

Group of Electron Beam Lithography (EBL)

Department of New Technologies

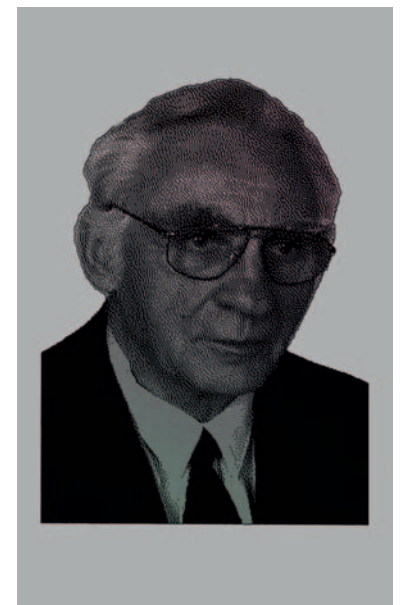


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Armin Delong, 1925–2017 —
optically variable image device
(25 mm × 40 mm) composed of
light-absorbing and light-scattering
building blocks (0.1 mm × 0.1 mm)

THEMATIC RESEARCH FOCUS

Research area

- Electron beam lithography (EBL)
- Diffractive optically variable image devices (DOVIDs)

Excellence

- Planar relief micro and nano structures on silicon wafers and glass masks
- Laser beam shaping by computer generated holograms (CGH)
- Diffractive optically variable image devices (DOVIDs)
- Masks for photo and UV lithography and special purposes

Mission

To be highly specialized EBL team with focus on relief and multilevel structures for large range of particular applications

UP-TO-DATE ACTIVITIES

Research orientation

- Theoretical and experimental activities related to the e-beam lithography writing process (electron emitter preparation and characterization, current density distribution, benchmarking patterns, proximity effect correction, writing strategies, sequencing, partitioning)
- Theoretical and experimental activity in the field of technologies related to e-beam nanopatterning (coating process, resist development, etching techniques, evaluation methodology, technology of nano structured nitride membranes)
- Diffractive structures (gratings, Fourier and Fresnel structures, DOVIDs, laser beam shaping)
- Micro-sensors and microscopy calibration specimens

Main capabilities

Basic research

- Study and evaluation of electron scattering effects, simulation and correction algorithms
- Experimental activities related to electron emitter preparation and characterisation
- Calculation and optimization of computer generated holograms (CGH)

Applied research

- Phase and amplitude computer generated hologram structures
- Diffractive optically variable image devices
- Electrochemical and biological sensors
- MMS and MEMS, e.g. micro and nano structured free standing nitride membranes

Sub-fields of group activities

- Scanning electron microscopy – calibration samples
- Optical microscopy – resolution and calibration samples
- Microtechnology, nanotechnology
- Laser beam shaping and splitting

KEY RESEARCH EQUIPMENT

List of devices

- E-beam writer (pattern generator) with shaped beam Tesla BS600: electron energy 15 keV, field deflection up to 3 mm × 3 mm, resolution 50 nm, rectangular stamp size range 50–6300 nm (standard mode), 17–2100 nm (TZ mode), writing speed > 1 cm² / hour (stamp size 1 μm × 1 μm, area filling factor 50 %)
- E-beam writer with Gaussian beam Vistec EBPG5000plusES: electron energy 50 or 100 keV, field deflection up to 0.25 mm × 0.25 mm, resolution 8 nm, beam size down to 2 nm, writing speed up to 1 cm² / hour (at beam step size 50 nm and area filling factor 50 %)

ACHIEVEMENTS

■ We deepened the methodology of e-beam lithography process using both the pattern generators as well as their combination. We also tuned up the technology processes with results useful in numerous application domains. Within the period 2012–2017 we published some 59 contributions in conference proceedings and journals. Within the same period we performed over 987 e-beam exposure runs.

