Group of Electron Beam Lithography (EBL)

Department of Electron and Plasma Technologies

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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

EBPG data testing pattern.

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 cm^2 / 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 cm^2 / hour (at beam step size 50 nm and area filling factor 50 %)

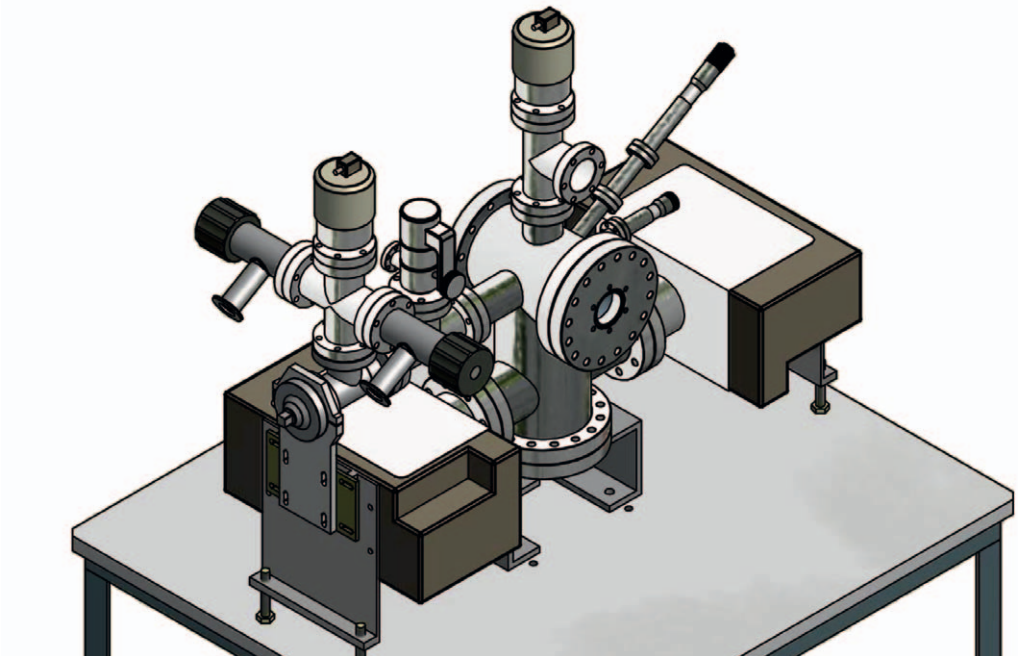
ACHIEVEMENTS

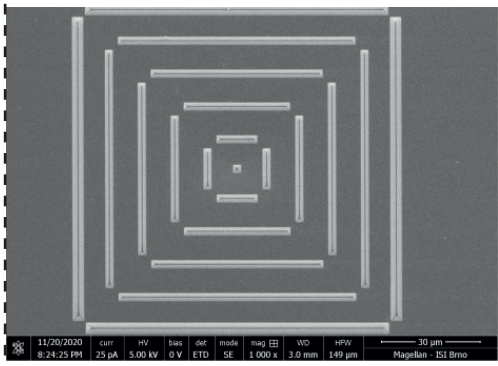
- **We deepened the methodology of e–beam lithography process using both the pattern generators as well as their combination. We also tuned up the technology processes with results useful in numerous application domains. Within the period 2012–2020 we published over 100 contributions in conference proceedings and journals. Within the same period we performed over 1597 e–beam exposure runs.**

- **Sharp tungsten tips are produced using an automated electrochemical etching set–up. Tips can then be used to operate as pure field emitters or to operate in thermal-field/ Schottky mode when they get additionally coated by oxide. Other applications of ultra-sharp tips (tip diameter < 100 nm) include the usage as STM probes or nanomanipulators. The tunneling tip performance can be analyzed using current–voltage characteristics, the Murphy-Good analysis, by emission pattern observation, by measuring fluctuations and the stability of the electron beam. The activation of uncoated tips and testing of the thermal-field emitters (or of Schottky emitters) can be done in situ, within our field emission microscope.**

