Engineering, University of Wollongong, NSW 2522, Australia*
[2] *Australian Key Centre for Microscopy & Microanalysis, The University of Sydney, NSW 2006 Australia*
[3] *Centre for Material and Fibre Innovation, Deakin University, Geelong, VIC 3127, Australia*

Abstract. The decomposition of martensite during tempering or ageing is an important phenomenon as it leads to changes in the mechanical properties. These changes could take place during both steel manufacturing or in-service. Thus, their understanding is required to predict the material performance. Recent advances in the development of local electrode atom probes has led to a significant increase in the analysed volume of material (up to 100 millions of atoms) and at the same time reduced the acquisition times. This allows improvement in data statistics when investigating fine nanoscale features, such as solute segregation, clustering and ultrafine precipitation. Selected results of atom probe studies on the decomposition of martensite from bake hardening of a pre-strained Transformation Induced Plasticity (TRIP) steel and ageing of FeNiTiMnAl maraging steel are presented.

Remarks:

A1.07 Regular Oral Presentation | Tuesday, Sept. 8, 9.00 - 9.15

Effect of martensitic transformation on eutectic cell count (ECC), dendrite arm spacing (DAS), grain size (GS) and ultimate tensile strength (UTS) of cryogenically solidified hypoeutectic cast iron

J. Hemanth[1]

[1] *Department of Mechanical Engineering, Siddaganga Institute of Technology (S.I.T.), Tumkur - 572 103, Karnataka, India*

Abstract. This paper presents the results obtained and the deductions made from a series of microstructural studies (martensitic transformation) to determine Eutectic Cell Count (ECC), secondary Dendrite Arm Spacing (DAS), and Grain Size (GS) along with the Ultimate Tensile Strength (UTS) of hypoeutectic gray cast iron which was cast using sub- zero (Cryogenic) end chills. It was found that the UTS, ECC, DAS and GS of the chilled cast iron is highly dependent on the rate of chilling especially the martensitic transformation that took place due to cryogenic chilling during solidification. Attempts were also made in this investigation to correlate the effect of matrensitic transformation on UTS, ECC, GS and DAS. Moreover, it was found that UTS decreases as DAS and martensitic phase increases and UTS increases as ECC increases. The results are compared with specimens of the same chemical composition which were sand cast. Analysis of the data on cryogenically treated cast iron show that the cooling rate has a marked effect on martensitic transformation and mechanical properties. Results of the investigation reveal the following: Martensitic transformation and UTS increases as the cooling rate increases, showing a direct relationship with ECC and inverse relationship with DAS. Therefore matrensite content present in microstructure, ECC and DAS was shown to be a major factor that affects UTS.

Remarks:

A1.08 Regular Oral Presentation | Tuesday, Sept. 8, 9.15 - 9.30

Influence of way of B19'-phase formation on B19' - B2 transition temperatures in TiNi shape memory alloy

N. Resnina[1], S. Belyaev[1]

[1] *Saint-Petersburg State University, Research Institute of Mathematics and Mechanics, Russia*

Abstract. It is known that in a TiNi alloy the B19' monoclinic phase may appear directly from B2 cubic phase or from intermediate R rhombohedral one. In the present study the influence of way of B19'-phase formation on a kinetics of reverse B19' - B2 transition was studied in Ti50Ni50 shape memory alloy. After preliminary thermal cycling, the alloy underwent two types of martensitic transformation on cooling: B2 - R - B19' and B2 - B19'. So the B19' crystals were formed by different ways – from the B2 phase and from the R one. The DSC measurements had shown the B19' crystals had different temperatures of a reverse transformation on heating. The transition of the B19'-phase, obtained from the R-phase, occurred at lower temperatures than the transformation of the B19'-phase, formed from the B2-phase. Apparently it meant that the non-chemical energy stored during the B2 - R - B19' transitions on cooling was larger the same energy stored on the B2 - B19' transformation.

Remarks:

A1.09 | Paper ID – 02026 Regular Oral Presentation | Tuesday, Sept. 8, 9.30 - 9.45

Mechanisms of austenite-martensite transition

V. Paidar[1]

[1] *Institute of Physics AS CR, 18221 Praha 8, Czech Republic*

Abstract. Martensitic transformations originate from the interaction of the short-wave (atomic plane shuffling) and long-wave (homogeneous deformation) processes. The mutual role of these movements is examined with the aim to elucidate formation mechanisms of the structures with lower symmetry at the atomic level. Generic many-body potentials differing in the stability of basic simple structures is employed in the calculations of the system energies in the course of phase transition.

Remarks:

A1.10 Regular Oral Presentation | Tuesday, Sept. 8, 9.45 - 10.00

In-situ synchrotron studies of ceramics to 2000°C in air

W. M. Kriven[1]

[1] *University of Illinois at Urbana-Champaign, USA*

Abstract. In this talk a novel methodology for high temperature, synchrotron, X-ray diffraction (XRD) using a Quadrupole Lamp Furnace (QLF) and a Curve Image Plate Detector (CIPD) will be presented. The combined configuration, together with today's intense X-ray synchrotron sources, offers considerable promise in revolutionizing the way in which high temperature XRD studies will be performed. The ability to rapidly acquire high resolution XRD data simultaneously over a wide 2q range, for temperatures extending from room temperature to 2000 °C in air, along with the capability of rapid heating ($\sim$ 200 °C/sec) and quenching is unique. Coupled with the Rietveld profile fitting method, various in-situ high temperature investigations are now possible including phase transformations, crystallographic thermal expansions and phase equilibria. A long term vision for applications of phase transformations will be presented in which unit cell volume changes or unit cell shape changes are considered. While positive volume changes occur on cooling and lead to "transformation toughening" (e.g as in zirconia, or the lanthanide sesquioxides), negative volume changes lead to "transformation weakening" (e.g., enstatite, cristobalite), leading to debonding of matrix- reinforcement interphases.

Remarks:

A1.11 | Paper ID – 02033 Regular Oral Presentation | Tuesday, Sept. 8, 10.00 - 10.15

Position of diffuse satellites appearing in Ti-44Ni-6Fe shape memory alloy

M. Todai[1], S. Majima[1], T. Fukuda[1], T. Kakeshita[1]

[1] *Department of Materials science and Engineering, Graduated School of Engineering, Osaka University, 2-1, Yamada-oka, Suita, Osaka 565-0871, Japan*

Abstract. We have investigated the instability of B2-type structure in a Ti-44Ni-6Fe alloy by transmission electron microscopy. This alloy exhibits negative temperature dependence in electrical resistivity below Tmin = 210K. The electron diffraction pattern taken near Tmin shows diffuse satellites at gB2+[$\zeta\zeta$0]* when the zone axises are [111] and [100]. For both the beam directions, the value ζ is slightly smaller than 1/3 and shows the same temperature dependence. On the other hand, the satellites are missing when the zone axis is [110]. This means that the incommensurate structure has a modulated structure with transverse movement of atoms in [1-10] direction. This modulation is obviously the consequence of softening of TA2 phonon branch with the propagation vector near 1/3[110]*. In addition to the satellite at gB2+[$\zeta\zeta$0]*, diffuse satellites appear at gB2+[$\zeta\zeta\zeta$]* with $\zeta \sim 0.62$ when the beam direction is [110]. Satellites also appear at gB2+<$\zeta\zeta$0>* with $\zeta = 0.5$ when the beam direction is [100]. However, these two satellites and rod-like streaks do not show clear temperature dependence, suggesting that these satellites are not directly related to the instability of the B2-type structure.

Remarks:

A1.12 | Paper ID – 02007 Regular Oral Presentation | Tuesday, Sept. 8, 10.15 - 10.30

Preferential selection of variants in ferromagnetic Fe-Pd alloys under magnetic field

S. Farjami[1], T. Fukuda[1], T. Kakeshita[1]

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Abstract. Effect of magnetic field on microstructure formation through a disorder-order transformation has been studied in Fe-Pd alloy. Single crystal of the disordered Fe-55at% Pd is subjected to an ordering heat-treatment under a magnetic field. When the ordering heat-treatment is performed without applying a magnetic field, three lattice corresponding variants are formed equivalently. On the other hand, when the ordering heat-treatment is made under a magnetic field of 4 T and higher applied along the [001] direction of the disordered phase, a single variant with an easy axis along the field direction is obtained. A tweed microstructure has been observed at early stage of ordering with streaks in the <011>directions. High density of antiphase boundary after formation of a single variant indicates the formation of homogeneous nucleation of the ordered L10 phase in a disordered fcc matrix at the early stage of ordering.

Remarks:

A1.13 | Paper ID – 02028 Regular Oral Presentation | Tuesday, Sept. 8, 11.30 - 11.45

A comparative study of martensite crystal lattice in nanostructured, quenched and deformed Ti-Ni shape memory alloys

S. Prokoshkin[1], A. Korotitskiy[1], V. Brailovski[2], K. Inaekyan[2], S. Dubinskiy[1]

[1] *Department of Plastic Deformation of Special Alloys, Moscow Institute of Steel and Alloys, 4, Leninsky prosp., Moscow 119049, Russia*

[2] *Mechanical Engineering Department, Ecole de Technologie Superieure, 1100, Notre-Dame Street West, Montreal, H3C 1K3, Canada*

Abstract. The crystal lattices of cooling-induced (thermal) martensites formed in thermally and thermomechanically treated Ti-Ni Shape Memory Alloys (SMA) and stress-induced, reoriented and plastically deformed martensites were studied using the X-ray diffraction method. The linear dependences of the quenched B19'-martensite lattice parameters (LPs), maximum transformation lattice strain in single- and polycrystalline B2-austenites as well as its crystallographic direction on nickel concentration in the hyperequiatomic range are presented. The lattice parameters and maximum transformation lattice strain of martensite formed from nanocrystalline or polygonized austenites differ from those of quenched martensite formed from recrystallized austenite. The averaged LPs of stress-induced, reoriented and moderately plastically deformed martensites are close to the lattice parameters of quenched martensite.

Remarks:

A1.14 | Paper ID – 02010 Regular Oral Presentation | Tuesday, Sept. 8, 11.45 - 12.00

Structural stabilities, elastic constants, generalized stacking fault energetics, and the martensitic transformation mechanisms for the Ni_{50-x}TiPt_{x}(x=0-30) ternary system: ab initio investigation

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Abstract. To determine the effect of ternary additions on the martensitic behavior of NiTi, we apply ab initio calculations using the highly precise full-potential linearized augmented plane wave method to the Ni-Ti-Pt system. We compare formation energies of various stoichiometries and the pair energetics between Pt atoms to create a number of model austenite structures, finding that Pt atoms prefer to decorate the lattice at third nearest neighbors from one another and establishing the hierarchy among the austenitic, martensitic, and intermediate phases. We present features of Fermi surfaces, phonon dispersions, and atomic reorganization in the crystal structure which indicate instabilities precursory to martensitic transformation. We examine the structural stability to determine the susceptibility toward displacive phase transformation: namely, we calculate planar generalized stacking fault energetics of major shear planes including the {100}, {011}, and {111} planes and we calculate and compare the elastic constants of each phase. We show that increased Pt causes a dramatic softening of the austenite C' elastic constant and increased rigidity in the martensite, and there is a high resistance to {100} shear similar to equiatomic NiTi. Finally, we explore a martensitic mechanism of this alloy and explain how the transformation path and energy barriers of the NiTi system are affected by Pt. This behavior is traced to the evolution of the electronic structures and phonon dispersions.

Remarks:

A1.15 Regular Oral Presentation | Tuesday, Sept. 8, 12.00 - 12.15

Thermal stability of the martensite in Ni-Mn-Ga based FSMA

I. Glavatskyy[1], N. Glavatska[1], J. Hoffmann[2], B. Ouladdiaf[3], J. Rodriguez-Carvajal[3]

[1] *Institute for Metal Physics, Kiev, Ukraine*
[2] *Helmholtz Centre Berlin for Materials and Energy, Berlin, Germany*
[3] *Institut Laue-Langevin, Grenoble Cedex 9 - France*

Abstract. Ni-Mn-Ga alloys became a growing source of interesting scientific results due to its multifunctional properties. In the present work we discuss the temperature evolution of the martensitic phase of Ni-Mn-Ga ferromagnetic shape memory alloys with respect to the crystal and magnetic structure and the influence of the magneto-mechanical treatment. For this reason we provided a complex study on bulk single crystals, utilizing methods of neutron thermodiffractometry, dilatation, magnetometry, calorimetry and optical thermometallography. Altogether fifteen ternary non-stoichiometric Ni-Mn-Ga alloys were studied, twelve of those in the range Ni45.7-52.5Mn27.1-31.5Ga20.3-24.8 having 10M type of martensite crystal lattice, and the rest – nonmodulated bct lattice. The provided complex studies prove that the crystal lattice of the martensite remain stable in the entire range of the martensite phase existence with no intermartensitic reaction occurred. The observed anomalies on the temperature dependence of the low field magnetic susceptibility, magnetic neutron scattering etc, often taken in the literature as signs of the intermartensitic transformation, are due to the relaxation of thermal and residual microstresses on the boundaries of nano- and micro- scale hierarchical twins. This microstress relaxation results in changes of the twinning and magnetic domain morphology because of the strong magnetoelastic coupling, leading to changes of the transport properties of the material.

Remarks:

A1.16 | Paper ID – 02008 Regular Oral Presentation | Tuesday, Sept. 8, 12.15 - 12.30

Phase stability during martensitic transformation in ZrCu intermetallics: crystal and electronic structure aspects

G. S. Firstov[1], A. N. Timoshevskii[2], Y. N. Koval[1], S. A. Kalkuta[2], J. Van Humbeeck[3]

[1] *G.V. Kurdyumov Institute for Metal Physics of the National Academy of Sciences of Ukraine*
[2] *Institute of magnetism of the National Academy of Sciences of Ukraine*
[3] *MTM Catholic University Leuven, Kasteelpark Arenberg 44, Leuven*

Abstract. It is known that ZrCu-based quasi-binary intermetallics belong to the group of high-temperature shape memory alloys (HTSMA). They, as well as the binary ZrCu, undergo the martensitic transformation (MT) from high temperature B2 austenite into two monoclinic martensites belonging to Cm and P21/m space groups. Stress-strain behavior of these HTSMA is characterized by the significant strain hardening and martensitic deformation is accompanied by the dislocation slip. As a result, shape recovery is incomplete. It was suggested that such unacceptable shape memory behavior takes place due to the crystallographic scheme of the B2→B19‘ MT, which becomes closer to the Bain correspondence with the increase of MT temperature. In this regard, close-packed (easy gliding) planes of the austenite are becoming the shear planes for MT and plastic deformation by dislocation slip is inevitable. In the case of the sole B2↔Cm MT in ZrCu, which is inseparable from the simultaneous B2↔B19‘ MT at the moment, it is unlikely to get the Bain correspondence, as Cm martensite unit cell is bigger than unit cell of B19‘. So, the aim of the present paper is to estimate the relative stability of the competing phases in ZrCu-based intermetallics with the help of the electronic structure calculations and crystal structure refinement. The possibilities of the sole formation of Cm martensite in these HTSMA will be discussed on the basis of the estimation mentioned above.

Remarks:

A1.17 Regular Oral Presentation | Tuesday, Sept. 8, 12.30 - 12.45

Dynamic theory of FCC-BCC (BCT) martensitic transformation in iron based alloys

M. Kashchenko[1], V. Chashchina[1]

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Abstract. Three variants of realization of fcc-bcc (bct) spontaneous (at cooling) martensitic transformations (MT) are discussed. The stage of nucleation is heterogeneous. The initial excited status arises in elastic fields of dislocations. For first and second variants of MT the dislocations with typical for austenite lines <110>and <112>are important at the nucleation. In all cases the controlling wave processes (CWP) provide speeds of martensite crystal growth exceeding speeds of longitudinal elastic waves. At first and second variants CWP1 and CWP2 stimulate development of Bein's deformation and do not demand the reshuffle of planes. The third variant of MT is possible if in austenite the dislocations with atypical orientations of lines lengthways <111>can be created. Then CWP3 stimulates the fastest transformation of austenite planes $\{111\}$ in martensite planes $\{110\}$. The dynamic reshuffle of the transformed planes is interpreted as additional controlling process. The first and third variants of MT describe the non-twinned martensitic crystals. CWP2 stimulates formation of twinned crystals by the coordinated action of concerning short-wave and long-wave displacements. The mechanism of formation of periodic twinned structures in the supersonic mode is established. It is shown, that growth speed of the basic components of the twin-structure in $\sqrt{2}$ times exceeds the speed of longitudinal waves in directions <111>. For all variants of MT the transitions from threshold to finishing deformations are considered and the macro morphological attributes (habit planes, orientation relationships (OR), macro shears) are discussed. In particular, the bright morphological feature for the third variant of MT is the orthogonality of a plane $\{11\text{-}1\}$ (included in OR) to expected habit plane $\{5\ 13\ 18\}$. The obtained results show that martensitic transformation in strongly overcooled austenite is initiated by the carriers of threshold deformation providing a minimality of transformation time.

Remarks:

A1.18 | Paper ID – 02025 Regular Oral Presentation | Tuesday, Sept. 8, 12.45 - 13.00

A new diffraction approach to crystal structure determination of nano-twined martensites

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Abstract. The intensity diffracted by crystals containing twin boundaries of the system $\{110\}$, <0n11>were calculated in the reciprocal space assuming a short-range order in the twin-boundary distribution. The calculated intensity distributions have been analyzed to find the effect on the diffraction pattern of such parameters as (i) ratio b/a (c/a) between the crystal lattice constants, (ii) density of the twin boundaries, (iii) ratio between thicknesses of the twin-related lamellae, and (iv) crystallographic direction along which the intensity distribution is simulated. It is found that each of these parameters affects the diffraction-peak profiles and positions including the diffraction peaks of the basic structure. Therefore, the problem of the diffraction pattern identification for a twin-modulated crystal should be approached only by a combined consideration of the diffraction features.

Remarks:

A1.19 Regular Oral Presentation | Tuesday, Sept. 8, 15.00 - 15.15

Strain glass in ferroelastic systems — premartensitic tweed vs. strain glass

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Abstract. Cluster-spin glass and ferroelectric relaxor have been well observed in defect-containing ferromagnetic systems and ferroelectric systems, respectively. However, it was unclear whether or not there exists an analogous glass state in the physically-parallel ferroelastic (or martensitic) systems. In 1990's theoretical studies suggested the premartensitic tweed can be viewed as a strain glass. However, there has been no experimental verification for such a hypothesis. Here we provide an experimental test of this hypothesis by measuring the possible glass signatures in two well-known premartensitic tweed systems prior to their martensitic transformation; one is Ni63Al37 and the other is Ti50Ni47Fe3 martensitic alloy. Our experiment showed that there exist no glass signatures for the premartensitic tweed in both systems. (i) There exists no mechanical susceptibility/modulus anomaly in the tweed temperature regime, suggesting no glass transition exists; (ii) the tweed remains to be ergodic, inconsistent with a frozen glass. We show that strain glass indeed exists in ferroelastic/martensitic systems, but it exists only in defect-containing ferroelastic/martensitic systems with defect concentration exceeding a critical value. This strain glass is a mechanical analogue of cluster-spin glass or ferroelectric relaxor, and it possesses all the features of a glass. We further show that the tweed is equivalent to an "unfrozen state" of a strain glass.

Remarks:

A1.20 | Paper ID – 02019 Regular Oral Presentation | Tuesday, Sept. 8, 15.15 - 15.30

Charactersitic of burst transformations in pseudoelasticity and shape memory effect-A review

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Abstract. This paper reviews effect of the burst transformations in pseudoelasticity and shape memory effect in shape memory alloys (SMA). However, we will give some of our un-published results on tensile testing of Ti-49.83 at% Ni SMA wire sample which shows that burst transformations accompanying in-homogenous deformation of the stress-strain curve in pseudoelasticity region (above austenite finish temperature-Af) proceeds to the upper yielding followed load drop similar to the upper and lower yield observed in the mild steel specimens. Though our stress-strain curve look similar to the one reported by P.Feng and Q.P.Sun, the stress before getting yield was 720 MPa as compared to approx. 380 MPa reported by them. An attempt was made to explain upper and lower yield point phenomenon with help of micro-mechanical modeling. Further research has to be directed to identify the relationship between microstructural changes with respect to the burst transformations and test temperature of the sample.

Remarks:

A1.21 Regular Oral Presentation | Tuesday, Sept. 8, 15.30 - 15.45

Stress-induced martensitic transformation and martensite deformation with controlled stress-strain dependence

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Abstract. As known, an austenite-martensite transformation under stress is accompanied by an intrinsic (thermodynamic) hysteresis. Although this phenomenon is successfully used for designing materials with gigantic damping, it dose not allow one to obtain fully controlled stress-strain behaviour for high quality single crystals and films. Imposing constraint makes possible to diminish the hystersis and control the deformation. It can be an external constraint (substrate clumping , composite engineering) or an internal constraint due to the non-uniformity of phase distribution or martensite microstructure. Such non-uniformities may be created intentionally if a transformation proceeds in a graded material. We will present experimental observations and theoretical analysis of microstructure evolution and stress-strain dependence at a martensitic transformation and martensite deformation in graded films and multilayers.It is shown that it is possible to get a highly reversible stress-induced transformation in a compositionally graded austenite. Deformation of graded martensite structure demonstrates a strong non-linear pseudo- elastic behaviour that can be governed by manipulating the grading. The perspective application of graded films and multilayers for new type activators will be discussed.

Remarks:

A1.22 | Paper ID – 02036 Regular Oral Presentation | Tuesday, Sept. 8, 15.45 - 16.00

In-situ TEM study of stress-induced transformations in CuAlNi

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Abstract. Stress-induced martensitic transformations and twinning processes were studied in thin foils of CuAlNi single crystals strained in-situ in a transmission electron microscope. A detailed structure analysis comprised identification of phases existing under stress and determination of their mutual crystallographic orientation. Three transformation processes were detected: i) transformation of austenite into 2H martensite at low stress levels; ii) twinning/detwinning processes in 2H martensite, and iii) transformation between austenite and 18R martensite at higher stress levels. Nucleation and growth of martensite plates were followed, and morphology of the austenite/martensite habit planes was examined. Existence of planar interfaces between a single variant of 2H martensite and austenite on microscopic level was proved.

Remarks:

A1.23 | Paper ID – 02034 Regular Oral Presentation | Tuesday, Sept. 8, 16.00 - 16.15

Non-martensitic needle-like structures on Ni-Ti alloys - occurrence and origin

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Abstract. In the present work the occurrence of needle-like structures that are observed on martensitic and austenitic NiTi after metallographic preparation and etching is described. The investigations show that the needle-like structures form in less than 10s during the etching process if solutions containing HF are applied. The needle-like structures look very similar to martensitic structures. Hence it is tempting to interpret them as martensite. Distinguishing the structures from martensite is not straightforward since standard analysis e.g. by EDX does not yield any differences in chemical composition of the needle-like structures and NiTi. Application of surface sensitive methods like grazing incidence X-ray diffraction clearly shows that the needle-like structures are different from martensitic structures of NiTi. In the present study the options of altering the etching process with the objective of avoiding the formation of the needle-like structures are presented and the origin of the needle-like structures is discussed.

Remarks:

A1.24 Regular Oral Presentation | Tuesday, Sept. 8, 16.15 - 16.30

Thermodynamic study and modelling of the temperature memory effects in Cu-Al-Ni shape memory alloys.

J. Rodríguez-Aseguinolaza[1], I. Ruiz-Larrea[1], M. Nó[1], A. López-Echarri[1], J. San Juan[1]

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Abstract. A thermodynamic study based on high sensitivity adiabatic calorimetry of the β'-3 martensitic transformation undergone by Cu-Al-Ni shape memory alloys is presented. From the specific heat data, the thermodynamic function values, and in particular the crystal free energy, as functions of temperature have been obtained [1]. This permitted a careful estimation of the phase transformation temperature of each martensite plate as a function of its stored elastic energy. Within this frame, the distribution density of the elastic energy states in the martensitic phase is directly derived from the specific heat data. It favours a simple analysis of the nucleation processes and gives a convincing explanation about the different temperature memory effects. These appear after successive partial transformations from the martesnitic state by heating the sample to an intermediate temperature Ta. The following complete reverse martensitic transformation is characterized by the presence of a secondary Cp peak closely related to Ta, reinforced by increasing the number of partial cycles. These experimental results can be described by means of a simple thermodynamic model which explains the delay of the transformation progress. It is found to depend on the elastic energy release during the partial transformations. Finally, optical observations were performed which support the calorimetric results. [1] Rodríguez-Aseguinolaza J et al. Acta Materialia, 2008;56:6283

Remarks:

A1.25 | Paper ID – 02005 Regular Oral Presentation | Wednesday, Sept. 9, 15.00 - 15.15

Transmission electron microscopy study of low-hysteresis shape memory alloys

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Abstract. Recent findings have linked low hysteresis in shape memory alloys with phase compatibility between austenite and martensite. In order to investigate the evolution of microstructure as the phase compatibility increases and the hysteresis is reduced, transmission electron microscopy was used to study the alloy system Ti50Ni50-xPdx where the composition is systemically tuned to approach perfect compatibility. Changes in morphology, twinning density and twinning modes are reported along with special microstructures occurring when the compatibility is achieved. In addition, the interface between austenite and a single variant of martensite was studied by high-resolution and conventional electron microscopy. The atomically sharp, defect free, low energy configuration of the interface suggests that it plays an important role in the lowering of hysteresis. Finally, dynamical modeling of the martensitic transformation using the phase-field micro-elasticity model within the geometrically linear theory succeeded in reproducing the change in microstructure as the compatibility condition is satisfied. Latest results on the extension of these findings in other Ni-Ti based ternary/quaternary systems are also reported.

Remarks:

A1.26 | Paper ID – 02001 Regular Oral Presentation | Thursday, Sept. 10, 9.00 - 9.15

Isotropic phase transformation in anisotropic stainless steel 301LN sheets

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Abstract. The phase transformation due to mechanical loading in cold-rolled stainless steel 301LN sheets is investigated experimentally. A series of uniaxial tension experiments is performed to quantitatively investigate the effect of initial anisotropy on the martensitic transformation kinetics. Three methods are employed to measure the martensite content: (1) micrography, (2) global magnetic saturation, and (3) local magnetic induction. The first two methods require interrupted tests, while the third method allows for the in-situ detection of the evolution of the martensite volume ratio. All three methods are able to detect the increasing martensite content with plastic strain, and in addition they show that the rate of austenite-to-martensite transformation is not loading direction dependent. In particular, the local magnetic induction technique appears to be sufficiently sensitive to detect these relative differences. The results show that micrography has limited accuracy in quantifying the absolute martensite content due to material preparation. However, the global magnetic method is deemed to be an accurate method to quantify the absolute martensite content, and measurements using this method can be used to calibrate the local magnetic induction method for in-situ monitoring of martensite content evolution. In addition, it was determined that the martensite evolution in this textured material has no directional dependence.

Remarks:

A1.27 | Paper ID – 02023 Regular Oral Presentation | Thursday, Sept. 10, 9.15 - 9.30

Effect of carbon and cold rolling on the latent heat upon $\epsilon \rightarrow \gamma$ transformation in metastable Fe-Mn alloys

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Abstract. Metastable Fe-Mn alloys exhibit a non-thermoelastic martensitic transformation which is accompanied by a significant thermal effect (ca. 20 J/g). Among Fe-Mn alloys, the highest value of latent heat was registered in alloys with 17-18 wt. % Mn. In this work we investigate effects of carbon (up to 0.4 wt. %) and cold rolling (5-25% of thickness reduction) on latent heat and temperature hysteresis of martensitic transformation. Changes in chemical and phase composition are analyzed based on the goal of enthalpy maximizing. The martensite $\leftrightarrow$ austenite transitions are registered using differential scanning calorimetry and dilatometry. The phase composition is determined by means of X-ray diffraction. An effect of thermocycling is considered in connection with microstructural and enthalpy changes.

Remarks:

A1.28 Regular Oral Presentation | Thursday, Sept. 10, 9.30 - 9.45

Structural analysis of a new precipitate phase in high-temperature Ni30Pt20Ti50 shape memory alloys

L. Kovarik[1], F. Yang[1], A. Garg[2], R. D. Noebe[3], D. Diercks[4], M. J. Kaufman[5], M. J. Mills[1]

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[5] *Colorado School of Mines, Golden, USA*

Abstract. Shape memory alloys based on the NiPtTi system represent a promising material for high temperature actuation up to 300°C. The excellent work output and the transformation strains of aged Ni30Pt20Ti50 alloys have been previously correlated with a precipitate phase that forms in the B2 matrix by nucleation and growth. This previously unidentified precipitate phase has been analyzed using electron diffraction and STEM HAADF imaging. The observations were performed on an FEI Tecnai TF20 operated at 200kV and an FEI Titan 80-300 with Cs-correction on the electron probe, and operated at 300kV. Both the electron diffraction and HAADF imaging reveal that the precipitates have a close structural connection with the B2 austenitic phase, but with a previously unidentified and unique crystallographic structure. The full crystallographic description of the precipitate will be discussed in light of the experimental observations as well as ab initio calculations exploring the energetics of candidate structures. It will be shown that the structure lacks a long-range periodicity along one of its primary directions; however, it can be conceptually explained in terms of Pt ordering on the B2 lattice with associated shuffle displacements. Apart from the crystallographic analysis, the possible role of the ordered phase in promoting desirable high temperature shape memory properties will be described.

Remarks:

A1.29 Regular Oral Presentation | Thursday, Sept. 10, 9.45 - 10.00

In-situ TEM straining investigations on stress induced R-phase transformation in Ni48Ti50Fe2 single crystals

C. Somsen[1], T. Simon[1], A. Kröger[1], A. Dlouhy[2], G. Eggeler[1]

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Abstract. Recent investigations on compression aged Ni50.7Ti49.3 single crystals with only one family of Ni4Ti3 precipitates reveals that the thermal induced martensitic transformation can appear in two steps from B2 to R to B19'-phase. However, traces of stress induced R-phase could be observed in this material state by in-situ transmission electron microscopy (TEM) straining experiments. It is well known that an addition of Fe in Ni48Ti50Fe2 shape memory alloys stabilizes the R-phase. Therefore, in the present study in-situ TEM straining experiments have been carried out in order to investigate the stress induced martensitic transformation in Ni48Ti50Fe2 single crystals. In-situ TEM straining samples in [111]B2-direction were machined by spark erosion. Differential scanning calorimetry (DSC) analysis reveals that first on cooling a B2 to R-phase transformation appears at about -13°C followed by a R- to B19'-phase transformation starting at about -85°C. TEM straining investigations show that stress induced transformation from B2 to R-phase appears in the vicinity of the hole of the TEM-sample. With further straining a transformation to B19'-phase could be observed so that R-phase and B19'-phase are co-existing. The TEM straining results will be compared with the macroscopic stress strain behavior obtained from [111] tensile tests.

Remarks:

A1.30 | Paper ID – 02004 Regular Oral Presentation | Thursday, Sept. 10, 10.00 - 10.15

3D FIB/SEM study of Ni4Ti3 precipitates in Ni-Ti alloys with different thermal-mechanical histories

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Abstract. The three-dimensional size, morphology and distribution of Ni4Ti3 precipitates growing in binary Ni-rich Ni-Ti alloys have been investigated via a slice & view procedure in a Dual-Beam FIB/SEM system, in order to better understand their influence on the B2 to B19' martensitic transformation. In the present work, both a stress-free Ni50.8Ti49.2 alloy with all four variants of precipitates and a compressed Ni51Ti49 alloy with aligned precipitates in one family were studied. The Ni4Ti3 precipitates reach a volume fraction of 9.6% in the reconstructed region of the stress-free alloy and 4.3% in the compressed one. In both cases, the mean volume, specific surface area, sphericity and aspect ratio of the precipitates are calculated and the Pair Distribution Functions of the precipitates are obtained. It is shown that most precipitates in the stress-free sample grow larger and have a more lenticular shape, while those in the compressed sample are more cylindrical. Deviations from these ideal shapes reveal internal steps in the stress-free sample and lamellae formation in the compressed one.

Remarks:

A1.31 | Paper ID – 02011 Regular Oral Presentation | Thursday, Sept. 10, 11.15 - 11.30

Aging effect on martensitic transformation at cryogenic temperatures in Cu-Al-Mn alloy

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Abstract. It has been reported that Cu-Al-Mn shape memory alloy exhibits martensitic transformation (MT) below 77 K by Lovey et al. This suggests that this alloy is one of the promising shape memory alloys for cryogenic applications. On the other hand, MT of Cu based shape memory alloys are strongly affected by aging, due to the migration and annihilation of quenched-in vacancies causing a change in long and/or short range ordered structures. In this study, we have investigated the aging effect on the MT in Cu83-XAl17MnX alloys (X = 10,12,14) by using differential scanning calorimeter (DSC) and electric resistivity (ER) measurements. In Cu71Al17Mn12 aged at 373 K for 0.6 ks, we found that MT occurred at around 100K in ER measurement. And we also confirmed that the transformation temperatures increased with aging temperature and time. In addition, an enthalpy of reverse transformation increased with increasing of aging temperature, but it exhibit no systematic dependence on aging time. The enthalpy of reverse transformation in Cu71Al17Mn12 alloy aged at 423K for 0.6ks (As = 180 K), was estimated to be about 50 J/mol by DSC measurements, and it was much less than that in Cu-Al-Mn alloy transformed around room temperature.

Remarks:

A1.32 | Paper ID – 02015 Regular Oral Presentation | Thursday, Sept. 10, 11.30 - 11.45

Role of Si on the shape memory property of Fe-Mn-Si-C based alloys

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Abstract. The Fe-Mn-Si based shape memory alloys (SMAs) contain about 6% Si (mass%). Although numerous attempts have been made to clarify the positive effects of Si on the shape memory effect (SME), its key role is still controversial. Neel temperature, stacking fault energy, short range ordering, volume change, and solution hardening are among the factors that have been discussed which are affected by the Si addition. From a perspective of the solution hardening against slip deformation, the development of a carbon added SMA (Fe-17Mn-6Si-0.3C) with a better SME than that of the Fe-33Mn-6Si ternary alloy has been reported. Nevertheless, there is no conclusive evidence which indicates that the key role of Si is solution hardening. In the present work, four kinds of Fe-17Mn-xSi-0.3C (mass%) alloys (x=0,2,4,6) are investigated to discuss the solution hardening by Si addition. The SME is evaluated through the process of tensile deformation at ambient temperature followed by heating up to 873K. If the dominant effect of Si is the solution hardening and the additive effects of Si and C to the solution hardening are held, a small reduction of Si content may not affect the SME. However, a mere 2% reduction from 6% to 4% results in a marked deterioration of SME. This indicates that the effect of Si cannot be explained simply by the solution hardening. The role of Si is discussed in more detail along with the results of mechanical properties, transformation temperatures, and lattice parameters.

Remarks:

A1.33 | Paper ID – 02006 Regular Oral Presentation | Thursday, Sept. 10, 11.45 - 12.00

R-phase stabilization in ultra-fine grain NiTi wires after mechanical cycling

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Abstract. Loading-unloading cycles repeatedly induce forward and reverse martensitic transformations B2 <->(R) <->B19' during mechanical fatigue of ultra-fine grained NiTi (50.9 at% Ni) wires. Related stress-strain hysteresis loops exhibit an evolution with increasing number of loading cycles. It has been observed that the upper plateau stress, which corresponds to the forward transformation induced in the loading part of the cycle, decreases considerably during the fatigue life. In contrast, the reverse transformation is characterized by an only moderate drop of the lower plateau stresses before the hysteresis loops attain their saturated shape. Moreover, a permanent plastic strain of the order of 1% accumulates before the process comes to the saturation. An extensive transmission electron microscopy investigation has been performed in the present study in order to account for the observed hysteresis loop evolution on the nano-grain scale. A representative sample of the selected area diffraction (SAD) rings was evaluated for both, the initial state of the wire before the fatigue experiment and the mechanically cycled material. Results of the SAD analysis suggest that the loading cycles stabilize the R phase. However, no evidence can be provided for even a small amount of retained B19' phase after fatigue. Some consequences of these microstructural findings are discussed.

Remarks:

A1.34 Regular Oral Presentation | Thursday, Sept. 10, 12.00 - 12.15

High field magnetisation study of the isothermal martensitic transformation kinetics in maraging steel

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Abstract. We have performed time-resolved measurements of the isothermal transformation kinetics of the austenite phase into the martensite phase in a metastable austenitic steel for temperatures from 4 to 298 K and continuous applied magnetic fields up to 30 T. We observed that the transformation kinetics, which demonstrates a maximum rate at a temperature of about 213 K, can be accelerated several orders of magnitude when high magnetic fields are applied. The transformation rate as a function of magnetic field and temperature gives direct information on the energy barrier for martensite nucleation.

Remarks:

A1.35 | Paper ID – 02024 Regular Oral Presentation | Thursday, Sept. 10, 12.15 - 12.30

Characteristic Feature Found in Typical TATARA Product, Japanese Sword

A. K. Das[1], T. Ohba[1], S. Morito[1], G. Takami[1], T. Fujikawa[1], M. Yaso[2]

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Abstract. TATARA is traditional iron making method developed around San-in area in Japan. Typical product of TATARA is Japanese sword, which is tough and strong and is also known as an art object. It is said that Japanese sword cannot be produced without TATARA iron. Thus microscopic observations of Japanese sword attracted researchers and were performed for example by Tawara with optical microscopy at the beginning of 1900s. Since then a few microscopic observations have been performed but not so many. A lot of knowledge of steels has been accumulated and new equipments, which give information on atomistic scale, have been also developed. Thus the precise microstructural observations of Japanese sword using such as SEM/EBSD have been made and are compared with ordinary steel. The preliminary experiments indicated that the length of martensite block is shorter than ordinary steels and crystal orientation distribution is different from ordinary one.

Remarks:

A1.36 | Paper ID – 02022 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

On the influence of crystal defects on the functional stability of NiTi based shape memory alloys

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Abstract. The cyclic application of the shape memory effect in NiTi based shape memory alloys is associated with a degradation of the functional roperties. In the present work, we show how the functional stability of NiTi based shape memory alloys depends on various microstructural defects like grain boundaries, dislocations and substitutional elements (Fe replacing Ni). As a general trend, it was observed that thermal cycling results in a decrease in phase transformation temperatures. Nano-grained microstructures provide a significantly higher functional stability than coarse grained microstructures due to reduced dislocation activity. Cold work impedes phase transformation processes and provides a slight improvement of the functional stability. Fe additions to NiTi are associated with the occurance of two-step transformations (cooling: B2 $\Rightarrow$ R $\Rightarrow$ B19', heating: B19' $\Rightarrow$ R $\Rightarrow$ B2) which allow partial thermal cycling (B2 $\Leftrightarrow$ R and R $\Leftrightarrow$ B19'). We show that B2 $\Leftrightarrow$ R cycling has a better stability than R $\Leftrightarrow$ B19' cycling due to a better crystallographic compatibility between B2 and R.

Remarks:

A1.37 | Paper ID – 02017 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

The influence of defects and composition on the electronic structure and magnetic properties of shape memory Heusler alloys

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Abstract. The electronic structure and magnetic properties in the Ni2MnZ series, where Z=Al, Ga, In, Sn, Sb, are studied using the first first-principles methods within density functional theory. The formation energies of several kinds of defects (atomic swaps, antisites. vacancies) are estimated. It is shown that Ni-antisites on the Mn sublattice have the lowest formation energy in the investigated series.