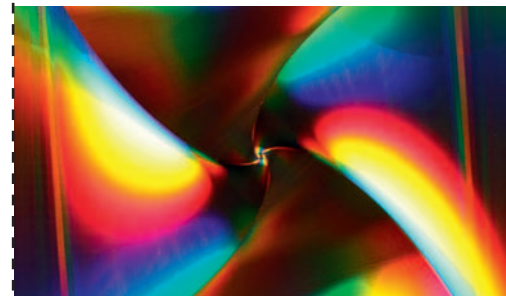
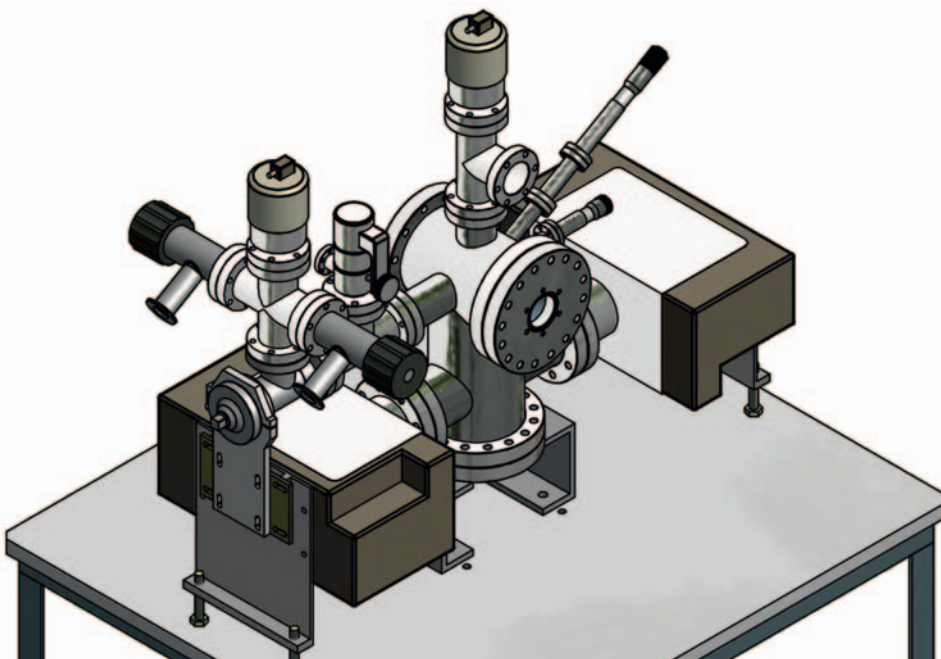
■ Apparatus for cathode processing, activation and testing

- M. Horáček et al.: “Nano Modification of the W(100)/ZrO Electron Emitter Tip Using Reactive Ion Etching”, NANOCON 2012: 4th Int’l Conf. Proc’s, 2012

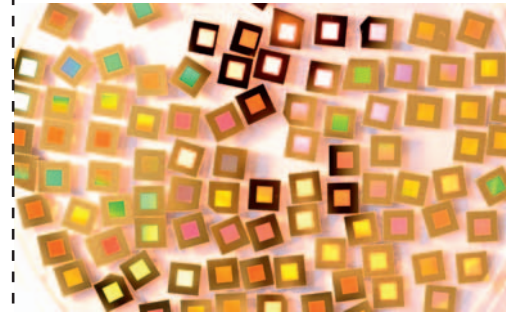
■ Cathodes with ultra-sharp tips are produced using automated set-up utilizing electrochemical etching method (both single-crystalline and poly-crystalline can be used). Cathodes which are based on cold field emission and thermal field emission (Schottky cathodes) are tested at ultra-high vacuum conditions. The following properties are obtained: I–V characteristics, Fowler–Nordheim analysis, an emission pattern of the electron beam, a long time stability of the electron beam, a surface characterization and a diagnostics of a cathode surface using scanning electron microscopy

- A. Knápek et al.: “Programmable set-up for electrochemical preparation of STM tips and ultra-sharp field emission cathodes”, *Microelectronic Engineering*, 2017, 173: 42–47
- A. Knápek et al.: “Field emission from the surface of highly ordered pyrolytic graphite”, *Applied Surface Science*, 2017, 395: 157–161

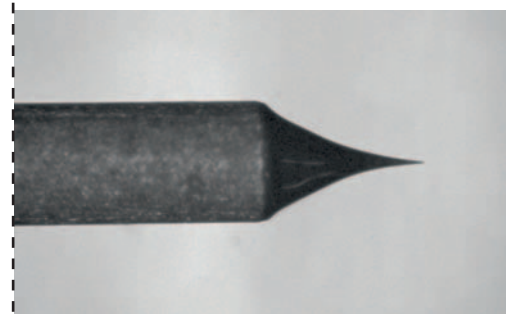
Field-emission microscope: ultra-high vacuum system for development and testing of single-crystal and alternative electron emitters