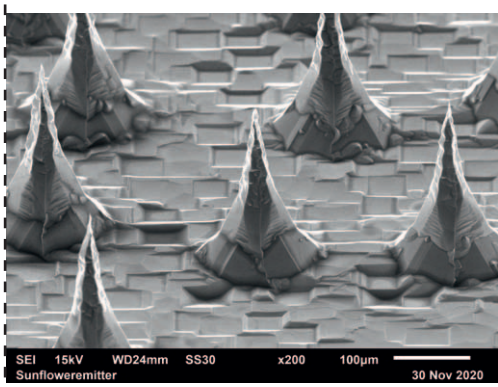
- A. Knápek et al.: *"Programmable set-up for electrochemical preparation of STM tips and ultra-sharp fi eld emission cathodes"*, Microelectronic Engineering, 2017, 173: 42–47
- A. Knápek et al.: *"Polymer graphite pencil lead as a cheap alternative for classic conductive SPM probes."* Nanomaterials, 2019, 9.12: 1756.
- A. Knápek et al.: *"Fluctuations of focused electron beam in a conventional SEM."* Ultramicroscopy, 2019, 204: 49–54.

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

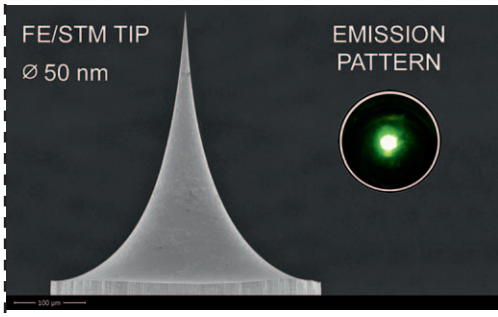




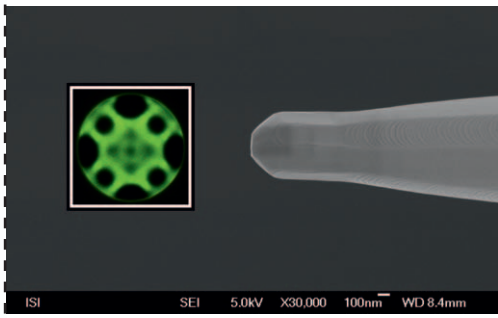
µSCALE calibration sample for SEM.



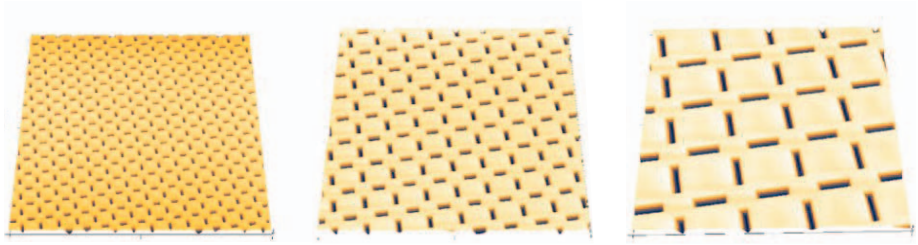
Non-orthogonally oriented field emission array made by direct laser nanostructuring in collaboration with OTH Regensburg.



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



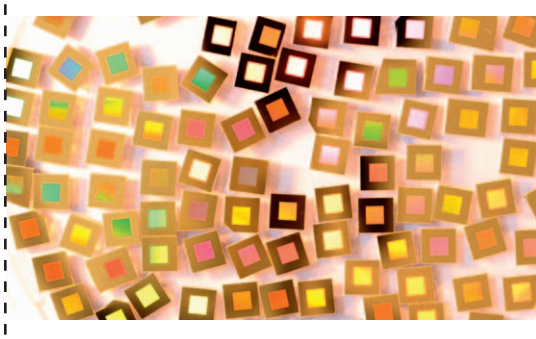
ZrO coated <100> oriented tip in thermal-field emission mode.