Remarks:

A1.38 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

The features of stress-induced B2-B19' martensitic transformation in [001]-oriented Ti-Ni single crystals

E. Y. Panchenko[1], Y. I. Chumlyakov[1], H. J. Maier[2], I. Karaman[3]

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Abstract. In the present study the effects of crystal axis orientation, test temperature, size and volume fraction of Ti3Ni4 dispersed particles on the shape memory effect (SME) and superelasticity (SE) of Ti-Ni single crystals in quenched and aged state. Ti-Ni crystals oriented along [001] directions possess high-strength in the B2-phase because the Schmid factor for active a<100>{110}slip systems is equal to zero, and thus, dislocation slip is suppressed. For the first time it was observed that in [001]-oriented Ti-50.6 at. % Ni crystals the SME strain can reach 6.2 % in tension in quenched state and aged state if particles with a size of 20-40 nm were present. This value exceeds the previously reported value for the B2-B19' martensitic transformation (2.7 %). This more than two-fold increase can be rationalized by deformation twinning of B19'-martensite on {100}, {201}, {113} planes. These deformation twins can disappear at reverse transformation at heating. By contrast, in "soft" orientations like <111>, <011>of this processes is suppressed because of dislocation slip activity. It could be demonstrated that in quenched Ti-Ni crystals the conditions for the occurrence of the SE are achieved only in the high-strength crystals oriented near the [001] direction. However, hardening of the B2-phase by dispersed particles leads to the occurrence of SE for all orientations. In the aged [001]-oriented crystals, the temperature interval of SE is 50 K higher than in the "soft" orientations.

Remarks:

A1.39 | Paper ID – 02003 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Intragranular austenite orientation evolution of a Cu-Al-Be SMA during an in-situ tensile test

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Abstract. Previous studies we performed on Cu-based SMA have pointed out a huge heterogeneity of austenite stress state inside a grain. In that study, we focused on the evolution of the austenite intragranular crystallographic orientation during in-situ tensile test. Measurements were done using synchrotron radiation (3DXRD technique and the Laue microdiffraction) at the ESRF. The 3DXRD gives access to the lattice rotation; the spot size is 200*200microns. For the first time, this technique was extended to phase transformation materials, with evolving phase volume fraction. We obtained that the austenite cell rotates slightly in the elastic domain and more significantly as the martenistic transformation occurs; the formation of sub-domains with an orientation different from the mean one is also observed. Unloading, a reverse rotation takes place. The rotation magnitude depends on the crystallographic orientation: it can reach up to 3°. To identify the origin of sub-domains formation, we used the Laue microdiffraction. Thus austenite orientation map can be drafted during in-situ tensile test. We confirm that the austenite orientation rotates and heterogeneities appear : from one side to the other side of a martensite plate, two different orientations were measured in the austenite. This shows a strong interaction between the martensitic transformation and the austenite state. These results were compared then to macroscopic diffraction peaks broadening.

Remarks:

A1.40 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Intermartensitic transformations - measurement of In-situ deformations

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Abstract. Using in-situ digital image correlation to obtain full-field measurements, we studied the intermartensitic transformations in single crystal NiFeGa. Full-field strain measurements identified the coexistence of modulated martensite phases during the first plateau of the multistage stress-strain curve at room temperature. At a higher temperature, the measurements indicated the bypassing of one of the modulated phases. Strain as high as 13% was measured as a result of the transformation to the intermediate monoclinic modulated and final tetragonal phase. Based on the full-field strain measurements, the phase fractions during the nucleation and the progression of the transformation were obtained. The evolution of the local strain and the phase fractions proved critical in explaining strain softening, hysteresis and other phenomena observed in the stress-strain curves. Stress-induced martensitic transformations are also clarified in classes of NiMnGa alloys. Meso-scale DIC measurements quantify inter-martensite strain levels, which are indistinguishable from macro-scale stress–strain and strain–temperature responses.These results, obtained from DIC, would prove difficult and in some instances impossible to obtain using other conventional techniques.The DIC technique has far-reaching implications for phase identification, strain measurements, and heterogeneous deformation in new materials displaying complex mechanical response.

Remarks:

A1.41 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Influence of low-temperature annealing on martensitic transformation kinetics in Ti50Ni50 shape memory alloy

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Abstract. Effect of annealing at low temperatures in range of 120 ˚ C - 300 ˚ C on kinetics of martensitic transformation is studied in TiNi shape memory alloy. It is found that keeping samples at low temperatures results in a decrease of the martensitic transition temperatures. The lower is temperatures of annealing the stronger is a decrease of martensitic transformation temperatures. It is observed that annealing affects not only the kinetics of the phase transformation but the sequence. For instance, before annealing alloy undergoes B2 - B19' transformation but after annealing at 150 ˚ C for 4 hours B2 - R -B19' transitions are observed. The higher is the temperature of annealing the larger duration is needed to induce the direct transformation through the R phase. Moreover it is found that low-annealing assists in stabilization of characteristics of phase transitions during thermal cycles. The X-ray study has shown that no precipitates appears during the annealing. Apparently the variation of defects distribution is responsible for influence of low-annealing on the martensitic transformation kinetics.

Remarks:

A1.42 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Influence of experimental procedure on Clausius - Clapeyron relation for R-B19' transformation in Ti49.2Ni50.8 alloy

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Abstract. According to a theory of non-equilibrium thermodynamics of martensitic transformations, the non-chemical correction to Clausius – Clapeyron relation should result in a dependence of proportional coefficient between stress and Ms temperature on an experimental procedure and thermal mechanical history of alloy. This work is devoted to an experimental examination of this statement. In this study the R - B19' transition has been realized in Ti49.2Ni50.8 single crystal by two ways: on cooling under a constant stress or on deformation at a constant temperature. The simultaneous measurements of temperature, strain, stress and resistivity have been carried out during the experiments. The temperature of martensitic transformation Ms has been determined from a resistivity dependence on temperature and the stress necessary to induce the R - B19' transition has been determined from a resistivity dependence on strain. As expected, the relation between stress and Ms is linear independently on the experimental procedure. However the proportional coefficient is found to be different. The results have shown that the lower stress is necessary to initiate the R - B19' transition during isothermal deformation than during cooling under a constant stress.

Remarks:

A1.43 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Ageing under compressive stress in Co-Ni-Ga single crystals

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Abstract. The pseudoelastic behaviour of a Co49Ni21Ga30 ferromagnetic shape memory alloy under compression along [100] and [110] has been studied in the temperature range 300 – 650 K. In such a crystals, the effect of ageing under a constant stress close to the critical stress to induce the martensitic transformation (MT), produces its separation in two stages. This is due to the different ordering behaviour of parent and martensite under ageing. Increasing order of parent phase leads to a decrease of transformation temperatures, therefore raising the critical stress to induce the transformation, whereas ageing of martensite produces its stabilization – increase of MT temperatures -. It is remarkable that this stabilization has a very slow recovery, as compared to other alloys systems. Examples of the effects of ageing at 485 K on both stress and temperature induced MT will be given. Precipitation takes place under ageing at $T \geq 550$ K. Simultaneous application of stresses well below the critical stress to induce the transformation, leads to the growing of oriented precipitates in the parent phase. Stresses in the range 150 – 550 MPa, at temperatures between 620 and 770 K have been applied for different times. The effect of these treatments on the microstructure and the pseudoelastic behaviour are analized.

Remarks:

A1.44 | Paper ID – 02012 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Transformation behavior of low temperature crystallized TiNi shape memory alloy films

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Abstract. TiNi shape memory alloy (SMA) films are expected to be promising material for micro actuators in micro-electro mechanical systems because their work output per volume exceeds that of other micro-actuator materials. TiNi SMA films are commonly produced by using a high temperature (above 723 K) annealing process during and/or after deposition in order to promote crystallization. Therefore, the films could not be deposited on unstable materials at high temperature. In this paper, we report on transformation behavior of TiNi SMA films sputter-deposited on Si(001) and polyimide substrates. An RF magnetron sputtering system equipped with four separate confocal sources as well as with a heating and ion-irradiating system for substrates was used to make the films crystalline. Without using the system, the films deposited on ambient-temperature substrate have been amorphous. However, we find that by crystallized film is deposited even at 473 K of substrate temperature applying pulse bias voltage to the substrate. Shape memory effect of the crystallized film which was sputter-deposited on a polyimide film of 0.025 mm in thickness was observed. From the relationship between the normalized curvature of film and temperature, it was recognized that the start and finish temperatures of shape changes were 353 K and 383 K on heating process, respectively. While on cooling process, its reverse shape changes were observed. The shape was recovered to the original curvature at about 363 K.

Remarks:

A1.45 | Paper ID – 02016 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

The structure and functional properties of Ni–Ti–Cu alloy rapidly quenched ribbons with different parts of crystalline phase

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Abstract. The structure and thermomechanical properties of NiTiCu partially crystallized rapidly quenched ribbons are studied in the present paper. The technique of controlled isothermal annealing in the differential scanning calorimeter was used for production of the samples with determined relations of extracted thermal energies to the full crystallization energy. The thermomechanical properties were studied in temperature interval -100..100 C. It was found that temperature dependence of bend deformation demonstrate hysteresis for the samples with more then 29% of crystalline phase. The shape memory effect manifests itself in these samples. The value of the reversible strain rises with the crystalline phase increase. The TEM studies show that crystallites have spherical shape in samples with 15% crystalline phase. Their sizes vary from 100 to 600 nm. The DSC studies show peaks corresponding to the direct and reverse martensitic transformation at temperatures Tam = 15C, Tma = 29C. The accretion of crystallites with plane boundaries formation was observed in samples with 29% of crystalline phase. The martensitic transformation is suppressed in crystallites less than 300 nm at room temperature. The structure of martensitic twins was observed in big (~ 1 μm) crystallites. The transition zone between crystal and amorphous phases of the alloy on crystallites' boundaries was studied by HRTEM technique. The model for the description of the transition zone width and structure is discussed.

Remarks:

A1.46 | Paper ID – 02037 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Boron nanotubes and their properties: semiempirical investigation

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Abstract. The problem of formation possibility nanotubular structures is actively discussed now. We considered the fragments of single-wall boron nanotubes (n, n) (n=4, 5, 6, 9, 11, 12). Calculations were carried out by IB-CCC method. The analysis of band-gap showed that all of them are semiconductors. Energy of deformation decreases with increase of the diameter of B-tubes (n, n). We considered the B-nanotubes (n, 0) (n=4, 5, 6, 8, 12). In this case deformation energy is increases with increase of the diameter of tubes (n, 0). Calculations of boron tube (6, 6) which contained various defects of structure were obtained by the semiempirical MNDO scheme. We research substitution imperfection of B atom by atom C, ions C+, C-. We found out substitution energy of defects and its energy level. We studied the B-tube with atomic vacancy and determined the energy of defect activation and the relative portion of vacancies.At the moment active search of new surface structures capable of effective adsorption of different gases is being carried out. We have investigated an binding opportunity between the H, F, O, Cl atoms and the outer surface of B-nanotube (6,6) and have studied the mechanism of this process. The calculations are carried out with the use of quantum chemical MNDO scheme. Regular hydrogenation of boron nanotubes was investigated. We can confirm that generation of gas-phase hydrogen composite materials based on boron nanotube is possible.

Remarks:

A1.47 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Paramagnetic to ferromagnetic transition of He+ ions irradiated stainless steel studied by XMCD: A new perspective for early stage detection of defects in solids

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Abstract. The Fe-Cr-Ni-Mo alloys find applications in many industrial processes and not last are suitable candidates for Generation IV and fusion reactors vessels. The investigation of the magnetic transitions, paramagnetic to ferromagnetic, frustrated spin glass and anti-ferromagnetic in this class of materials is of high interest to meet the challenges of developing advanced materials resistant to irradiation. In this frame we investigated the possibility to use X-ray magnetic circular dichroism to study the magnetic properties of stainless steel 316 before and after irradiation with He+ ions with a nominal fluence of 5x10ˆ15 ions /cmˆ2. The combination of microscopic and spectroscopic techniques together with molecular dynamics simulations gives important information about the paramagnetic-ferromagnetic transitions at an early stage. The atomic specificity of synchrotron based x-ray magnetic circular dichroism (XMCD) open new perspectives in understanding the transformation of irradiated alloys at the atomistic level. The results show a different behaviour under irradiation of the single alloy components.

Remarks:

A1.48 | Paper ID – 02032 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

3D strain fields surrounding Ni4Ti3: direct measurement and correlation with the R-phase

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Abstract. Strain fields introduced by coherent Ni4Ti3 precipitates in austenitic NiTi are believed to be a possible origin of why the R-phase transformation is introduced as an extra step before transforming to the B19'. The presence of this strain field was already confirmed in the past by conventional transmission electron microscopy (TEM) techniques and measured quantitatively by high resolution TEM (HRTEM). This time the geometrical phase method is applied on HRTEM micrographs to measure the full 3D strain tensor of the strain fields. Since each atomic resolution micrograph only results in a 2D measurement of the strain, observations in two different zone orientations are combined to retrieve the 3 x 3 strain tensor. In this work observations in a [1-1 1]B2 and [1 0-1]B2 zone orientation are used and this in case of precipitates with a diameter around 50nm. In a next step the measured strain tensor is compared to the calculated eigenstrain of the R-phase in reference to the B2 matrix. This comparison shows that the introduced strain is very similar to the eigenstrain of one R-phase variant. Since for both structures: Ni4Ti3 and R-phase four orientation variants are possible, each variant of the R-phase is able to accommodate the strain field of one of the Ni4Ti3 variants.

Remarks:

A1.49 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Deformation-induced phase transformations in Ni3Al and Fe3Al

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Abstract. Phase transformations induced by trigonal deformation in Ni3Al and Fe3Al intermetallics were studied from first principles. The ground-state configuration of Ni3Al is the L12 structure, cP4(221), whereas Fe3Al exhibits the D03 structure, cF16(225). As both compounds are very similar in many respects we investiaged both of them in both above-mentioned structures. If a uniaxial loading along the [111] direction is applied to those structures, the cubic symmetry is lost and may re-appear at a special value of strain, where another high-symmetry structure is encountered. When applying a trigonal compression to the L12 (cP4) structure, where the atoms occupy the fcc positions, we hit the cI8 structure with atoms at the simple-cubic positions. In contrast, the trigonal deformation of D03 lattice does not lead to any high-symmetry structure. The calculated values of the ideal tensile strength (for a uniaxial deformation of a defect-free solid along the [111] direction) is very closely related to the above-mentioned phase transitions. For Ni3Al it amounts to 29 GPa, for Fe3Al it is equal to 20 GPa. As to the magnetic behavior, Ni3Al looses its ferromagnetic ordering at some strains, whereas Fe3Al remains ferromagnetic in the whole region of volume and shape deformation studied. This is explained by means of Stoner model and by local environmental analysis, i.e. by investigating the number and type of atoms in the first coordination spheres.

Remarks:

A1.50 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

TEM study of martensite-β phase habit planes and their OR in Cu-Al-Ni SMA by a fast method

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Abstract. The austenite-martensite interphases are usually determined by the phenomenological theory (PT). In the present work we propose a new method to determine the habit plane (HP) and the orientation relationship (OR) between the β phase and the martensite plate. This method is based in the fast Δg method proposed to characterize the interphases during precipitation /1/. A Cu-13,70Al-5,00Ni (wt%) in martensite phase at RT was heated during the Transmission Electron Microscopy experiments at 363K in order to show simultaneously the γ'3 or β'3 martensite and the β phases. An experimental study of several habit planes and orientation relationships has been realized. Then, an analysis of the interphases in the reciprocal space shows that they cannot be univocally determined by the two-dimensional edge-to-edge method. Finally we propose a new method to determine the irrational interfaces /2/. It only requires one selected area diffraction pattern on the edge-on interface and a three dimensional simulation in the reciprocal space for both structures. The good fit between the obtained results and those predicted by the PT shows that both theoretical approaches are equivalent. Although the PT also offers information about the strain matrix transformations the present method offers the advantage of being quicker to perform, so both methodologies could be complementary. /1/ E. Conforto, D. Caillard; Acta Materialia 55 (2007) 785 /2/ M.L. Nó, D. Caillard, J. San Juan; Acta Materialia, 57 (2009) 1004-1014

Remarks:

A1.51 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Martensitic transformation kinetics in a Cu-Al-Ni shape memory alloy

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Abstract. A single crystal of Cu-Al-Ni shape memory alloy has been studied by adiabatic calorimetry. When cooling from the common parent phase it shows two martensitic phases β'-3 and γ'-3. The specific heat behaviour around the forward and the reverse phase transformations has been carefully observed by means of dynamic experiments by using very low thermal rates of about 4K/h. These have permitted the analysis of the double-step reverse transformation which takes place in two independent temperature ranges. Due to the noticeable differences in the thermal hysteresis shown by both processes, their forward transformation takes place simultaneously leading to complex nucleation kinetics. The calorimetric signal provides the basis for a quantitative analysis of this phenomenon. It allows for a careful estimation of the successive latent heat release following any individual transformation event, characteristic of the γ'-3 plate nucleation in single crystals. Moreover, the interacting (β'-3)-(γ'-3) nucleation has been observed. Due to this coupling, the martensitic transformation is strongly affected by the various cooling processes, which lead to very different martensite microstructures. As a consequence, the reverse transformation shows non repetitive calorimetric results, with different (β'-3) /(γ'-3) ratio. However, the latent heat of the total martensitic transformation remains unchanged.

Remarks:

A1.52 | Paper ID – 02009 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Effect of aging and solution annealing on transformation and deformation mechanism of superelastic Ti-50.9at.% Ni alloy in nanoscale

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Abstract. Effects of aging and solution annealing treatment on the super elastic respond of the cold-worked Ni50.9% -Ti thin wire was studied in nano scale utilizing instrumented nanoindentation. The nanoindentation results were coupled with the tensile test results to provide better insight to the governing deformation mechanisms. The first applied heat treatment consisted of solution annealing treatment (850 ˚C for 60 minutes) followed by aging at 450 ˚C for 30 minutes and as second heat treatment the cold-worked wire was aged at 450 ˚C for 30 minutes with no prior solution annealing treatment. Both tensile test and nanoindentation results showed better super elastic behavior for the wire subjected to second treatment. Indentation displacement bursts were observed in loading course after both treatments. However, slope changes in unloading course of indents were recorded after second heat treatment which might be due to reverse phase transformation. Surface asperities on the post-indented surface after first treatment were observed far away from indentation stress field by atomic force microscopy.

Remarks:

A1.53 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Austenite arrest in Ni-Mn based shape memory alloys

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Abstract. Ferromagnetic Ni-Mn based shape memory alloys undergo martensitic transformation and exhibit magnetic shape memory, magnetic field induced strain and kinetic arrest. In the presence of a cooling magnetic field applied in the austenite state influences martensite nucleation. Even at low temperatures a rest-austenite phase can be observed. We report on the results of temperature-dependent strain and neutron diffraction and discuss austenite arrest.

Remarks:

A1.54 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Influence of Co and Fe addition on Ni-Mn-Ga ferromagnetic shape-memory alloys

D. E. Soto Parra[1], X. Moya[2], L. Mañosa[2], A. Planes[2], F. Alvarado Hernandez[3], H. Flores Zúñiga[3], R. Ochoa Gamboa[1]

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Abstract. We present a comparative study of the effect of Fe and Co substitution on the magnetic and structural transitions in Ni-Mn-Ga alloys from calorimetric and ac-magnetic susceptibility measurements. Phase diagrams corresponding to substitution of each element by Fe and Co have been determined. While valence electron per atom concentration is still the essential factor governing phase stability, our results show that the addition of both Fe and Co elements modifies the relative stability of the different phases available to the studied system. Addition of Fe results in a shift of the magnetic transition to higher temperatures and in a shift of structural transitions to lower temperatures. The effect of Co is more complex and strongly affects the stability of intermediate and intermartensitic phases.

Remarks:

A1.55 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

HRTEM analysis of ultrafine stand-alone Ni-Al spark erosion powder particles

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Abstract. Crystal structure and chemical compositions studies of ultrafine Ni-Al powders with the nominal composition of Ni64-Al36at.% obtained by spark-erosion method in liquid argon were made by the methods of analytical and HR TEM. The particles with the sizes between 5 and 200 nm have spherical shape and appear both in an agglomerates and separately. As-processing particles are covered with the oxides layers of 1-3 nm, which increase with the time of storage of powder. While the relative composition of Ni and Al is very stable, the absolute value is not due to the difference in the amount of oxygen.The average content of Ni and Al in separately particles is Ni64.6-Al36.4at.% , which is close to the master alloy content. Many of the nano-size particles have distinct twinned structure like martensitic transformation microtwins. The atomic structure of such twinned particles could be treated as L10 structure typical for Ni-Al alloys with such composition. Because of L10 and Ni5Al3 structure are very similar and also the chemical composition of the particles is close to Ni5Al3, one cannot exclude that the particles have Ni5Al3 structure. Other arguments confirm hypothesis about martensitic structure of particles: a) – at this composition, the martensitic transformation occurs above 300°C; b) – during the spark erosion processing rapid quenching in liquid argon provides rather martensitic transformation in the particles than diffusion controlled formation of Ni5Al3.

Remarks:

A1.56 | Paper ID – 02031 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Structural behavior of Ni-Mn-(In, Sn) Heusler alloys melt spun ribbons

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Abstract. In present contribution we discuss the structural properties of the austenite and martensite phases that form in as-spun ribbons of some selected compositions of the ternary system Ni50Mn50-x((In,Sn)x, their characteristic crystallographic texture and the effect of vacuum annealing. X-Ray diffraction analysis showed that in all the cases austenite crystallized in an ordered cubic L21-type structure. For thermally annealed samples diffraction lines becomes narrower in comparison with those of as-quenched samples, cell parameters tend reduce and crystallographic texture is preserved and improved. Furthermore, the structure and the martensitic temperature transformation can significantly differ from that of bulk alloys. Thus, materials with different structure, magnetoelastic behavior and transformation temperatures can be produced by melt spinning controlling starting composition and quenching conditions. In textured ribbons, the columnar, almost 1-dimensional, shape of the grains makes structural changes more difficult than in bulk materials (3-dimensional shape), thus explaining the differences observed in their structure and temperature magnitudes involved.

Remarks:

A1.57 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Heat treatment induced oxidation of near-equiatomic NiTi

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Abstract. This study investigated the oxidation behaviour of a Ti-50.5at% Ni alloy in dry air environment during heat treatment. It was found that heating in air to elevated temperatures resulted in the formation of 4 zones including, in order from the surface to the interior of the sample, a pure TiO2 layer, a composite layer comprised of TiO2 and Ni(Ti), a thin layer of TiNi3, and finally a Ti-depleted zone in the matrix of the alloy. The mechanisms for the formation of these layers are discussed in terms of diffusion and reaction thermodynamics. Based on the analysis it is concluded that the oxidation process evolves in three consecutive stages: (i) the formation of TiO2 and depletion of Ti in the surface layer, (ii) appearance of TiNi3, (iii) appearance of the composite layer, which signifies the beginning of the steady state of the oxidation process. The effects of the formation of these layers on the transformation and deformation behaviour of the alloy were also characterised.

Remarks:

A1.58 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Interfacial characteristics of stress induced martensitic transformations in TiNi shape memory alloys

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Abstract. The basic conditions of the materials which show the shape memory effect are as follows: the martensite proceeds thermoelastically and the lattice invariant strains in the martensite phase are not dislocations but twins. The self accommodating characteristics of the martensite variants studied in stressed (30% cold rolled without subsequent annealing) and unstressed (cold rolled with annealing) in Ti-49.83 at. % Ni Shape memory alloys with the help of the optical microscopy, SEM, tensile test, and XRD studies. As is well known, the thermal martensite variants exhibit self-accommodation morphology in the specimen before cold rolling deformation, with the various twin boundaries straight and well-defined. Between the R-phase and B2 parent phase, there are four equivalent lattice correspondence with respect to the, [010]H , and [001] H and plane of the (0001) H , normally hexagonal lattice directions of the [100] H structure designated as a twin planes instead of martensites. The resulting four orientation variants of the R-phase are twin related to each other and there are two types of twin relations. The one is (1121) H [112] H type compound twin and the other is the(1122) H [111] H type compound twin. Any two type of the 4 variants are twin related by either one of there two schemes. Self accommodations of the R-phase is achieved by arranging these twin-related four variants around one of the <001>B2 in axes.

Remarks:

A1.59 | Paper ID – 02018 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

In-situ XRD investigations of two step R-phase transformations in aged NiTi shape memory alloys

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Abstract. The characteristics of R-phase transformations in aged Ti-49.83 at% Ni (Nitinol) shape memory alloys at 300ºC were explained with the help of Differential scanning Calorimeter (DSC) and In-situ X-ray Diffraction (In-situ XRD) studies. The solutionized and short duration aged samples (0 h and 48hrs) did not alter the B2-B19' transformation path and medium aged samples (72 and 96 hrs) exhibit single-step R-phase with B2-R-B19' transformation path and pro-longed aged sample (125 hrs) evolves two-step R-phase transformations with B19'↔R1↔R2↔B2. The carefully crafted in-situ XRD studies showed emerging of B2 (110) phase from merging of R (011) and R (-101) at 100ºC and it is equal to the transformation temperature determined by the DSC experiments. The two-step R-phase transformation behavior is attributed to structural inhomogeneity of the matrix, both in terms of composition and of internal stress field, caused by the formation of Ni4Ti3 precipitates.

Remarks:

A1.60 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

An evolution of an ordered TiNi3 precipitates in aged TiNi shape memory alloys

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Abstract. The ageing characteristic of the Ti-49.84 at.% Ni shape memory alloys investigated in this present study. The intermetallic TiNi3 precipitates was observed in low temperature aged TiNi shape memory specimens. The existence of TiNi3 precipitates was confirmed with the help of XRD phase index pattern. The microstructure of the TiNi3 precipitates were observed as small dots, eventually distributed in a regular array of matrix along the grain boundary and interior of the grains with the help of SEM pictures. The TiNi3 phase has the hexagonal DO24 type ordered structure. The lattice constants are a=0.5010 nm, c=0.83067 nm and c/a=1.6284 with the space group of P63/mmc. The formations of the ordered TiNi3 phase involves local segregation of Ni atoms from the TiNi (B19') matrix along the (201), (202), and (220) planes, which was confirmed from the XRD analysis. The DSC study of this specimen shows an exothermic peak on heating cycle suggests that formations of an unexpected peaks. Based on the DSC study, an evolution of the exothermic peak confirms that the formations of the DO24 type ordered structure of the TiNi3 precipitates. This paper proposes a new transformation path which includes ordered H-phase (TiNi3) along with R-phase transformation occurs in aged TiNi shape memory alloys: B19'→H→R→B2 [2]. The formations of the DO24 type ordered (H-Hexagonal) structure involves diffusional transformations. The nucleation energy required for the formations of the H-phase is higher.

Remarks:

A1.61 | Paper ID – 02020 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

B19-phase transformations in aged NiTiCu shape memory alloys

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Abstract. This paper gives details about the B19-rhombohedral martensitic transformations in TiNi44.5Cu5.5 Shape Memory Alloys (SMA) aged at 1500C. The martensitic phase transformation sequences observed in this present study by using differential scanning calorimeter (DSC) as follows: As-solutionized and aged for 4 hrs samples exhibits B19↔B2; Aged for 24 h, 48h and 72 h sample exhibits B19↔B19'↔B2 and pro-longed aged sample for 96 hrs exhibits B19'↔B2 transformations. The strong diffraction peak can be identified as the (020)B19 in TiNiCu aged at 150ºC for 24 hrs. It is clear from X-ray diffraction phase analysis formation of equilibrium Ni3Ti (S.G. P63/mmc (194), Hexagonal crystal structure) precipitates reaches maximum counts with (020) plane in aged for 48 h sample as compared to the aged for 24 h sample. The high DSC values (J/g) of the exothermic peak was recorded in aged for 48 hrs samples was concluded formations of the B19' martensites.

Remarks:

A1.62 | Paper ID – 02035 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Study of decomposition of thermoelastic and non-thermoelastic martensite in Cu-Zn-Al alloys

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Abstract. Cu based alloys are considerable traditional material with good shape memory effect. Reversal thermoelastic transformation from parent phase to martensite is necessary requirement for taking place of shape memory effect. The significant phase for taking place shape memory effect in Cu-Zn-Al alloy is ordered β phase with ideal ratio of valence electrons to atom e/a=1,48. The alloys with ratio e/a lesser than 1,42 after quenching from single phase β region undergo non-thermoelastic martensitic transformation and thereby don't possess shape memory effect. That can be obtained by quenching from dual phase α+β region. The paper deals with comparison of decomposition at elevated temperatures of thermoelastic and non-thermoelastic martensite to more stable products. Influence of stabilization of martensite on decomposition at elevated temperatures is also studied. Depending up initial state of material and condition of decomposition it can be possible to obtain structure containing α and β or γ phase with miscellaneous morphology. It can be used for example for modification of definitive structure or for modification of structure before another heat treatment. Study of differences between thermoelastic and non-thermoelastic martensities can be useful for intensification of shape memory properties of Cu based alloys.

Remarks:

A1.63 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Strain glass induced by nano-sized particles in aged Ti48.7Ni51.3 alloys

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Abstract. Strain glass, a frozen short-range strain-ordered state reported very recently, has been suggested to originate from the existence of sufficient amount of point defects (or dopants) in a ferroelastic system. These point defects creates high frustration and hence result in the formation of strain glass. Here we report that dispersed nano-sized particles can also lead to a strain glass. In the present study, we studied a Ti48.7Ni51.3 alloy, which undergoes a normal B2-B19' ferroelastic or martensitic transition in a solution-treated (i.e. precipitation-free) state. We found that when nano-sized Ti3Ni4 precipitates were introduced into the alloy by a low-temperature aging treatment, the sample showed no sign of martensitic transition. However, ac elastic modulus shows a frequency-dependent dip at Tg, which obeys Vogel-Fulcher relationship. A zero-field-cooling/field-cooling measurement of the static strain showed a characteristic broken ergodicity around Tg. All these results suggest that this heterogeneous system undergoes a strain glass transition, which may be related to the fine-scale frustration introduced by nano-sized precipitates. Our finding shows that strain glass can be formed by introducing nano-sized precipitates into a normal ferroelastic system. The present work may have the implication that similar precipitate-induced glass formation may be found in other ferroic glasses like cluster spin glass and ferroelectric relaxor.

Remarks:

A1.64 | Paper ID – 02014 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Structural and microhardness changes during long-term storage of Ti-Ni shape memory alloys after plastic deformation

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Abstract. Quenched Ti-50.26at.% Ni and Ti-50.6at.% Ni shape memory alloys samples were subjected to cold rolling (CR) with true strains from moderate (logarithmic thickness reduction e = 0.25) to severe (e = 2.1). The evaluation of structural changes in the material during its long-term storage was performed using Vickers microhardness (HV), Differential Scanning Calorimetry (DSC) and X-ray diffraction techniques. It was shown that during storage, microhardness varied following a dome-shaped trend, thus reflecting the commonly encountered interaction between two concurrent time-dependent phenomena, the first responsible for material post-deformation hardening, and the second, for material post-deformation softening.

Remarks:

A1.65 | Paper ID – 02013 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Structure development in Co38Ni33Al29 ferromagnetic shape memory alloy

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Abstract. In the present study, a set of the directionally solidified samples from ferromagnetic shape memory alloy with the nominal composition Co38Ni33Al29 was prepared using the Bridgman method. It is shown that various growth rates result in various solidification structures of the crystals, mainly in different ratios of the disordered phase γ - cobalt solid solution and the ordered phase β - B2 (Co,Ni)Al. This ratio has the fundamental effect on the temperature of the martensitic phase transition. The results are compared with the structure of samples prepared by the floating zone method. The structures of samples prepared with the different growth rate were studied by metallography, SEM, EDX, and EBSD methods. The samples without high-angle grain boundaries were cut from the prepared crystals for the mechanical testing.

Remarks:

A1.66 | Paper ID – 02002 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

On the temperature and stress dependence of transformation strain in single crystalline Cu-Al-Ni shape memory alloys

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Abstract. In the austenite to martensite phase transformation of shape memory alloys the transformation strain, ϵ_tr, usually has definite dependence on the external fields while the change in entropy or volume can be considered constant. Under uniaxial loading this dependence of ϵ_tr is related to the change of the martensite variant distribution with increasing field parameters. The stress and temperature dependence of the elastic and dissipative energy contributions to the transformation can be correlated with the η dependence of ϵ_tr, where η is the volume fraction of the stress induced (single) variant martensite structure. Obviously, this dependence leads to deviation from the linear Clausius-Clapeyron relation too. In this paper we discuss and compare experimental results in single crystalline Cu-17.9wt.% Al-2.6wt.% Ni and Cu-11.5wt% -Al5.0wt% Ni alloys obtained from stress-strain and strain-temperature hysteretic loops at different constant temperatures and stresses, respectively. Furthermore, it is shown that the field dependence of ϵ_tr is reflected in the field dependence of the dissipative and elastic energy terms too.

Remarks:

A1.67 | Paper ID – 02029 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Pinning of martensitic microstructures by dislocations in Cu74.08Al23.13Be2.79

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Abstract. A single crystal of Cu74.08Al23.13Be2.79 undergoes a martensitic phase transition at 246K and 232K under heating and cooling, respectively. Surprisingly, the martensite phase is elastically much harder than the austenite phase showing that interfaces between various crystallographic variants are strongly pinned and can not be moved by external stress while the phase boundary between the austenite and martensite regions in the sample remains mobile. This unusual behavior was revealed by Dynamical Mechanical Analysis and Resonant Ultrasound Spectroscopy. Transmission Electron Microscopy shows that the pinning is generated by dislocations, which are inherited from the austenite phase. Such dislocations can hinder the movement of stacking faults in the 18R martensite structure or twin boundaries between martensite variants.

Remarks:

A1.68 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Stress-induced strain-glass to R transition in Ti-Ni-Fe strain glass

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Abstract. Strain glass was recently discovered in a Ni-rich Ti-Ni system, which possesses a frozen R-like local strain order. It was further found very recently that the strain glass can undergo a stress-induced transition into normal B19' martensite, and such a transition is the origin of a new kind of shape memory effect (SME) and superelasticity (SE) in these strain glass alloys. In the present work, we show that such a stress-induced strain glass to martensite transition also exists in Ti-Ni-Fe strain glass system. However, in this system the transition is from a frozen R-like state into a normal R martensite, based on tensile test, in-situ XRD, TEM experiments. Furthermore, we provide a phenomenological explanation for why such stress-induced transition can happen and why the transition product is R rather than B19' in our Ti-Ni-Fe strain glass. We show that such a difference arises from the competition in the thermodynamic stability between the R-phase and B19' martensite. Our model suggests that stress-induced STG to a long-range strain order may be a general phenomenon for strain glasses, and it may also provide insight into similar field-induced transitions in other ferroic glasses like ferroelectric relaxors.

Remarks:

A1.69 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Layer modulation and martensitic transformation in epitaxial Ni2MnGa films

Y. Luo[1], K. Samwer[1]

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Abstract. Epitaxial films Ni2MnGa were sputtered at 550°C onto MgO(001) substrates. Results from x-ray diffraction (XRD) and scanning electron microscopy demonstrate a low-symmetric and layer-modulated martensitic phase at room temperature (RT) with an orthorhombic lattice of a=0.624nm, b=0.573nm and c=0.544nm respectively. The twin orientation is 45°to the substrate with a twin width of about 40nm and 110nm measured for the film of 120nm and 400nm respectively. The film concentration was determined by EDX, having 51.2% Ni, 29.6% Mn and 19.2% Ga. In-situ heating XRD measurements were carried out up to 350°C to show a martensitic transformation. It starts at about 200°C and ends at 220°C with a cubic austernite (A) phase (a=0.584nm). The transformation is reversible, as can be followed by intensity oscillation surrounding the (400)A reflection with a temperature rocking slightly up and down the transition temperature. A hysteresis temperature was found to be about 10°C by cooling the film. Additionally, an intermartensitic transformation below RT could be identified by SQIUD and resistive measurements. Influences from the film thickness and precipitations were observed and discussed. (Supported by BMBF-project 13N10061 MSM-Sens)

Remarks:

A1.70 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Shape memory effect in Fe-X% Mn-5% Cr-5% Co-Y% Si melt-spun ribbons

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Abstract. The effects of solidification structure and alloying element on the shape memory effect have been studied in Fe-X% Mn-5% Cr-5% Co-Y% Si alloy ribbons which was fabricated by melt-spinning process. Two-way shape memory effect(TWSME) as well one-way shape memory effect(OWSME) is revealed in the melt-spun ribbons, and both TWSME and OWSME depands on grain size and alloying element. Both SMEs increase with decreasing grain size because of the supression of thermal epsilon - and α'-martensites. Mn and Si have effective alloying elements for improving TWSME and OWSME in melt-spun Fe-X% Mn-5% Cr-5% Co-Y% Si ribbons. However, OWSME increases with increasing Mn and Si contents but TWSME increases only with increasing Si content. The TWSME revealed in the melt-spun ribbon might be related to the reversibility of strain induced ϵ-martensite slowing distinctive morphology.

Remarks:

A1.71 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Microstructure and transformation characteristics in melt-spun Cu-12.2% Al-4% X(X=Ni, Fe, Nb, Mn) ribbons

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Abstract. Effect of alloying elements on microstructure and transformation characteristics has been investigated in melt-spun Cu-12.2% Al-4% X(X=Ni, Fe, Nb and Mn) alloy ribbons. Fine grains in size below 4 μm can be obtained by adding the 3rd alloying elements to a melt-spun Cu-Al binary alloy ribbon. However, the degree of grain refinement is much higher in case of the addition of Fe and Nb than that of Mn and Ni due to the formation of precipitates with a size less than 0.1 μm in matrix. Only martensite is revealed in Cu-Al-X ternary alloy ribbons by alloying Ni, Fe and Nb to Cu-Al binary alloy. However, the addition of Mn drastically falls Ms temperature below a sub-zero temperature, resulting in the presence of parent phase at room temperature. Transformation temperature range and hysteresis of Cu-Al-X ternary alloy ribbon generally become larger than those of Cu-Al binary alloy. On the other hand, the addition of Fe and Nb increases the temperature range of order-disorder(B2→A2) transformation, while the addition of Ni has a little effect on that of the B2→A2 transformation in comparison with Cu-Al binary alloy.

Remarks:

A1.72 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Influence of Co Addition on Magnetic Properties and Magnetic-Field-Induced Phase Transformation in Ni-Mn-Sn Magnetic Shape Memory Alloys

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Abstract. Magnetic shape memory alloys (MSMAs) display a shape memory effect upon the application of an external magnetic field, showing large output strain and fast dynamic response, and thus have promising prospects in the applications as actuators and sensors. For the MSMAs showing a shape recovery as a result of magnetic-field-induced reverse transformation from weak magnetic martensite to ferromagnetic austenite, the large difference between magnetization of austenite and martensite and the low transformation entropy change are quite essential. In this study, the effect of Co addition on phase transformation, magnetic properties and magnetic-field-induced phase transformation (MFIPT) of Ni-Mn-Sn alloys was systematically investigated. It was found that the addition of Co increases the Curie temperature and decreases the phase transformation temperature and the transformation entropy change of the alloys. When the Co content is low, both the austenite and martensite of the alloys have low magnetization, so there is no MFIPT occurring. When the Co content becomes higher, the alloys have a ferromagnetic austenite and weak magnetic austenite, resulting in a large magnetization difference between the two phases. Therefore, MFIPT can be easily achieved in these alloys. However, when the Co content exceeds a critical value, the martensitic transformation completely disappears and consequently no MFIPT could be achieved. The phase diagram of the Ni-Mn-Sn-Co system was finally established.