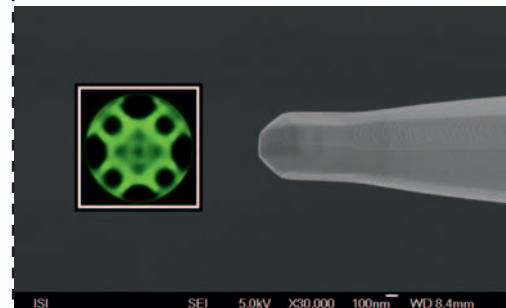
EBPG homogeneity testing pattern



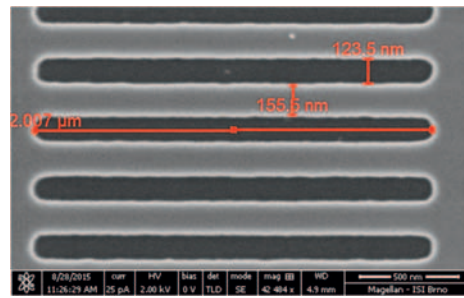
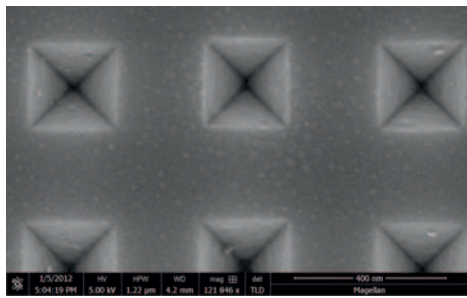
Specimens for Raman spectroscopy — etched silicon with Au nano-islands



Electrochemically etched micro/nano tungsten wire with controllable tip profile for the field emission cathodes and SPM probes applications



Electron emitter tip and its emission pattern (inlay)



Anisotropically etched silicon grating — resolution testing pattern (left)

Grating motif of patterned free-standing nitride membrane (right)

Technology of combined e-beam lithography patterning using writers with variable-shape beam and Gaussian-type beam. Proximity effect correction — reliability of the method for 3D e-beam nanopatterning of diffractive optical elements.

- S. Krátký et al.: “Combined E-Beam Lithography Using Different Energies”, in 42nd Int’l Conf. on Micro and Nano Engineering, 2016
- S. Krátký et al.: “PEC Reliability in 3D E-beam DOE Nanopatterning”, *Microscopy and Microanalysis* **21**, S4, 230–235, 2015

Lithographic and etching technological processes, MEMS preparation, planar nanostructures on silicon nitride membranes

- M. Matějka et al.: “Nanopatterning of Silicon Nitride Membranes”, *NANOCON 2016: 8th Int’l Conf. Proc’s*, 2016
- M. Urbánek et al.: “Plasmochemical Etching of Silicon in Diener Nano Device” (in Czech), *Chemické listy* **108**, 592–595, 2014

Benchmarking patterns allowing visual check of e-beam patterning performance

- P. Meluzín et al.: “Some Other Gratings: Benchmarks for Large-Area E-Beam Nanopatterning”, *NANOCON 2014: 6th Int’l Conf. Proc’s*, 2014
- Vox Populi Award IMC2014
- Raith Micrograph Special Art Award 2014

Planar structures with structural colors, plasmonic structures, optical antireflective structures

- V. Kolařík et al.: “Structural Color of Metallic Surfaces”, *METAL 2014: 23rd International Conference on Metallurgy and Materials*, 2014

Various samples for microscopy (optical, SEM, SPM, confocal): dimension specimens, bi-metal samples, defined height step sample, USAF 1951 sample (ranged from the set 0 down to the set 11)

- V. Kolařík et al.: “Calibration specimens for microscopy”, *NANOCON 2012: 4th Int’l Conf. Proc’s*, 2012

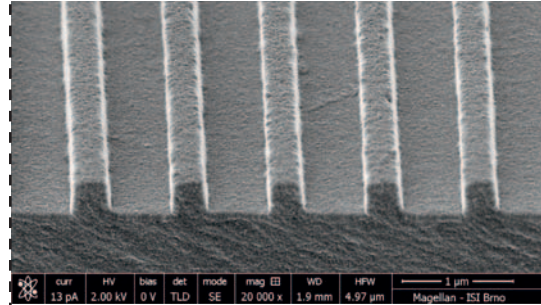
Utility models of diffractive optically variable image devices

A monograph on practical aspects of e-beam lithography techniques and related technologies was released. A miniature of this book (size 1.7 mm x 2.7 mm, 101 600 dpi) was performed with the BS600 system.

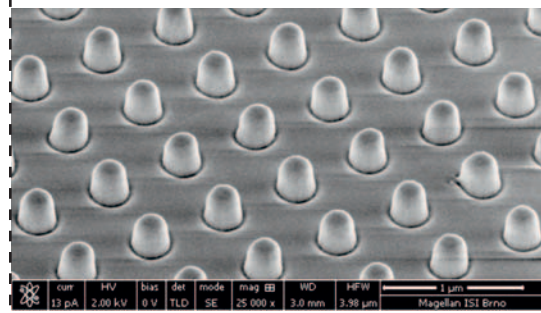
- F. Matějka: “Practical E-Beam Lithography” (in Czech), *ISI CAS*, Brno, 2013, 100 pages

Various highly specialized samples: dozens of dedicated samples were performed with both origination systems, e.g. masks for vortex beam generation, masks for Bragg fiber grating exposures, masks for seismology applications, gold finger micro biosensors, CGH annular frame set, masks for micro fluidic applications, etc.

