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Giant effects in Co- and In-doped NiMnGa multifunctional alloys: Magnetic field induced reversible deformation and Giant Magneto-Caloric effect

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The vast family of Ni-Mn based Heusler alloys provide an extended playground of physical The vast family of Ni-Mn based Heusler alloys provide an extended playground of physical properties. The interplay between a reversible martensitic transformation (MT) and magnetically ordered states gives rise to a series of functional properties, such as giant magneto- and baro-caloric effects, giant magnetoresistance, magnetic shape memory and magnetic superelasticity, that can be exploited for developing innovative devices. The path towards the technological application of these materials relies on the enhancement of the sensitivity of the MT to external forces, such as magnetic field (dT_M/dH) or pressure (dT_M/dp), which could lead to the reversible actuation of the transformation itself beyond the limits imposed by the hysteresis. We have shown that by proper Co-doping Mn-rich Ni_2MnGa alloys it is possible to revert the order of the structural and magnetic transitions, giving rise to a reverse MT between a paramagnetic low temperature phase and a ferromagnetic high temperature one [1]. The reverse transformation increases the magnetization jump between the two phases and consequently the dT_M/dH well beyond the maximum values showed by the ternary alloy NiMnGa. The corresponding magnetocaloric effects are greatly enhanced [2, 3]. Here we will present the effects of hydrostatic pressure on magnetism and martensitic transformation; Co-doping increases the sensitivity of the MT to the applied pressure, allowing for remarkable values of the dT_M/dp parameter. A possible explanation to such behavior could be related to the structural modifications induced by the stoichiometric changes; temperature dependent X-ray diffraction measures show that the volume difference between the parent and product phases is greatly enhanced by Co; $\Delta V/V$ values higher than any other NiMnX Heusler alloy are found (X being a IIIa-Va element). Recently performed magnetostriction measurements in extremely high magnetic fields (up to 30 T) confirmed the remarkable structural ($\Delta V/V$) and magnetic (dT_M/dH) changes related to the MT and account for the behavior of these alloys in extreme conditions. Finally, we will show how the additional doping of In further improves the aforementioned functional properties, pushing these materials among the most promising candidates for future applications.

[1] S. Fabbrici *et al.*, Appl. Phys. Lett. **95**, 022508 (2009).
[2] S. Fabbrici *et al.*, Acta Mater. **59**, 412-419 (2011).
[3] G. Porcari *et al.*, Phys. Rev. B **86**, 104432 (2012).