Remarks:

A1.73 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Transformation-Induced Plasticity During Pseudo-Elastic Deformation in Ni-Ti Microcrystals

D. M. Norfleet[1], L. Kovarik[2], P. M. Sarosi[3], S. Manchiraju[2], M. F. Wagner[4], M. D. Uchic[5], P. M. Anderson[2], M. J. Mills[2]

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Abstract. [110] oriented microcrystals of solutionized 50.7 at% Ni-Ti were prepared by focused ion beam machining and then tested in compression to investigate the stress-induced B2-to-B19' transformation in the pseudoelastic regime. The compression results indicate a sharp onset of the transformation, consistent with little prior plasticity. Post mortem scanning transmission electron microscopy reveals no apparent retained martensite but rather a macroscopic band of dislocation activity within which are planar arrays of $\sim$100 nm dislocation loops involving a single a$<$010$>${101} slip system. Micromechanics analyses show that the angle of the band is consistent with activation of a favored martensite plate. Further, the stress from the individual variants within the plate is shown to favor activation of the observed slip system.

Remarks:

A.2 Mathematical Modelling

A2.01 Invited Oral Presentation | Wednesday, Sept. 9, 8.30 - 9.00

Nucleation and kinetics of phase boundaries in peridynamics

K. Dayal[1]

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Abstract. The nucleation and kinetics of phase boundaries is critical to predict hysteresis and dynamic behavior in active materials. This requires more than the stress-strain relation,ie, a nucleation criterion and a kinetic relation. Further, computation is difficult as one needs to track these defects. Phase field avoids this by using gradients, but these add to the computational complexity. We report on an alternative approach using peridynamics. This is a nonlocal model of continua that uses only the displacement field, and not its spatial derivatives. This makes it attractive to model phase boundaries. We show that nucleation and kinetic information is contained in the model. We find that phase boundaries may be viewed as traveling waves, and their motion induces a kinetic relation. We derive a nucleation criterion by examining the dynamic stability of a nominally single phase displacement field. Our analysis shows good agreement with direct dynamics calculations. This provides a new perspective on nucleation as a dynamic instability and phase boundaries as traveling waves in microscopic theories. We then use peridynamics to study a 2D phase boundary impinging on a defect. Our calculations show a new mechanism for the phase boundary to bypass the defect without requiring large distortions. As the acoustic waves leading the phase boundary interact with the stress field of the defect, they nucleate a new phase boundary that propagates, as the original phase boundary comes to rest.

Remarks:

A2.02 Invited Oral Presentation | Wednesday, Sept. 9, 10.45 - 11.15

First principles calculations of energy barriers in martensitic phase transformation of NiTi

H. Sehitoglu[1]

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Abstract. An important issue associated with MT is the understanding of the mechanisms and the pathways involved in the phase transformation in terms of simple shears or volume dilation of the parent crystal accompanied by local displacements (shuffles) of the (internal) atoms. Classically, phenomenological martensitic transformation theories have proposed transformation pathways by relating the initial and the transformed phases through pure geometry without considering the atomistic pathways and the mechanisms that drive the transformation at the micro- or mesoscale. Determining the actual, energetically favorable pathway is important since the associated energy barriers govern the reversibility of the transformation. The present study addresses this need using ab initio calculations. First-principles calculations are presented for parent B2 phase and martensitic B19 and B19' phases in NiTi. The results indicate that both B19 and B19' are energetically more stable than the parent B2 phase. By means of ab initio density functional theory, the complete distortion–shuffle energy landscape associated with B2 to B19 transformation in NiTi is then determined. In addition to accounting for the Bain-type deformation through the Cauchy–Born rule, the study explicitly accounts for the shuffle displacements experienced by the internal ions in NiTi. The energy landscape allows the energy barrier associated with the B2 to B19 transformation pathway to be identified.

Remarks:

A2.03 | Paper ID – 03005 Regular Oral Presentation | Wednesday, Sept. 9, 9.00 - 9.15

Modeling of non-local interactions on a phase transformation interface

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Abstract. If an interaction between phases of different composition at an interface is significant, the classical model of an interface is no longer satisfactory. In such cases, the transition layer has to be modeled as a surface phase with intrinsic non-local properties. The boundary of separation, which defines the interface, must possess its own internal structure in order to allow accommodation of complex phenomena while balancing opposite tendencies on each side of the interface. Consequently, an extended model is needed that is capable of describing the intrinsic properties of the interface. To achieve this goal, we employ a special model of an interface with simple structure, where the mathematical notion of a simple structure corresponds to the material model without rotational degrees of freedom in each lattice point of the interface. By employing characteristic features of the model, we are in a position to describe quantitatively and qualitatively the structural and compositional non-local changes across the interface.

Remarks:

A2.04 Regular Oral Presentation | Wednesday, Sept. 9, 9.15 - 9.30

Numerical study of the martensite formation in nanostructured niti shape memory alloys

W. Pranger[1], T. Antretter[1], T. Waitz[2], F. D. Fischer[1]

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[2] *University of Vienna, Austria*

Abstract. The morphology of twinned martensite in nanostructured NiTi alloys is governed by competing energy contributions coming into play when the cubic B2 parent phase transforms into the monoclinic B19' product phase. The crystallographic change entails a transformation eigenstrain that must be accommodated elastically. This paper is taking advantage of recently published results for the full elastic tensor of the product phase whose pronounced elastic anisotropy inevitably requires employing numerical methods for the evaluation of the strain energy. It turns out that the experimentally observed martensite morphology is strongly dependent on the grain size. Typical patterns include "martensite laminates", i.e. alternating sequences of (001) compound twin-related Bain correspondence variants, either entirely filling the grain or else again alternating with other such laminates. Consequently all chemical energies arising at the twin interfaces as well as at the austenite to martensite boundaries have to be taken into account in addition to the strain energy. Minimization of the total energy allows to quantitatively predict the morphology. The calculations are in good agreement with experimental results obtained by transmission electron microscopy. The presented energetic concept can also be applied to partially transformed nanograins with wedge-shaped martensite forming interfaces with the embedding austenite.

Remarks:

A2.05 Regular Oral Presentation | Wednesday, Sept. 9, 9.30 - 9.45

MD studies on the effect of the transformation dynamics on martensitic microstructure.

O. Kastner[1], G. Ackland[2]

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[2] *The University of Edinburgh, United Kingdom*

Abstract. We present molecular dynamics (MD) simulations of a martensitic phase transformation studying post-transformation microstructure and moving austenite-martensite interfaces. Unlike in energy-minimisation theories, the transformation dynamics dominate the martensite morphology. We use a binary Lennard-Jones potential to describe a square-to-hexagonal transformation in 2D and a B2 to L11 type of transformation in 3D, respectively. In 2D, the high-T stable square lattice and low-T hexagonal lattice represent austenite and martensite, giving four martensitic variants. Here, compatible twin variants have no lattice misfit and zero interfacial energies which makes our model directly comparable with the crystallographic theory of martensite. Although our dynamical interpretation is different to previous work, the 2D MD simulations exhibit very similar martensitic morphologies to real materials. The nucleation of wedge-shaped, twinned martensite plates, plate growth at narrow, travelling transformation zones, subsonic transformation waves, elastic precursors inducing secondary nucleations and the formation of martensitic domains are observed. In contrast to the 2D, martensitic variants exhibit interface energies in 3D Lennard-Jones solids. However, in both cases 2D and 3D, the martensite is produced within narrow transformation zones where atoms change their lattice sites in a co-operative manner so as to form crystallographic layers. These motions produce inertia forces on the mesoscopic length-scale which affect the formation of twin variants.

Remarks:

A2.06 Regular Oral Presentation | Wednesday, Sept. 9, 9.45 - 10.00

Ab initio search for the NiTi ground state with shape-memory ability

D. Holec[1], M. Friak[2], J. Neugebauer[2]

[1] *University of Leoben, Leoben, Austria*
[2] *Max Planck Institute for Iron Research, Düsseldorf, Germany*

Abstract. We report on first-principles calculations of structural transitions in stoichiometric NiTi allotropes under quasi-static pressure changes. At each simulation step of the pressure-induced transitions we kept the volume constant and all the other structural degrees of freedom were optimized with respect to the total energy. In contrast to the scenario proposed in previous theoretical studies, the BCO phase does not transform into the experimentally observed B19' phase within the range of hydrostatic pressures between -20 to 60 GPa. We ascribe this to the highly symmetrical environment of atoms in the BCO structure. The B19' state does not transform into the BCO phase in the studied pressure range either but instead distorts into a newly identified monoclinic shape-memory (MSM) phase located structurally in between the B19' and BCO phases. The MSM phase has been found to have the energy comparable to that of the previously suggested candidate for the ground-state of NiTi, the BCO phase, within the precision of our calculations. Importantly, the newly identified MSM phase has a lower symmetry than the BCO phase. As a consequence, the MSM structure can, in principle, store the shape information.

Remarks:

A2.07 | Paper ID – 03013 Regular Oral Presentation | Wednesday, Sept. 9, 10.00 - 10.15

On dissipation, interfacial energy and size effects in shape memory alloys

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Abstract. This work presents a multiscale approach aimed at the modelling of evolution of martensitic microstructures with account for the interfacial energy effects. The total Helmholz free energy and the energy dissipated in the system are split into contributions from the bulk material, from phase interfaces and from other boundaries. Microstructure evolution is then determined by the incremental energy minimization. As an application, stress-induced transformation is considered which proceeds by formation and growth of internally twinned martensite plates within the austenite matrix. The interfacial energy is examined at three scales, namely at twin boundaries, austenite-martensite interfaces and at grain boundaries. Both atomic-scale and the elastic microstrain interfacial energies are included and respective estimates are taken from the materials science literature or predicted using micromechanical finite element analysis. Examples are provided for the cubic-to-orthorhombic transformation in a CuAlNi shape memory alloy. They illustrate the effect of grain size on the macroscopic stress-strain response including the hysteresis width.

Remarks:

A2.08 Regular Oral Presentation | Wednesday, Sept. 9, 11.15 - 11.30

Martensite microstructure. Formation principles and scaling phenomena

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Abstract. Modern investigations on martensitic transformation kinetics in different metallic shape memory alloys (SMA) require adequate development of new analysis and control methods for the multi-phase microstructural distribution of transformation products and its evolution under external thermal and mechanical driving forces. Traditionally these problems are solved by the ordinary statistical metallography technique. In addition to these methods, a two-dimensional (2D) Fourier analysis was recently proposed to obtain the regular quantitative information on the microstructures of multiphase systems. The most well known and widely investigated examples of the scaling-invariant behavior are usually observed in the systems undergoing different types of phase transitions near their critical points. In our report the correlation Fourier analysis is applied to study the spatial distribution of martensite domains in some single crystal shape memory alloy during the martensitic transformation. An evident spatial self-similarity and scaling behavior is observed indicating fractal-like distribution of the martensitic phase. Fourier power spectrum obtained from the micrograph images and represented as a function of the wave number shows several regions of scaling behavior with different scaling dimensions and a crossover region between them. Scaling dimensions associated to different Fourier power spectrum components were quantitatively determined and discussed.

Remarks:

A2.09 | Paper ID – 03011 Regular Oral Presentation | Wednesday, Sept. 9, 11.30 - 11.45

Energy bounds for polycrystalline shape-memory alloys

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Abstract. In polycrystalline shape memory alloys at equilibrium under a prescribed loading, one typically observes the formation of austenite/martensite microstructures in each grain. The prediction of the resulting effective energy is a difficult question that still remains largely open. A related problem is the prediction of the set of recoverable (or zero-energy) strains of polycrystals. This article presents some recents results that have been achieved in that field, contrasting the geometrically linear theory ('infinitesimal strains') with the geometrically nonlinear theory ('finite strains').

Remarks:

A2.10 Regular Oral Presentation | Wednesday, Sept. 9, 11.45 - 12.00

First principles investigation of Fe-Pd magnetic shape memory alloys

M. E. Gruner[1], P. Entel[1]

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Abstract. In disordered off-stoichiometric Fe-Pd, ordered Fe_3Pt as well as in Ni-Mn-Ga full Heusler alloys magnetic shape memory (MSM) behavior is observed, allowing large macroscopic strains to be achieved in realistic magnetic fields. However, especially for the Fe-based systems, the martensitic transition temperatures are still too low for practical applications. First principles methods within the framework of density functional theory allow the determination of structural and electronic properties on the atomistic level and therefore ideally complement experimental investigations while the link to the electronic structure will help to understand the relevant properties and to predict improved materials. Within this contribution we provide a comparison between stoichiometrically ordered Fe_3Pd and disordered Fe-Pd alloys. The disorder is modeled implicitly within the coherent potential approximation assuming the ideal lattice positions as well as explicitly within a supercell approach. While being computationally expensive, it is straightforward to allow for a relaxation of the atomic positions in the latter case. The calculations demonstrate that such local distortions provide an important contribution to the total energy and are thus necessary for the correct description of the binding surface. Based on our ab initio results, we furthermore discuss the prospects of improving MSM properties by addition of a suitable third component.

Remarks:

A2.11 | Paper ID – 03006 Regular Oral Presentation | Wednesday, Sept. 9, 12.00 - 12.15

FEM modelling of elastically strained interfacial microstructures in Cu-Al-Ni single crystals

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Abstract. In this paper, construction of FEM models of particular microstructures forming between austenite and mechanically stabilised 2H-martensite of the Cu-Al-Ni shape memory alloy is presented. Since these microstructures appearing during the shape recovery process (the so-called X-interfaces or the X-microstructures) are not minimisers of the entire free energy, their mesoscopic morphology cannot be determined from any known thermodynamic extremal criterion, but must be taken directly from the experimental observations. For the elastic coeffcients of both austenite and martensite phase of this alloy known from the ultrasonic measurements, such model enables determination of elastic strains within the microstructure and, thus, evaluation of the stored elastic energy in the microstructure. The model (implemented in COMSOL Multiphysics FEM environment) is applied to analyse interfacial microstructures observed experimentally in a prismatic bar of a single crystal of the examined alloy, and to find optimal morphology of this microstructure by means of the free energy (local) minimisation.

Remarks:

A2.12 | Paper ID – 03007 Regular Oral Presentation | Wednesday, Sept. 9, 12.15 - 12.30

On the numerical simulation of material inhomogeneities due to martensitic phase transformations in poly-crystals

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Abstract. Experimental results show that martensitic phase transformations in shape-memory alloys occur in localized zones. Based on a micromechanical model we want to simulate these eects. The mathematical treatment is accompanied by a finite-element calculation which includes, due to the model modication, a regularization. The result of this effort is a micromechanically well motivated algorithm which shows qualitatively a good agreement with experiments. Numerical examples are presented.

Remarks:

A2.13 | Paper ID – 03004 Regular Oral Presentation | Wednesday, Sept. 9, 14.00 - 14.15

Numerical study of mean-field approach capabilities for shape memory alloys matrix composites description

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Abstract. With the development of SMA devices, new alloys are developed to enhance some specific properties like temperature hysteresis, plastic yield limit, change of transformation temperatures... Phase precipitation or inclusions addition are often use for these purposes. To predict the behavior of these heterogeneous materials and allow structures simulations, mean-field approaches like Mori-Tanaka homogenization scheme are convenient. But for phase transformation strain mechanism, localization of deformation and, in a second step, saturation of transformation strain around inclusions have a significant impact on the global behavior. To check the capability of Mori-Tanaka scheme to predict the behavior of these heterogenous functional materials, a unit cell finite element analysis is considered as reference solution. One inclusion is embedded in the matrix, with respect to the fraction volume of both phases. Two situations are performed, both for NiTi-based materials. First represents the precipitation effect of Ni-rich elastic precipitates Ni4Ti3 for annealed Ni-rich materials. Second case considers elastoplastic Nb inclusions in a NiTi matrix, which induce a wide variation of reverse transformation temperatures. Limits of the homogenization approach chosen are studied in these two cases.

Remarks:

A2.14 | Paper ID – 03008 Regular Oral Presentation | Wednesday, Sept. 9, 14.15 - 14.30

Computations of geometrically linear and nonlinear Ginzburg-Landau models for martensitic pattern formation

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Abstract. Computations show that a two dimensional geometrically nonlinear Ginzburg-Landau model with inertia exhibits long lived metastable states, that have martensite domains with split tips and bent needles similar to those observed in NiAl. In comparison, the geometrically linear model quickly relaxes to states with twins which extend all the way across the sample and have only short lived tip splitting and needle bending.

Remarks:

A2.15 | Paper ID – 03002 Regular Oral Presentation | Wednesday, Sept. 9, 14.30 - 14.45

Enhanced micromechanical modelling of martensitic phase-transitions considering plastic deformations

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[2] *TU Dortmund, Institute of Mechanics, Dortmund, Germany; Lund University, Division of Solid Mechanics, Lund, Sweden*

Abstract. The purpose of this contribution is the presentation of a micromechanical model for martensitic phase transformations which can be applied to a wide range of materials like shape memory alloys (SMA), TRIP-steels (TRansformation Induced Plasticity) and piezoceramics. One of the key-features of the model is the consideration of several martensitic variants in addition to the parent phase austenite based on crystallographic theories. According to a specifically chosen microstructure, a fluctuation field is superimposed to the local, homogeneous deformations. These fluctuations implicate several additional internal variables which are partially supposed to minimize the microscopic energy density. Furthermore, the variables assumed to be 'dissipative', like the volume fractions of martensite, are determined by evolution laws. Another focal point of our work is the combination of martensitic phase transformations and plasticity. As a first step towards a complete micromechanical description of this problem, we make use of a phenomenological approach for plasticity here. The results of our computations reveal significant diferences of the single-crystalline behavior to the well-known macroscopic material response, which is indeed verified by experimental studies.

Remarks:

A2.16 | Paper ID – 02021 Regular Oral Presentation | Wednesday, Sept. 9, 14.45 - 15.00

Martensitic transformations with a classical isotropic two body potential: Intrinsic hysteresis and superelasticity

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Abstract. We constructed an isotropic interaction potential for a set of classical identical particles that displays a discontinuous change of its crystalline ground state when a parameter is varied. We used this model to study some properties associated to martensitic transformations. We concentrate here on the triangular-rombohedral transformation in two dimensions, focusing on the hysteresis of the transition, and present also results for the superelasticity effect.

Remarks:

A2.17 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Elastically anisotropic finite element simulations of stresses at martensitic B19' twin boundaries in NiTi

C. Grossmann[1], M. F. Wagner[1]

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Abstract. Due to elastic anisotropy, compatibility stresses can arise at twin boundaries when twinned microstructures are subjected to external loading. Several twin systems occur in NiTi. <110>-type II twins and compound twins of type (100) are generally considered to be the most important ones. In the present study, we consider twin boundary compatibility stresses in NiTi for the first time. The elastic anisotropy of individual martensite variants is fully taken into account by using novel data for the elastic constants of. Compatibility stresses are estimated from a simple continuum mechanical model. For selected load cases (tensile loading perpendicular to the twin boundary; shear stresses applied parallel to the twin boundary), the predicted compatibility stresses are compared to the results of Finite Element simulations for a stack of thin martensite twins. The stress state in the center of the stack agrees well with the analytical solution. Additional stresses arise near the free surfaces. Most interestingly, compatibility stresses in <110>-type II twins are of the same order of magnitude as the applied stresses. In contrast, (100) compound twins, because of their higher symmetry, exhibit only negligible compatibility stresses. These findings clearly have implications for twin boundary motion and dislocation nucleation associated with the stress-induced martensitic transformation, and provide a detailed picture of the mechanical properties of B19' twin boundaries in NiTi.

Remarks:

A2.18 | Paper ID – 03010 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Cu-Al-Ni microstructure in the phenomenological theory of martensite with lattice invariant deformation.

A. Ostapovets[1], V. Paidar[1], N. Zarubova[1]

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Abstract. Geometrical analysis of interfaces in a Cu-Al-Ni alloy is performed on the basis of the phenomenological theory of martensite. The austenite-martensite interfaces in the foils of the Cu-Al-Ni alloy are faceted. In order to assess possible facet planes, lattice invariant deformation in the form of a simple shear is included into the phenomenological theory. The experimentally observed normals to the facet planes lie in the predicted regions. Experimentally observed lines in the intervariant interfaces are interpreted as slip steps. The directions of these lines agree with theoretical predictions.

Remarks:

A2.19 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Molecular dynamics simulations of strain glass transition

X. Ding[1], T. Suzuki[2], X. Ren[2], J. Sun[1], K. Otsuka[2], M. Shimono[2]

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Abstract. Glass is a generic term for a frozen state of an essentially disordered system with local order only. An essential feature of glass transition is that glass undergoes a dynamic freezing transition from a dynamically disordered state to a frozen disordered state, in which the ergodicity of the system is broken. Very recently, a new class of glass, "strain glass" was found in a Ni-rich Ti-Ni system,. However, all the available evidence for the freezing process of strain glass transition is macroscopic evidence, and the most critical microscopic evidence that directly demonstrate such a transition is lacking. In the present study, we studied the whole process of a strain glass transition by means of molecular dynamics simulations. First, we introduce various concentrations of point defects into a generic martensitic system. We found the martensitic transformation temperature decreases dramatically with increasing point defect concentration. With the concentration of point defects exceeding a critical value, no martensite can be found even down to 1K; instead, the system shows a freezing of nano-sized strain domains, i.e., strain glass. Furthermore, we found the strain glass can be forced to transform into a normal martensite under external stress. Our atomic level simulations of strain glass transition and the associated effects provide a microscopic understanding of the macroscopic strain glass behavior, as well as the stress-induced transition from strain glass into martensite.

Remarks:

A2.20 | Paper ID – 03009 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Effect of plastic slip on thermomechanical behavior of NiTi polycrystals investigated by micromechanics modelling

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Abstract. An earlier developed micromechanics crystallographic model of SMA polycrystals has been modified by incorporating plastic deformation as additional deformation mechanism. It is assumed that dislocation slip proceeds in austenite and B19' martensite phases in parallel with the processes derived from B2-B19'martensitic transformation in NiTi alloy. The model was used to simulate the responses of NiTi polycrystal in three thermomechanical cycles typically carried out in the SMA research – cyclic tensile tests at low temperature, thermal cycles under constant stress and recovery stress tests. Based on the simulation results, it is proposed that, due to the dislocation slip occurring simultaneously with transformation related processes, the stresses and strains in the transforming polycrystal are redistributed in a deformation history specific way. Internal stresses modify further macroscopic thermomechanical responses of the polycrystal. These internal stresses are very different depending on whether the plastic deformation had taken place in the austenite or martensite phases at high or low temperatures respectively. Internal stresses of different magnitude and character are also created in pseudoelastic cycling, thermal cycling under stress or recovery stress tests. The simulation results shed new light on the existence of remaining unrecovered martensite linked to the internal stresses and on its peculiar stability towards overheating.

Remarks:

A2.21 | Paper ID – 03001 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

The influence of hydrogen on martensitic transfomation of austenitic steels

A. I. Balitskii[1], L. M. Ivaskevich[1], V. M. Mochulskyi[1]

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Abstract. The effect of hydrogen on the mechanical properties of the quenched and deformed specimens of Cr-Ni and Cr-Mn steels in 293...773 K temperature range has been investigated. Non-hydrogenated and hydrogenated (623 K; 35 MPa H2; 5 h) polished plane specimens with 3620 mm working part were subjected to static tension with displacement rate of 0,1 mm/min in helium and hydrogen under 35 MPa pressure. It was established that all tested steels are sensitive to hydrogen degradation. The maximum effect of hydrogen has observed at room temperature, when decreased the elongation and reduction of area of specimens. Martensitic transformation of nitrogen-containing austenite (stable on air) was caused by hydrogen. In unstable steels hydrogen change the intensity of γ-α transformation. Formation of polygonal dislocation substructure by preliminary mechanical or thermomechanical treatment decreases the hydrogen degradation of steels.

Remarks:

A2.22 | Paper ID – 03003 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Modeling of shape-memory alloys on the mesoscopic level

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Abstract. This contribution presents some recent results on modeling of phase transformation in the pseudo-elastic regime within the framework of continuum mechanics. We recall an efficient concept for quasi-static evolution of microstructure in the isothermal rate-independent case. We then concentrate on simulation results obtained by the presented model, performed on a single-crystal prismatic NiTi -specimen. Algorithmic details, i.e. energy-estimates-based optimization, are also given.

Remarks:

A2.23 | Paper ID – 03012 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Mathematical analysis of experimental results in polycrystalline shape memory samples subject to a simple uniaxial tension test

J. C. Pérez[1], J. G. Reyes[2], J. C. Bolaños[3], H. F. Zúñiga[4]

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Abstract. A set of experimental results reported in the literature was analysed by the application of a mathematical model developed previously. The experimental results analysed consist in a set of shape memory polycrystalline samples which was subject to simple uniaxial tension test. The crystalline orientation of several grains of the polycrystalline samples was measured and the variant formed was determined by the maximum Schmid factor criteria. Also the stress tensor was measure by the application of X-ray diffraction in situ technique. The information of the experimental study was employed for simulated the material behavior by the application of a mathematical procedure previously developed. A full analysis of the same experimental results was done and compared with them. The analysis procedure consists in generate for the 24 martensite variants: a) the distortion on the sample surface, b) the displacement field and c) The distortion of a mark on the sample's surface. Also the plane stress stated transformational diagram was employed to stress state analysis. The theoretical analysis shown a total characterization of the material behavior and therefore several important features during the stress induced martensite transformation as the identification of the variants formed in each grain with good agreement and the possibility of the apparition of other tensor stress components. Also, the simulation would be useful for the strain compatibility problem.

Remarks:

A.3 Advanced Materials

A3.01 | Paper ID – 04008 Invited Oral Presentation | Thursday, Sept. 10, 14.00 - 14.30

Rearrangement of crystallographic domains driven by magnetic field in Fe3Pt and CoO and new phase appearance in Ni2MnGa

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Abstract. We have investigated the rearrangement of crystallographic domains driven by magnetic field in a ferromagnetic shape memory alloy of Fe3Pt and an antiferromagnetic oxide of CoO. Also, we have determined the equilibrium stress-temperature phase diagram in a ferromagnetic shape memory alloy of Ni2MnGa. Following results are obtained ; (i) We confirm that magnetic field promotes the rearrangement of crystallographic domains in Fe3Pt and CoO and the condition of the rearrangement in the present two systems is the same, that is, the magnetic shear stress, which corresponds to the magnetic anisotropy energy divided by the twinning shear, is equal to or larger than the twinning stress. (ii) We construct the equilibrium stress-temperature phase diagram of Ni2MnGa by compressive tests and magnetic susceptibility measurements, and show the existence of the new phase of X-phase. Moreover, we evaluate the triple point at which the I-, P- and X-phases coexist and suggest the existence of a critical point of the successive P–>X –>I transformation.

Remarks:

A3.02 Invited Oral Presentation | Friday, Sept. 11, 11.15 - 11.45

Magnetic after-effect and isothermal martensitic transformation in metamagnetic shape memory alloys

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Abstract. We show that the direct martensitic transformation (MT) in metamagnetic shape memory alloys (MSMA) bears features of the isothermal transformation, phenomenon so far not recognized in numerous investigations in this class of materials. At the same time, the reverse MT remains perfectly athermal. We attribute this phenomenon to a necessity to destroy ferromagnetic ordering during the MT from ferromagnetic parent phase to the non-magnetic martensite, creating thus an additional energy barrier, which is overcome with the assistance of thermal fluctuations. The kinetics of the abovementioned magnetic relaxation, which controls the direct MT, has been studied in isothermal conditions both upon perturbation introduced by external magnetic field and under zero field in Ni-Mn-In and Ni-Mn-In-Co alloys. We have shown that the kinetics of both the fraction of transformed martensite m and of the magnetic permeability, representing magnetic properties of the system, perfectly follows logarithmic dependence, characteristic of a classical model of magnetic thermal activation after-effect. Experiments show that the temperature dependence of the magnetic viscosity is controlled mostly by the MT temperature rate dm/dT and reflects the density of relaxing magnetic elements. We argue that the observed isothermal direct MT and concurrent magnetic after-effect are generic in MSMA and are responsible for a number of unusual phenomena related to the so-called kinetic arrest of the MT in MSMA.

Remarks:

A3.03 | Paper ID – 04006 Regular Oral Presentation | Thursday, Sept. 10, 10.45 - 11.00

Experimental evaluation of the rheological properties of veriflex® shape memory polymer

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Abstract. Shape memory polymers (SMPs) are materials with a great potential for future use in smart materials and structures. When heated from cold state (below the transformation temperature, which can either be the glass transition temperature or the melting temperature of the polymer) to hot state (above the transformation temperature) they undergo transformation which can be compared with martensitic transformation of shape memory alloys. This process induces great changes of the mechanical properties and some shape memory phenomenon can be observed. This study is an experimental evaluation of the mechanical properties of SMP Veriflex® under different test conditions. Veriflex® was chosen because of its easy accessibility. Furthermore its properties are similar to epoxy resins which make it very suitable for usage in a wide variety of technical applications. Dynamic mechanical analysis (DMA) was used to determine evolution of the viscoelastic properties versus temperature and frequency under cyclic harmonic loading. The glass transition temperature clearly appears in a range from 45°C to 60°C depending on loading frequency. The master curve of Veriflex® was created and allows the time-temperature superposition to be constructed for this material. Finally results from all these experimental investigations were used to design a demonstrator showing the possibility of application in engineering and especially for shape control.

Remarks:

A3.04 Regular Oral Presentation | Thursday, Sept. 10, 11.00 - 11.15

Characteristics of superelasticity in ferromagnetic <001>-single crystals of a CoNiGa alloy during compressive deformation

I. V. Kireeva[1], Z. V. Pobedennaya[1], Y. I. Chumlyakov[1], I. V. Kretinina[1], E. Cesari[2], J. Pons[2], I. Karaman[3]

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Abstract. The effect of the growth direction and the volume fraction of the g-phase on a value of shape memory effect (SME) and superelasticity (SE) has been investigated in <001>single crystals of a CoNiGa alloy during compressive deformation. It is established that the <001>compression directions in single crystals of a CoNiGa alloy appear to be not equivalent in respect to the values of SME and SE. It is shown that the [001] compression direction coincides with the crystal growth direction; and the values of SME and SE, which are connected with the B2-L10 MT, are 4.5% . [010] and [100] compression directions appear to be perpendicular to the crystal growth direction. During compression along [010] and [100] the values of SME and SE are equal to 7-9% . It is established that the high values of SME and SE during compression along [010] and [100] are associated with twinning deformation in L10 – martensites. Not equivalent behavior of <001>single crystals at compression also is due to the nucleation of the g-phase oriented in the (111) plane. If the g-phase is absent the <001>compression directions are equivalent.

Remarks:

A3.05 Regular Oral Presentation | Thursday, Sept. 10, 11.15 - 11.30

Structural, magnetic and phase transformation properties of ferromagnetic shape memory Fe-Pd-X thin films

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Abstract. Ferromagnetic shape memory alloys (FSMA, e.g. Ni-Mn-Ga and Fe70Pd30) are attractive for the realization of new sensors and actuators due to their magnetic field induced strain (MFIS) effect. This work focuses on the development of new ternary Fe-Pd-X FSMAs with enhanced intrinsic properties: (high martensitic transformation temperatures [Tt >100°C], high Curie temperature [TC >250°C], hysteresis width <10 K and high saturation magnetization [μ0MS >1 T]). Therefore Fe-Pd–X thin films (X= W, Mn, Pt, Cu) were fabricated in the form of composition spread materials libraries using combinatorial magnetron sputtering and high-throughput measurement methods. All thin films were annealed (850°C for 30 min) and quenched in order to obtain transforming phases. The materials were investigated by energy dispersive x-ray spectroscopy, electrical resistance versus temperature measurements, temperature dependent x-ray diffraction, vibrating sample magnetometry measurements and transmission electron microscopy. All presented Fe-Pd-X systems showed increased transformation temperatures and met the above defined requirements. The Fe-Pd-W system was found to decompose by forming Fe67W33 precipitates embedded into a transforming Fe70Pd30 structure. The other systems did not show precipitates or decomposition. The reasons for the increased transformation temperatures will be discussed with respect to compositional and stress effects.

Remarks:

A3.06 Regular Oral Presentation | Thursday, Sept. 10, 11.30 - 11.45

Martensitic transformation in Cu-Al-Mn alloy melt-spun ribbons

L. E. Kozlova[1], V. V. Kokorin[1], S. M. Konoplyuk[1], A. O. Perekos[2], V. M. Nadutov[2]

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[2] *Institute of Metal Physics*

Abstract. We have investigated the changes of martensitic transformation characteristics with ageing time of Cu-Al-Mn shape memory alloy ribbons obtained by melt-spinning techniques. The transformation temperature and the microstructure have been analyzed using the low-field magnetic susceptibility, electrical resistance measurements and X-ray diffraction. The system of disperse ferromagnetic inclusions in a non-ferromagnetic matrix forms as a result austenite aging of Cu-Al-Mn alloy. The X-ray patterns obtained from aged ribbons have allowed to determine the average size of these particles. The ribbons of Cu-Al-Mn alloys were also annealed in the magnetic field H = 1.5 kOe perpendicular and parallel to their plane to create the magnetic field induced structure changes.
Keywords: Cu-Al-Mn shape memory alloy, melt-spun ribbon, thermomagnetic treatment

Remarks:

A3.07 | Paper ID – 05013 Regular Oral Presentation | Thursday, Sept. 10, 11.45 - 12.00

Mechanical properties of high alloyed cast and rolled CrMnNi TRIP Steels with varying Ni contents

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Abstract. High alloyed metastable austenitic or austenitic-martensitic steels show a strain induced formation of martensite during mechanical loading. These kinds of steels are well known as material for rolled products. Based on the System Fe-Cr-Mn-Ni a new generation of cast steels with TRIP effect will be discussed. The investigations show how the mechanical properties and the fraction of the formed martensite are influenced by varying Ni contents. The mechanical properties in the cast state of the material are quite similar to those in the rolled state. This is valid for tensile as well as compression loading. Under certain conditions, an isothermal formation of martensite was observed in some of the steels. The experimental results are based on tensile and compression tests. The specimens were analysed by optical microscopy, electron backscatter diffraction (EBSD), dilatometer tests and a special method for the detection of the ferromagnetic phase contents, the magnetic balance.

Remarks:

A3.08 Regular Oral Presentation | Thursday, Sept. 10, 12.00 - 12.15

Stress-induced magnetization and magnetoelastic coupling in ferromagnetic martensites

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Abstract. Stress-induced magnetization (magnetoelastic coupling) has been studied in Ni53.5Fe16.5Ga27Co3 polycrystals, in the martensitic state. The experiments were performed applying an oscillatory stress (elastic strain) to the sample at a frequency of around 100 kHz, over a wide range of strain amplitudes (between 10-7 and 10-4), in a temperature interval from 80 to 330 K, under constant or periodic axial polarizing field. We found that the stress-induced magnetisation as a function of temperature changes its sign twice at low fields: very close to the Curie temperature and also at temperatures about 40 K below. For high polarizing fields, this peculiarity of stress-induced induction disappears. The observed behaviour of the stress-induced induction reflects changes of the sign of magnetoelastic coupling (direct and inverse magnetostriction). In the material investigated, the magnetostriction is positive at high polarizing fields, but becomes negative at low fields over the temperature range of about 40 K just below the Curie temperature. We have found that these changes of the sign of magnetoelastic coupling are detected also by the DSC and resistivity measurements. We suggest that these peculiarities of magnetoelastic coupling can be behind various structural modifications observed in ferromagnetic martensites.

Remarks:

A3.09 Regular Oral Presentation | Thursday, Sept. 10, 12.15 - 12.30

From superplastic to springlike behavior and beyond by tailored martensite twin structures in low twinning stress Ni-Mn-Ga alloys

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Abstract. In this work, we show that tailored martensite twin structures can be easily created by external stress and magnetic field in Ni-Mn-Ga magnetic shape memory single crystals with low twinning stress (∼0.2 MPa). The created twin structures were further studied in order to determine their influence on the (magneto-)mechanical response (magnetic shape memory effect), which is known to be sensitive to twin structure [1,2]. The performed experiments showed that the same crystal can exhibit significantly different mechanical response depending on the twin structure present, ranging from superplastic to springlike. The resulting impact on the magneto-mechanical response (magnetic shape memory effect) was also experimentally investigated and discussed. It seems that a desired magneto-mechanical response can be "programmed" into a crystal by tailoring its martensite twin structure.
References: [1] P. Müllner et al., J. Mag. Mag. Mat. 267 (2003) 325; Mat. Sci. Eng. A 387-389 (2004) 965 [2] L. Straka et al., Acta Mat. 56 (2008) 5492; ICFSMA 2009 Bilbao, Spain

Remarks:

A3.10 Regular Oral Presentation | Thursday, Sept. 10, 14.30 - 14.45

Three-dimensional Monte Carlo model for study of magnetocaloric properties of Heusler Ni-Mn-Ga alloys

V. Buchelnikov[1], V. Sokolovskiy[1], S. Taskaev[1], P. Entel[2]

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Abstract. Recent researches have shown that Ni-Mn-Ga Heusler alloys are attractive for the application in magnetic refrigeration, as can be judged by the large magnetic entropy change at the room - temperature. In this work we study theoretically magnetocaloric effect of the Ni2+xMn1-xGa ($0.18<x<0.27$) Heusler alloys undergoing first order magnetostructural phase transitions by means of a classical Monte Carlo method. In the proposed model we consider the three-dimensional cubic lattice with real unit cell of Ni-Mn-Ga alloys. The magnetic subsystem is described by a five-state Potts model for Mn atoms and a three-state Potts model for Ni ones for first order magnetic phase transition from ferromagnetic to paramagnetic state. In the magnetic subsystem we consider the interaction only between the Mn and Ni atoms and the values of magnetic exchange constants we take from ab initio calculations for Ni2MnGa alloy. The structural subsystem is described by a twofold degenerated Blume – Emery – Griffiths model for structural transformations from high-temperature cubic austenitic phase to low-temperature tetragonal martensitic phase. In the structural subsystem we propose the interaction between Mn, Ni and Ga atoms. By the help of proposed model the temperature dependences of the magnetization, specific heat and the isothermal entropy change for magnetic field variation from 0 to 5 T are obtained. It is shown that the theoretical results agree qualitatively with experimental ones.

Remarks:

A3.11 Regular Oral Presentation | Thursday, Sept. 10, 14.45 - 15.00

Straining martensitic Fe70Pd30 films along the bain path by coherent epitaxial growth

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Abstract. The quenched, disordered Fe70Pd30 magnetic shape memory alloy transforms from the fcc austenite to the fct (bctI) martensite around room temperature in bulk. In agreement with this martensitic instability, theory predicts structural instability of fcc Fe70Pd30 with respect to tetragonal distortions. According to density functional calculations, a flat energy landscape is expected along the Bain path. Since changes in tetragonal distortion from fcc to bcc cost only little elastic energy, this allows for stabilization of tetragonally distorted states by an epitaxial interface in thick films. Straining of Fe70Pd30 is realized by film growth on different epitaxial buffer layers having different lattice mismatches to the Fe70Pd30 film. Deposition of the 50 nm thick Fe70Pd30 films is performed by magnetron-sputtering at room temperature. XRD measurements reveal coherent epitaxial film growth. Due to the lattice mismatch to the buffer layers, the in-plane lattice constants of the Fe70Pd30 fcc-like unit cell are strained. By volume conservation this causes a tetragonal distortion. In dependence on the lattice parameter of the buffer layer, the tetragonal distortion of Fe70Pd30 can be varied systematically. It reaches exceptionally high values of up to (c-a)/a = 27.5% , covering most of the Bain path from fcc to bcc in the films.