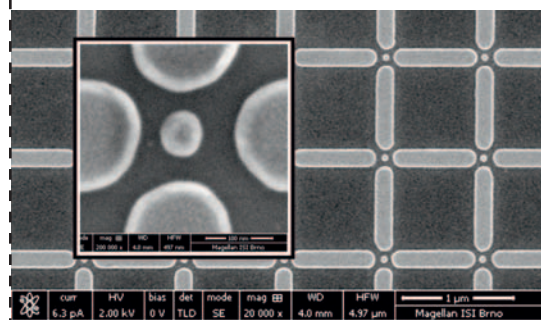
- S. Krátký et al.: “Differential conductometry biosensors prepared by lift-off technique by using of e-beam writer with shaped beam”, *MNE2013: 39th International Conference on Micro and Nano Engineering*, p. 387



Phase photo mask for Bragg fiber grating



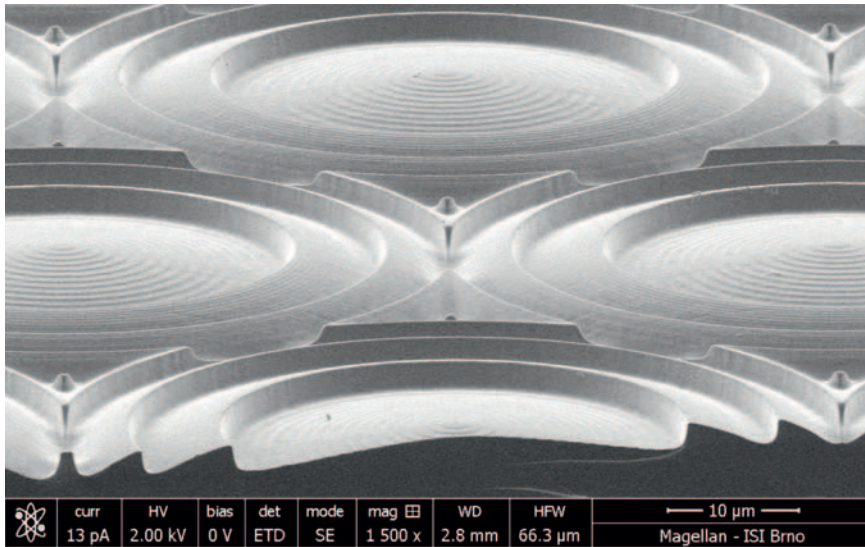
Quartz nano-pillar template for NIL



Ni-Fe nanostructures prepared by lift-off



Multi-axial diffractive zonal lens



Hexagonal array of zonal micro lenses

MAIN COLLABORATING PARTNERS

Collaboration with academic partners

- Brno University of Technology (Brno, CZ)
- CEITEC (Brno, CZ)
- Institut NEEL (Grenoble, FR)
- Institute of Informatics SAV (Bratislava, SK)
- Institute of Thermomechanics CAS (Praha, CZ)
- Jozef Stefan Institute (Ljubljana, SI)
- Masaryk University (Brno, CZ)
- University Olomouc (Olomouc, CZ)
- Slovak University of Technology in Bratislava (Bratislava, SK)
- Tomas Bata University in Zlín, Centre of Polymer Systems (Zlín, CZ)

Collaboration with companies

- Czech Metrology Institute (Brno, CZ)
- Delong Instruments (Brno, CZ)
- FEI Czech Republic / Thermofisher Scientific (Brno, CZ)
- IQ Structures (Řež u Prahy, CZ)
- NETWORK GROUP, s.r.o. (Brno, CZ)
- Optaglio (Lochovice, CZ)
- Optometrics (USA)
- TESCAN Brno, s.r.o. (Brno, CZ)
- Thermofisher Scientific (UK)

EXPECTATIONS

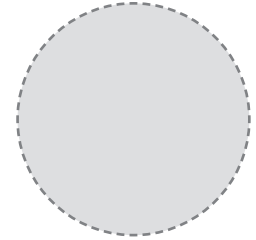
Offers

We offer collaboration in the areas of our expertise. Custom development and manufacturing of particular planar microstructures and nanostructures, e.g. optical focusing / splitting / beam shaping elements, photolithography masks, dimension and material calibration samples for microscopy.

Requirements

We look for cooperation with academic partners as well as application partners in the fields of lithography and complementary techniques, microtechnologies, nanotechnologies, applications of planar nanostructures.

Diffractive optically variable image devices based on deterministic aperiodic mesh of nano-pillars and/or nano-holes



Detail of the optically variable image device from the front page: light-absorbing (a) and light-scattering (b) 100-micron square building blocks