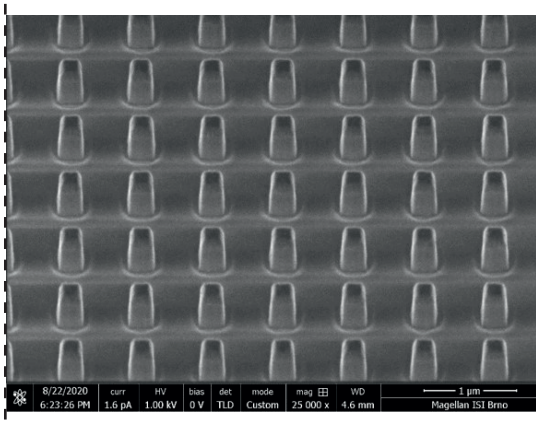
μSCALE calibration sample for SEM. Grid image with a line period of 3 μm (left), 5 μm (middle), 10 μm (right). AFM images.

Recent publications

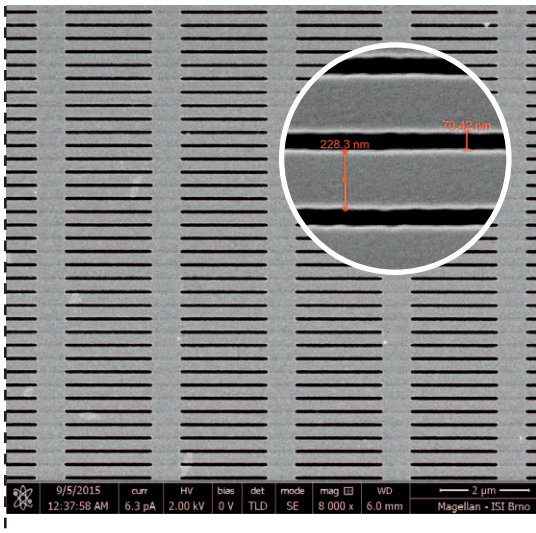
- M. Horáček, V. Kolařík: *"Optically Variable Image Devices and method of preparing the same"*. Patent specification 306 956., 2017
- M. Matějka, S. Krátký, T. Řiháček, A. Knápek, V. Kolařík: *"Functional nano-structuring of thin silicon nitride membranes"*. Journal of Electrical Engineering 2020, 71(2)
- M. Saqib, J. Jelenc, L. Pirker, S. D. Škapin, L. De Pietro, U. Ramsperger, A. Knápek, I. Müllerová, M. Remškar: *"Field emission properties of single crystalline W5O14 and W18O49 nanowires"*. Journal of Electron Spectroscopy and Related Phenomena. 2020, 241(MAY)
- A. Knápek, J. Šikula, M. Bartlová: *"Fluctuations of focused electron beam in a conventional SEM"*. Ultramicroscopy. 2019, 204(SEP)
- Z. Pilát, M. Kizovský, J. Ježek, S. Krátký, J. Sobota, M. Šiler, O. Samek, T. Buryška, P. Vaňáček, J. Damborský, Z. Prokop, P. Zemánek: *"Detection of chloroalkanes by surface-enhanced raman spectroscopy in microfluidic chips"*. Sensors. 2018, 18(10)
- D. Sobola, S. Ramazanov, M. Konečný, F. Orudzhev, P. Kaspar, N. Papež, A. Knápek, M. Potoček: *"Complementary SEMAFM of Swelling Bi-Fe-O Film on HOPG Substrate."* Materials. 2020, 10(13)
- K. J. Abrams, M. Dapor, N. Stehling, M. Azzolini, S. J. Kyle, J. S. Schäfer, A. Quade, F. Mika, S. Krátký, Z. Pokorná, I. Konvalina, D. Mehta, K. Black, C. Rodenburg: *"Making Sense of Complex Carbon and Metal/Carbon Systems by Secondary Electron Hyperspectral Imaging."* Advanced Science. 2019, 6(19)
- A. Al Soud, A. Knápek, M. S. Mousa: *"Analysis of the Various Effects of Coating W Tips with Dielectric Epoxylite 478 Resin or UPR-4 Resin Coatings under Similar Operational Conditions."* Jordan Journal of Physics. 2020, 13(3)
- S. Krátký, V. Kolařík, M. Horáček, P. Meluzín, S. Král: *"Combined e-beam lithography using different energies."* Microelectronic Engineering. 2017, 177(JUN)
- A. Knápek, D. Sobola, D. Burda, A. Daňhel, M. Mousa, V. Kolařík: *"Polymer Graphite Pencil Lead as a Cheap Alternative for Classic Conductive SPM Probes."* Nanomaterials. 2019, 9(12)
- S. Ramazanov, D. Sobola, F. Orudzhev, A. Knápek, J. Polčák, M. Potoček, P. Kašpar, R. Dallaev: *"Surface Modification and Enhancement of Ferromagnetism in BiFeO3 Nanofilms Deposited on HOPG."* Nanomaterials. 2020, 10(10)
- P. Kaspar, D. Sobola, K. Částková, A. Knápek, D. Burda, F. Orudzhev, R. Dallaev, P. Tofel, T. Trčka, L. Grmela, Z. Hadaš: *"Characterization of Polyvinylidene Fluoride (PVDF)Electrospun Fibers Doped by Carbon Flakes."* Polymers. 2020, 12(NOV)
- A. Knápek, R. Dallaev, D. Burda, D. Sobola, M. M. Allaham, M. Horáček, P. Kaspar, M. Matějka, M. S. Mousa: *"Field Emission Properties of Polymer Graphite Tips Prepared by Membrane Electrochemical Etching."* Nanomaterials. 2020, 10(7)