Remarks:

A3.12 Regular Oral Presentation | Thursday, Sept. 10, 15.00 - 15.15

Acoustic emission experiments with magnetic field in Ni_2MnGa magnetic shape memory alloys

A. Planes[1], B. Ludwig[2], C. Strothkaemper[2], U. Klemradt[2], X. Moya[3], L. Mañosa[1], E. Vives[1]

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Abstract. Acoustic emission measurements were performed in a Ni_2MnGa alloy during both thermally induced martensitic transition under applied magnetic field and isothermal field induced rearrangement of martensitic variants. The amplitude, energy, and duration distributions of the acoustic emission events show power law behaviour in both cases which reflects the absence of characteristic scales associated with transition and rearrangement processes. In the case of the transition, the exponent that characterise these distributions has been found to depend on the applied magnetic field. This proves that its dynamics is strongly influenced by magnetostructural coupling taking place at multiple length scales. The comparison of the acoustic emission activity with and without an applied field supports the idea that the martensite grows in two processes: the nucleation of twin related variants satisfying the invariant habit plane condition followed by rearrangement of the variants at the late stage of the transformation

Remarks:

A3.13 Regular Oral Presentation | Thursday, Sept. 10, 15.15 - 15.30

Shape memory and superelasticity in BCC metal nanowires

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Abstract. Shape memory effect (SME) and superelasticity (SE) are traditionally associated with conventional bulk shape memory alloys (SMAs) derived from martensitic phase transition. Recently, such unique behavior was also discovered in a class of face-centered-cubic (FCC) nanowires, which is originated not from a phase transition, but from a reversible twinning process driven by surface energy reduction. Compared with conventional SMAs, FCC nanowires can exhibit a large recovery strain exceeding 40% . So far, almost all the observations have been focused on FCC metallic systems. It is unclear whether such phenomenon is generic to nanowires with other crystal structure. In the present study we perform molecular dynamics (MD) simulations demonstrating that, besides FCC systems, body-centered-cubic (BCC) nanowires can also exhibit SME and SE through a recoverable twinning mechanism, being similar to FCC nanowires. Our results indicate that shape memory recovery may be a general phenomenon at nanoscale, which is driven by a reduction of surface energy. Compared with the FCC nanowires, the BCC nanowires show some interesting new features, which will be discussed at the conference. The present findings may have some useful implications in nano-electromechanical systems (NEMS).

Remarks:

A3.14 | Paper ID – 04003 Regular Oral Presentation | Thursday, Sept. 10, 15.30 - 15.45

Structural and magnetic properties of Ni-Mn-Ga films sputter-deposited on cube-textured polycrystalline substrate

V. A. Chernenko[1], P. Bassani[2], R. Lopez Anton[3], S. Besseghini[2], J. M. Barandiaran[1], A. Tuissi[2], I. Orue[4], P. Lazpita[4], M. Ohtsuka[5]

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Abstract. Texture, magnetic and micromagnetic properties of the martensitic thin films with different thicknesses prepared by magnetron sputtering of Ni52Mn24Ga24 target on paramagnetic Ni-Cr-W cube-textured thin tape are studied. The films exhibit 220-fiber texture. The texture features together with a large magnetocrystalline anisotropy lead to the conclusion about particular domain structure.

Remarks:

A3.15 Regular Oral Presentation | Friday, Sept. 11, 9.00 - 9.15

High-temperature superelasticity in ferromagnetic single crystals with thermoelastic martensitic transformation

Y. I. Chumlyakov[1], I. V. Kireeva[1], E. Y. Panchenko[1], H. J. Maier[2], I. Karaman[3], E. E. Timofeeva[1], Z. V. Pobedennaya[1], V. A. Kirillov[4]

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Abstract. The research on temperature interval of superelasticity in dependence of crystal axis orientation, stress state (tension/compression) of ferromagnetic Ni-Fe-Ga (A), Co-Ni-Ga (B), Co-Ni-Al (C) single crystals in monophase and aged state is carried out. These single crystals undergo thermoelastic martensitic transformations from high-temperature B2-phase in tetragonal L10- martensite (alloys B, C) and from L21-phase in 10M, 14M and L10 martensite. It is shown, that the temperature interval of superelasticity is defined by two factors: 1) the strength properties of a high-temperature phase; 2) the yield stress to the beginning of stress-induced martensitic transformation. The maximum temperature interval of superelasticity TSE (400 K (A), 450 K (B), 250 K (C)) in monophase crystals is reached, when crystals are " hard" in a high-temperature phase and "soft" at development stress-induced martensitic transformation. The increasing of strength properties of high-temperature phase by the precipitation of dispersed particles leads to increase temperature interval TSE by 50÷150 K as compared to monophase crystals. The thermodynamic criterion for development of high-temperature superelasticity is suggested.

Remarks:

A3.16 Regular Oral Presentation | Friday, Sept. 11, 9.15 - 9.30

Temperature-stress phase diagram and the properties of Ti48.5Ni51.5 strain glass

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Abstract. A newly found strain glass transition [1] and its corresponding stress-induced strain glass to martensite transition [2] were reported in the non-transforming composition regime of Ti50-xNi50+x system. These findings demonstrate that the properties of strain glass system strongly depend on temperature and stress. In this study, we investigate systematically the temperature and stress dependence of the properties of Ti48.5Ni51.5 strain glass alloy. We found that the freezing temperature of strain glass decreases with increasing stress. The temperature dependence of the critical stress of stress-induced strain glass to martensite transformation violates the Clausius-Clapyeron relationship in the frozen state of strain glass. These findings ultimately lead to the establishment of the temperature-stress phase diagram of strain glass. We also show that the strain glass can first undergoes a glass transition and then it is followed by a martensitic transition with the assistance of external stress, which is predicted from the temperature-stress phase diagram of strain glass. Finally, we provide a phenomenological explanation for the origin of strain glass and the corresponding stress-induced strain glass to martensite transition.
1. S. Sarkar, X. Ren and K. Otsuka, Physical Review Letters, 95,205702(2005) 2. Y. Wang, X. Ren and K. Otsuka, Physical Review Letters, 97, 225703 (2006)

Remarks:

A3.17 | Paper ID – 04010 Regular Oral Presentation | Friday, Sept. 11, 9.30 - 9.45

Peculiarities of structure and thermomechanical strengthening of martensitic structural steels microalloyed by nitrogen

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Abstract. The effect of thermomechanical treatments on structure and properties of structural C(0.35-0.50)CrNiMoV steels microalloyed by nitrogen were studied using optical microscopy, X-ray diffraction analysis and mechanical testing. The hardness of martensite change as a function of austenitization temperature is presented for the steels with the same main composition but various summary C and N contents. Microalloying of structural steels by nitrogen results in complication of phase transformations and raising austenitization temperature for quenching and HTMT. A small quantity of undissolved carbonitrides promotes fine-grained structure preservation and heredity of the initial as-cast structure. The heat and thermomechanical treatment regimes were determined which allowed the use of nitrogen-microalloyed structural steels as high-strength ones. A complete dissolution of special carbonitrides during HTMT and following low-temperature tempering provide high strength level (by 300-500 MPa higher than for nitrogen-free analogs) combined with sufficient ductility and fracture toughness.

Remarks:

A3.18 | Paper ID – 04004 Regular Oral Presentation | Friday, Sept. 11, 9.45 - 10.00

Characterization of new ferromagnetic Fe-Co-Zn-Ga alloys by ab initio investigations

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Abstract. We have calculated structural energy differences, magnetic interaction constants and mixing energies of Fe-Co-Ga(Zn) alloys in order to gain information about their suitability for ferromagnetic shape memory devices. We considered the classical Heusler structure as well as an ordering type in which the Co and one Fe sublattice are interchanged. The results of our density functional theory investigations suggest high Curie and martensitic phase transition temperatures for the Ga-based as well as for the Zn-based systems. In case of hypothetical Fe2CoZn alloys, the classically ordered Heusler structure is energetically preferred. In Ga based alloys, the ordering type with Co partially on Fe sites appears to be more stable. We propose that a systematic variation of composition by successive addition of Zn and Co to Fe-Co-Ga may result in a promising new ferromagnetic shape memory alloy of type $Fe_{2-x}Co_{1+x}Ga_{1-y}Zn_y$.

Remarks:

A3.19 Regular Oral Presentation | Friday, Sept. 11, 10.00 - 10.15

TEM, XRD and DSC analysis of a HPT deformed NiTiHf shape memory alloy

G. Steiner[1], T. Waitz[1], H. Karnthaler[1]

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Abstract. High temperature Ni49Ti36Hf15 shape memory alloys show a martensitic phase transformation from a cubic high temperature phase (B2 austenite) to a monoclinic structure (B19´ martensite) with temperatures of martensite finish at 166 and austenite finish at 257°C. In the present work the NiTiHf alloys were deformed by high pressure torsion (HPT) followed by annealing. HPT (4 GPa, 12 turns) was applied to discs (8mm ø, 0.8mm thick). Specimens with a strain of 25000% were analysed. Transmission electron microscopy (TEM), X-ray diffraction (XRD) and differential scanning calorimetry (DSC) were carried out to study the phase structures and transformation behavior. The HPT deformed samples show a heterogeneous martensitic microstructure containing a mixture of coarse grains and few nanocrystalline areas; austenite is not encountered. DSC measurements from 20 to 450°C followed by an isothermal treatment at 450°C for 30 min and cooling to -100°C showed no peaks indicating a B19' to B2 transformation upon heating nor a B2 to B19' transformation during cooling. After this heat treatment, TEM and XRD analysis carried out at room temperature showed an unexpected change from the coarse grained B19' structure to a mainly nanocrystalline structure containing B2. The absence of the DSC signals is explained as follows: During heating the B19' to B2 transformation is smeared out over a large temperature range; during cooling the martensitic phase transformation is suppressed in the B2 nanograins

Remarks:

A3.20 Regular Oral Presentation | Friday, Sept. 11, 10.15 - 10.30

Influence of the valence electron density (e/a) on the magnetic properties and martensitic transition temperatures of Ni-Mn-X (X=Ga, In, Sn, Sb)

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Abstract. We report systematic studies of magnetic Ni-Mn-X (X=Ga, In, Sn, Sb) based Heusler alloys by employing density functional theory using pseudopotentials for the case of stoichiometric compounds and the KKR CPA method to treat the non-stoichiometric cases. In particular, we focus on the rich phase diagram of Ni-Mn-Sb showing coexisting ferromagnetic and antiferromagnetic interactions in the composition region where shape memory effect (MSE) and magnetocaloric effect (MCE) compete with each other [1]. A systematic investigation of the reconstruction of the Fermi surface as a function of the valence electron number per atom (e/a) shows that in all systems under investigation, the Fermi surface looses parts of its nesting properties when entering the composition range where the MCE dominates. Calculated structural energy differences allow to predict the variation of martensitic transformation temperatures.
[1] For a recent survey, see P. Entel et al., Mater. Sci. Forum 583, 21 (2008)

Remarks:

A3.21 Regular Oral Presentation | Friday, Sept. 11, 10.30 - 10.45

Inverse transition from low temperature paramagnetism to high temperature ferromagnetism in Co-doped NiMnGa alloys

S. Fabbrici[1], F. Albertini[1], A. Paoluzi[1], F. Bolzoni[1], R. Cabassi[1], M. Solzi[2], L. Righi[3], G. Calestani[3], J. Kamarad[4], Z. Arnold[4], M. Souckova[4]

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Abstract. NiMnGa alloys display several "giant" effects (magnetocaloric, magnetoelastic, magnetoresistive) due to the interplay between magnetic and structural degrees of freedom. A large magnetization difference, DM, between martensitic (MP) and austenitic (AP) phases is of great importance to obtain higher performances due to the improved possibility of driving structural transformations by magnetic fields. DM enhancement was recently achieved by adding Co to Mn-rich NiMnGa alloys [1]. To contribute to the understanding of Co effects we have mapped the behaviour of Co-substituted alloys. Samples of composition Ni50-xCoxMn25+yGa25-y (x=5-13 and y=5-7) were arc melted and characterized by microprobe analysis and, as a function of temperature, by X-ray diffraction and magnetic measurements. Using the dependence of magnetic order and of martensitic transition on Mn and Co content, we have been able to tune the critical temperatures and to obtain the Curie temperature of the MP much lower than the AP and lower than the structural transformation temperatures. For peculiar compositions (e.g x=9, y=7) we have thus obtained an inverse transition from a low temperature (tetragonal) paramagnetic phase to a high temperature (cubic) ferromagnetic one. This behaviour, that leads to a further DM enhancement (up to 50 emu/g) and to a negative field dependence of the transformation temperature is of great interest for possible applications. [1] S.Y. Yu et al. Appl. Phys. Lett. 91, 102507 (2007)

Remarks:

A3.22 | Paper ID – 04001 Regular Oral Presentation | Friday, Sept. 11, 11.45 - 12.00

Determining the liquidus and ordering temperatures of the ternary Ni-Mn-Ga and quaternary Ni-Mn-Ga-Fe/Cu alloys

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Abstract. The high temperature transformations (e.g. liquidus, ordering temperature) of the alloys Ni47.7Mn31.2Ga21.1, Ni49.7Mn28.7Ga21.6, and Ni49.6Mn24.0Ga26.6, Ni47.3Mn30.3Ga20.3Fe2.1, Ni49.9Mn28.3Ga20.1Fe1.7, Ni51.3Mn14.4Ga26.3Fe8.0, Ni47.3Mn25.5Ga24.5Cu2.7, Ni48.3Mn29.7Ga21.1Cu0.9, and Ni49.4Mn23.3Ga25.6Cu1.7 were studied for the practical melting and annealing purposes. At first the chemical compositions (SEM-EDS) and the martensitic and magnetic transition temperatures (DSC, ac magnetic susceptibility) of the alloys were determined. High temperature DSC measurements were made in argon with 10 K/min. Two first measurements were carried out in the solid state (301 - 1273 K) and in the third measurement the material was melted (max meas. temp. 1573 K). The ordering temperature was obtained from the measurements in the solid state. As the e/a ratio was above 7.53 the ordering temperature was in the range of 1019-1039 K, otherwise a clear change was observed. The variation in heating and cooling was less than 5 K with small quaternary additions, but alloying of 8% Fe increased this difference to 18 K. Alloys with close Ni/Mn/Ga-ratio showed only minor differences in solidus and liquidus temperatures, but if there was a clear change in the Ni/Mn-ratio even those alloys having close e/a ratios showed a clear difference in melting behavior. When Ni/Mn is 1.5-1.6 the liquidus was 1364±2 K, and with 1.7-1.8 it is 1384±5 K, while with higher values not clear region could be determined.

Remarks:

A3.23 Regular Oral Presentation | Friday, Sept. 11, 12.00 - 12.15

Grain size dependence of martensitic phase transformation in Ni -Mn-Ga

N. Scheerbaum[1], J. Liu[1], S. Weiß[1], O. Gutfleisch[1], L. Schultz[1]

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Abstract. The magnetic shape memory alloy Ni-Mn-Ga shows a relatively large magnetic field induced strain within the martensite phase of up to 11% . The martensitic phase transformation temperature Tm is known to depend strongly on composition. To study the grain size dependence of Tm, Ni2MnGa melt spun ribbons were investigated. The as-spun ribbons (wheel speed 35m/s) were annealed at various conditions (800°C - 1050°C, 10min - 2h) above the L21 ordering temperature under an argon atmosphere. Always the same slow cooling procedure was used, especially to ensure the same state of atomic order for all samples. The grain size was subsequently determined by optical and scanning electron microscopy. Tm as well as grain size increase gradually with annealing temperature and are independent on the annealing time. This indicates strongly on a grain size dependence of Tm, and other influences are likely to be excluded. With decreasing grain size Tm decreases, as the constrains on the grains require in increasing amount of undercooling.

Remarks:

A3.24 Regular Oral Presentation | Friday, Sept. 11, 12.15 - 12.30

First principles determination of phase transitions in magnetic shape memory alloys

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Abstract. Magnetic shape memory alloys have recently attracted a lot of ex- citement, since they allow shape changes of more then 10% with a frequency in the kHz regime. The fundamental origin of this property is related to a martensitic phase transition. The material system Ni2MnGa is the most promising candidate for applications, but its operation temperatures and ductility still need to be improved. Hence, an extension of the currently limited knowledge on the phase diagram is decisive. In order to identify the stable structures and their transitions we performed ab initio calculations of free energies for the austenite, the (modulated) pre-martensite and the unmodulated martensite. Quasiharmonic phonons and [U+FB01]xed-spin magnons are considered, employing density functional theory. Using this approach we were able to successfully describe the phase transition in detail, to reveal the involved delicate interplay of vibrational and magnetic excitations and to accurately determine the transition temperature. The methods are used to interpret the experimental [U+FB01]ndings and to make predictions for modi[U+FB01]ed material compositions.

Remarks:

A3.25 | Paper ID – 04007 Regular Oral Presentation | Friday, Sept. 11, 12.30 - 12.45

In-situ TEM straining of tetragonal martensite of Ni-Mn-Ga alloy

Y. Ge[1], N. Zárubová[2], Z. Dlabáček[2], I. Aaltio[1], O. Söderberg[1], S. Hannula[1]

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Abstract. The in-situ straining of tetragonal martensite of Ni-Mn-Ga alloy was studied in a transmission electron microscope (TEM) JEM 1200EX equipped with a double tilt straining stage. The sample was analyzed before and after the straining experiments using the conventional as well as high resolution TEM (Tecnai F20 G2 200kV FEG). Before straining, the martensitic structure of the samples consisted of thermally induced self-accommodated multi-variants. During the in-situ straining, detwinning processes were recorded. The volume fraction of the twin variants preferably oriented to the applied tensile force increased at the expense of the less favorably oriented ones. The movement of the twin boundaries was followed in detail. The analysis performed after straining suggested that the detwinning processes occurred by movement of twinning dislocations. The interface between two twinned bands acted as a nucleation source for emitting the twinning dislocations.

Remarks:

A3.26 Regular Oral Presentation | Friday, Sept. 11, 12.45 - 13.00

Magnetically induced martensite transition in freestanding epitaxial Ni-Mn-Ga films

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Abstract. The effect of magnetic field on martensitic transformation in freestanding Ni-Mn-Ga films obtained by epitaxial growth on NaCl (001) is analyzed and compared with bulk crystal which transforms to the same form of martensite, i.e. five layered (5M) martensite. The martensitic phase, exhibiting a higher magnetization compared to austenite, is favored by an external field. A shift of martensite temperature of dT/dH = 0.36 K/T observed in the film is in good agreement with the value calculated from a Clausius-Clapeyron equation using measured saturation magnetization of both phases. Temperature - magnetic field phase diagram is constructed. Twin variant distribution after transformation in high magnetic field is compared with field-free transformation and the effect of field is evaluated. Energy input for actuation using magnetically induced martensitic transition and its practicality is compared with a magnetically induced reorientation of martensitic variants.

Remarks:

A3.27 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Martensitic transformation in epitaxial Ni-Mn-Ga films investigated by in-situ methods

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Abstract. The Ni-Mn-Ga system is a magnetic shape memory alloy. Epitaxial growth of this material is the most favorable approach for the preparation of active films for microactuators. The martensitic transformation of epitaxial Ni-Mn-Ga films on rigid substrates is examined with respect to changes of structure, microstructure, magnetic and electronic properties. For this, temperature dependent atomic force microscopy (AFM), X-ray, magnetization and resistivity measurements are used. The combination of these in-situ methods give a comprehensive understanding of the martensitic transformation and allows to identify differences of constrained epitaxial films compared to bulk. Experiments show the formation of a twinned, orthorhombic martensite with high uniaxial magnetocrystalline anisotropy from the austenite around room temperature. While most features are similar to a first order transformation, the transformation proceeds continuously to lower temperatures, an effect which could be explained by the constrain of the rigid substrate. The highresolution AFM micrographs directly reveal how martensite variants grow and show the converging of variants from different nucleation origins. A crystallographic modell is presented which explains the regular, triangular morphology observed by AFM in the martensite state.

Remarks:

A3.28 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Thermal and mechanical properties of amorphous/nanocrystalline Ti-Ni and Ti-Ni-Cu wires

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Abstract. Recently deformation-induced amorphization of TiNi shape memory alloys has been investigated extensively using cold rolling, shot peening and high pressure torsion. Recently we have reported the amorphization of TiNi wire. Wires of Ti-50.9mol% Ni alloys and Ti-41mol% Ni-8.5mol% Cu were deformed severely by cold drawing. Changes in mechanical properties and microstructures were investigated by means of X-ray diffractometry, TEM observations, micro-hardness measurements and tensile tests at room temperature. X-ray diffractometry and TEM observations revealed that the severely deformed TiNi wires were composed of the mixture of amorphous and nanocrystalline B2 phase. Hardness measured on the cross-section for the as-draw amorphous/B2 TiNi were over 600Hv for 70% reduction. The hardness value further increased by aging at 473 K for 3.6 ks. The tensile stress-strain curves had no-stress plateau, yet exhibited over 3% recoverable strain. Slope of the initial part of the tensile-stress strain curves increased with the reduction in area. The wire deformed aged at 573 K for 3.6 ks exhibited the tensile strength of 2.4 GPa, 5 % recoverable strain and apparent elastic modules of 71 GPa. X-ray diffraction patterns of Ti-Ni-Cu also exhibited significant peak broadening. Tensile strength of 62% drawn Ti-Ni-Cu wires was about 1.9 GPa. Such high strength wires with the hybrid structures composed of amorphous and nanocrystalline phase can be useful in medical devices.

Remarks:

A3.29 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

R-phase dominated transformation behaviour in nanocrystalline Ti-Ni-Ag shape memory alloy thin films

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Abstract. Advanced deposition methods based on wedge-type multilayer thin films sputtered from elemental targets were applied for the fabrication of Ti-Ni-Ag thin films within a broad composition range (materials library). Automated energy dispersive X-ray spectroscopy (composition), X-ray diffraction (microstructure), as well as temperature-dependent resistivity measurements (R(T)) were applied for the high-throughput characterization. Temperature-dependent stress measurements (σ(T)) on micro-structured cantilever Si-wafers with linearly varying compositions e.g. Ti45-xNi45+xAg10 (-15 <x <+15 at.%) were applied to characterize the actuator behaviour. Transmission electron microscopy (TEM) analysis revealed the existence of Ag precipitates, which were found to be coherent with the Ti-Ni matrix. The Ag precipitates lead to a R-phase dominated transformation behaviour for all transforming compositions. Further the Ag and Ti2Ni precipitates for Ti-rich compositions, as well as the Ag and Ni3Ti precipitates for Ni-rich compositions were found to significantly limit the grain growth during annealing of the multilayer film. For thin films with typicall grain sizes <100 nm the R-phase->B19' transformation upon cooling is significantly suppressed, leading to a significant temperature separation of the two transformation steps upon cooling (B2->R-phase, R-phase->B19'). Thus the B2->R phase transformation can be exploited independently, producing a stress change of up to 250 MPa.

Remarks:

A3.30 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Monte Carlo model for study of magnetostructural phase transitions in Heusler Ni-Mn-X (X= In, Sn, Sb) alloys.

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Abstract. In recent years, ferromagnetic Heusler Ni-Mn-X (X= In, Sn, Sb) alloys have attracted much attention in view of their unique properties such as the shape memory effect, giant magnetocaloric effect, large magnetoresistence. In this work we present the modeling magnetic properties in Heusler Ni-Mn-X (X= In, Sn, Sb) alloys by the help the Monte Carlo study. In the proposed model we consider the three-dimensional cubic lattice with real unit cell of Ni-Mn-X alloys. This lattice may be considered as four interpenetrating fcc sublattices. The whole system can be represented by two interacting parts. There are the magnetic subsystem and the structural one. For the magnetic part we choose the q-state Potts model for the first order magnetic phase transition. Here, we propose the ferromagnetic (FM) interaction between Mn and Ni atoms and for the non-stoichiometric cases we assume that, the excess of the Mn atoms occupying the sites of X atoms, interact with the Mn atoms on the Mn sites antiferromagnetically (AF). The values of FM and AF exchange constants we take from ab initio results for Ni-Mn-X alloy. The structural part is described by the degenerated three states Blume-Emery-Griffiths model allowing for a structural transformation from the austenitic phase to the martensitic phase. By the help of our model the thermomagnetization curves of Ni-Mn-X alloys are obtained. It is shown that these curves are in qualitatively agreement with the experimental data.

Remarks:

A3.31 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Effect of second phase particles on magnetostructural transition and magnetocaloric effect in Ni46In35In14Co5 ribbons

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Abstract. Ni-Mn-based Heusler alloys have attracted much attention due to some unusual magneto-responsive properties, such as magnetically induced shape memory, large magnetoresistance and inverse magnetocaloric effect.. Here, a study of the magnetic-field induced martensitic transformation and the magnetocaloric effect was carried out in Ni46Mn35In14Co5 melt-spun ribbons. Annealing significantly increases the degree of ordering in the austenite phase, reduces the critical field and hysteresis of the magnetically induced martensitic transformation, and increases the magnetically induced shift of martensitic transformation temperatures. A second phase (γ phase) starts to form after annealing at 900 ºC for 1 h and develops more pronounced after annealing for 2 h. The second phase has an f.c.c. structure with a = 0.365 nm and the Curie temperature of 370 K. The granular-like γ particles are mainly distributed at grain boundaries, but can also be observed within some large grains. Inside the austenite grains, the γ particles appear to be aligned along specific, for each grain different, directions. The formation of the second phase has little impact on the hysteresis, but broadens the transformation interval and reduces the magnetic entropy change. In order to obtained a narrow transformation hysteresis and a high magnetic entropy change, the second phase should be avoided by tailoring annealing parameters, either decreasing annealing temperature or shorten holding time.

Remarks:

A3.32 | Paper ID – 04009 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Martensitic transformation and stress relaxation in cold-deformed metastable steels

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Abstract. The elastic aftereffect and stress relaxation after testing in stable and metastable sheet steels of different structural classes subjected to monotonic and alternating loading under various conditions have been studied. Dependence of the material mechanical behavior and distribution of residual stresses on the strength, possibilities of phase transformations under load and sequence of alternating loading have been shown. A mathematical model for stamping test of sheet steels taking into account phase transformations and stress relaxation has been developed.

Remarks:

A3.33 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Adaptive martensite in epitaxial Ni-Mn-Ga films

S. Kaufmann[1], U. Rößler[1], M. Wuttig[2], R. Niemann[1], O. Heczko[3], J. Buschbeck[1], L. Schultz[1], S. Fähler[1]

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Abstract. Following the concept of adaptive martensite by Khachaturyan et al. [1] we show that the modulated 14M martensite phase in Ni-Mn-Ga is built of nanotwinned nonmodulated (NM) martensite. On the local scale, this was already suggested by Pons et al. [2] from (high-resolution) transmission electron microscopy. By means of epitaxial film growth we could confirm this concept by X-ray diffraction measurements and probe the transformation path in detail. The constraint by the substrate leads to films with austenite, 14M and NM phase coexisting over a very broad temperature range, contrary to the first order phase transformation common for bulk. The rigid substrate is used as a reference frame and allows confirmation of the transformation matrix from austenite to the 14M martensite in agreement with the Wechsler-Lieberman-Read theory [3]. Pole figure measurements show that the orientation of macroscopic NM variants is identical to the orientation of nanotwinned NM variants forming the 14M adaptive martensite phase. The results prove the orthorhombic 14M phase in our films not to be an intermediate, thermodynamically stable phase but an adaptive phase stabilized due to the constraint by the substrate-film-interface. The concept furthermore allows to explain the resulting complex microstructure.
[1] Khachaturyan A.G. et al., Phys. Rev. B 43, (1991) 10832 [2] Pons J. et al., Acta mater. 48, (2000) 3027 [3] Thomas M. et al., New J. Phys. 10, (2008) 023040

Remarks:

A3.34 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Stability of B2 austenite in severely deformed binary NiTi shape memory alloys

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Abstract. The martensitic phase transformation occurring in binary NiTi upon heating yields a transformation from the B19´ martensitic phase, stable at room temperature (RT), to the high temperature B2 austenitic phase. Impurities, composition and defects influence the transformation path and temperature. In the present work the influence of accumulative roll bonding (ARB) on the structure of NiTi and its martensitic phase transformation is studied. A coarse grained Ni49.9Ti50.1 alloy was made by arc melting using high purity components. During ARB the samples were cold rolled and folded 20 times leading to a degree of deformation of 1600% . By transmission electron microscopy (TEM) and differential scanning calorimetry (DSC) an analysis of the structure and the martensitic transformation was carried out. TEM of NiTi deformed by ARB shows at RT B2 nanocrystals that survived the deformation and are embedded in an amorphous phase. Isochronal DSC heating experiments agree with the TEM observation of retained austenite since an endothermic peak corresponding to a martensite to austenite transformation is not observed. A sharp exothermic peak occurs at 381°C indicating crystallization of the amorphous phase. After annealing at 500°C the martensitic phase transformation recovers at a reduced transformation temperature with a reduced reaction enthalpy as compared to an undeformed sample; this indicates that austenite is partially retained during cooling to RT.

Remarks:

A3.35 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Annealing effect on the structural and magnetic properties of melt spun Ni50Mn37Sn13 Heusler alloy ribbons

B. Hernando[1], J. L. Sanchez-Llamazares[1], M. L. Sánchez[1], M. J. Perez[1], V. M. Prida[1], J. J. Suñol[2], L. Escoda[2], C. Garcia[3]

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Abstract. Present contribution reports the effect of vacuum annealing at 550oC during 2 hours on the elemental chemical composition, martensitic transformation temperatures, phase structure and magnetic properties of as-quenched Ni50.6Mn36.3Sn13.1 Heusler alloy melt spun ribbons [1]. Annealing at this relatively low temperature slightly shifted the average elemental composition to Ni49.6Mn36.3Sn14.1, and preserved the highly oriented columnar-like microstructure of samples as well as their single-phase character (a cubic L21-type austenite that with the lowering of temperature transforms into a 7M orthorhombic martensite with MS = 221 K, Mf = 209 K, AS = 221 K, and Af = 236 K). Annealing led to a narrowing of X-ray diffraction lines with respect to as-quenched samples together with a cell volume reduction. A moderate change in transition temperatures was observed. The most important change consisted in the significant magnetization enhancement at low and high fields (50 Oe and 50 kOe, respectively) in the whole temperature interval. Hysteresis loops show well higher initial magnetic susceptibility than the one showed by as-quenced ribbons and consequently virgin magnetization curves show a fast approach to saturation. A significant magnetic hardening of martensite was observed.
[1] J. D. Santos, T. Sanchez, P. Alvarez, M. L. Sanchez, J. L. Sánchez Llamazares, B. Hernando, Ll. Escoda, J. J. Suñol, R. Varga, J. Appl. Phys., Vol. 103 (2008) 07B326.

Remarks:

A3.36 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Structural and magnetic properties of melt span Ni2.15Mn0.79Fe0.06Ga ferromagnetic shape memory ribbon

V. Khovaylo[1], E. Avilova[1], B. Hernando[1], V. Koledov[1], D. Kuchin[1], H. Miki[1], N. Resnina[1], J. Sanchez Llamazares[1], V. Shavrov[1], J. Suñol[1], T. Takagi[1], V. Zolotorev[1]

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Abstract. Recently, thin films and melt spun ribbons of ferromagnetic shape memory alloys have received considerable attention with respect to their functional properties. In this work we report on structural and magnetic properties of ribbons prepared from the master alloy of Ni2.15Mn0.79Fe0.06Ga composition. Ribbon flakes of several centimeters in length and a thickness of 10 - 14 μm were produced by single roller melt spinning in argon environment. Microstructure and nominal composition of the ribbons were examined by a scanning electron microscope. Martensitic and magnetic phase transitions were studied by DSC and magnetization measurements. The results obtained revealed that in the as-prepared ribbons magnetic order sets at TC $\sim$ 325 K and transform to the low-temperature martensitic state at Tm $\sim$ 250 K. These phase transition temperatures are significantly lower than those observed in the bulk Ni2.15Mn0.79Fe0.06Ga. Thermal treatment of the as-prepared ribbons increases both the martensitic and magnetic phase transition temperatures. Particularly, for a ribbon annealed at 473 K for 2 h the martensitic transition was found to increase to Tm $\sim$ 290 K. Thermoelastic properties under bending stress were studied by a multipoint technique. These measurements revealed that the ribbon demonstrates $\sim$ 0.65% bending strain upon transformation from austenitic to martensitic state. This work was partially supported by RFBR (Grants No. 06-02-39030 and No. 08-02-91317).

Remarks:

A3.37 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Magnetic Field Induced Phase Transformation in NiMnCoIn Metamagnetic Shape Memory Alloys

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[4] *University of Paderborn, Germany*

Abstract. Magnetic Shape Memory Alloys (MSMAs) have emerged as a new class of functional materials that are capable of magnetic field-induced actuation, sensing, magnetic refrigeration, and energy harvesting. In the present work, the magnetic field-induced martensitic transformation in Ni45Mn36.5Co5In13.5 MSMA single crystals is characterized as a new actuation mechanism with potential to result in high actuation work outputs. The effects of applied field on the phase transformation temperatures, lattice parameters, magnetization, and superelastic response are systematically investigated and selected results will be presented. The magnetic work output of NiMnCoIn alloys is determined to be more than 1 MJm$-$3 per Tesla, which is one order of magnitude higher than that of the most well-known MSMAs, i.e. NiMnGa. In addition, the work output of NiMnCoIn is orientation independent, potentially surpassing the need for single crystals, and not limited by a critical field, thus by a maximum work output. Transformation strains and magnetostress levels are also determined as a function of crystal orientation. It will be shown that crystals with a [111] orientation can demonstrate a magnetostress level of 140 MPa/Tesla with 1.2% strain under compression. These stress and strain levels are significantly higher than those from piezoelectric and magnetostrictive actuators. A thermodynamical framework will be introduced to comprehend magnetic energy contributions during the martensitic transformation.

Remarks:

A3.38 | Paper ID – 04011 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Effect of pulsed heat treatment on thermomechanical properties of rapidly quenched TiNiCu alloys

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Abstract. The present work is concerned with the investigation of shape memory Ti50Ni25Cu25 (at.%) alloy fabricated by melt spinning technique. The parameters of technology were optimized to produce the alloy in amorphous state. Dynamic crystallization of the alloy was performed by single electric pulse with duration from 2 ms to 100 ms. TEM and DSC investigations shown that the decrease of the pulse duration down to 2 ms resulted in significant refinement of the alloy structure with formation of nanosized martensitic plates (20-60 nm), and to decrease in critical temperatures of martensite transformations. The shape memory behavior of the studied alloy was characterized by strain-temperature curves obtained by thermal cycling the specimens through the transformation range under constant stress. It was found that the nanostructurization of the alloy led to some increase of completely recovery strain.

Remarks:

A3.39 | Paper ID – 04002 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

The effect of post annealing on structure, microstructure and magnetic properties of thin Ni-Mn-Ga films

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Abstract. The magnetic shape memory (MSM) alloy Ni-Mn-Ga is an active material where large strains are obtained by magnetically induced reorientation (MIR) of martensitic variants. For the integration in microsystems, epitaxial thin films are in the centre of interest since the highest strains have only been obtained in single crystals. In order to minimize the technological effort, sputter deposition at low deposition temperatures is favoured. However, for obtaining high degree of order and thus a high Curie temperature, an additional post heat treatment at elevated temperatures is necessary. We report on the consequences of the post annealing process on thin epitaxial Ni-Mn-Ga films. In addition to increasing the Curie temperature, the annealed film shows a secondary Ni-rich Ni3(Mn,Ga) phase. This phase has a well defined interface to the high temperature austenitic phase of Ni-Mn-Ga. Ni3Ga is formed due to evaporation losses of Mn and Ga. The formation of those precipitates can be avoided by preparing thin Ni-Mn-Ga films directly at elevated temperatures.

Remarks:

A3.40 | Paper ID – 04005 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Study of the martensitic transformation in the Hafnium-Palladium system

C. Declairieux[1], P. Vermaut[1], R. Portier[1], P. Ochin[2], V. Kolomytsev[3], A. Pasko[3], G. Monastyrsky[4]

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Abstract. High temperature shape memory alloys have received a large interest for many years but none of the systems studied so far has led to industrial applications. Those alloys are expected to develop an actuating role in high temperature environment as for example aircraft turbines. Lots of criteria are required in order to substitute or optimize heavy existing actuators. Here are presented a few results obtained with the system hafnium-palladium, not so documented for the moment, that develops a martensitic transformation at around 773 K. According to the characteristics of very well-known alloys such as NiTi, some compositions around the equiatomic are explored. The main objective of our work is to know the infuence of a stoechiometry gap on the microstructure of the alloys and the martensitic transformation.

Remarks:

A3.41 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Resonant ultrasound spectroscopy measurement of elastic properties of the CoNiAl alloy

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Abstract. Resonant ultrasound spectroscopy (RUS) is method for study of elastic properties of solids based on the inversion of natural frequencies of free elastic vibrations of a small simply shaped specimen. RUS methods is usually employed for measurements of temperature dependences of elastic constants, which is suitable for investigation of single crystals near the phase transition temperature. However, individual phases of CoNiAl ferroelastic alloy, which are the subject of interest, exhibit specific behaviors, especially strong anisotropy and low symmetry. Moreover, the available specimens usually have a general crystallographic orientation. These unique properties complicate automatic and reliable resonance detection and classification, stability of the inversion procedure, initial guess independence, and accuracy estimation. The elastic coefficients obtained by the RUS measurements are determinable with different accuracies, therefore a novel method employing also additional data from complementary measurements by the pulse-echo method , is suggested. In this paper, the theoretical background of RUS method, the experimental setup, and recent improvements are outlined and described. The results obtained from the measurements on a single crystal of CoNiAl will be presented and discussed. Influence of the microstructure of austenitic phase on the elastic properties will be examined.

Remarks:

A3.42 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Effect of composition of the atomic order influence on the martensitic and magnetic transformation temperatures of Ni-Mn-Ga ferromagnetic shape memory alloys

V. Sánchez-Alarcos[1], J. Pérez-Landazábal[1], V. Recarte[1], C. Gómez-Polo[1]

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Abstract. The effect of the long-range atomic order on the structural and magnetic transformations of Ni-Mn-Ga ferromagnetic shape memory alloys has been investigated. In particular, a comparative study of the evolution of the transformation temperatures of several alloys subjected to the same post-quench aging thermal treatment has been performed. The transformation temperatures have been obtained by "in-situ" Differential Scanning Calorimetry (DSC) measurements whereas the atomic order variations have been determined from neutron diffraction experiments. Surprisingly, two well differentiated behaviours are found depending on whether the martensitic transformation (MT) takes place on a ferromagnetic or paramagnetic state. For the alloys transforming from ferromagnetic austenite to ferromagnetic martensite (showing a modulated superestructure) a parallel increase of both the MT and the Curie temperatures (Ms and Tc, respectively) is observed upon post-quench heating. This increase has been related to a L21 ordering process. For the alloys transforming from paramagnetic austenite to non-modulated martensite, however, the behaviour of Ms and Tc is rather different and the evolutions of both transformation temperatures seem to be not longer correlated. The different influence of the atomic order on the respective transformations has been related to the crystallographic structure of the martensite and a key role of the quenching vacancies on the MT process is proposed.

Remarks:

B. Applied Research and Applications
B.1 Engineering Materials with MT

B1.01 | Paper ID – 05011 Invited Oral Presentation | Tuesday, Sept. 8, 8.30 - 9.00

Microhardness of binary near-equiatomic Ti-Ni alloys after severe cold rolling and post-deformation annealing

K. Inaekyan[1], V. Brailovski[1], S. Prokoshkin[2], A. Korotitskiy[2], A. Chernavina[2]

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Abstract. Comparative HV-microhardness and TEM studies of Ti-50.0at% Ni and 50.26at% Ni alloys subjected to cold-rolling (e=0.3, 1 and 1.72) and post-deformation annealing at 100-700°C (1 hour) are presented. Based on the TEM-measured grain size data for Ti-50.0at% Ni alloy as a function of an annealing temperature (Tpda) higher than 250°C, it was possible to evaluate the grain size (d) of the near-equiatomic Ti-Ni alloys at Tpda<250°C, using exponential extrapolation distribution of the d-Tpda data. It was shown that below a critical grain size (dc = 10 nm), the smaller the grain size (as a result of the decrease in annealing temperature), the lower the microhardness. This softening phenomena can be described, with good correlation between the approximation and experimental data, by the normal-abnormal Hall-Petch transition caused by the influence of the intercrystalline regions and by the melting temperature grain-size dependence.

Remarks:

B1.02 | Paper ID – 05021 Invited Oral Presentation | Tuesday, Sept. 8, 11.00 - 11.30

Shape recovery in high temperature shape memory alloys based on the Ru-Nb and Ru-Ta systems

A. Manzoni[1], A. Denquin[1], K. Chastaing[1], P. Vermaut[2], R. Portier[2]

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Abstract. This work investigates the high-temperature behaviour of three RuTa alloys and three RuNb alloys. The first step was to determine how Ta or Nb content affects the MT temperatures. The monoclinic Ru50Ta50 and Ru50Nb50 alloys undergo two successive displacive transformations from the high temperature β phase field: β (B2) - β' (tetragonal) - β" (monoclinic) whereas Ru45 Nb55 , Ru45Ta55 , Ru43Nb57 , and Ru43Ta57 exhibit a single transition from cubic to tetragonal on cooling. All alloys exhibit a highly twinned microstructure with a (011) compound twinning mode. The main feature of the β' - β" transformation is the formation of domains boundaries separating translation variants instead of formation of new twin separating orientation variants. The shape memory effect was studied through compression tests performed in the β' or β" phase. The total shape recovery is mainly due to the β' - β transformation and appears to decrease from about 3% for the monoclinic alloys to about 0.1% for alloys with 43% Ru in accordance with the evolution of the lattice parameters of martensites.

Remarks:

B1.03 | Paper ID – 05002 Invited Oral Presentation | Tuesday, Sept. 8, 14.30 - 15.00

Collaborative research center TRIP-matrix-composite

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Abstract. A novel composite material is presented, composed of a metastable austenitic stainless steel as matrix which shows the TRIP-effect and MgO-partially stabilized zirconia (PSZ) as reinforcement. Two processing routes will be applied: Cast infiltration of the steel into ceramic performs and powder metallurgy, respectively. In this paper, we will present the principle idea of the collaborative research center.

Remarks:

B1.04 Invited Oral Presentation | Thursday, Sept. 10, 14.00 - 14.30

Deformation twinning-induced grain boundary engineering and microstructural refinement in martensitically transforming materials

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Abstract. Shape Memory Alloys (SMAs) exhibit reversible martensitic phase transformation and shape change in a relatively narrow temperature range. SMAs are also unique due to their ability to undergo at least two modes of plastic deformation: mechanical twinning and dislocation slip in both martensite and austenite. The latter mechanism causes irreversibility in shape change during thermal and/or mechanical cycling. Here we show the possibility of manipulating grain morphology, grain size and grain boundaries of the austenite, in the most well-known SMA - NiTi, using a severe plastic deformation technique, by taking advantage of nano deformation twin formation in martensite. We propose a unique mechanism in which the nanotwins are associated with thermoelastic martensitic transformation and they transform back to austenite as new ultrafine grains with twin related grain boundaries. We also show the evidence of this mechanism in other SMAs and non-SMA intermetallics that undergo martensitic transformation. More surprisingly, severe plastic deformation is not a requirement for this mechanism to take place, as we have observed the same martensite twins and twin related austenite grains in Ni-rich NiTi with coherent precipitates without severe plastic deformation. The nanotwin-engineered grain structure significantly enhanced the reversibility of shape memory effect and may offer possibility for less embrittlement in corrosive biological environments utilizing low energy grain boundaries.

Remarks:

B1.05 | Paper ID – 05028 Regular Oral Presentation | Tuesday, Sept. 8, 9.00 - 9.15

Influence of minor additions of boron and zirconium on shape memory properties and grain refinement of a Cu-Al-Mn shape memory alloy

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Abstract. Cu-base alloys with 12.5 wt. % Al and 5 wt. % Mn with different amounts (0.05-2.00 wt.%) of boron or zirconium were prepared by ingot metallurgy route. The alloy ingots were homogenized followed by step quenching so as to obtain a structure that is completely martensitic. They were subsequently characterized by optical emission spectrophotometry, differential scanning calorimetry and optical microscopy. The shape memory and superelastic properties of the alloys were studied by bend and tensile test. The present study brings to light that boron acts as a good grain refiner, resulting in a reduction of about 80% in grain size. While it also increases the transformation temperatures by $\sim$ 10oC, it decreases the strain recovery by shape memory effect by 4% , and that by superelasticity by $\sim$ 2% . A comparison of the results of the alloy with B addition with that with Zr addition reveals that B is a better grain refiner for Cu-Al-Mn SMAs.

Remarks:

B1.06 | Paper ID – 05018 Regular Oral Presentation | Tuesday, Sept. 8, 9.15 - 9.30

Effect of martensite structure in graphitization process in hypereutectoid steel

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Abstract. Graphitization process in steels is referred to the decomposition of meta-stable cementite phase to more stable phases of graphite and ferrite. In steels this transformation often occurs in the range of 600-700 ºC. In common commercial steels the occurrence of graphitization process requires long periods of time due to the lack of carbide stabilizer elements such as chromium and manganese. Based on experimental observations, the initial microscopic structure of steels before graphitization has a considerable effect on shortening the time of this phase transformation. In this respect a structure with martensite matrix is identified as one of the best structures for making graphitized steels. However the way of effect and kinetic investigation of graphitization transformation of this structure is less performed by researchers. In this study graphitization behavior from martensite structure in comparison with other structures is investigated by using dilatometric tests, optical microscopic and scanning electron microscope micrographs.

Remarks:

B1.07 | Paper ID – 05003 Regular Oral Presentation | Tuesday, Sept. 8, 9.30 - 9.45

Comparative study of the structures of Fe-Mn-Si-Cr-Ni shape memory alloys obtained by classical and by powder metallurgy, respectively

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Abstract. Hot rolled specimens of low-manganese Fe-Mn-Si-Cr-Ni shape memory alloys, produced by classical and by powder metallurgy (CM and PM) with mechanical alloying, respectively, were analysed by tensile loading-unloading tests (TENS), by dilatometry (DIL), by X-ray diffraction (XRD) and scanning electron microscopy (SEM). Solution annealed specimens had two-phase structure, comprising γ-austenite and thermally induced α-martensite. The formation of α'-stress-induced martensite during TENS was ascertained by SEM and XRD being accompanied by rounded loading portions on stress-strain curves, characteristic to transformation induced plasticity, which preceded long stress plateaus with low tilt. Even if loading behaviour changed from transformation induced plasticity, on first loading, to slip induced plasticity, during subsequent ones, the specimens maintained their pseudoelastic behaviour on each unloading. DIL responses of the elongated CM and PM specimens emphasised a thermally-induced reversion, noticeable only during first heating, which was associated with thermally induced reversion of α-stress-induced martensite.

Remarks:

B1.08 | Paper ID – 05025 Regular Oral Presentation | Tuesday, Sept. 8, 9.45 - 10.00

Shape memory behaviour of nanostructured Ti-Ni alloy

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Abstract. The paper focuses on the study of the shape memory effect (SME) and two-way SME (TWSME) in nanostructured Ti-50.7 at.% Ni alloy. Two different types of structure were studied: nano-subgrain structure (after the moderate deformation with true strain e = 0.3) and nanocrystalline structure (after the severe plastic deformation with true strain e = 1.55). The homogenizing annealing at 700 deg, 20 min as well served as a reference heat treatment (RHT). In all cases isothermal annealing at 430-450 deg. was performed. The aging time, the initial phase state and external action parameters were varied. The SME training procedure was carried out under a bending mode; the constrained strain ϵt was varied from 3.9 to 25% and the loading time from 30 s to 3 min. Aging time, constrained strain and loading time strongly affect all studied SME and TWSME parameters. The combined effect of 10 h –aging, loading through B2RB19' transformation and 15,0 − 17,5% loading strain bring the highest combination of the recovery strain ϵr and the two-way shape memory effect ϵTW in the first training sycle. Multi-cycle training procedure does not bring significant changes. Variation of training parameters enables additional precise regulation of final functional properties. The obtained results can be used for development elements functioning in conditions of the SME and TWSME manifestation.

Remarks:

B1.09 | Paper ID – 05027 Regular Oral Presentation | Tuesday, Sept. 8, 10.00 - 10.15

TEM study of the mechanism of Ni ion release from Nitinol wires with original oxides

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Abstract. The surface of commercial Nitinol wires with original oxides and a thickness in the 30-190 nm range was investigated by different state of art TEM techniques. The oxide surface layer was identified as a combination of TiO and TiO2 depending on the processing of the wire. Between the core of the wires and the oxidized surface, an interfacial Ni3Ti nanolayer was observed while Ni nanoparticles are found inside the original oxide. The particle sizes, their distribution in the surface and the Ti-O stoichiometry were deduced from the analysis of the obtained data. Molecular dynamics calculations performed for evaluation of the stability of Ni particles relative to the atomic state revealed that a pure Ni particle has a lower energy than free Ni atoms inside the TiO2 lattice. The obtained results are discussed with respect to surface stability and Ni release in the human body.

Remarks:

B1.10 Regular Oral Presentation | Tuesday, Sept. 8, 10.15 - 10.30

Analysis of twin boundary movement under stress in polycrystalline Ni50Mn29Ga21

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Abstract. Magnetic Shape Memory (MSM) alloys show a reversible strain due to a reorientation of twin variants. In contrast to conventional shape memory alloys, plastic deformation in the martensitic phase, which is due to twin boundary motion, may be caused not only by mechanical stress but also by an external magnetic field. Recently, this effect was demonstrated not only for single crystals but also for polycrystals. Polycrystalline samples were prepared by directional solidification with a <100>texture of the high temperature cubic pphase parallel to the heat flow. The samples were heat treated for chemical homogenization and stress relaxation in the austenitic state. In order to understand the effect of the thermo-mechanical training, the configuration of the twin boundaries and their movement were analysed by polarised microscope during the martensitic transformation at constant stress. The microstructures before and after the thermo-mechanical treatment were analysed by Electron Back Scatter Diffraction (EBSD).

Remarks:

B1.11 Regular Oral Presentation | Tuesday, Sept. 8, 11.30 - 11.45

Preparation of textured and coarse grained Ni-Mn-Ga to show MFIS

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Abstract. Ni-Mn-Ga alloys are interesting because of their possible application as magnetic shape memory materials. This effect is caused by the motion of twin boundaries in a magnetic field. Up to now most of the research was concentrated on single crystals. However, the preparation of single crystals is a time consuming and cost intensive process and compositional changes along the growth axis as well as segregations may occur. This is why for technical applications there is a great interest in polycrystals, which are easier to produce. To achieve magnetic field induced twin boundary motion in polycrystals, directional solidification was applied in order to prepare coarse grained, textured samples. Stationary casting in a pre-heated ceramic mold mounted on a copper plate was employed to generate a heat flow towards the bottom of the sample and thereby a directional solidification in the opposite direction. The preferred solidification-induced growth direction was determined by EBSD. The martensitic transformation temperature which strongly depends on the composition was monitored by DSC, and it is shown that the chemical homogeneity along the sample axis is improved in likewise treated samples. After a training process stress-strain curves with and without magnetic field were measured and MFIS was observed. The results are compared to samples, which were prepared by a Bridgeman method with draw rates in the range of range of several 100 mm/h to obtain a texture.

Remarks:

B1.12 | Paper ID – 05016 Regular Oral Presentation | Tuesday, Sept. 8, 11.45 - 12.00

Functional properties of spherical segments made of Ti-Ni alloy with shape memory effect

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Abstract. The article is devoted to the investigation of changing behavior of force parameters developing in the material of spherical (buckled) segments at heating, depending on the temperature of overheat and presence of strain concentrators. It is shown that overheats of spherical segments relatively to the temperature of reverse martensitic transformations (Af) up to 50, 100, 150, 200, 250...600°C influence considerably the impact force and reactive forces. Specifically, the spherical segments exposed to overheat at temperatures in a free state always snap back with a stroke against the obstacle and with development of reactive forces at heating. Overheat of the spherical segments in a fixed state decreased the force parameters, and at annealing (200 – 250 °C), 1h the shape memory effect is suppressed completely. Influence of strain concentrators made up deliberately on the edges of the spherical segments depends on their length. It is shown that notches no more than 0,5 mm long do not influence the impact force and reactive force, while notches 1,0 mm long cause generation and development of nuclear cracks.

Remarks:

B1.13 Regular Oral Presentation | Tuesday, Sept. 8, 12.00 - 12.15

Properties of textured polycrystalline Ni50Mn29Ga21 after hot extrusion

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Abstract. Single crystals of Ni-Mn-Ga show magnetic-field-induced strain (MFIS) due to twin boundary motion. It could be proved in the last time, that coarse grained polycrystals with solidification texture show MFIS by twin boundary motion as large as 1 % after proper treatment including two step annealing and mechanical training. Recently textured polycrystalline NiMnGa rods of 25 mm diameter and 400 mm length were prepared by hot extrusion. The resulted grain size was approximately 100 μm. The presence of martensitic twins can be clearly seen within the recrystallized grains. The fibre texture of Ni-Mn-Ga samples has been measured with high-energy synchrotron radiation and neutron diffraction. A new experimental set-up for step annealing was used for the optimization of microstructure. After multi-step heat treatments the microstructural morphology was characterized. All structural features strongly depend on preparation conditions. The results of microstructure are discussed with respect to post-processing and phase transformations including variant selection of martensite. Furthermore, magnetic properties were determined by a VSM before and after various heat treatments as a function of field. Finally, the mechanical training of cubic Ni-Mn-Ga samples leads to a strain of 4 % at 100 MPa by mechanically-induced motion of twin boundaries.

Remarks:

B1.14 Regular Oral Presentation | Tuesday, Sept. 8, 12.15 - 12.30

Probing the martensitic transformation in low-alloyed TRIP steels at the level of individual grains

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Abstract. Low-alloyed transformation-induced plasticity (TRIP) steels are currently considered as promising materials for demanding technological applications due to their outstanding combination of strength and formability. The processing route of TRIP steels is designed to produce a final microstructure at room temperature that contains three phases: ferrite, bainite and austenite. The austenite phase (less than 20 vol.%) is retained in the TRIP microstructure in a metastable condition. The so-called TRIP effect stems from the transformation of the metastable soft austenite phase into the hard martensite phase. This phase transformation is induced by changes in temperature and/or the presence of external stresses. We have obtained in-situ experimental information about the martensitic transformation of individual austenite grains with a diameter of 1-5 micron embedded in the complex multiphase TRIP microstructure, by performing high-energy synchrotron X-ray micro-beam diffraction experiments. The observed austenite stability as a function of temperature and applied stress has been correlated to local microstructural parameters such as the local carbon content or the grain size. We have found a clear dependence of the austenite stability on the grain size, revealing the existence of a critical size below which the martensitic transformation is completely suppressed.

Remarks:

B1.15 | Paper ID – 05009 Regular Oral Presentation | Tuesday, Sept. 8, 12.30 - 12.45

Microstructural investigations of laser welded dissimilar Nickel-Titanium-steel joints

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Abstract. Nickel-Titanium based shape memory alloys are used in a variety of applications. These applications desire joining techniques that provide only local degradation of the functional properties and are compatible to the special mechanical properties of shape memory materials. Laser welding of nickel-titanium based shape memory alloys is an established process in medical application. Similar and especially dissimilar joints of Nickel-Titanium shape memory alloys, in particular joints of Nickel-Titanium and steel, are requested combinations to open additional fields of applications. A detailed investigation of the microstructural changes of laser welded parts is necessary to provide a good weld quality and to consider the related changes of the mechanical properties in the design process of applications. The formation of phases in the heat-affected zone and in the fusion zone as well was investigated by means of optical microscopy, scanning electron microscopy, electron backscatter diffraction and X-Ray diffraction. Focused ion beam was used for aim preparation of transmission electron microscopy samples at the interface NiTi/fusion zone, the center of the fusion zone and the interface fusion zone / steels.

Remarks:

B1.16 Regular Oral Presentation | Tuesday, Sept. 8, 12.45 - 13.00

Enhancement of superelasticity in Fe-Ni-Co-Al based alloys by texture control

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Abstract. Fe-based shape memory(SM) alloys, such as Fe-Mn-Si and Fe-Ni based alloys are commercially attractive systems for the practical applications because they are much cheaper and show better workability than Ni-Ti based SM alloys. In particular, Fe-Mn-Si based SM alloys, which exhibit the SM effect associated with γ(fcc) to ϵ(hcp) martensitic transformation, have been extensively studied, and they are now applied for some applications utilizing the SME, such as the pipe joining. However, in the Fe-based SM alloys, superelasticity(SE) have not been obtained, and they are prevented the practical application [U+3000] utilizing the SE. Recently the present authors have found that the Fe-Ni-Co-Al-based alloys undergo γ(FCC) to α'(BCT) thermoelastic martensitic transformation and that this alloys exhibit a SE of about 1% due to the thermoelastic transformation. [U+3000] In this study, microstructure control by thermomechanical treatment was carried out to improve the SE properties of Fe-Ni-Co-Al-based alloys. [U+3000] It was found that a strong {035}<100>recrystallization texture can be obtained by heavy cold reduction of over 90% and solution-treatment of over 1250 [U+2103], which drastically improves the ductility and SE properties. Consequently, SE strain of about 10% , which is larger than that of Ni-Ti based alloys, can be obtained in the specimen with the strong texture. This new system of Fe-Ni-Co-Al based alloys is expected to have high potential practical applications as SE component materials.

Remarks:

B1.17 Regular Oral Presentation | Tuesday, Sept. 8, 15.00 - 15.15

Effects of severe plastic deformation and quaternary additions on the shape memory response of NiTiPd high-temperature shape memory alloys

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Abstract. There is a growing demand in the aerospace, automotive, and oil exploration industries for high-temperature shape memory alloys (HTSMA) that can operate at temperatures greater than 100°C. NiTiPd HTSMAs have attracted considerable attention, since their transformation temperatures can be as high as 500°C. However, as the deformation temperature is increased, dislocation processes and thermally driven mechanisms become more dominant and the amount of recoverable strain drops significantly. The objective of this study is to strengthen NiTi-25Pd alloys against permanent deformation mechanisms to obtain enhanced shape-memory characteristics, in particular dimensional stability under repeated thermal cycles. This is accomplished through thermomechanical processing using severe plastic deformation via equal channel angular extrusion (ECAE) and solid solution hardening with quaternary additions of Sc and Ta. For ECAE processed NiTiPd and NiTiPd-X alloys, isothermal monotonic tensile tests are performed to assess the critical stress for slip of both martensite and austenite phases. Thermal cycling experiments at various constant stresses are utilized to characterize transformation temperatures, dimensional stability, transformation strain, and work output. The effects of Sc and Ta additions and the selected processing parameters on the dimensional stability will be discussed in the light of the results of these experiments and microstructural findings from electron microscopy.

Remarks:

B1.18 | Paper ID – 05024 Regular Oral Presentation | Tuesday, Sept. 8, 15.15 - 15.30

Final thermomechanical treatment of thin NiTi filaments for textile applications by electric current

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Abstract. Functional properties of NiTi filaments can be in a large extent controlled by the heat treatment after final cold drawing. Conventionally, this is being performed by straight annealing in long tubular electrical furnace by SMA providers. An alternative heat treatment method by Joule heating called Final Thermomechanical Treatment by Electric Current /FTMT-EC/ is presented in this work. Results of key experiments performed while developing the method are discussed in this paper. A prototype of a compact device for FTMT-EC treatment of continuous NiTi filaments is presented and differences compared to the conventional heat treatment in a furnace are discussed.

Remarks:

B1.19 | Paper ID – 05023 Regular Oral Presentation | Tuesday, Sept. 8, 15.30 - 15.45

Nonconventional production technologies for NiTi shape memory alloys

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Abstract. The development of new production technologies for NiTi Shape Memory Alloys (SMAs) is always challenging. Recently, we introduced two powder metallurgical (PM) processing routes involving mechanical activation of elemental powder mixtures and densification through extrusion or forging. Those processes were named Mechanically Activated Reactive Extrusion Synthesis (MARES) and Mechanically Activated Reactive FOrging Synthesis (MARFOS). Heat treatments were performed in order to adjust the B2-NiTi matrix composition, yielding a microstructure consisting of a homogeneous dispersion of Ni4Ti3 precipitates embedded in nanocrystalline B2-NiTi matrix. In the present study, we demonstrate the viability of those PM processes for producing NiTi SMAs. With in-situ X-ray diffraction and differential scanning calorimetry it is shown that B2-NiTi matrix undergo a B2-R-B19' two-step phase transformation.

Remarks:

B1.20 Regular Oral Presentation | Tuesday, Sept. 8, 15.45 - 16.00

Influence of Mn doping on the martensitic transformations and magnetic properties of Fe-Pd alloys

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Abstract. The influence of the partial substitution of Fe by Mn on the structural and magnetic properties of Fe-Pd ferromagnetic shape memory alloys has been investigated. A series of polycrystalline Fe69.4-xPd30.6Mnx alloys (x=0, 1, 2.5 and 5) were elaborated. The Martensitic Transformations (MT) on these alloys have been characterized by DSC calorimetry, optical and SEM observations and neutron diffraction measurements whereas the magnetic properties have been studied by SQUID magnetometry. It is found the fact that the substitution of 1% of Fe by Mn fully inhibits the undesirable irreversible FCT-BCT transformation without decreasing the FCC-FCT temperature, which means that the temperature range for giant magnetic field-induced strain is highly improved. On the other hand, it is especially interesting the fact that the substitution of 2.5% of Fe by Mn gives rise to the highest thermoelastic MT temperature observed up to now in the Fe-Pd system. Furthermore, the magnetocaloric effect and the magnetic field effect on the MT temperatures have been also evaluated in this alloys system for the first time.

Remarks:

B1.21 | Paper ID – 05029 Regular Oral Presentation | Tuesday, Sept. 8, 16.00 - 16.15

Deformation microstructure of TRIP/TWIP steels at the early deformation stages

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Abstract. Deformation microstructures of austenitic Fe-30Mn-(6-x)Si-xAl(x=2, 3 mass %) steels have been investigated at different nominal strains by the combined use of atomic force microscopy (AFM), electron backscatter diffraction (EBSD) and transmission electron microscopy (TEM). Three kinds of deformation products, i.e. planar dislocation bands, ϵ martensite plates and deformation twins are commonly formed on $\{111\}$ habit planes and exhibit a plate-like morphology in AFM images. At the very early stage of plastic deformation the main microstructure of Fe-30Mn-4Si-2Al steel is ϵ martensite. Some of the ϵ maretensite plates transform to the deformation twins with increasing tensile strain. On the other hand, the main microstructures of Fe-30Mn-3Si-3Al are planar and wavy dislocations at the onset of plastic deformation. The deformation twins generate and increase as deformation proceeds. In spite of the quite different microstructures between the two alloys, they exhibit the similar deformation behavior with strain hardening rates comparable to each other.

Remarks:

B1.22 Regular Oral Presentation | Tuesday, Sept. 8, 16.15 - 16.30

Shape memory behaviour of Ni-rich NiTi(Cu,Pd)Hf high temperature shape memory alloys (HTSMAs)

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Abstract. Although the shape memory phenomenon has been observed in a variety of materials, there are few practical alloys for use at temperatures greater than 100 °C due to their low transformation temperatures (TTs), poor material strength and ductility, unstable cyclic behavior, or unsatisfactory shape memory properties (especially under stress). Due to its relatively low cost and moderate ductility, NiTiHf seems to be the most promising HTSMA for use up to temperatures of ∼200 °C, with specific applications identified in the aerospace, automotive, and energy exploration industries. In this study, alloying and thermomechanical treatments are employed to tailor Ni-rich NiTi(Cu,Pd)-(20 at.%)Hf alloys with high strength, stable shape memory response, and good ductility. It is shown that TTs can be tailored through alloying and heat treatment and that stable cyclic behavior in the 100-200 °C temperature range can be achieved. Formation of precipitates by aging can be used to tailor shape memory and mechanical properties and significantly improves the shape memory behavior in Ni-rich NiTiHf alloys, by serving as barriers to dislocation motion. Furthermore, it has been observed that the critical stresses for phase transformation and dislocation slip, and temperature hysteresis are all thermomechanical treatment dependent. The initial results of this study indicate that Ni-rich NiTiHf alloys are promising shape memory materials for high temperature applications.

Remarks:

B1.23 Regular Oral Presentation | Thursday, Sept. 10, 14.30 - 14.45

Gradient ageing of functionally graded NiTi

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Abstract. This paper reports on a novel heat treatment method for the creation of functionally graded near-equiatomic Ni-Ti shape memory alloys. The method is artificial ageing within a graded temperature field, thus to create a structural gradient within the matrix of a Ti-50.8at% Ni alloy. It is based on the principle that the transformation behaviour and the thermomechanical properties of near-equiatomic Ni-Ti alloys are sensitively dependent on the precipitate structure. For the Ti-50.8at% Ni alloy used, it was found that the gradient-ageing resulted in varying thermal transformation behaviour along the length of wire samples aged within the gradient temperature field and a unique pseudoelastic behaviour with a positive stress gradient. Such behaviour provides improved controllability for actuation applications.

Remarks:

B1.24 Regular Oral Presentation | Thursday, Sept. 10, 14.45 - 15.00

Role of severe plastic deformation on cyclic reversibility of Ti50Ni30Pd20 high temperature shape memory alloy

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Abstract. Potential applications of high temperature shape memory alloys (HTSMAs) have been growing in recent years. However, their shape memory and cyclic stability behavior are poor, especially at high temperatures, due to the dislocation plasticity, propensity of which increases at high temperatures accompanying phase transformation. Therefore, this study addresses the improvement of shape memory and cyclic behavior of a TiNiPd alloy via severe plastic deformation using Equal Channel Angular Extrusion (ECAE). Ti50Ni30Pd20 HTSMA was ECAE processed at temperatures from 400°C to 600°C isothermally for four ECAE passes. Grain sizes of the processed samples were refined down to 100 nm. The effect of the ECAE process on the thermal cyclic reversibility under constant stress levels was investigated. The irrecoverable strain levels were dramatically reduced and the enhanced cyclic stability was attained in isobaric heating/cooling and constant stress thermal cyclic experiments which can be attributed to the increase in critical shear stress (CSS) for slip due to the microstructural refinement after ECAE process. A thermodynamical framework was introduced to better understand the effect of microstructural evolution on the different energy contributions to reversible phase transformation.

Remarks:

B1.25 | Paper ID – 05022 Regular Oral Presentation | Thursday, Sept. 10, 15.00 - 15.15

Investigations on martensite formation in CrMnNi-TRIP steels

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Abstract. A new generation of high alloyed cast CrMnNi-TRIP-steels was developed exhibiting high strength (UTS) as well as high uniform elongation for a maximum of energy-absorption. The nature of the high elongation is the formation of α'-martensite in the most deformed areas of the metastable austenitic steel, so that necking is de-layed. Because of the low stacking fault energy, due to the high alloying concept, deformation is mainly accompa-nied by the development of deformation bands in coarse austenitic grains and further the formation of α'-martensite. Within this study, stress-strain curves will be evaluated by the corresponding microstructure information obtained by LOM, SEM and EBSD examinations. The formation of α'-martensite is discussed for tensile and compressive loading at room temperature. The arrangement of martensite within the microstructure and the local deformation dependency of the α'-martensite fraction is considered. Martensite kinetics will be presented for interrupted defor-mation tests, determined via magnetic balance (MS), EBSD and light optical metallography (LOM).

Remarks:

B1.26 | Paper ID – 05007 Regular Oral Presentation | Thursday, Sept. 10, 15.15 - 15.30

Low cycle fatigue behavior and microstructure of a high alloyed metastable austenitic cast TRIP-steel

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Abstract. Total strain-controlled low-cycle fatigue tests were performed at room temperature on a high alloyed metastable austenitic stainless cast steel in the range of 1x10-3 $\leq$delta epsilon t/2$\leq$3x10-2 at constant strain rate of 4x10-3 s-1. The cyclic stress response revealed combinations of cyclic hardening, saturation and cyclic softening, depending on the applied cyclic total strain amplitude. Total train amplitudes higher than 8x10-3 result in a pronounced secondary hardening up to fracture. In the case of metastable austenitic steels, at higher strain amplitudes the secondary hardening is an indicator for the austenitic-martensitic transformation. The deformation-induced α'-martensite content was detected using a nondestructive magnetic measuring technique (feritscope). The microstructure was investigated for different total strain amplitudes applying optical and scanning electron microscopy (SEM). It could be observed that with an increasing total strain amplitude the deformation band density increased considerably.

Remarks:

B1.56 | Paper ID – 06020 Regular Oral Presentation | Thursday, Sept. 10, 15.30 - 15.45

Interaction of creep with the martensitic transformation in TiPdNi High Temperature Shape Memory Alloys

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Abstract. High Temperature Shape Memory Alloys (HTSMAs) represent a class of Shape Memory Alloys with transformation temperatures greater than 100ºC. However, as a consequence of their high transformation temperatures, these alloys can be exposed to a temperature regime where creep behavior can occur. Creep tests in NiTi were typically conducted in austenite and the creep and the transformation behavior never interacted in these studies due to the separation in the temperatures at which each of these phenomena are realized. Depending on the transformation temperatures of a HTSMA rate dependent plastic strain generated, can significantly impact the actuators performance. The present effort focuses on understanding the interaction between transformation and creep occurring simultaneously in a chosen HTSMA.
For the purpose of this study a HTSMA with transformation temperatures within the creep regime of the material is fabricated by hot rolling. Compression specimens are machined from the rolled material and standard creep tests are conducted at constant temperature at specific stress levels. In addition transformation induced thermal cycling is conducted to study the simultaneous transformation/creep behavior. TEM and XRD are conducted on the tested specimen to study the underlying microstructure. Based on the thermomechanical tests and the microstructural observations suitable conclusions are drawn for the interaction between the two mechanisms.

Remarks:

B1.27 | Paper ID – 05012 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Low temperature aging behaviour of transformation temperatures in some Cu-based and NiTi SMA

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Abstract. Effects of aging at intermediate temperatures (near 400ºC) in SMA have been found to produce precipitation, which affects the transformation behaviour. In this work, we observe some dependences (recoverable or not) of transformation temperature with aging at temperatures near or under 100ºC in β phase. Two copper-based SMA alloys have been analyzed, CuZnAl and CuAlBe. Also, some analysis has been done on pseudo-elastic NiTi. By aging at temperatures near 100ºC, the two copper alloys show changes in transformation temperatures, which can be related univocally to the changes in the temperature at which the alloy is kept. In both alloys, by staying long time at a given temperature, an asymptotic value of the transformation temperature is reached, and further coming to the same temperature produces the transformation temperature to evolve to that asymptotic value. The maximal amplitude of the changes is about 16% of the amplitude of the change in aging temperature. The changes are much faster in CuZnAl than in CuAlBe, and the sign of the changes is opposite in CuAlBe respect to that in CuZnAl. The process can be well modelled by a system of differential equations with one or two terms, giving a ”tracking” of the transformation temperature respect the temperature at which the alloy is kept. The activation energies for the time evolution suggest atomic-order related processes as cause for the transformation temperature changes. For NiTi, the evolution is much slower, and seems to be monotonic with time, suggesting a precipitation-related mechanism as the origin of the transformation temperature changes, even at temperatures near 100ºC. From the data, some conclusions may be drawn concerning long-time effects on the applications of the alloys

Remarks:

B1.28 | Paper ID – 05006 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Control loops with detection of inner electrical resistance and fatigue-behaviour by activation of NiTi - shape memory alloys

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Abstract. Shape memory alloys are thermally activated smart materials. Due to their ability to change into a previously imprinted actual shape through the means of thermal activation, they are suitable as actuators for microsystems and macroscopic systems. To apply these smart materials to a wide range of industrial applications, a simple method of controlling the actuator effect is required. The detection of inner electrical resistance allows to gauge the actuator movement. By usage of a microcontroller a smart system without any hardware sensors can be realized. Changes of outer boundary conditions and material fatigue (affecting the control loop) can be compensated by software. Furthermore an analysis and a description of the fatigue performance are of particular importance. A fatigue calculator dependent upon duty cycle is subjoined to the existing actuator simulation implemented in MATLAB/ SIMULINK. The focus of the simulation-model is on the activation behaviour of the SMA actuator, which defines its rate of heating and cooling. These parameters describe the dynamical characteristics of the actuator and the complete SMA powered system. Different load conditions and various actuator geometries and shapes, e.g. wire or spring actuator are simulated by calculation of the energetic balance of the whole system. The numerical model can be used to simulate time variant heating currents in order to achieve an optimal system performance for a defined time response of the actuator.

Remarks:

B1.29 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Recovery stress and shape memory stability in NiTi and NiTiCu ultrathin wires after aging under stress at high temperatures

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Abstract. Ultrathin NiTi and NiTiCu shape memory alloy (SMA) wires have excellent mechanical and functional properties e.g. high strength $\sim$ 1600 MPa, high values of recovery stress ($\sim$ 1000 MPa) generated when constrained martensitic wire is heated, large recoverable strains $\sim$ 6 - 8 % etc. Those properties allows them to be used as a reinforcement fibres in composite structures or act as an actuators where high recovery stress is desired. For the proper implementation of the SMA wires to the real application it is essential to know the recovery stress response in constrained conditions. Moreover for the fabrication procedure of the composites the high curing temperature and quite long holding time at this temperature is frequently desired. In this work we systematically studied recovery stress behaviour of ultrathin NiTi and NiTiCu wires during thermal cycling to high temperatures (150°C - 250°C) using dynamic mechanical analyzer. One thermal cycle consisted of heating to desired temperature, 60 minutes isothermal holding at this temperature and cooling to room temperature. It was observed that the NiTiCu wires are less sensitive to the effect of stabilization of martensite and generate higher recovery stress than NiTi wires. Evolution of the recovery stress during isothermal holding as well as the stress relaxation phenomena after each thermal cycle is discussed. Moreover the influence of different annealing conditions on recovery stress behaviour in NiTi and NiTiCu wires is shown.

Remarks:

B1.30 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Chemical elements distribution, variation of martensitic transformation kinetics and micro-hardness in stainless steel/TiNi bimetal composite produced by explosion welding

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Abstract. A bimetal composite “stainless steel – TiNi alloy” was produced from stainless steel Cr18Ni10Ti and shape memory alloy Ti49.4Ni50.6 by explosion welding. A chemical elements mixture, kinetics of martensitic transformations and micro-hardness in a bimetal sample were studied. The length of mixture zone between steel and TiNi alloy was found to be 6 micrometers. Outside this interval, the composition of the samples corresponded to the composition of steel and TiNi alloy. The data had shown that the explosion resulted in strong hardening of steel and slightly affected the TiNi alloy. Moreover, the micro-hardness had complex non-monotonic behaviour in the vicinity of a joint. It was observed that the explosion influenced significantly kinetics of phase transition in TiNi alloy. The temperatures both the direct transformation and the reverse one increased. Before explosion, the TiNi plate underwent B2 - R - B19’ transitions at temperatures TR = 7 C, MS = -26 C, and after welding the martensitic transformations in a bimetal composite were realized at TR = 60 C, MS = 47 C. Besides the transformation energy decreased from 17.8 J/g down to 4 J/g. The main reason for observed phenomena was a strong plastic deformation imparted to joint plates.

Remarks:

B1.31 | Paper ID – 05005 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Stable phase formation in a 85.67 wt.% Cu- 9.9 wt.% Al- 4.43 wt.% Ni shape memory alloy

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Abstract. 85.67 wt.% Cu- 9.9 wt.% Al- 4.43 wt.% Ni shape memory alloy has been studied. Polycrystalline specimens have been quenched, into water, after heat treatment at high temperature and followed by two successive runs from room temperature to 650°C and inversely. The microstructural and thermodynamic studies presented in this work have been performed using DSC (Differential Scanning Calorimetry), X-ray diffraction analysis at a variable temperature and TEM (Transmission Electron Microscopy) analysis. Stable phase precipitation of AlNi type was observed to appear in this alloy.

Remarks:

B1.32 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Influence of annealing temperature on crystalline structure and martensitic transformation in TiNi alloy fabricated by SHS process.

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Abstract. TiNi alloy were fabricated by Self-propagating High-temperature Synthesis (SHS) at a temperature of 337 C. DSC study had shown that TiNi alloy underwent B2-B19' transitions at two temperature ranges (Mp1 = 65 C, Ap1 = 98 C, Mp2 = -47 C, Ap2 = 1 C). It indicated that the TiNi alloy had a variation in the Ni concentration in specimen. The sample was subjected to isochronous annealing in the temperature range from 300 C to 700 C with the temperature step of 100 C and the duration of 20 minutes. After each annealing temperature the DSC and X-ray measurements were carried out. The results had shown that the kinetics of high temperature B2 - B19' transformation was not affected by annealing. The temperatures and the enthalpy did not changed. Contrary, the kinetics of martensitic transformation, occurring at low temperatures, depended on annealing temperature. It was observed the shift of transformation temperatures and split of heat peak. It was found that the variation of the transformation kinetics was due to the precipitation formation. Annealing of TiNi alloy produced by SHS could be used as a control parameter of its structure and properties.

Remarks:

B1.33 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Porosity, structure and martensitic transformation in TiNi shape memory alloy fabricated by SHS at different temperatures

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Abstract. Porous samples of TiNi alloy were prepared by Self-propagating High-temperature Synthesis (SHS) at different temperatures in the range of 337 C - 550 C. Data obtained showed that the porosity of samples was about 65 % . The TiNi, Ti2Ni and Ti3Ni4 phases were found in samples. However the alloys prepared at 480 C and 500 C did not contain Ti3Ni4 particles. The DSC data had shown that the alloys underwent B2 - B19' transformation at two temperature ranges. Firstly, the B2 - B19' transition was observed at high temperatures (Ms = 68 C, Mf = 58 C) and secondly - at low temperatures (Ms = -33 C, Mf = -67 C). These two transitions had different temperatures of reverse transitions at 87 C and -55 C, respectively. The variation of SHS temperatures changed slightly the kinetics of transformations. The comparison of X-ray and DSC data led to the conclusion that the TiNi alloys had the gradient of Ni concentration from 50 at. % to 51.5 at. % and more. Thus a transformation kinetics and porosity of TiNi alloy varied hardly at different synthesis temperatures in the range of 330 C - 550 C.

Remarks:

B1.34 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Influence of annealing on kinetics of martensitic transformations and structure in bimetal composite "stainless steel – TiNi" produced by explosion welding

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Abstract. A bimetal composite "stainless steel – TiNi" was produced from stainless steel Cr18Ni10Ti and shape memory alloy Ti49.4Ni50.6 by explosion welding at a room temperature. The results of the DSC analysis had shown that a TiNi alloy underwent the B2 - R - B19' martensitic transformations on cooling and B19' - B2 transition on heating. Explosion welding resulted in an increase of the phase transition temperatures more than 40 – 60 C; broadening the transformation temperature range and a decrease of a transition energy. The sequence of a transformation did not change. A recovery of martensitic transformation kinetics was studied during isochronous annealing. Annealing at temperatures 400 - 550C decreased the martensitic transformation temperatures and increased the energy of transitions. It was established that there were two processes in the alloy – elimination of a plastic deformation effects and the precipitation formation during annealing and they realized one after another.

Remarks:

B1.35 | Paper ID – 05017 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

The production of new structures from graphitized hypereutectoid steel

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Abstract. Graphitization process in steels is done during the dissociation of the cementite phase to ferrite and graphite. Since cementite is a metastable phase and graphite is more stable than it, graphitizing transformation occurs during a longer period of time. The presence of alloying elements such as chrome and manganese in common commercial steels results in the necessity of graphitization to be passed at a longer period of time which is not appreciated from the economical viewpoint. However, improving wear resistance and machinability is accounted as one of the main advantages for this process in steels. The final structure obtained after graphitization has been reported mainly as a mixture of ferrite, graphite and a few amounts of cementite. Prolonged annealing time for producing graphitized structure creates a little hardness because of the existence of the ferritic matrix. Therefore matrix has been changed by selecting various heat treatment cycles from ferritic to other types of phases besides new structures that also consist of graphite. Finally their hardness have been measured and compared as a criterion for determining mechanical properties and wear resistance.

Remarks:

B1.36 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Characterization of Cu based polycrystalline shape memory alloys

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Abstract. Previous works have shown that powder metallurgy Cu-Al-Ni shape memory alloys exhibit good mechanical and themomechanical properties [1]. In this work a detailed analysis of the microstructure of powder metallurgy samples, with a Cu-14,4% Al-4,21% Ni (% wt) composition, has been carried out. Two series of samples have been studied, from powders with diameter size between 25-200 μm and 25-50 μm, respectively. Samples undergo two different stages of the elaboration process: one after compacting by hot isostatic pressing (HIP) and the other after HIP and hot rolling (HR). The microstructural analysis of the different samples was carried out by optical microscopy (OM) and scanning electron microscopy with electron backscatter diffraction (EBSD). The martensitic transformation for the different samples was analysed by OM and transmission electron microscopy (TEM) by using a cooling stage. For different samples, the grain size and misorientation distribution, the lacking or presence of subboundaries, the thermal transformation and the kind of martensite observed during the thermal transformation have been analyzed. The results have been discussed in order to explain the relation between the microstructure of the polycristalline samples and their thermomechanical and mechanical properties.
[1] R.B. Pérez-Saez et al. Adv. Eng. Mat. 2 49-53 (2000)

Remarks:

B1.37 | Paper ID – 05004 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Particularities of phase transitions in thermomechanically processed Cu-Al-Mn shape memory alloys

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Abstract. The thermally and stress induced phase transitions occurring in a Cu-Al-Mn Shape Memory Alloy (SMA) have been investigated by means of thermal analysis techniques, tensile testing and microscopic observations. On heating a hot rolled solution annealed Cu-Al-Mn SMA, up to 873 K, two phase transformations, related to equilibrium phase precipitation and to 2-step order-disorder transition, respectively, were revealed by Differential Scanning Calorimetry (DSC). During tensile testing, the Cu-Al-Mn SMA under study experienced almost complete superelasticity, after five mechanical training cycles, as well as good ductility and tensile resistance. On trained specimens the formation of stress induced martensite was revealed by optical microscopy (OM) observations. The reversion to austenite of stress induced martensite was accompanied by relatively large increases of elastic modulus and internal friction, determined on Dynamic Mechanical Analyzer (DMA) and by marked variations of relative elongation, thermal expansion coefficient and elongation rate, determined by dilatometry. Since it is a two step transition, it was associated with the two morphologies of stress induced martensite observed by Scanning Electron Microscopy (SEM).

Remarks:

B1.38 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Precipitation of Ni4Ti3 in ultrafine grained NiTi shape memory alloys

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Abstract. In NiTi shape memory alloys (SMAs), the elementary processes of the martensitic transformation strongly depend on the microstructure of the material. It has been shown in previous publications that grain boundaries play an important role during the precipitation of Ni4Ti3 in NiTi SMAs with conventional grain sizes. In the present work, we show how such precipitation processes proceed in ultrafine grained NiTi and how aging affects the phase transformation behaviour of the material. Two ultrafine grained initial material states were produced by high pressure torsion (HPT) in combination with crystallization annealing, and by equal channel angular pressing (ECAP). The HPT material had an average grain size of 30nm and the ECAP material of 200nm. A third reference material of same composition with conventional grain sizes (about 10μm) was obtained by swaging and recrystallization annealing. All materials were subjected to aging treatments at 400°C for different durations. The microstructures were characterized by transmission electron microscopy (TEM) and X-ray diffraction (XRD), and the phase transformation behaviour was evaluated by differential scanning calorimetry (DSC). It was found that annealing at 400°C results in a slight grain growth while no evidence for precipitation was found. However, once the grain size reaches a critical threshold value of about 200nm, the nucleation and growth of Ni4Ti3 was observed. We conclude that the high density of internal interfaces is associated with increased nucleation stresses impeding the formation of precipitates.

Remarks:

B1.39 | Paper ID – 05015 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Structure and shape recovery characteristics of Ti-50.0% Ni thermomechanically treated industrial wire

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Abstract. The effect of post-deformation annealing (PDA) temperature in a range 300 to 700oC and induced stain (3 to 24%) on shape recovery temperature range (SRTR) was studied for an industrial Ti-Ni wire. To determine the characteristic temperatures of martensitic transformations, a differential scanning calorimetry was used. SRTR was determined by the method of bending deformation followed by heating for shape recovery. The wire structure was studied by X-ray diffraction and TEM methods. The original structure of wire is a B19'-martensite or a mixture of B19', R -phase and B2- austenite containing a well-developed dislocation substructure. To obtain structure uniformity along the wire length, the PDA temperatures of 500-600ºC are recommended. The SRTR at the wire of near-equatomic Ti-Ni alloys produced by warm drawing can be controlled using PDA in the temperature range 400 to 700oC. SRTR in the 70-100oC range is achieved by means of PDA at 400 to 650oC (SRTR increases in this PDA range). With the increasing of induced strain from 5 to 24% , the high-temperature shape memory effect appears and grows: a nonmonotonic Ak growth from 90 to 150oC and SRTR expansion are observed. Shape recovery parameters of studied wire are high: the maximum completely recoverable strain of 4 - 5% , the maximum recoverable strain of 7 - 13% , and they can be controlled using PDA.

Remarks:

B1.40 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Microstructure defects in thin films of TRIP steels

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Abstract. The deformation process of TRIP steel leads to a phase transformation, which is often described as a martensitic one in the literature. In order to be able to investigate the nature of this transformation and the related microstructure changes in the TRIP steels, we deposited thin films of the TRIP-steel by magnetron-sputtering on various substrates. Subsequently, these thin films were studied regarding their microstructure. X-ray diffraction (XRD), scanning electron microscopy (SEM) and transmission electron microscopy (TEM) were applied as the crucial experimental methods for the microstructure analysis. XRD data were used for the phase analysis, for the texture analysis and for the analysis of the density of microstructure defects. The information on the phase composition was obtained from the Rietveld method. The texture analysis was performed via the pole figure measurements. The analysis of the density of microstructure defects was done by using the line profile analysis. SEM was applied for the investigation of the morphology and the thickness of the deposited thin films. The results of XRD were verified and complemented by the high resolution TEM (HRTEM) that was combined with Fast Fourier Transformation (FFT). HRTEM/FFT was used for description of the local orientation relationship, for the characterisation of the interfaces between individual crystallites of different phases and for the description of the defect structure at the interfaces between different phases.

Remarks:

B1.41 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

In-situ study of the microstructure defects in TRIP steels

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Abstract. The TRIP steels are prospective materials for the use in the safety and light constructions. The most important applications like high energy absorption are based on the TRIP effect that arises during the martensitic phase transformation. Samples of the TRIP steels were investigated regarding their microstructure development during deformation. The aims of the structural studies were the determination of the type and density of the microstructure defects like dislocations and stacking faults. These studies were complemented by the investigation of the kinetics of the defect formation. The description of the kinetics is based on the ex-situ and in-situ analysis of the stress and/or strain induced martensitic phase transformation. The results of the microstructure analytics using optical microscopy, X-ray diffraction, scanning electron microscopy (SEM) and transmission electron microscopy (TEM) will be presented; a preliminary microstructure model of the defect structure in selected TRIP steels was built. A strong correlation was observed between the changes of the lattice parameter and the line broadening during the plastic deformation of the in-situ bent samples as seen by the in-situ X-ray analysis. Formation of the shear bands was observed using optical microscopy. The TEM analysis shows the creation of micro-twins at the boundaries between neighbouring phases.

Remarks:

B1.42 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Effects of constrained aging on the shape memory response of Ni-Rich NiTi shape memory alloys

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Abstract. Precipitation heat treatments notably affect the phase transformation behavior of Ni-rich NiTi shape memory alloys (SMAs). Aging NiTi under mechanical constraints is expected to influence the number of precipitate variants providing a method for manipulating the internal stress fields in the material. This in turn should influence two way shape memory effect (TWSME) and thermo-mechanical cyclic stability, and possibly provide a mechanism for processing dimensionally stable alloys that require little or no training. To better understand the effects of different constraining conditions during aging on TWSME and cyclic stability, two Ni-rich NiTi compositions (50.6at.% Ni and 52at.% Ni) in single crystalline (oriented along the [112] and [100] directions) and polycrystalline forms were aged under different tensile and compressive stress levels at either 400C or 450C for times ranging from 1.5 to 48 hours. The goal was to produce different precipitate variants and control their size, coherency, and volume fraction. The samples then underwent isobaric thermal cycling and isothermal pseudoelastic tensile experiments. Transformation strains up to 10% were observed in the single crystals. During the isobaric thermal cycling experiments, the R-phase transformation was observed at stress levels up to 400 MPa. Notable irrecoverable strain levels were detected upon the cease of R-phase formation, above 400 MPa. Selected results from this body of work will be presented in detail.

Remarks:

B1.43 | Paper ID – 05001 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

The effect of loss of stability of an arc-plate made of Ti-Ni shape memory alloy

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Abstract. Mechanical behavior of an arched Ti-Ni strip with shape memory effect is investigated. It is shown that an arched Ti-Ni strip bent inversely to its initial shape at heating restores its initial shape with a snap ("the snap effect"). This type of behavior is caused by loss of stability at reverse martensitic transformation. It should be noted that the clap is heard when the strip's ends rest on the stationary hinged grips. If one or both ends are free, the transition to the austenitic state and the form changing process occur steadily. Shift of one of the edges of an arched strip at phase transformation is a necessary condition for loss of stability with a realization of a snap with a clap. Regular patterns and peculiarities of form changing of an arched strip at different displacement values are found out.

Remarks:

B1.44 | Paper ID – 05008 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Martensitic transformation in NiTiCo strip covered by nanocrystalline platinum layer

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Abstract. The surface modifications and their effects on the transformation characteristics of shape memory alloys are of interest. The NiTiCo strip was produced applying twin roll casting technique and after that covered by platinum layer using magnetron sputtering. Structure of the layer was studied by means of X-ray diffraction and electron microscopy. Transformation temperatures were determined using differential scanning calorimeter (DSC). The investigations show that in the NiTiCo strip occurs two-steps (by the R-phase) reversible martensitic transformation between the parent B2 phase and the monoclinic martensite B19'. The platinum layer reveals nanocrystalline structure with average grain diameter of 41 nm. It was stated that the nanocrystalline platinum layer does not limit martensitic transformation in the covered strip and can be used as a protective layer.

Remarks:

B1.45 | Paper ID – 05010 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Low temperature crystallization of TiNi films by ion irradiation

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Abstract. TiNi films are well known as a typical shape memory alloy (SMA), and are expected to be promising materials for micro actuators. The film crystallization needed for making the shape memory property appear had been usually realized by high temperature (above 450 °C) annealing process during and/or after the sputtering deposition. As a special case, it was reported that the crystallization temperature could be lowered by enhancing the energies of sputtered particles with a single-target sputtering deposition. However, this method could not be applied to the multi-target sputtering deposition, which was essential to precisely controlling the TiNi film composition. Furthermore, it also had a difficulty in freely controlling the energies of sputtered particles. In order to resolve the problem we developed a new apparatus as well as a new process for lowering the crystallization temperature by using ion irradiation, and realized the crystallization at 200 °C of substrate temperature. The details of the film characteristics were reported in another paper. In order to further lower the crystallization temperature we try to improve the bias-voltage introduction into vacuum as well as to optimize the ion irradiation conditions. Resultantly, we have realized the low temperature crystallization at 150 °C of substrate temperature.

Remarks:

B1.46 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Shape memory behavior in (Ti,Zr,Hf)50(Ni,Cu)50 alloys prepared by glass devitrification

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Abstract. For transformation temperatures Af above 400K, conventionally produced shape memory intermetallic compounds are often brittle. One of the opportunities to overcome problem is realization of the temperature regime of the glass transition on cooling from the metallic melt state in order to obtain bulk metallic glass precursor of a shape memory material, and subsequently crystallize it with appropriate thermal treatment. Series of multielementary AB-type shape memory intermetallic compounds with the effective element A containing a mixture of the early transition A elements (Ti, Zr, Nf) and the effective element B containing mixture of the late transition elements B=(Ni, Cu) have been produced by means of the melt-spinning /ribbons/, twin-roll /strips/ and mould casting /bars/ techniques. Glass forming ability is analyzed through characteristic temperatures obtained by means of calorimetric study (Tg is the glass forming temperature, Tm is melting temperature, Tx is temperature of crystallization, reduced glass transition temperature TRG=TG/TM). GFA is found strongly dependent on the specific ratio between constituent alloying elements. We report here a choice of composition, which after fast cooling, is amorphous and after an adequate thermal treatment recover a reversible B2<=>(B19)<=>B19' martensitic transformation sequence and demonstrate shape memory and superelastic properties (up to MS∼400 K, AF∼450 K). Nature of specific microstructure in mould cast bars is discussed.

Remarks:

B1.47 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Explosive welding of stainless steel/TiNi bimetal composite

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Abstract. TiNi joining to other metals is considered to be difficult process. The strength of such joints is often low due to formation of intermetallic phases and overheating of the material. The laminar composite "steel-TiNi" and "steel-TiNi-steel" was obtained using explosive welding. Ti49.4Ni50.6 plates and 12Cr18Ni10Ti steel plate were used as initial materials. The microstructure of welded joint and its mechanical properties were studied. The application of explosive welding can provide composite materials that combine the functions of executing mechanism with shape memory effect and counter body.

Remarks:

B1.48 | Paper ID – 05014 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Ageing effects on phase transformations in NiTi alloys

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Abstract. Phase transformation behaviour of Ti-rich and Ni-rich NiTi SMAs subjected to two rounds of heat treatments are compared. The first group of samples, received as straight-annealed, was subjected to a series of heat treatments in the temperature range from 200 to 900ºC (designated in the text as 1st round of heat treatments). A second group of samples was subjected to a previous annealing at 900ºC, followed by heat treatments in the temperature range from 200 to 900ºC (designated in the text as 2nd round of heat treatments). Phase transformation temperatures are determined by electrical resistivity (ER) measurement in the temperature range from -140 to +130ºC. It was observed that Ti-rich NiTi alloy, previously annealed at 900ºC during the 1st round of heat treatments, does not show any change in transformation characteristics after the 2nd round of ageing treatments, whereas, for Ni-rich NiTi alloy, it was found that there is a difference in the transformation behaviour after the 2nd round of ageing treatments.

Remarks:

B1.49 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Structural study of extruded CuAl13Ni4 shape memory alloy

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[2] *University Dunarea deJos of Galati, Romania*

Abstract. This paper presents a structural study for a copper based shape memory alloy. The behavior of CuAl13Ni4 alloy, is evaluated by X-ray diffraction. On cooling, the martensitic transformation takes place from the ordered structures to long period two layered structure. The crystalline phase transformations of those alloys are very sensitive to the heat treatments, deformation degrees and also to the undesired aging effects. In particular, the study has been made on the CuAl13Ni4 shape memory alloy samples after hot extrusion, quenching and aging in martensitic state.

Remarks:

B1.50 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

High pressure torsion (HPT) applied to Cu-Al-Ni cooper based shape memory alloy

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Abstract. CuAlNi alloys have been one of the Shape Memory Alloys (SMA) deployed in the non-medical applications as an alternative to the conventional NiTi alloys due to their easy machining and less price. In this study, a modified technique of High Pressure Torsion (HPT) is applied on CuAlNi SMA. When compared to the classical technique, in the present HPT system the pressure is applied on the high speed rotating piston. The rotation speed can be changed up to 650 rpm. The hard-to-deform CuAliNi SMA could be deformed and the heat generated heats the sample up to 900ºC in just a few seconds. Microstructural studies reveal the formation of ultrafine grains with nano sized precipitates. In-situ X-ray Diffraction (XRD) is employed to determine the phase transformation in the temperature range from -80 to +240ºC.

Remarks:

B1.51 | Paper ID – 05019 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Effect of carbon on the cavitation erosion resistance of Fe-Ni-C austenitic alloys

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Abstract. The effect of strain-induced martensitic transformation on the cavitation erosion resistance of Fe-20Ni-xC (x= 0.4 to 0.9-wt.%) carbide-free and fully austenitic alloys was investigated with respect to strain energy as an initiator for strain-induced martensitic transformation. The strain energy increased with increasing carbon concentration. The cavitation erosion behavior of High-C specimens is worse than that of low-C specimens. The cavitation erosion resistance decrease was thought to occur as a result of the higher incremental energy required to initiate martensitic transformation, which then made it difficult to transform austenite into martensite with respect to increasing carbon concentration. Therefore, in this study, the effect of carbon on strain-induced martensitic transformation was investigated by measuring the critical energy required to initiate strain-induced martensitic transformation (CESIMT). The relationship between the critical energy and the cavitation erosion resistance was also investigated with Fe-20Ni-xC (x=0.4 to 0.9-wt.%) alloys.

Remarks:

B1.52 | Paper ID – 05020 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Surface modification of Ni-Ti alloy by low-temperature nitriding process

J. Lelatko[1], T. Goryczka[1], T. Wierzchon[2], M. Ossowski[2], B. Losiewicz[1], E. Rowinski[1], H. Morawiec[1]

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Abstract. In order to create new applications and enhance the performance of NiTi alloys, surface modifications are important to improve their biocompatibility. TiN coatings, due to its low chemical reactivity, high hardness and resistance to wear and corrosion, have been adopted for protecting surface of the NiTi alloys. In presented work the structure of layers formed at surface of the NiTi alloy was reported. The layers were formed using glow discharge technique at low temperature: 300 - 400°C. Thickness, surface roughness, interface roughness, density were calculated using reflectivity measurement. The X-ray grazing diffraction was applied for phase analysis. The chemical composition was determined using the XPS method. Corrosion resistance was studied applying the potentiodynamical method. Electrochemical characteristics of the samples were measured at the room temperature in Tyrod's solution. Results have shown that low temperature nitriding produced the layers, which consisted from the nanocrystalline TiN phase. Relatively high values of corrosion and breakdown potentials proved that the TiN layers as well as the intermediate Ti3Ni phase effectively protect surface of the NiTi alloys against nickel ion release.

Remarks:

B1.53 | Paper ID – 05026 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Processing technologies of Ni-Ti based shape memory alloys

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Abstract. Transformation characteristics and properties of the Ni-Ti based shape memory alloys are in the first place highly dependent on processing technology. It is known that small deviation from the required composition can cause very important change of transformation temperatures. For this reason it is necessary to pay special attention to the metallurgy of these alloys. The current key technologies for processing are in most cases realised in vacuum, and various methods of melting are used (electron-beam melting, arc melting, induction high-frequency melting). Plasma melting is another possibility. Complications during preparation are caused mainly by carbon, nitrogen and oxygen, which form non-metallic inclusions. Carbon is in the alloys related mainly with their preparation in graphite crucibles. Other problems are connected with observation of appropriate conditions for crystallisation and with related minimisation of possible micro- and macro-segregations. Formation of titanium carbide and titanium oxide in Ni-Ti shifts concentration of individual elements and thus leads also to change of the temperature of martensitic transformation. Creation of a low-melting phase Ti2Ni, which causes a distinct susceptibility to hot formation of cracks, is another issue arising during melting of Ni-Ti alloys. The presented article is focused on comparison of individual methods of preparation of the alloys mentioned above, i.e. induction vacuum melting, plasma and electron-beam melting.

Remarks:

B1.54 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Effect of annealing on the martensitic transformation of a single crystalline Ni-Fe-Ga alloy

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Abstract. For the ferromagnetic shape memory alloys belonging to the Ni-Fe-Ga system, the martensitic and the magnetic transitions are both expected to occur close to room temperature for a composition Ni54.5Fe18.5Ga27. Such an alloy would therefore be a good candidate for technical applications (including, in a prospective way, the magnetocaloric effect). However, the transformation temperatures for Ni-Fe-Ga alloys are known to be strongly dependent on the heat treatment. The main mechanisms underlying this effect are L21 ordering and precipitation, but the relative importance of each at intermediate temperatures (500-1100 K) is not well known. The Curie temperature also changes upon heat treatment, thus overlapping of the martensitic and magnetic transition takes place only for selected heat treatments. In this work, the evolution of the martensitic transformation temperatures of a single crystalline Ni54.5Fe18.5Ga27 alloy submitted to annealing at temperatures ranging between 470 and 1170 K is studied. The results, obtained by means of DSC measurements, allow distinguishing several stages, namely ordering up to 800 K and precipitation above this temperature. It is interesting to note that L21 ordering seems to be incomplete even after prolonged ageing at temperatures as low as 570 K. On its turn, precipitation is accompanied by a drop of transformation temperatures and loss of transformation heat.

Remarks:

B1.55 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Magnetocaloric effect and entropy change linked to martensitic transformation in a metamagnetic Ni-Mn-In-Co shape memory alloy

V. Recarte[1], J. I. Perez-Landazabal[1], C. Gomez-Polo[1], V. Sanchez-Alarcos[1], S. Kustov[2], E. Cesari[2]

[1] *Public University of Navarra, Spain*
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Abstract. Ferromagnetic shape memory alloys (FSMA) based on Heusler compounds show large values of MCE at the martensitic transformation (MT) due to the abrupt change in the magnetization through the structural transition. The different magnetic state in each phase promotes a discontinuous magnetization and consequently a magnetic entropy change at the MT temperature. Regarding the study in Heusler alloys, giant inverse MCE ($DS>0$), where the adiabatic application of a magnetic field causes a cooling of the sample, was reported in Ni-Mn-Sn, Ni-Mn-In and Ni-Mn-Sn-Fe. In this work, the analysis of the MCE in a Heusler type Ni-Mn-In-Co alloy is reported. For samples of the same composition, the variation of thermal treatments (i.e. the order degree of the alloy) promotes strong variations of the value of MCE at the MT, from DS=8.5 J/kg K to DS=30.5 J/kg K for 6 T. A similar dependence of MT temperature and transformation entropy has been found by Differential Scanning Calorimetry measurements. In this way, a correlation between the entropy change induced by the magnetic field DS and the MT entropy change DSMT has been determined and a limiting value of the MCE, with $DS \approx DSMT$ has been observed.

Remarks:

B.2 Testing and Modelling

B2.01 | Paper ID – 06001 Invited Oral Presentation | Wednesday, Sept. 9, 14.00 - 14.30

Thermomechanical cyclic behavior modeling of SMA materials and structures

S. Arbab Chirani[1], L. Saint-Sulpice[2], S. Calloch[2]

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[2] *LBMS/ENSIETA, Brest, France*

Abstract. A 3D thermomechanical macroscopic model describing the cyclic eects in SMA has been developed by Sant-Sulpice et al.. The essential of this model is based on the introduction of a variable describing the development of jammed martensite. As it is known, a residual strain under cyclic thermomechanical load- ings is developed in SMA like the ratcheting eect in plasticity. The origin of the evolution of the residual strain in SMA can be the plasticity or the development of jammed martensite. In some SMAs, its origin has been veried and it has been concluded that it is mainly due to the jammed martensite. This permits to justify the models constitutive equations. The developed model has been validated by simple thermomechanical cyclic tests. It has been integrated numerically in Cast3M nite elements code. This study is organised in two parts. The rst one concerns the numerical scheme and the validation tests on a volumic element under simple cyclic loadings, cyclic proportional and non proportional loadings. The second part concerns the numerical study of SMA structures. Two coil sprins actuators under cyclic assisted shape memory eect are also studied.

Remarks:

B2.02 | Paper ID – 06008 Invited Oral Presentation | Thursday, Sept. 10, 8.30 - 9.00

Numerical simulation of nitinol peripheral stents: from lasercutting to deployment in a patient specific anatomy

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[2] *IBItech, Ghent University, Belgium*

Abstract. Cardiovascular disease (CVD), which is often related to atherosclerosis, is the most common cause of death in European countries. At present, the trend is to apply percutaneous techniques, using nitinol self-expanding stents, to treat peripheral occluded vessels such as carotid or superficial femoral arteries. Although this class of stents addresses the biomechanical requirements (i.e. flexibility, kink resistance, etc.), it has been observed that many of these stents implanted in peripheral vessels are fractured. Numerical simulations have shown to be very useful in the investigation and optimization of stents and also to provide novel insights into fatigue/fracture mechanics. To date most finite element based stent simulations are performed in a straight simplified anatomy and neglect the actual deployment process; consequently there is a need for more realistic simulations taking the different stages of the stent design process and the insertion in the target anatomy into account. This study proposes a virtual framework to numerically analyze nitinol stents from the lasercutting stage to the deployment in a (patient specific) tortuous anatomy. The developed framework consists of two simulation steps: 1) creation of a 3D parametric finite element model of a laser-cut stent and expansion of the stent before heat treatment; 2) crimping/bending of the expanded stent mimicking the stent insertion by the delivery system and gradual deployment of the stent within target vessel.

Remarks:

B2.03 | Paper ID – 06010 Invited Oral Presentation | Friday, Sept. 11, 11.15 - 11.45

From the thermal and kinematical full-field measurements to the analysis of deformation mechanisms of NiTi SMAs

P. Schlosser[1], D. Favier[1], H. Louche[2], L. Orgéas[1], Y. Liu[3]

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Abstract. Intensive experimental investigations have been carried out to understand deformation mechanisms associated with the superelasticity of polycrystalline Nickel-Titanium Shape Memory Alloys. This paper analyses results concerning superelastic tensile tests on thin walled tubes and sheets of NiTi. During the deformation, thermal and kinematical full-field measurements were simultaneously carried out thanks to the use of both visible and Infrared cameras. Heat source fields were estimated from the thermal measurement during both homogeneous and localised stages of deformation of these tests. Local heat energy values were then obtained by integrating heat sources over time for any given location on the sample. This provides in situ local calorimetry measurements similar to a local Differential Scanning Calorimeter all along the specimens. Deformation mechanisms can be analysed from the simultaneous knowledge of heat source-strain rate fields or of heat energy-strain fields. It is shown that forward and reverse transformation deformation mechanisms are involved in all homogeneous stages usually considered as elastic deformation of austenitic and of martensitic phases. Transforming material fractions are estimated based on thermomechanical analysis of the data. The kinematic and morphology of deformation localisation during stress plateaus are also investigated. It is shown that forward (loading) and reverse (unloading) transformations are not complete inside the localised bands.

Remarks:

B2.04 | Paper ID – 06024 Regular Oral Presentation | Wednesday, Sept. 9, 14.30 - 14.45

Structural and textural evolution during cold work in Ti-Rich Ni-Ti shape memory alloy

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Abstract. The properties and cost have made the Nickel-Titanium (NiTi) shape memory alloys (SMA) attractive for a variety of applications wherein shape memory effect (SME) / superelasticity (SE) and biocompatibility are important. Anisotropy of the shape recovery associated with shape memory effect strongly depends on the type of preferential orientation, that is present, as well as the 'strength' of the texture. The goal of the present work is to investigate the structural and textural evolution in annealed (at 500ºC for 30 minutes in air) Ti-Rich Ni-Ti SMA (Ni-51at% Ti) when subjected to cold rolling at 8 distinct thickness reduction (2, 4, 6, 8, 10, 20, 30 and 40%). The textural results were obtained by X-Ray Diffraction (XRD) at room temperature (B19' phase). The structural evolution was observed by temperature dependent XRD spectra. Indentation hardness test at room temperature (B19') was also performed. Differential Scanning Calorimetry (DSC) was used to identify the transformation temperatures and the phase stabilization after all steps of cold work treatments.

Remarks:

B2.05 Regular Oral Presentation | Wednesday, Sept. 9, 14.45 - 15.00

Two-way shape memory effect and magnetic field induced strain in Ni-Fe-Ga-Co single crystals

F. Masdeu[1], J. Pons[1], E. Cesari[1], S. Kustov[1], Y. I. Chumlyakov[2]

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Abstract. Single crystals of Ni49Fe18Ga27Co6 oriented along [001] direction were submitted either to superelastic or thermomechanical cycling (thermal cycling under constant stress) in compression. In the first case, the compression tests, performed at different temperatures between 300 and 450K, induced a superelastic strain of 5.5% , consistent with formation of stress-induced L10 martensite, as observed by TEM. The thermomechanical cycling was performed under external stresses ranging from 7 to 88 MPa, the total 5.5% transformation strain being obtained for 60 MPa or higher. For both types of cycling, after a quite low number of cycles ($\sim$ 20) the samples exhibited the two-way shape memory effect, with 5.5% and 2.8% strain upon cooling for superelastic and thermomechanical training, respectively. In spite of the formation of L10 martensite, the same [001] crystals exhibited magnetic-field-induced strains (in tension) larger than 2% , under an assisting tensile stress around 16 MPa and fields below 15 kOe. In martensitic samples previously compressed, application of a constant tensile stress along the same axis together with a perpendicular magnetic field produces the elongation of the sample by variant reorientation, as one of the variants rotates its c axis from the field direction to the stress-axis direction. An estimated magnetostress of $\sim$0.8 MPa is in good agreement with the theoretical value given by the ratio of magnetocrystalline anisotropy constant and twinning shear.

Remarks:

B2.06 | Paper ID – 06037 Regular Oral Presentation | Wednesday, Sept. 9, 15.00 - 15.15

Thermo-mechanical properties of shape memory alloys at nano-scale

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Abstract. Shape Memory Alloys (SMAs) are more competitive, in comparison with other functional materials, when decreasing the size of the device. So, they are good candidates to be applied as functional materials in Micro Electro-Mechanical Systems (MEMS). This requires a good knowledge of the martensitic transformation at small scale. In the present work the thermo-mechanical properties of Cu-Al-Ni SMAs have been studied by nano-indentation and nano-compression tests, as a continuation of previous works [1]. In particular, superelastic behaviour and shape memory effect have been studied at nano-scale in micro and sub-micrometer pillars produced by focussed ion beam milling. The obtained results allow conceive new applications of SMAs at micro and nano scale, and open the door for a new generation of MEMs integrating SMAs functional devices.
[1] J. San Juan, M.L. Nó, C.A. Schuh, Advanced Materials 20 (2008) 272-278.

Remarks:

B2.07 | Paper ID – 06006 Regular Oral Presentation | Thursday, Sept. 10, 9.00 - 9.15

NiTi thermal sprayed coatings characterization

N. Cinca[1], A. Isalgue[2], J. Fernandez[1], J. Guilemany[1]

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Abstract. NiTi alloy has been studied over many years for its shape memory properties, excellent corrosion and wear resistance, and biocompatibility. The present study explores the thermal spraying of atomized NiTi powders by VPS (Vacuum Plasma Spray) as well as by APS (Atmospheric Plasma Spray) and HVOF (High Velocity Oxygen Fuel Spray), in order to obtain wear-resistant coatings. X-ray diffraction studies revealed that the feedstock powder presented a NiTi R-phase at -100ºC, and at room and higher temperatures the result was β-phase. DSC experiments also detected the phase transformations. After spraying, according to the thermal history of the particles in each case, it is observed the retention of the β-NiTi phase as well as the appearance of metastable phases, amorphization and nanocrystalline areas (detected by TEM), and some oxidation. The HVOF coating had the structure closer to the original powder, because of the moderate heat input of the process.

Remarks:

B2.08 Regular Oral Presentation | Thursday, Sept. 10, 9.15 - 9.30

Combinatorial development of quaternary Ti-Ni-Cu-Pd shape memory alloys

R. Zarnetta[1], S. Thienhaus[1], A. Savan[1], M. L. Young[1], R. Takahashi[2], I. Takeuchi[2], A. Ludwig[1]

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[2] *University of Maryland, Maryland, USA*

Abstract. This contribution demonstrates how the combinatorial approach for fabrication and characterization of ternary Ti-Ni-X shape memory thin film materials libraries [1] can be extended to quaternary Ti-Ni-X-Y systems. Advanced deposition methods based on wedge-type multilayer thin films sputtered from elemental targets yield materials libraries that cover large continuous regions of quaternary systems [2]. These combinatorial thin film libraries consist of nine continuous four-component regions producing planes in the quaternary composition space. Automated temperature-dependent resistance measurements (R(T)) and energy dispersive X-ray analysis (EDX) were applied for the high-throughput characterization of the quaternary composition spreads. Characterization of the crystal structure was carried out using standard X-ray diffraction, as well as synchrotron X-ray microdiffraction at the beamline 2-BM of the Advanced Photon Source, Argonne National Laboratory. Results will be presented for the Ti-Ni-Cu-Pd system, where the phase transformation characteristics were mapped by R(T) for compositions with Ti-content close to 50 at.% . A composition region with “zero” thermal hysteresis was found as predicted by [3] based on the crystallographic theory of martensite. [1] Zarnetta R, Savan A, Thienhaus S, Ludwig A. App Surf Sci 2007;254:743 [2] V Chevrier, JR Dahn. Meas Sci Technol 2006;17:1399 [3] RD James, Z Zhang (Eds.) Magnetism and Structure in Functional Materials, Springer, 2005;79:1

Remarks:

B2.09 | Paper ID – 06005 Regular Oral Presentation | Thursday, Sept. 10, 9.30 - 9.45

Influence of pre-strain and carbon content on delayed cracking phenomenon in unstable austenitic steels

S. Berveiller[1], M. Kemdehoundja[1], E. Patoor[1], D. Bouscaud[1], M. R. Berrahmoune[1]

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Abstract. The delayed cracking phenomenon is observed mainly in the unstable austenitic stainless steels. Austenite in those steels is unstable and transforms to martensite under plastic deformation. In this study, we establish a relation between the occurrence of martensitic transformation and delayed cracking sensitivity in the 301LN unstable austenitic steel: the effect of a pre-strain and the carbon content are taken into account. For that, deep drawing tests were carried out for different ratios, at room temperature. In the reference grade (low carbon and no strain), only high drawing ratio cups showed delayed cracks through the thickness whereas other grades exhibit failure even for lower drawing ratios. The breaking patterns showed that there is a change in fracture mode from intergranular and transgranular to ductile fracture through thickness. These observations were compared with matrensite stress state and volume fraction (both measured by X-Ray diffraction). In all drawn cups, stress values both in the martensite and the austenite are positive. The magnitude of stresses in the martensite was found to be higher than in the austenite and the difference exceeds 300MPa. Through the thickness, residual stresses in the martensite increases when the volume fraction of this phase decreases but it becomes negative as the fracture pattern becomes ductile. The stress values are compared between the 3 grades.

Remarks:

B2.10 | Paper ID – 06033 Regular Oral Presentation | Thursday, Sept. 10, 9.45 - 10.00

Deformation behavior at rolling and tension under current in TiNi alloy

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Abstract. The paper presents data on pulse current effects on deformability, strength and ductility of shape memory TiNi alloy, processed by electroplastic rolling (EPR). It was found that deformability and elongation to failure can be enhanced by electropulse current. It has considered deformation behavior of the TiNi alloy both at EPR processing and tension with pulse current. It is shown that EPR increases significantly strain to failure and refines microstructure to grain size less 100 nm. Stresses jumps up and down were observed on the stress-strain curves at tension with current. Different direction of stress jumps is conditioned by martensite transformation and electroplastic effect, correspondingly

Remarks:

B2.11 | Paper ID – 06009 Regular Oral Presentation | Thursday, Sept. 10, 10.00 - 10.15

Nonlocal modelling of superelastic behavior of shape memory alloys

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Abstract. Recently, various constitutive laws based on phenomenological or micromechanical approaches have been developed to describe the behavior of shape memory alloys (SMA). They are particularly well adapted for modelling the effects of phase transformation and martensite reorientation on the thermomechanical behavior of the bulk material. Nevertheless, these models fail to describe phenomena such as transformation localisation or size effects which may appear in wires and thin films. Indeed, to describe such phenomena, the influence of the neighbouring area of the material point should be taken into account. This can be achieved through a nonlocal formulation of the constitutive equations. In the present work, we propose a nonlocal modelling of the superelastic behavior of SMA. It uses for the martensite volume fraction, besides the usual local variable, a corresponding nonlocal contribution. This latter is governed by a partial differential equation defined on an influence zone whose size is dependent on an internal length parameter of the material. Based on this formulation, a 1D specific finite element is developed where the nonlocal state variable is an additional degree of freedom. Simulations are made to study the influence of the internal length parameter and nonlocality on the mechanical response during superelastic loadings. A comparison will be made with experimental datas on NiTi wires exhibiting transformation localisation under tensile loading at constant temperature.

Remarks:

B2.12 | Paper ID – 06038 Regular Oral Presentation | Friday, Sept. 11, 9.00 - 9.15

Phase transformation fronts propagation during the stress induced martensitic transformation at impact strain rates in NiTi shape memory alloy wires

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Abstract. Propagation of phase transformation fronts during the stress induced martensitic transformation (SIM) at impact strain rates, on the order of 10 s-1, was observed in situ by measuring changes in infrared radiation on the surface of superelastic NiTi wires. The nucleation during forward SIM transformation usually occurs at both ends of the sample near the grips, where stress concentrations are unavoidable. During unloading, nucleation of the reverse SIM transformation takes place at point where the forward SIM transformation was finished. At impact no more nucleations were observed so that only the phase transformation fronts arising from the mentioned nucleations appear. In the non-transformed zone, the temperature remains similar to that observed for the test in which only the elastic deformation of the austenitic phase occurs. This feature shows that the SIM transformation at impact strain rates is inhomogeneous though no multiple transformation fronts appear as commonly observed in quasistatic experiments. For specimens cycled at impact, the nucleation at the beginning of the SIM transformation occurs at several locations and during the deformation more nucleation points arise since the stress necessary to initiate another nucleations is lower than necessary to continue the propagation of the active fronts. These locations are similar for different cycles showing that they do not arise by chance, but rather because there are locations more favourable for the nucleation.

Remarks:

B2.13 | Paper ID – 06029 Regular Oral Presentation | Friday, Sept. 11, 9.15 - 9.30

Finite – element model for simulations of fully coupled thermomechanical processes in shape memory alloys

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Abstract. The Müller-Achenbach-Seelecke model for shape memory alloys is able to address full thermomechanical coupling of mechanical and thermal fields. The model roots in a stringent interpretation of thermodynamical principles and interprets the behavior as resulting from an interplay of austenite with two generic martensite twin variants. Its constitutive behavior covers both pseudoplasticity, pseudoelasticity and the characteristic shape memory effect upon temperature changes. Thus, the model reflects the complex, nonlinear hysteretic and thermomechanically coupled material behavior of SMAs on a physically sound basis. In this contribution we investigate the capability of the MAS model in a typical engineering setting, viz. the shrink fitting of a SMA bushing onto a linear-elastic shaft. In this case, the shrink fitting is caused by a martensite-austenite phase transition of the bushing upon temperature change from low to high level (shape memory effect). To address all geometrical implications we employ a finite-element implementation of the MAS model into ABAQUS ™. The reliability of the FEM model is proven by comparison to the classical solutions for the linear-elastic and the ideally elastic-plastic case. The MAS model is implemented into ABAQUS using the UMAT interface. The results arrived at with this model are validated against the classical solutions and show the significance for the full thermomechanical coupling which becomes particularly evident in this setting.

Remarks:

B2.14 Regular Oral Presentation | Friday, Sept. 11, 9.30 - 9.45

Strain mapping of crack extension in pseudoelastic NiTi shape memory alloys

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Abstract. Crack extension in pseudoelastic NiTi shape memory alloy (SMA) compact tension (CT) specimens was examined during static loading using in-situ synchrotron X-ray diffraction. The material composition was 50.7 at.% Ni (austenitic, pseudoelastic). From this composition, a miniature CT specimen was developed, which is small enough to allow in-situ testing in a synchrotron beam line to identify phases, textures, and lattice strains near the crack tip. Stress-induced martensite in the pseudoelastic NiTi SMA was mapped in front of the crack of the CT specimen during static loading using synchrotron radiation. Two zones of stress-induced martensite are observed. Tensile strains in the martensitic phase are observed just ahead of the crack tip, while compressive strains in the martensitic phase are observed at the back of the CT specimen. Larger compressive strains are observed in the austenitic phase just before the stress-induced martensitic transformation occurs. Anisotropic effects observed in various crystallographic reflections of both the austenitic and martensitic phases are discussed. The results are compared with optical and thermographic images from pseudoelastic NiTi SMAs.

Remarks:

B2.15 | Paper ID – 06031 Regular Oral Presentation | Friday, Sept. 11, 9.45 - 10.00

Strain mapping at propagating interfaces in pseudoelastic NiTi

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Abstract. Pseudoelastic NiTi often exhibits an inhomogeneous martensitic phase transformation: Martensite bands propagate through the specimen, distinct phase interfaces separate transformed from untransformed regions, and local strains increase step-like but smoothly by ∼5 % across these interfaces. In the present study, we use an advanced strain mapping method (digital image correlation) to characterize local strain states and strain rates at propagating phase interfaces in a thin NiTi ribbon. The resulting strain data allows a detailed analysis of the interface geometry. The narrow transition regions are characterized by a finite width of 4-5 mm which generally increases near the outer edges of the specimen. Furthermore, the maximum local strain rates at the interfaces are one order of magnitude higher than the macroscopic strain rate that is usually used to characterize thermo-mechanical loading conditions.

Remarks:

B2.16 | Paper ID – 06027 Regular Oral Presentation | Friday, Sept. 11, 10.00 - 10.15

TEM investigation of the microstructural evolution during nanoindentation of NiTi

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Abstract. The continuous measurement of loads and displacements during nanoindentation of shape memory alloys allows a detailed investigation of pseudoelasticity on the nano-scale. However, the resulting load-displacement data simultaneously reflect several elastic and inelastic deformation processes (i.e., stress-induced martensitic transformation, plastic deformation). In the present study, we perform microstructural investigations in order to analyze the complex interactions between these mechanisms in a Ni-rich alloy. The microstructures below indents from experiments with different maximum indentation loads are characterized post-mortem by transmission electron microscopy. For small maximum indentation loads, load-displacement data exhibit considerable pseudoelastic recovery, whereas higher indentation loads are associated with a more pronounced residual deformation after unloading. These differences are clearly related to microstructural changes below the indenter tip: While both stress-induced martensitic transformation and dislocation slip occur in general, higher maximum loads are associated with an increase in plastic deformation. The corresponding higher dislocation densities impede the reverse transformation to austenite. Stabilized martensite can be observed directly below the surface for high indentation loads. Our results show that nanoindentation of NiTi allows a systematic analysis of the interaction of plastic deformation and stress induced martensitic transformation.

Remarks:

B2.17 | Paper ID – 06015 Regular Oral Presentation | Friday, Sept. 11, 10.15 - 10.30

Study of nanostructured NiTi shape memory alloy's structure and functional properties

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Abstract. The present work is aimed to study of nanostructured NiTi shape memory alloy's (SMA) structure and functional properties depending on the type of thermo mechanical treatment and it's parameters. Structure, recoverable strain and recoverable force which take place during martensite transformation were compared for high grained alloys (HG) and nanostructured alloys (NS) which were prepared by equal canal angular pressing (ECAP) and post deformational annealing (PDA). The Structure of the SMA was studied means of TEM. Functional properties were studied by three-point bending method in -70..100C temperature range. Notably that ECAP with 450C results in mixed crystallized and amorphous structure of the alloys. It's fully crystallized by PDA with 300C in the way that final grain size approximately 100 nm and structure doesn't have developed dilatational structure that could result in softening processes. Functional properties of NS and HG alloys were compared in terms of maximal recoverable strain, maximal recoverable force, specific energy capacity and functional inflexibility. It was found that NS alloy generates essentially higher recoverable force, has higher specific energy capacity and functional inflexibility than HG alloy deformed as well (approximately 7%). These advantages are most favorable in the field of applications of SMA to surgical or dental implant's production.

Remarks:

B2.18 | Paper ID – 06035 Regular Oral Presentation | Friday, Sept. 11, 10.30 - 10.45

Coupling between experiment and numerical simulation of shape memory alloy multicrystal

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Abstract. This paper deals with the experimental and numerical analysis of the effect of stress-strain heterogeneities due to elastic anisotropy, grain orientations and their effects on martensitic transformation for a Cu-Based SMA multicrystal. The shape of each grain is measured successively by optical microscopy and Electron Back Scattered Diffraction technique. During a tensile loading at room temperature, the displacement field of the free surface is measured by Digital Image Correlation. The considered shape for the finite element analysis is designed on the basis of the experimental characterization of the shape of each grain. The model is intended to simulate the behaviour of the multicrystal. The experimentally obtained data, such as the actual applied boundary conditions at the edge of the area, crystallographic orientation, and few more material parameters are introduced in the numerical model designed by the ABAQUS finite element code. A SMA micromechanical constitutive law, implemented in this FE code, is considered for the behaviour description of each grain. It describes the effect of a martensitic transformation on the behaviour of a single crystal by taking into account the possible activation of various martensite variants. The experimental and numerical results are in good agreement. Moreover, numerical results show, the stress state in grains is disturbed by the neighboring grains and this disturbance has a strong influence on the martensite variant activation.

Remarks:

B2.19 | Paper ID – 06032 Regular Oral Presentation | Friday, Sept. 11, 11.45 - 12.00

Relation between crystal quality and fatigue life of a Cu-Al-Be single crystal shape memory alloy under repeated bending.

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Abstract. The purpose of this study is to determine the parameters influencing the life of single crystalline Cu-Al-Be shape memory alloys. A strong correlation is found between crystal quality and fatigue life. For that purpose, a special device located at ILL (Institut laue-langevin) in Grenoble is employed. This device is a hard X-ray diffractometer using a transposition at high energy of the Guinier-Tennevin method. Thanks to these X-ray studies, it is found that mechanical lifespan is very sensitive to crystalline quality. In presence of sub-grains (even if disorientation between subgrain is lower than 3°) or in presence of mosaïcity (distribution of the orientation of reticular planes around a mean value), the lifespan can be reduce by a factor of 10.

Remarks:

B2.20 | Paper ID – 06028 Regular Oral Presentation | Friday, Sept. 11, 12.00 - 12.15

Microstructure and functional superelasticity property changes in thin NiTi wires heat treated by electric current

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Abstract. High energy synchrotron X-ray diffraction, transmission electron microscopy and mechanical testing were employed to investigate the evolution of microstructure, texture and functional superelastic properties of 0.1 mm thin as drawn Ni-Ti wires subjected to a nonconventional heat treatment by controlled electric current (FTMT-EC method). As drawn Ni-Ti wires were prestrained in tension and exposed to a sequence of short DC power pulses in the millisecond range. The annealing time in the FTMT-EC processing can be very short but the temperature and force could be very high compared to the conventional heat treatment of SMAs. It is shown that the heavily strained, partially amorphous microstructure of the as drawn Ni-Ti wire transforms under the effect of the DC pulse and tensile stress into a wide range of annealed nanosized microstructures depending on the pulse time. The functional superelastic properties and microstructures of the FTMT-EC treated Ni-Ti wire are comparable to those observed in straight annealed wires.

Remarks:

B2.21 Regular Oral Presentation | Friday, Sept. 11, 12.15 - 12.30

Strain recovery at fast heating of a pre-tensioned shape memory alloy specimen

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Abstract. Strain recovery in a shape memory alloy rod preliminarily tensioned in the martensitic state and subjected to fast heating is studied theoretically and by an experiment. Two models are considered. In the first it is supposed that heating is infinitely fast and the rod experiences an immediate transition into austenite. The second model assumes that the transformation occurs during some time corresponding to the temperature rate. An analytical expression for the dependence of the displacement of the tip of the rod on time is obtained with the help of the Laplace transform. In the experiment a wire specimen of titanium nickelide was heated by a short pulse of the electric current. The time dependence of the specimen length was registered. A comparison of the experimental and theoretical results has shown that the dynamics of the shape recovery is determined mainly the temperature rate and the inertia of the specimen, the martensitic transformation itself taking apparently the time less than 1 mks.

Remarks:

B2.22 | Paper ID – 06004 Regular Oral Presentation | Friday, Sept. 11, 12.30 - 12.45

Two-dimensional thermomechanical model for combined loading of NiTi wire structures

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Abstract. Thin NiTi wires with unique thermomechanical properties due to shape memory effects are considered to be promising material for a wide range of new engineering applications (knitted and woven smart textiles, complex NiTi wire supported actuators, medical stents). Optimal design of NiTi structures, composed generally from curved shape set wires, requires reliable knowledge and modeling tool, particularly since the multiple deformation mechanisms are usually involved. This sets a new area for SMA experimentation and modelling. In the present contribution, we describe a newly proposed 2-D SMA model developed for the purpose of simulating 3-D NiTi wire structures and textiles behavior under combined mechanical and thermal loading. The model captures i) the strains due to deformation mechanisms in NiTi transforming via B2-B19' martensitic transformation induced by thermal and/or mechanical loading, ii) reorientation processes in martensite in tension, torsion or combined loading, iii) internal cycles including the return point memory, and iv) asymmetric behavior in tension and compression if bending deformation is employed. The model is parametrized by realistic physically based material parameters and it can be implemented into finite element codes. Some numerical simulations (simulated behaviors of a NiTi wire actuator, a knitted self-expanding stent and shape memory fasterner hook) are shown and discussed to demonstrate the early practical applications of the model.

Remarks:

B2.23 Regular Oral Presentation | Friday, Sept. 11, 12.45 - 13.00

Martensitic phase transformations in NiTi. Lagrangian dynamics simulations

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Abstract. We present a theoretical study of the microstructure formation of NiTi shape memory alloy during the martensitic phase transformation using a Lagrangian dynamics modeling. The appropriate Landau free energy functional is derived in order to describe simultaneously all three phases, B2 (cubic), R (trigonal) and B19' (monoclinic) occurring at the austenite-martensite phase transformations in NiTi. A complete set of the 13 independent elastic constants of the B19' phase and the 3 elastic constants of the B2 phase, together with the latent heat value, were considered in order to fully determine coefficients of the Landau free energy functional. A microstructure formation scenario for the direct B2-B19' transformation is studied. The resulting microstructure is analyzed by comparison to the theoretically predicted and experimentally observed twinning modes.

Remarks:

B2.24 | Paper ID – 06012 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Influence of fatigue on the nanohardness of NiTiCr-wires

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Abstract. The fatigue life of pseudoelastic NiTi shape-memory alloys (SMA) is critical to their functionality in many technological and medical applications. The addition of 0.25 wt.% Cr to NiTi increases the torqueability and strength and lowers the phase transformation temperatures. It is known that parameters, such as rotational speed, bending radius, and wire diameter, have a strong influence on the fatigue life of pseudoelastic NiTi. In our study, we examine the influence of these parameters on pseudoelastic NiTiCr SMA wires using nanoindentation after fatigue testing. The fatigued wires were indented along the wire axis and in the middle and near the outer surface of the sample. In the first part of our study, the influence of rotational speed (200, 400, and 800 rotations min-1) and bending radius (30, 40, and 60 mm) on fatigue was examined using nanoindentation. The resulting nanohardness and recovery ratios are discussed and correlated with microstructural observations. In the second part of our study, the influence of wire diameter (1.2 and 1.4 mm) on fatigue was examined using nanoindentation. Wires with two different diameters were fatigued at the lowest rotational speed (200 rpm) and subjected to an equivalent strain of 1 and 2 % . Nanoindentation was performed after fatigue testing. The resulting nanohardness and recovery ratios are discussed.

Remarks:

B2.25 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

The influence of cyclic dynamic strain on the biocompatibility of cell loaded nickel-titanium

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Abstract. Nickel-titanium shape memory alloys (NiTi-SMA) are of increasing biomedical interest due to an unusual pseudo-elasticity and the shape memory effect. However, the high nickel content of NiTi-SMA may result in adverse tissue reactions especially with long-term implants under mechanical strain. It was reported that mechanical strain increased the nickel ion release from NiTi-wires. NiTi is currently analyzed as carrier material for human mesenchymal stem cells (hMSCs). In order to analyze biocompatibility of mechanically strained NiTi-SMA tensile specimens were preloaded with human mesenchymal stem cells. The specimens were transferred to a sterile PTFE cell culture tube equipped with a cell culture circulation system and fixed to the pull rods of the tensile testing machine. The cell culture tube was located into a conventional cell culture incubator located within the tensile testing machine. 86,400 strain cycles were performed for a period of 24h and 7d. Interleukins (IL-6, IL-8, IL-11 and VEGF) and nickel ion release were determined. The cells on the tensile specimens were stained by calcein-AM and propidium iodine to analyze cell viability. Dynamic loading under the used conditions did not influence the biocompatibility of NiTi-SMA. Nickel ion and IL-6 release increased. The presented experimental approach will provide information on the biocompatibility and fatigue behaviour of metallic specimens using sample size and dynamic strain relevant for orthopaedic implants.

Remarks:

B2.26 | Paper ID – 06022 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Effect of thermomechanical training on the transformation temperatures and properties of NiTi melt-spun ribbons

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Abstract. The present work aims to study the influence of thermomechanical training and two-way shape memory effect (TWSME) on the transformation behaviour of Ni-50.3at% Ti melt-spun ribbons by differential scanning calorimeter (DSC). The results showed that the transformation temperatures decrease with increase in the number of training. The austenitic transformation temperatures remain a one stage transformation, while the martensitic transformation temperatures change to a two-stage transformation. These changes are due to the appearance of an intermediate phase which was stabilized probably by the accumulation of defects introduced by thermomechanical training. The phase that is present after training were studied by X-ray diffraction, transmission and scanning electron microscopy.

Remarks:

B2.27 | Paper ID – 06016 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Mechanical behavior of a metastable austenitic stainless steel

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Abstract. Austenitic stainless steels are used for cold forming (deep-drawing) at room temperature. Increasing need for conserving the strategic elements such as Ni and Cr impel the steel-makers to lower the content of these elements in stainless steels. The low Ni content can lead during the forming process to the deformation-induced martensitic transformation. The residual stresses together with the internal stresses induced by martensitic transformation can lead after deep-drawing to the phenomenon of delayed cracking. A good knowledge of kinetics of the martensitic transformation is therefore essential for the control of forming. The mechanical properties of the austenitic steel similar to AISI301 were characterized by means of tensile and cupping tests. High sensitivity to the strain rate was observed. The fracture mechanism in tensile specimens changed from the combination of cleavage and ductile dimpled rupture at lower strain rates to entire ductile dimpled rupture at higher strain rates. Fracture mechanisms were very different in deep drawn cups. After deep drawing, delayed cracking by means of intergranular decohesion occurred. The mechanical behavior was described by a two-phase model incorporating martensitic transformation. Identification of parameters was carried out on complex loading paths (tensile test, shear test, cyclic loading-unloading). The model was implemented in a finite element method code and used for the simulation of cupping test.

Remarks:

B2.28 | Paper ID – 06034 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Analysis of the phase transformation near the crack tip in Shape Memory Alloys

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Abstract. A new analytical prediction of the phase transformation zone around the crack tip is proposed for shape memory alloys. The present analysis integrates the asymmetry between tension and compression in the yield surface of phase transformation around the crack tip. Shapes and sizes of the phase transformation zone are predicted for loading modes I, II and III. Furthermore, an experimental investigation for mode I loading fracture tests on edge-cracked specimens of a nickel-titanium alloy is currently performing with a particular attention devoted on displacement and temperature fields evolution around the crack tip.

Remarks:

B2.29 | Paper ID – 06039 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Influence of compound twinning on Young's moduli in NiTi martensite

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Abstract. NiTi shape memory alloy has been widely used in many engineering applications (e.g. mechatronic devices, medical tools, seismic sensors etc.). In this work, the Young's moduli of twinned NiTi martensite in selected crystallographic directions are calculated from first principles and compared with previous data for perfect (untwinned) NiTi structure. The obtained results show that the selected twinning mode does not have a significant influence on the Young's moduli and, thus, their reduction observed in some experiments is probably caused by changes in martensitic microstructure (arrangement of twinning variants).

Remarks:

B2.30 | Paper ID – 06013 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Giant elasticity in the Ni-Mn-Ga single crystalline FSMA martensites

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Abstract. The phenomenon of the giant elastic completely reversible linear strain is found at constant temperatures in Ni-Mn-Ga martensites. Single crystals of some off-stoichiometric Ni-Mn-Ga compositions possess rubber-like behavior in the martensite phase with completely elastic strain reaching over 10% at some 90MPa compressive stress at room temperature. The observed phenomenon is different from the conventional (two-phase) superelasticity, since it is found completely in the martensite phase and no intermartensitic reaction is observed during the load-unload cycling. The main features of the observed rubber-like behaviour are: 1) complete elasticity and giant values of the strains achieved; 2) the linear character of stress-strain dependence; 3) excellent stability to the mechanical cycling, stress rate and temperature variation, in contrast to the conventional two-phase superelasticity due to the stress induced martensite transformation. Current work is directed to study the structural mechanisms of the found phenomenon by means of the neutron diffraction in-situ under compressive stress cycling.

Remarks:

B2.31 | Paper ID – 06003 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Investigations of solid phase processes in CuAlNi base shape memory alloys

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Abstract. Cu based Shape Memory Alloys are favored because of their high transformation temperatures and low price. However, their brittle behavior and the ageing processes due to cycle heating limit the alloys' practicability. To extend their suitability, Mn and Fe were added to the base CuAlNi alloy in order to increase ductility. The ageing processes and the effect of the Mn and Fe addition were examined using differential scanning calorimetry, optical microscopy, scanning electron microscopy, transmission electron microscopy and in-situ optical microscopy. Transformation temperatures shifted to higher temperatures in the CuAlNi alloy as the ageing time was increased. In CuAlNiMn and CuAlNiMnFe alloys the thermoelastic martensitic transformation disappeared in the aged samples. The cause of this effect turned out to be an exothermic process starting at around 300°C, which was previously not known. The examinations were focused to characterize and identify this exothermic process.

Remarks:

B2.32 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Cyclic stability of NiTi based spring actuators

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Abstract. In actuator applications, shape memory wires are often applied as helical coil springs. The objective of the present work is to understand functional fatigue of binary NiTi and ternary NiTiCu spring actuators. We characterize the cyclic thermomechanical behavior of NiTi based spring actuators by using an automated functional test rig where springs are forced to contract by electric current heating and a reverse stroke is provided by a counter weight arrangement on cooling. Temperatures and counter weight displacements were monitored during testing. We investigate the dependence of the functional stability on material parameters and testing parameters. NiTi(Cu) springs with different compositions were produced by induction melting, swaging, wire drawing and shape setting treatments. Our results show that thermomechanical cycling results in an irreversible elongation of the spring whereas the actuator stroke remains constant. We provide phenomenological equations which allow to briefly describe functional fatigue. We further show that Cu additions are beneficial in order to improve cyclic actuator stability because less defects accumulate in the microstructure in NiTiCu SMAs during cycling. The present work also shows that functional fatigue is strongly dependent on the spring load. Higher loads are associated with a faster degradation of the functional properties because external stresses and transformation stresses overlap and more defects accumulate in the microstructure during each transformation cycle.

Remarks:

B2.33 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Phase transitions and mechanical properties of a hot rolled Co-Ni-Al alloy

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Abstract. A Co39Ni34Al27 alloy was melted and cast under argon atmosphere by induction melting using elements of purity better than 99.9 % . After homogenization the alloy was hot rolled at 900°C up to thickness reduction of about 90% . Finally, the alloy was annealed at 1250°C for 3 hours and water quenched. DSC runs of quenched alloy revealed the direct martensitic transformation at Ms = -15°C and Mf = -42°C and reverse transformation at As = -16°C and Af = 15°C. Aging the alloy at 250ºC and 300°C caused the shift of transformation about 25°C and 35°C respectively to lower temperatures due to the change of the atomic order degree and precipitation effects. Microstructural investigations of the alloy after quenching and aging showed elongated γ particles and L1o twinned or not twinned martensite. Tensile test of the as quenched alloy show a first plateau at 80 MPa due to the stress induced martensitic transformation and at further stress increase attains the ultimate tensile strength UTS = 630 MPa at elongation of 8.7 % . EBSD measurements of hot rolled and subsequently quenched sample allowed determination of the texture of L1o martensite as $\{110\}$ $<011>$, volume fraction of γ phase of less than 10% and crystallographic relationship between γ and martensite phases.

Remarks:

B2.34 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Calculation of the stress-strain state of shape memory alloy cylinder and plate subjected to cooling or hearting with different temperature Rates

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Abstract. A connected thermomechanical boundary problem for an infinite shape memory alloy cylinder and plate loaded by an external force and subjected to heating or cooling from the surface is solved. The evolution of stress-strain state is calculated for processes of the transformation plasticity and the shape memory effect. The mechanical properties of a material point are given by a micromechanical model. The iteration procedure with variable iteration parameter is used to solve the thermomechanical problem. The influence of the ambient temperature rate on the transformation plasticity is investigated. It is shown, that the transformation plasticity strain decreases with the increasing ambient temperature rate. This phenomenon can be explained by an inhomogeneity of the temperature and stress fields causing different conditions for the phase transformation in different points of the body.

Remarks:

B2.35 | Paper ID – 06023 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Kinetics of precipitation and mechanical behavior of CuAlBe single crystal drawn-wires

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Abstract. Shape memory alloys containing copper and aluminium are well studied since the years 1990. In 1991, Zuniga has studied the kinetics of precipitations for a polycrystalline CuAlBe alloy not deformed and proposed a ≪time-temperature-precipitation≫ diagram corresponding to the precitation time start at a given temperature. This precipitation leads to a hardening of the materials. The aim of this work, based on CuAlBe alloy, is to determine the kinetics of precipitations, considering the influence of a pre-strain (here by wire-drawing) in a polycrystal and a single crystal: results are compared. A single crystal and a polycrystal of same composition are welded together in the aim to be submitted to identical drawing process and annealing parameters. The heat treatments conditions were selected in order to be compared with the experimental points of the ≪time-temperature-precipitation≫ diagram obtained by Zuniga. Optical microscopy and X-Ray diffraction were used. A pre-strain shifts the kinetics towards the lower time. Precipitates are in coherence with the matrix. Macroscopic tensile tests at room temperature are undertaken on each sample. The effect of tensile deformation rate and the thermal treatment on monocrystalline and polycrystalline wire-drawed samples are analysed.
Keywords : shape memory alloy, metal-forming, wire-drawing, microstructure, mechanical properties

Remarks:

B2.36 | Paper ID – 06002 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Martensitic transformation temperatures and microstructural features of FeMnCr alloys

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Abstract. FeMn based alloys are a low cost alternative to traditional SMAs due to their convenient one-way shape memory effect. While alloy systems containing several elements have received considerable attention along the last few years, namely FeMnSiCr, FeMnSiCrNi and modifications of these two containing precipitates, there is still scarce information about some of the related ternary systems. An important example is the FeMnCr system. Information about phase stability and transformation temperatures in this ternary system would be useful as input data for higher order alloy design. We present experimental fcc/hcp martensitic transformation temperatures of selected FeMnCr alloys measured by means of dilatometry and electrical resistivity. We have found that these transformation temperatures suffer an evolution when samples are thermally cycled, up to an asymptotic state. In the case of the studied samples, this asymptotic state is reached after a small number of cycles (n $<$5). TEM observations aimed at elucidating the origin of this behavior found two main microstructural features: 1) the presence of very small precipitates in the alloy matrix, and 2) a tendency to form mono-oriented martensite inside each grain.

Remarks:

B2.37 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Crack resistance of low carbon steel, alloyed with chromium, nickel and tungsten, under different structure conditions

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Abstract. The effect of the heat treatment of low-carbon 0,25 % C steel, alloyed with 1,65 % chromium, 4,55 % nickel and 0,96 % tungsten, on the steel impact toughness and crack resistance is investigated in the present study. Some of the Charpy V-notch specimens were quenched and tempered at different temperatures, some were austempered. The specimens were X-ray analyzed and examined by optical and scanning electron microscopy, after measuring their hardness. Sub-cracks were originated at the tip of the notch that to start a brittle crack at the Charpy tests allowing in this manner the measurement of the crack resistance of the steel under different structure conditions.. The volume fraction of retained austenite, bainite, martensite and austenite-carbon-content results were then correlated with micro structural changes and impact toughness.

Remarks:

B2.38 | Paper ID – 06030 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Deformation induced martensite formation in metastable austenitic steel during in situ fatigue loading in a scanning electron microscope

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Abstract. Aim of the study is to identify quantitatively the influence of deformation-induced phase transformation on the fatigue damage of a metastable austenitic steel during loading in the high cycle fatigue regime. Cyclic deformation tests were carried out in situ in a scanning electron microscope (SEM) in combination with automated electron backscatter diffraction (EBSD) used for phase analysis and crystallographic orientation mapping. The in situ experiments were supported by ex situ cycling in a servohydraulic testing machine. The examined metastable austenitic steel (AISI 304L) transforms from the fcc austenite lattice to the bcc α' martensite lattice either spontaneously at very low temperatures or at room temperature when a critical value of monotonic or accumulated cyclic plastic strain is exceeded. Nucleation of martensite occurs after initial $\sim$10,000 cycles of fatigue loading at stress amplitudes close to the fatigue limit as needles near activated slip systems as a consequence of localized plastic deformation. Once first microstructurally short cracks have nucleated, strong martensitic transformation occurs within the plastic zone ahead of the crack tip. Due to the higher specific volume the martensite is considered to shield the crack tip, i.e., transformation-induced crack closure takes place. The effect of deformation-induced phase transformation on (i) crack initiation and (ii) mechanism of fatigue microcrack propagation is discussed in detail in the present paper.

Remarks:

B2.39 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Modeling of ultrasonic heating for TiNi waveguides

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Abstract. The influence of ultrasonic vibrations on metals and alloys in some cases causes significant heating. For materials undergoing thermoelastic phase transitions, ultrasonic influence results in temperature increase in the range of transformations up to the Tf , that leads to the change of physical and mechanical properties of the material. Temperature field for TiNi waveguides at ultrasonic influence has been calculated. Temperature dependence of nonlinear internal friction character and heat capacity, as well as degradation of phase transition was taken into account. The calculated results are in good agreement with the experimental data that allows the use of the proposed mathematical model for predicting and modeling the phenomena associated with ultrasonic initiation of shape memory effect. The research results can be used to develop a new type of ultrasonic devices for which one-sided access to the working body of material with shape memory is required.

Remarks:

B2.40 | Paper ID – 06021 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Influence of thermomechanical pre-treatment on efficiency and temperature stability of shape memory alloys

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Abstract. The functional "programming" of one SMA-component is of substantial interest in the case of actuator applications regarding standardisation of components and integration of component parts. For the programming of the components it is necessary to make a thermomechanical pre-treatment. But this treatment influences not only the effect characteristic and the transformation temperatures, but also characteristics like the efficiency and temperature stability. In order to study the influence of the thermomechanical pre-treatment on the efficiency and temperature stability, in the present study wires of Ni-rich pseudoelastic and Ni-poor pseudoplastic alloys under change of various parameters were functionally characterised. In this context tension tests and temperature-controlled heating tests were carried out. Especially for the heating tests a test stand was developed. The heating tests were implemented on the one hand for the determination of the one-way effect properties, like the transformation temperatures, hysteresis, the irreversible strains etc. and on the other hand for the determination of the short-time and permanent temperature stabilities. In addition the tests were carried out with different loads. Particularly the Ni-rich alloys showed a very large potential. Among the well-known pseudoelastic applications by defined pre-treatment they can be used also as actuators.

Remarks:

B2.41 | Paper ID – 06011 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Bulge tests on ferroelastic and superelastic NiTi sheets with full field thermal and 3D-kinematical measurements. Experiments and modelling.

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Abstract. Superelastic and ferroelastic behaviour of polycrystalline Nickel-Titanium Shape Memory Alloys have been extensively studied, mostly via uniaxial tension and compression, simple shear and more recently in combination of tension (compression)-torsion tests. This paper reports on a study of tensile tests and thin plate bulging tests of NiTi. The bulging tests were performed on a circular diaphragm in both superelastic and ferroelastic states at room temperature. Thermal and 3D kinematical full-field measurements were simultaneously conducted owing to the use of one Infrared camera and two visible ones. Loading including loops leads to plane strain state in the edges of the bulge specimens and to equibiaxial deformation state in the region close to the centre. In this region, the measurements of the curvature radius and of the bulging pressure allow to determine the equibiaxial stress values. Occurrences of localisation phenomena during tensile and bulge tests are studied as function of the deformation mechanisms and of the type of loading. Experimental results are compared with simulated results obtained with the "Herezh" Finite element software in which an "elastohysteresis" constitutive equation is implemented. The parameters of the law are determined on one hand from tensile tests performed on the two sheets and on the other hand on the analysis of the equibiaxial deformation behaviour in the region close to the centre of the bulge specimens.

Remarks:

B2.42 | Paper ID – 06025 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Textural evolution by multiple steps of marforming in Ti-Rich Ni-Ti shape memory alloy

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Abstract. The Nickel-Titanium (Ni-Ti) alloys are the most attractive amongst shape memory alloys (SMA) due to their good functionality properties coupled with high strength and good ductility. The transformation temperatures in Ti-rich NiTi SMA can be altered with suitable thermal and/or mechanical treatments to obtain martensitic transformation in one or more steps above 0ºC. The goal of the present work is to investigate the textural evolution in Ti-Rich Ni-Ti SMA (Ni-51at% Ti) that will contribute to different phase transformation sequences (one, two and multiple steps) after being subjected to (i) two distinct thermal treatments (500 ºC for 30 minutes in air and 800ºC for 300 minutes in vacuum), (ii) followed by multiple steps of marforming (30% thickness reduction by cold rolling), intercalated with thermal treatment at 500ºC for 30 minutes in air and (iii) four distinct final thermal treatments (400, 450, 500 or 600ºC for 30 minutes in air). The textural results were obtained by X-Ray Diffraction (XRD) at room temperature (B19' phase) and at 150ºC (B2 phase). Differential Scanning Calorimetry (DSC), Electrical Resistivity (ER) and X-Ray Diffraction (XRD) were used to identify the transformation temperatures and the phases that are present after all steps of thermomechanical treatments.

Remarks:

B2.43 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

TiNi shape setting by means of ultrasound treatment

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Abstract. There is a necessity of shape setting for the usage of shape memory alloys as constructional parts. With the present purpose the heat treatment is carrying out traditionally at the temperatures 450÷500ºC during different intervals (from one to several hours). The present research is devoted to study of the possibility of nitinol wire shape setting with the help of ultrasonic influence. The samples of Ti-50,4at.% Ni wire were deformed by bending in martensitic state and ultrasonic vibrations were excited with the frequency of 22 kHz in them. In the process of ultrasonic influence the samples were heating up to the finite temperature of reverse phase transformation and theirs temperature was remaining at the same level ($\sim$ 50ºC) to switching off of ultrasound. The next heating and cooling of samples in unload state showed that the samples "memorize" up to 3% deformation. It is determined that the ultrasonic treatment at more higher temperatures ($\sim$ 100°C) increase the value of "memorized" deformation. Thus the experimental data showed the possibility of TiNi wire shape setting by means of ultrasound treatment. The main advantage of this method is the little time of treatment (1-3 min) and minimal heating of material ($\sim$ Af).

Remarks:

B2.44 | Paper ID – 06017 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

The effects of nickel and carbon concentrations on the wear resistance of Fe-Ni-C austenitic alloys

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Abstract. The effects of nickel and carbon concentrations on the wear resistance of Fe-xNi-yC (x=14∼20 wt. % , y=0.6∼1.0 wt. %) were investigated with respect to strain energy initiation of the martensitic transformation and hardness. The strain energy needed to initiate the martensitic transformation increased with increasing carbon and nickel concentrations, except in 1.0 wt. % C alloys. The wear resistance of the material decreased with increasing carbon concentration up to 0.9 wt. % C. This effect is most likely due to decrement of the martensite volume fraction with increasing carbon concentration induced by the incremental strain energy required to begin the martensitic transformation. In the case of 1.0 wt. % C, the improved wear resistance may be due to carbide precipitation

Remarks:

B2.45 | Paper ID – 06018 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

The effect of boron on the abrasive wear behavior of austenitic Fe-base hardfacing alloys

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Abstract. The effect of boron on the abrasive wear behavior of the austenitic Fe-Cr-C-Si-B hardfacing alloys was investigated with varying boron concentration. It was found that the abrasive wear resistance of the hardfacing alloys increased up to 50% compared to that of boron free alloys with increasing boron concentration. The mechanism of the abrasive wear resistance changed at 0.6 wt.% boron. Below 0.6 wt.% boron concentration, the abrasive wear resistance was improved almost linearly and strain-induced martensitic transformation was considered as the controlling factor for improving the resistance. Above 0.6 wt.% boron, it was observed that the primary borides started to precipitate. Further increase in boron concentration was not able to enhance the resistance due to the negligible change of primary borides' size and volume fraction. With these results, it was concluded that two different effects of boron on the wear resistance of the austenitic Fe-Cr-C-Si-B hardfacing alloys existed depending on the boron concentration

Remarks:

B2.46 | Paper ID – 06019 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Effect of nickel alloying on corrosion and wear resistance of the strain-induced martensitic transformable wear resistant Fe-20Cr-1.7C-1Si alloy

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Abstract. The strain-induced martensitic transformable wear resistant Fe-20Cr-1.7C-1Si alloy was investigated with regard to its corrosion and wear behavior with variations in nickel content. The weight loss of 10 wt.% nickel added alloy decreased below a half of that of the alloy in the absence of nickel. Also, in terms of electrochemical properties with increasing nickel, the corrosion potential was shifted toward the noble direction and the corrosion current density was reduced. Although an amount of 10 wt.% nickel was not enough to form the passive layers on the surface of the alloys, it was clearly explained that the presence of nickel in the alloy is beneficial to corrosion resistance in the saline medium. Meanwhile, 3 and 5 wt.% nickel-containing alloys were almost retained the excellent wear resistance of the nickel-free alloy during the wear test up to 2000 cycles. However, that of 7 and 10 wt.% nickel-containing alloys were abruptly deteriorated due to lowering the hardness of matrix and being insignificant the role of strain-induced martensitic transformation. Results of the study suggest that the nickel addition was apparently attributable to be beneficial effect on the corrosion resistance of the alloy. However, it was shown that the wear resistance of the alloy contained above 5 wt.% nickel was remarkably deleterious.

Remarks:

B2.47 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Microstructure, mechanical and functional properties of NiTi alloys processed by ECAP technique

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Abstract. In recent years considerable attention has been focused on processing and investigation of NiTi alloys with ultrafine-grained (UFG) structure because they possess a combination of elevated mechanical and functional properties. Equal-channel angular pressing (ECAP) is the most interesting technique here as it allows avoiding pollution by impurities and obtaining bulk samples, that suitable for practical use. The aim of the given work is to systematically investigate the influence of regimes of ECAP on the microstructure, mechanical and functional properties of the NiTi alloys. It is shown that as a result of ECAP an equiaxed, homogeneous in volume, UFG structure with the grain size up to 200 nm is formed in the bulk rods (with the diameter 16-20 mm) of NiTi alloys. High strength (yield stress up to 1300 MPa) with enhanced functional properties (maximum recovery stress σr_max to 1100 MPa and maximum fully recoverable strain ϵr_max to 9.2%), which is considerably higher than in the coarse-grained state is achieved.

Remarks:

B2.48 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Nanoindentation studies of Ni-Ti alloy processed by electroplastic rolling

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Abstract. Recently bulk long-sized nanostructured Ni-Ti shape memory alloys have been effectively produced by electroplastic rolling and subsequent annealing. Since their microstructures are refined and show local variations, the studies of local mechanical characteristics of these alloys are highly expected. In this paper we present the nanoindentation studies on a Ni50.7Ti49.3 alloy which were processed by electroplastic rolling and subsequently annealed for 1 hour at different temperatures up to 600 [U+2103]. A series of nanoindentations were made on the mechanically polished samples at mN load levels with a Berkovich indenter. After indentation AFM was used to map the remnant impression. The mechanical properties (hardness and elastic modulus) were systematically studied and finally summarized.

Remarks:

B2.49 | Paper ID – 06014 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Response of NiTi SMA wire electrically heated

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Abstract. In the present work an experimental-numerical approach is used to study the thermo-mechanical behaviour of NiTi wire for defining what parameters are the most important in actuator designing. Tests were carried out by heating a wire having a diameter of 0.150 mm by electrical current under constant stresses of 200 MPa. Strain, applied current and voltage are recorded by PC while wire temperature by thermographic system. The numerical code integrates the ordinary differential equation describing the volumetric wire heating and cooling transients assuming that the electrical power is the only external heating source. Temperature distribution in the wire is considered uniform and its change in time depends on wire specific heat, latent heat of the martensitic transformation, free convection heat exchange coefficient and total emissivity of the surface wire. Comparisons between experimental and numerical results show that the wire heating rate mainly depends on the applied electrical power, latent heat of the martensitic transformation and free convection heat exchange coefficient. The decrease of the wire temperature is strongly affected, once the free convection heat exchange coefficient is defined, by the shape of the martensitic transformation curve. Simulations show that the time necessary to obtain the maximum strain can be reduced to few ms if current of 10 A is used. Moreover, the strain dependence on time can be tailored by choosing the suitable heating transient.

Remarks:

B2.50 | Paper ID – 06007 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Choice of SMAs for damping applications in Civil Engineering: simulations and realistic experiments

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Abstract. There have been published many papers and several reviews on the application of SMA's as damping devices in civil engineering by using the pseudoelastic effect, but they are difficult to apply because the behaviour of the alloys is not carefully analyzed. In particular, the summer-winter temperature effects, aging long time at low temperature, self-heating or residual strains requirements for the given applications are rarely well established. In this work, we analyze and compare two cases, the damping of earthquake effects on relatively small structures as family homes, and the damping of stayed cables in large bridges. The requirements for the materials are different, and in each case a different commercial alloy with appropriate conditioning might provide acceptable answers. To confirm the usefulness of the dampers, the hysteretic behaviour of two SMAs (CuAlBe and NiTi) has been analyzed, and later modelled and introduced in finite element codes for the simulation of structures. The behaviour of the structures without and with dampers have been analyzed and compared. Also, some realistic experiments with cable 1 in the ELSA Joint Research Centre of the EU in Ispra have been done with NiTi wire of 2.46 mm diameter as damper, to compare with simulations.

Remarks:

B2.51 | Paper ID – 06036 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Wear of NiTi coatings obtained by thermal spraying

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Abstract. Shape Memory Alloys are interesting not only for shape memory and pseudoelastic properties, but also for relevant wear resistance near their transition temperature. NiTi has also high oxidation and corrosion resistance, and these properties together with the wear resistance suggest its use as coating to increase the lifetime of some parts. In this work we exposed the results obtained with thermally sprayed coatings of NiTi using vacuum plasma spray (VPS), atmospheric plasma spray (APS) or high velocity oxy-fuel spray (HVOF). The wear behaviour has been studied by rubber-wheel equipment (ASTM G65-91) and ball-on-disk test (ASTM G99-90). The results obtained at room temperature show that the APS coatings exhibit a preferential dry sliding wear mechanism, while the VPS and HVOF coatings show an abrasive mechanism.

Remarks:

B2.52 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Pseudoelastic cycling in Cu-Al-Be single crystals: Interaction with diffusive phenomena

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Abstract. CuAlBe alloys exhibit martensitic transformations and several properties related to this transformation such as the shape memory effect, pseudoelasticity and the two way shape memory effect. In this work results concerning pseudoelastic cycling of CuAlBe single crystals are presented and discussed. Particularly noticeable is the strong effect of diffusive phenomena on the stress strain curves obtained at test temperatures between 333 K and 373 K. In effect, a stronger stabilization of the martensite is observed during cycling as compared with the stabilization effect upon static conditions, which was found to be negligible at the same test temperatures. Results also indicate that the recovery of the austenitic phase plays a significant role during cycling. The generation of vacancies and the increase in their mobility have been considered in order to explain the observed behavior.

Remarks:

B2.53 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Experimental determination of the initial yield surface of a NiTi based shape memory alloy under tension-tension proportional and nonproportional loading

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Abstract. Compliant mechanisms are a peculiar class of mechanical systems designed to produce controllable large deformations by exploiting structural flexibility. Mechanisms which are based on conventional materials, like spring steel, are constrained in their deformability due to limitation in allowable strain. The superelastic behaviour shown by Shape Memory Alloys can be exploited to overcome this restraint. Planar compliant mechanisms are generally realised as an arrangement of rigid members and so-called flexures, i.e. elements designed to provide a defined degree of bending flexibility. The mechanical behaviour of flexures is usually analysed by the beam theory, assuming uniaxial states of stress. In many cases, two- or even three-dimensional stress states may occur, e.g. in a thin leaf hinge due to plane strain bending. This paper deals wit experimental investigations on the multiaxial behaviour of NiTi based Shape Memory Alloys. In particular, the focus is on biaxial tension-tension tests on superelastic thin sheets, as most of the biaxial test data available in the literature are based on tension (compression) torsion tests. The experimental results are compared to finite element analysis based on a published constitutive model.

Remarks:

B2.54 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Shape memory alloy wire actuated tilting table

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Abstract. SMA actuators are simple, have very high energy densities, can deliver large forces over long distances and can even work with TTL-level voltages. However, high current needs for Joule heating and passive cooling cause their cycling frequency (and hence the bandwidth) to be low. The hysteresis makes control of SMA actuated structures complicated. In order to develop successful actuator application, the design should utilize the key advantages and minimize the shortcomings of SMA actuation. In this work, a design of a SMAWATT (Thin SMA Wires Actuated Tilting Table) actuated by thin NiTi wires is presented and analyzed from the point of view of SMA actuation performance.

Remarks:

B2.55 Poster Presentation | Tuesday, Sept. 8, 17.00 - 18.30

Effect of heat treatment conditions on mechanical properties in an Fe-12% Cr-0.8% Mo-0.3% V-1.4% C steel

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Abstract. Effects of austenitizing and tempering temperatures on hardness and abrasive wear properties have been investigated in an Fe-12% Cr-0.8% Mo-0.3% V-1.4% C steel. Primary and eutectoid carbides are sufficiently dissolved and martensite and primary M7C3 carbides are observed in matrix by austenitizing at 1,020[U+2103]×40min. However, when the specimens are austenitized above or below 1,020[U+2103]×40min, some carbides or retained austenite are revealed after quenching. Needle-like carbides are precipitated in matrix by tempering at 400[U+2103]×60min after quenching at 1,020[U+2103]×40min, but they are spheroidized and the volume fraction of them increased at a higher tempering temperature, 600[U+2103]. Hardness values of which the specimens tempered at 200 ∼ 600[U+2103] are higher in the specimen austenitized at 1,020[U+2103]×40min than those austenitized at 970[U+2103]×40min or 1,070[U+2103]×40min. Hardness values decrease by raising tempering temperature up to 400[U+2103] but those increase due to secondary hardening by tempering at 600[U+2103]. Amount of wear loss decreases by lowering austenitizing temperature, while it decreases with raising tempering temperature in comparison with the specimens austenitized at same temperature.

Remarks:

B.3 Applications

B3.01 | Paper ID – 07001 Invited Oral Presentation | Wednesday, Sept. 9, 8.30 - 9.00

Application of nanostructural nickel titanium implants with shape memory effect to modern dental practice

V. S. Afonina[1], N. I. Borisenko[2], R. M. Gizatullin[2], D. V. Gunderov[3], V. S. Kalashnikov[1], V. V. Koledov[2], E. P. Krasnoperov[3], V. G. Shavrov[2], V. I. Suslov[3], N. A. Yusov[3]

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Abstract. The results of clinical treatment of severe periodontal diseases by application of the new functional implants based on nanostructural NiTi alloy with shape memory effect are presented. The nanostructure in NiTi alloy is attained by severe plastic deformation, particularly by equal channel angular pressing. Several new types of NiTi implants are developed, including dental implants (to replace the removed teeth) and trans radix implants (to enforce teeth and to attach teeth to the jaw bone). The surface of nanostructured NiTi implants is covered by the carbyne layer in order to ensure high bio-compatibility. The new treatment procedure is proposed which includes the injection into the jawbone tissue of the mixture based on powdered NiTi alloy. These injection implants will be incorporated into living bone tissue. The result will be the growth of the shell of the new healthy dense bone. The NiTi particles behave structurally similar to healthy bones, i.e. living tissue cells incorporate with them followed by small vessels and nerves. As a result the implants will not be rejected for a long time. The summary results of 3 years' practice of the successful application of these new implantation system in dentistry are presented. The ease of implementation of the new NiTi dental shape memory implants and the ease at which they can be adopted to bone tissue, especially in cases where it's in deficit are highlighted

Remarks:

B3.02 | Paper ID – 07017 Regular Oral Presentation | Wednesday, Sept. 9, 9.00 - 9.15

Fastening of shape memory hook arrays

D. Vokoun[1], D. Majtás[1], M. Frost[2], P. Sedlák[2], P. Sittner[1]

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Abstract. Shape memory (SM) fasteners based on the SM effect are already well-known applications. However, it has just been recently that NiTi hook arrays working as probabilistic fasteners were fabricated. Similarly to Velcro-type fasteners our fasteners are releasable with hooks returning back to their original shape after releasing. NiTi hooks may be incorporated into textiles and function in the same manner as Velcro fasteners do or they may be incorporated into a rigid substrate. The main objective of our research is twofold: First, we would like to show the influence of the material properties and geometry parameters of pseudoelastic NiTi micro-hooks on the interlocking force necessary for releasing the NiTi hook connection. Secondly, we show a method for aligning of the micro-hooks into an array and attaching them to a substrate.

Remarks:

B3.03 | Paper ID – 07013 Regular Oral Presentation | Wednesday, Sept. 9, 9.15 - 9.30

Magnetic-field-induced reorientation in single crystalline Ni-Mn-Ga foil actuators

F. Khelfaoui[1], Y. Srinivas Reddy[1], M. Kohl[1], A. Mecklenburg[2], R. Schneider[2]

[1] *University of Karlsruhe, Germany*
[2] *Helmholtz-Zentrum Berlin, Germany*

Abstract. The coupled magnetic and mechanical properties of single crystalline Ni-Mn-Ga foil actuators are investigated for decreasing thicknesses in the range from 200 μm down to 60 μm. The foils exhibit a narrow martensitic phase transformation above room temperature below the Curie temperature of 369 K. Single crystalline Ni-Mn-Ga beam actuators are fabricated by laser micromachining. As-prepared specimens show enlarged twinning stress and thus no measurable magneto strain. Therefore, several training methods are adapted to the quasi-two-dimensional geometry of the foils. As compression training can no longer be applied in lateral direction of thin foils, more sophisticated magneto-thermo-mechanical treatments are required. We show that the low twinning stress of the bulk reference specimens can be recovered. Magnetization experiments and the direct observation of magneto strain on trained foil actuators show different degrees of reorientation up to 1% depending on the training method. The observed partial reorientation effect is discussed in terms of the foil geometry and training parameters.

Remarks:

B3.04 | Paper ID – 07018 Regular Oral Presentation | Wednesday, Sept. 9, 9.30 - 9.45

Study of microstructures on cross section of JAPANESE SWORD

M. Yaso[1], T. Takaiwa[1], Y. Minagi[1], K. Kubota[2], S. Morito[3], T. Ohba[3], A. Das[4]

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Abstract. An old, famous Japanese sword has been studied metallurigically to observe its microstructure by optical microscopy and scanning electron microscopy. The microstructure in the sharp edge of cross-sectional part is fine martensite and the morphology is lath type martensite. The other parts of sword, side and central part, of cross section show the structure of fine pearlite or coarse pearlite dominantly. The hardness of the sharp edge is high enough to possess the sharp cutting property. SEM-EDX observations indicated that several kinds of non-metallic inclusions exist in the sword which are considered to be originated from the slag smelting reaction in Tatara process. The amount of non-metallic inclusions in the sword is 50-100 times more than that of the ordinary steel. In the sharp edge the amount of inclusions is fewer and the sizes are finer in comparison with side and central part of the sword. It is considered that repeatedly forging and folding operations in making sword process are responsible for that.

Remarks:

B3.05 | Paper ID – 07007 Regular Oral Presentation | Wednesday, Sept. 9, 9.45 - 10.00

A new control strategy for shape memory alloys actuators

P. Gedouin[1], C. Join[2], E. Delaleau[1], J. Bourgeot[1], S. Arbab Chirani[1], S. Calloch[3]

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[3] *LBMS/ENSIETA, Brest, France*

Abstract. Shape memory alloys (SMA) are more and more integrated in engineering applications. These materials with their shape memory effect permit to simplify mechanisms and to reduce the size of actuators. SMA parts can easily be activated by Joule effect but their modelling and consequently their control remains a problem, it is principally due to their hysteretic thermomechanical behaviour. A Second difficulty is that the characteristics of the material are time-varying, especially during cyclic loadings. So, most of successful control strategy applied to SMA actuator are particularly complex and used the Preisach model or neural networks to model the hysteretic behaviour of these materials but this kind of models are difficult to identify and to compute. That is why this study deals with an application of the new framework of model-free control and restricted model control applied to two kind of SMA spring based actuators. This control strategy is based on new results on fast derivatives estimation of noisy signals, its main advantages are: the simplicity, the robustness and its light computation. Experimental results and comparisons with PID control are exposed and demonstrate the efficiency of this new control strategy despite thermal perturbations.

Remarks:

B3.06 | Paper ID – 07003 Regular Oral Presentation | Wednesday, Sept. 9, 10.00 - 10.15

Analysis of Niobium precipitates effect on the thermo-mechanical behavior of a NiTiNb shape memory alloy and modeling

B. Piotrowski[1], T. Ben Zineb[1], E. Patoor[2], A. Eberhardt[3]

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[3] *LPMM, Paul Verlaine University, France*

Abstract. Commercial Ni47Ti44Nb9 Shape Memory Alloy (SMA) has attracted important attention for connection applications thanks to its wide transformation hysteresis. Indeed, it has been shown that reverse transformation temperature (As) can increase by 80 °C, with martensitic reorientation under tensile loading. The aim is to model this behavior in order to design industrial applications, by taking into account the Niobium inclusions effects upon the amplification of this phenomenon for NiTiNb. Niobium precipitates have been identified by Scanning Electron Microscopy (SEM) and X-Ray Diffraction (XRD), and characterized. It seems that the smallest β-Nb Niobium inclusions have the most important impact on the phenomenon, explained by Niobium low yield stress and important scattering and number of inclusions. A two phases thermo-mechanical model has been developed. It describes the global effective behavior of an elastic-plastic inclusion (Niobium precipitates) embedded with SMA Matrix. The constitutive law of the matrix is that developed by Peultier et al. and improved by Duval et al.. The elastic-plastic constitutive law for inclusion is a classical one proposed by Simo and Hughes, the Mori-Tanaka scale transition is adopted in order to lead to the effective constitutive law. Numerical results are discussed and compared to experimental ones.

Remarks:

B3.07 | Paper ID – 07016 Regular Oral Presentation | Wednesday, Sept. 9, 10.45 - 11.00

The SMA properties in civil engineering applications. The SMARTeR project: Use of SMA in damping of stayed cables for bridges

V. Torra[1], A. Isalgue[1], G. Carreras[1], F. Lovey[2], H. Soul[2], P. Terriault[3], B. Zapico[4]

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Abstract. One of the classical available applications of the SMA is their use in damping. In fact, using the hysteresis cycle associated to the martensitic transformation (classically, it is described as a first order phase transition). For each application is absolutely necessary a careful knowledge of the conditions required that the material need to be accomplished. In particular for the stayed cables in bridges, the oscillation frequencies are 1 Hz or greater and the SMA works in close contact with the external room temperature. The main requirements in the Iroise bridge related frequencies: between 1 and 3 Hz; and peak to peak oscillation amplitude: close to 10 cm. in fact, the Iroise bridge is a 2*2 lanes free highway situated between Brest and Plougastel (France). The main action is related with several days of intense winds or rain associated to strong storms. The conditions imposed to samples suggest positive work for, at least, 500000 cycles of working. The experimental analysis, centered on NiTi, is centered in 1) the fatigue life of the samples, 2) the evaluation of the Clausius-Clapeyron coefficient, 3) guaranteeing that the external evolution induced by stress and temperature is not relevant in the expected time scale of application, 4) modeling of the cable behavior shows, as expected, the positive effect of the SMA and 5) study in semi-realistic scale in the ELSA-JRC (Ispra, Italy) (a civil engineering facility) demonstrates the positive effect of the SMA.

Remarks:

B3.08 Regular Oral Presentation | Wednesday, Sept. 9, 11.00 - 11.15

Martensitic transformation and shape memory effect in NiTiCu alloy on submicron scale

P. Lega[1], K. Victor[1], K. Dmitry[1], S. Vladimir[1], I. Vladimir[2], I. Artem[3], P. Nikita[3], T. Ilya[3]

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[2] *State Technological University "Moscow Institute of Steel and Alloys", 119049, Moscow, Russian Federation*
[3]

Abstract. NiTiCu rapidly quenched alloy exhibit shape memory effect (SME), which is attributed to a thermoelastic martensitic phase transformation from high temperature phase (B2 structure) to the low temperature martensitic phase (B19 orthorhombic). This alloy demonstrates remarkable functional properties and find wide applications in the field of sensors and actuators technology. An important question arises whether the martensitic transformation and respective functional properties remain on submicron and nanometer scale of the dimensions of the alloy? In the present work we have proposed a new scheme which allows constructing the structures, demonstrating reversible bending strain, using only one-way SME. We have developed the technique on preparation of SME structures on submicron and nanoscale of dimensions using focus ion beam technology. The prototype of the nanotweezers with overall dimensions: 12x3x1 mcm3, NiTiCu SME layer thickness 500 nm have been prepared by this technology. The size of the grasped object – 10 to 1000 nm. The effective operation of the tweezers prototype under the control of semiconductor injection laser in the environment of scanning microscope (see video on the web: www.smwsm.org/ll/micropincer.html) have been proved. Theoretical estimation and experimental measurements show that martensitic transformation as well as SME manifest themselves similarly in 500 nm thick layers and in the original ribbons with 30 mcm thickness.

Remarks:

B3.09 | Paper ID – 07014 Regular Oral Presentation | Wednesday, Sept. 9, 11.15 - 11.30

Electrochemical parameters and biocompatibility of bare Nitinol surfaces

S. A. Shabalovskaya[1], G. Rondelli[2], M. Rettenmayr[1]

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Abstract. For understanding the nature of the variable thrombogenicity of bare Nitinol surfaces, a systematic study of electrochemical parameters was performed on disc and wire samples using cyclic potential polarization, open circuit potential and polarization resistance. The surfaces treated using chemical solutions showed consistent corrosion behavior, but mechanically polished and heat treated samples were prone to pitting. The polarization resistance of bare Nitinol surfaces varied in a range from 100 KΩ cm2 to 10 MΩ cm2, and the open circuit potentials from -440 mV to -55 mV implying the variability in corrosion rate and surface reactivity. Ni surface concentrations and ion release are discussed in terms of surface charge in connection with fibrinogen adsorption and platelet activation.

Remarks:

B3.10 | Paper ID – 07010 Regular Oral Presentation | Wednesday, Sept. 9, 11.30 - 11.45

Development of standardised and integrated shape memory components in “one-module”-design

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Abstract. Actuator systems based on shape memory alloys are nowadays mainly characterized by the alignment to specific applications. However, there is a considerable interest in shape memory actuator systems with complex and variable functions. One way to represent the realisation of such a system is a modular system. Modular systems do not only enable the adoption of the solutions for other applications, but also lead to a reduction of the diversity of variants and to a reduction of the development risk. An unsolved problem of modular systems is the increasing system complexity. Responsible are additional functions, like the mechanical and electronic coupling of the modules. Beyond the conventional form of a modular system there is the possibility to create a variable shape memory actuator system only by using the material configuration of one single SMA-component (“one module” modular system). Apart from the conventional point of view there is a new perspective with extreme integral and standardised set up. Therefore, the SMA-component can be programmed functionally for the scheduled utilisation. The purpose of the present study is to show options and the creation of such a universal SMA-component. Thus, an object of investigation is the analysis of designs, properties and capabilities. Structuring modular systems differently and re-arranging the production process represents a new way of thinking in the field of mechanical engineering.

Remarks:

B3.11 | Paper ID – 07004 Regular Oral Presentation | Wednesday, Sept. 9, 11.45 - 12.00

Phase transformations in NiTi endodontic files and fatigue resistance

S. V. Correia[1], M. T. Nogueira[2], R. J. Cordeiro Silva[2], L. Pires Lopes[1], F. M. Braz Fernandes[2]

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Abstract. NiTi endodontic files allow for clinical enlargement of harshly curved root canals. However, files rotated under severe flexion might fracture unexpectedly, remain inside teeth and thus, hinder treatment outcome. ProFile .06(35) are among the most commonly used rotary files. In the present study, 10 of these brand new instruments were used to perform DSC on their cutting regions and determine the amount of R-phase present at 10, 20, 37, and 65ºC, both during cooling and heating programmed cycles. Another 48 new ProFile .06(35) instruments underwent rotation/flexion assays at 300 rpm and 10 mm radius of curvature. Files were divided into four groups of 12 instruments each. Each group was tested at 10, 20, 37, and 65ºC. The number of cycles to fracture (Nf) and the length of the broken segment (Lf) were determined for each tested file. Results show no statistically significance (α =0,05) as for Lf in all groups. On the contrary, Nf depends highly on testing temperature: as temperature increases from 10 to 37 ºC, Nf strikingly decreases; from 37 and 65 ºC, no significant changes in Nf occur. As for DSC results, it is clearly shown that R-phase is most abundant at 10 ºC and consistently decreases up to 37ºC, both during heating and cooling; from 37 to 65 ºC, the quantity of R-phase in the alloy is negligible. In conclusion, it is shown that fatigue resistance in ProFile .06(35) instruments is not only highly enhanced but also proportional to the amount of R-phase in the alloy.

Remarks:

B3.12 | Paper ID – 07015 Regular Oral Presentation | Wednesday, Sept. 9, 12.00 - 12.15

Modelling and testing of a load limiting sandwich structure

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Abstract. A heavy gust causes a severe load peak to a Wind Turbine (WT) blade. Such load peaks and the consequent vibrations cause fatigue that reduce the lifetime of the blade. The fatigue loads are also a limiting factor in increasing size of WT blades. This paper deals with a load-limiting structure that will not allow the load peak to grow over a chosen limit. The targeted structure is an adaptive airfoil that automatically reduces camber at a heavy gust, which in turn immediately reduces the loads to the blade. This adaptive concept is totally passive, it needs no heating nor control system. The concept is based on an adaptive laminate that contains superelastic Shape Memory Alloy (SMA) wires in one direction, glass fibers in the other direction and a flexible special epoxy matrix. The feasibility of the system is tested by a planar sandwich beam under 3-point bending. The structure is modelled using the ABAQUS finite element program and two different SMA material models: the Aurichhio-Taylor model existing in ABAQUS commercial code and the new iRLOOP UMAT (ASCR-VTT). The modelled results are compared to each other and to experimental results. The results show that the load-limiting concept is feasible, but the tested structure contains too soft matrix and core.

Remarks:

B3.13 | Paper ID – 06026 Regular Oral Presentation | Wednesday, Sept. 9, 12.15 - 12.30

Martensitic transformation and its effect on the interfacial debonding in single Ni-Ti fibre/ epoxy composite

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Abstract. The effect of martensitic transformation in single Ni-Ti shape memory wire epoxy matrix composite was investigated. The Ni-Ti wire was received in as drawn condition and was subjected to three different heat treatments in order to obtain wires with different transformation characteristics. The in-situ observations of the interfacial debonding and sliding behaviour during the pull-out test were carried out. It is observed that when there is no phase transformation the debonding propagates rapidly whilst it is slow when there is wire phase transformation or matensitic reorientation. It is found that the debonding rate depends on the applied crosshead speed as well as the length change during phase transformation.

Remarks:

B3.14 | Paper ID – 07005 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Seismic retrofit for RC columns by NiTi and NiTiNb SMA wires

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Abstract. This paper conducted several flexural tests of RC (reinforced concrete) columns retrofitted by SMA (shape memory alloy). The RC columns with lap spliced reinforcements at the base show less ductile behaviour than those with continuous reinforcements. SMA wire jackets can increase the ductility of the RC columns with lap spliced reinforcements and thus this study used the two kinds of SMA wires to retrofit such RC columns; the first one is NiTi SMA wire that remains in martensite at room temperature and the other is NiTiNb SMA wire that is austenite at room temperature. Both the SMA wires show shape memory effect and provide active confinement for concrete. The SMA wires were prestrained to 7% strain and released. At the state, some residual strain remained and can be recovered by heating. The prestrained SMA wires were wrapped around the plastic hinge region of the RC columns and then the temperature of the wires raised by heating. Then, the SMA wires induced an active confinement on the RC columns. Each wire was measured for recovery and residual stress to obtain the information of active confinement. This active confinement and the resistance of the SMA wires increased the ductile behaviour of the RC columns in lateral direction. The parameters in this study are the kinds of SMA and the pitch of the wires. All types of the specimens retrofitted the SMA wires showed good ductile behaviour without degrading the flexural strength.

Remarks:

B3.15 | Paper ID – 07002 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Low-backlash worm gears with NiTi shape memory alloys

W. Predki[1], B. Bauer[1]

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Abstract. This paper investigates the use of martensitic Nickel-Titanium within worm gear transmissions in order to reduce the backlash of the gearwheels. In drive technology low-backlash transmissions are demanded. The backlash, adjusted at room temperature, decreases with increasing temperature as a consequence of different thermal expansions of the gear wheels and the housing. This can result in clamping of the teeth and leads to failure of the whole transmission. With NiTi-actuators, working in the extrinsic two-way effect, it is possible to realize two conditions of low-backlash and to avoid clamping of the gear wheels. The actuators induce a radial movement of the worm wheel depending on the increasing temperature within the gearbox. The decreasing backlash, as a result of different thermal expansions, is compensated by the expansion of the martensitic NiTi actuators while transforming to the austenite. The adjustment travel of the actuators has to correspond to the thermal change of the centre distance. By measuring the change of backlash on the test bench, the theoretical dimensioning of the actuator system can be verified. The variation of the main parameters like torque, the speed and different temperature levels as a result of the input power should demonstrate the effectiveness of the NiTi actuators.

Remarks:

B3.16 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Characteristics of Cu-Al-Mn shape memory alloy and its application to an ingrown nail correction device

T. Omori[1], Y. Sutou[1], N. Tabata[2], T. Suetake[3], R. Kainuma[1], K. Ishida[1]

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Abstract. Cu-based shape memory (SM) alloys are fascinating for use in industrial fields, although brittleness due to their high degree of order is a problem for practical applications. For the past decade, we have been developing Cu-Al-Mn SM alloys, in which the cold-workability is drastically improved by controlling the ordering transitions and a superelastic strain of about 8% can be obtained by suitable microstructural control of such factors as texture and grain size. Recently, a Cu-Al-Mn SM alloy has been applied to a medical device for treatment of ingrown nails. The new non-invasive method consists of simply clamping the tip of an ingrown nail with this device in order to achieve straightening of the curved nail by the recovery force of superelasticity. One of the important factors in the Cu-Al-Mn alloy is its good cold-workability necessary for forming the clip-on device, and another characteristic feature is the low temperature dependence of shape recovery stress, which means that the correction force is less affected by temperature. Nail correction treatments using the device have been carried out, and the device has been found to have sufficient corrective force and to quickly produce a satisfactory therapeutic result without any local pain. It is thus suggested that this simple technique be considered as a new method for ingrown nail treatment.

Remarks:

B3.17 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Low temperature behavour of TWSMA spring to apply for the intelligent thermal jacket

E. Kim[1]

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Abstract. In our previous studies, we have reported the possibilities of using two way shape memory alloy spring as an intelligent material to substitute thermal insulation padding. In this study, we prepared various wire and coil diameter springs to make better thermal clothing systemby increaing the stability of air layer formed by the expansion of the springs when the wearer is exposed to cold temperature. Two way SMA springs were prepared with aging temperatures from from 450°C to 540°C in intervals of 10°C to determine transformation temperatures of each spring. Nitinol with 0.8mm and 1mm wire diameter were wound to a mold of diameter 10mm and 17mm respectively. Then, the springs were homogenized at 780°C and aged at chosen aging temperatures. Hysteresis effect was measured between 40°C and 0°C. Compresssional resilience was determined by decreasing temperature from 40°C to -30°C in the Human-Clothing-Environment (HCE) simulator to expand the specimens to their latent length. Each specimen was loaded with weights (100g, 50g, 10g, 1g) until the SMAs were completely compressed at each temperature. Average thickness of air layer formed by the expanded springs and microclimate formed by air layer were measured. Results showed that the optimum aging temperature suitable to apply to thermal jacket ,which actuate at 21°C, was estimated as 510°C. Compresiional resililience reached over 1.5kg which was sufficient to apply as a thermal padding.

Remarks:

B3.18 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Combinatorial development of Ti-Ni-Hf shape memory thin film actuators

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Abstract. A combinatorial approach for the development of shape memory thin film actuators with respect to high transformation temperatures, low thermal hysteresis and good actuator response will be presented [1]. Thin film deposition and high-throughput characterization tools were applied for the fabrication and characterization of ternary Ti–Ni–Hf materials libraries. Continuous compositions spreads were used for identification of the composition regions showing reversible phase transformation using automated energy dispersive X-ray spectroscopy (composition), X-ray diffraction (microstructure), as well as temperature-dependent resistivity measurements (R(T)) revealing the phase transformation properties of the thin films. Temperature-dependent stress measurements (σ(T)) on micro-structured cantilever Si-wafers with linearly varying compositions e.g. Ti50-xNi50Hfx (0 <x <35 at.%) in a temperature range from -100°C up to 450°C were applied to characterize the actuator behaviour. Next to extending the knowledge about transforming compositions in the Ti-Ni-Hf system, the dependency of the transformation temperatures, thermal hysteresis, actuator response and thermal cycling fatigue on the composition was established. Reversible phase transformations where observed within a Ni composition range of ∼50 to 40 at.% . [1] Zarnetta R, Savan A, Thienhaus S, Ludwig A. App Surf Sci 2007;254:743 [2] Zarnetta R, Savan A, Thienhaus S, Ludwig A. ACTUATOR 2008, Bremen, Germany, 2008:378

Remarks:

B3.19 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Resistivity measurements of thin film shape memory micro-bridges for the determination of the stress-dependency of martensitic transformation temperatures

D. Koenig[1], S. Thienhaus[1], M. Ehmann[1], A. Ludwig[1]

[1] *Ruhr-University Bochum, Germany*

Abstract. The fabrication and characterization of Ti52Ni32Cu16 thin film shape memory micro-bridges is presented with a focus on the characterization of the shift of the martensitic transformation temperatures in dependency of thermal stress induced by the different thermal expansion coefficients of thin film and substrate. Both, substrate-attached and freestanding bridges were fabricated using photolithography and different etching processes. The underetching of the micro-brigdes was achieved by means of a modified ASE process. The bridges lengths and widths vary between 1 10 μm. Four electrodes, affixed to each bridge and allowing for resistivity measurements of the thin films, were used to determine the transformation temperatures of both, freestanding bridges and substrate-attached films. A comparison between the freestanding bridges and the substrate-attached thin films reveals a shift of the transformation temperature of up to 30 K. Using the Clausius-Clapeyron equation, these temperature shifts can directly be related to the stress differences between the freestanding bridge and the substrate-attached film. A similar shift of the transformation temperatures can be achieved by reducing the lateral size of the structure. These results are of high importance for miniaturized applications of shape memory alloys.

Remarks:

B3.20 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Contribution to the development of new biocompatible alloys with low modulus

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Abstract. Key words : β titanium, superelasticity, low modulus, martensitic transformation, prosthesis. Titanium and titanium alloys are widely used in the biomedical field to create hip prostheses or dental implants. Among the various kinds of alloys (α, $\alpha + \beta$ or β), the β metastable ones are particularly interesting as they present a low elastic modulus, as well as high ductility and superelasticity due to a stress-induced martensitic transformation. The aim of this work is to develop new alloys with lower modulus, closer to that of human bone (15-20 GPa) and free of non-biocompatible elements. A theoretical method developed by Morinaga et al. was used to optimize the chemical composition and lead us to two alloy compositions : Ti29Nb6Ta5Zr and Ti29Nb11Ta5Zr. These alloys were elaborated in a vacuum arc melting furnace and characterized after an homogenization. The chemical composition was analysed by EDS and the phases by XRD. The martensitic phase α" was shown by differential scanning calorimetry and transmission electronic microscopy. The pseudoelastic behavior and the martensitic transformation were highlighted through cyclic mechanical testing and the lowering effect of cold working on the elastic modulus was shown. Several brief heat treatments were applied to study the influence of the nanometric isothermal omega phase on the behavior. This study gave promising results and allowed to find ways to optimize the mechanical properties of new 100% biocompatible alloys.

Remarks:

B3.21 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Dynamical transition in solid-solid nucleation : microstructure, plasticity and novel excitations

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Abstract. Nucleation of a solid in solid generically creates localized plastic or non-affine zones (NAZs), whose dynamics decides the microstructure of the transforming solid[1,2]. Here we demonstrate, using various measures like equal time strain correlations and the full particle diffusion matrix obtained from molecular dynamics simulations that the distinct microstructures – ferrite and twinned martensite – occur across a sharp dynamical transition. Tagged-particle dynamics in the NAZs of the ferrite and martensite, changes abruptly from diffusive, with an enhanced local effective temperature, to ballistic and correlated, revealing an intriguing causal connection between microscopic particle trajectories, mesoscopic NAZs and macroscopic transformation. The nature of particle movement decides the fate of a transforming solid - on suppressing single particle (diffusive) excitations, the transformation proceeds via rare string-like correlated exicitations, giving rise to twinned nuclei with compatible parent-product interfaces. These stringlike excitations flow along ridges in the potential energy topography. We attempt to understand some of our results within a discrete model which has both spin flip and "sand-pile" like avalanche dynamics. Our study brings together the physics of glass, jamming, plasticity and solid nucleation. [1] J. Bhattacharya, A. Paul, S. Sengupta and M. Rao, J. Phys.: Condens. Matter 20 (2008) 365210. [2] A. Paul, J. Bhattacharya, S. Sengupta and M. Rao, J.

Remarks:

B3.22 | Paper ID – 07012 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Texture and magnetic anisotropy of polycrystalline extruded rods of Ni-Mn-Ga alloys

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Abstract. It is well known that a relatively high magnetic anisotropy and magnetic field can induce strain in the polycrystalline Ni-M-Ga alloy, especially, in the preferred <001>orientation. A significant technological improvement may be achieved by producing textured rods with axial orientation. This was realized by rods extrusion at high temperature with a proper reduction rate. The paper concerns the comparison of texture, magnetization and magneto-crystalline anisotropy constant for samples cut out from the columnar grain zone and cut from extruded rods.

Remarks:

B3.23 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Calculation of unelastic behaviour of a steel-TiNi bimetallic beam

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Abstract. The deformation of a steel-TiNi bimetallic beam under an active deformation when the TiNi part of the beam is in the martensitic state and subsequent heating and cooling thermal cycles has been calculated. It has been shown that the dependences of the deformations due to the shape memory and two-way shape memory effects on the ratio of thicknesses of the steel and TiNi elements are not monotone with the maximum determined by the mechanical characteristics of elements.

Remarks:

B3.24 | Paper ID – 07006 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Thermo-mechanical behaviour of a carbon fibre reinforced shape memory alloy hybrid composite

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Abstract. Shape memory effect, responsible for shape recovering of Shape Memory Alloys (SMA) after a cycle of deforming-heating, provides to these alloys functional properties associated with the possibility of generating mechanical work simultaneously to the shape recovery. Composite systems incorporating pre-strained SMA wires have the ability to actively change shape and other mechanical static and dynamic characteristics upon a heat driven actuation process. The functional properties of this type of adaptive composites are directly related to the reversible martensitic transformation in the SMA elements and to the constraining behaviour that the composite matrix has on the SMA wires. In this work the thermo-mechanical behaviour of a shape memory alloy hybrid composite (SMAHC) has been experimentally investigated. A hybrid composite plate was fabricated using pre-strained SMA wires as actuating elements embedded in an thermoset resin pre-preg carbon fibres composite system. Because of the electrical conductive nature of carbon fibres, electrically driven actuation cannot be performed. Hence, in the experimental tests, the plate was clamped at one side and actuated via an external heat source. During actuation, displacements will be collected using Bragg gratings. These optical sensors, properly attached on the plate surfaces, will be able to monitor the deformation state of the composite during the whole heating process.

Remarks:

B3.25 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

New cylindrical magnetic system for the magnetocaloric refrigerator

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Abstract. To improve the magnetic system for the active magnetocaloric device, which we produce in Chelyabinsk State University, and increase the magnetic flux we construct cylindrical array magnetic system which provides easier access for the wheel containing magnetocaloric beds. The cross sectional dimensions of the array are 97 cm2 and the air gap height is 18mm. Nd-Fe-B samples (the residual induction of each sample is in 1.189-1.206 T) were used as the permanent magnets and the soft magnetic stainless steel was used as a soft magnetic material for the yoke of the magnetic system. The magnetic field at the center of the air gap is 1.6 T and it is homogeneous within the range 20 mm. This magnetic system used in magnetocaloric refrigerator which is constructed in Chelyabinsk State University. The reduction of the magnetic system size (1.5 times in comparison with the previous one) allow us to reduce seriously the prime cost of the magnetic system (common price is about 450 euro) and save the magnetic field and the homogenious area of the magnetic field in the system.

Remarks:

B3.26 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Microstructure of multicomponent Ti35H15Ni50-xCux shape memory alloys supercooled after crystallization

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Abstract. Development of multicomponent Ti35H15Ni50-xCux shape memory alloys from precursor amorphous state continue attention due to unique mechanical properties in the supercooled liquid region and specific microstructure formed after crystallization. Amorphous ribbons were produced by single-roll casting technique. Those ribbons demonstrate high shaping ability near glass transition temperature. The material structure was followed by the XRD, TEM/SAD techniques; the thermodynamic properties were studied by DSC; the mechanical and functional (shape memory, superelacticity) properties were studied in tension. The effect of crystallization conditions ad the resulting microstructural state (partly or fully crystallized material, grain size distribution, precipitates, accompanying crystallization) on the characteristics of martensitic transformation has been investigated. Variation of the mechanical and functional properties with the material microstructure after various crystallization regimes is discussed.

Remarks:

B3.27 | Paper ID – 07011 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Two-way shape memory-clips for colonic anastomosis

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Abstract. The compression anastomosis clip (CAC) is an elliptic shape double-ring device produced from nickel-titanium shape memory alloy. Until now the CAC works basing on the one-way shape memory effect. The aim of presenting studies was finding out the technology of two-way shape memory (TWSME) clips formation which should fulfil the requirements for clinical application. The clips were formed by wires of an alloy with 51.02 at. % Ni – balance Ti. The best value of the TWME and uniform compression force of the clips was achieved by combining deformation, constrained aging and thermomechanical cycling.

Remarks:

B3.28 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Stress-induced martensite in surface layers of Co-Cr-Mo alloys for dental applications

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Abstract. Co-Cr-Mo alloys are widely used in dental applications. Despite their good corrosion resistance and machinability, these alloys require significant strengthening for certain cases of prosthesis design. The present paper is dedicated to strengthening of the surface layers of Co-Cr-Mo alloys by ultrasonic shock treatment (USST). It was observed that in the conditions of vacancy supersaturation, the dislocation structure is the Lomer-Kottrell sessile dislocations, for formation of which the simultaneous gliding of the Shocklee partial dislocation in the intersecting slip planes is needed. Dislocations, which are clustering beyond the Lomer-Kottrell barriers, are splitting in partials and lots of the chaotically located stacking faults are formed. At USST of the Co–Cr–Mo alloys plastic deformation due to shear processes results in formation of structure, which consists of the vacancy stacking faults, ϵ-martensite and deformation twins. It was also found that these kind of treatment produces up to 70% of martensite phase in the surface layer of 3-5 microns and strongly depends on the time of the treatment. Perspectives of the surface layer strengthening of dental Co-Cr-Mo alloys with the stress-induced martensitic transformation provided by USST are discussed.

Remarks:

B3.29 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

NiTi textile – new opportunities for SMAs

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Abstract. The textile industry offers a large number of technologies for processing filaments that are nowadays used not only in the wear industry but also in other industrial fields. The domain of composites is one of the best examples showing how the textile technologies can be applied to develop a completely new type of material structures. Therefore the textile processing methods such as weaving, braiding and knitting became naturally of interest in the search of new NiTi applications as soon as the technology for manufacturing of thin NiTi filaments were available. In this context, we will present three approaches that can be adopted when developing NiTi applications based on thin NiTi wires (<= 100 microns) processed by textile methods. First, an example application will show the simplest approach where a textile processing method is used only as an efficient tool to stitch the NiTi filament in a zig-zag pattern onto the fabric whereas the NiTi filament itself serves for a rather classical purpose i.e. an actuation by shortening upon heating. Then two examples will be presented to demonstrate approaches focusing on the use of fabrics made either partially or fully of NiTi filaments by using the weaving technique. Firstly, technological challenges related to the manufacture and heat treatment of NiTi textiles will be pointed out. Secondly, the peculiar properties and behaviour of those fabrics will be illustrated to show the application potential of such structures.

Remarks:

B3.30 | Paper ID – 07009 Poster Presentation | Thursday, Sept. 10, 16.15 - 17.45

Energy-saving and quick-responding SMA actuator

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Abstract. The main drawbacks of SMA actuators are a slow response and a waste of electric power. The power should be continuously supplied for SMA elements to remain austenite state until the actuator begins to take the other configuration. The problems are more serious when batteries and thick SMA elements are used. We develop a new SMA actuator which consumes little energy and responds very quickly. The actuator consists of a specially designed bias spring and two SMA elements which exert the force in opposite direction to each other. The bias spring, unlike a common spring which has one stable position, has two stable positions. A SMA element (1), for instance, contracts on heating by electricity, the actuator takes one stable configuration. No further power supply is necessary to maintain the stable position, providing enough time for the SMA element (1) to cool. When the other SMA element (2) is heated, it contracts with enough force to move the bias spring and to expand the already-cooled SMA element (1). Power supply stops immediately after the actuator takes the other stable configuration, causing power saving and quick response.

Remarks:

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