Specimens for Raman spectroscopy — etched silicon with Au nano–islands.

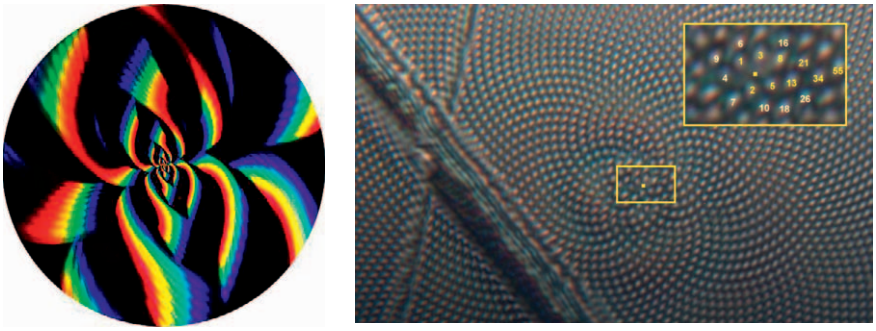


Pillar light guide structures etched in a thin layer of SiO2 on a YAG:Ce substrate.



SEM image of the final holey grating structure fabricated in the thin silicon nitride membrane. Size of the rectangle shape opening in the membrane is 70 × 2000 nm.

Example of a security hologram pattern in the layer of PMMA resist (left) and acrylic glass (right) specimens.



Diffractive Optical Variable Image Device (DOVID) using phyllotaxy arrangement. Real photo (left), light microscope image (right).

MAIN COLLABORATING PARTNERS

Collaboration with academic partners

- Brno University of Technology (Brno, CZ)
- CEITEC (Brno, CZ)
- Czech Technical University in Prague (CZ)
- Institut NEEL (Grenoble, FR)
- Institute of Informatics SAV (Bratislava, SK)
- Institute of Thermomechanics CAS (Praha, CZ)
- Karlsruher Institut für Technologie (Karlsruhe, DE)
- Masaryk University (Brno, CZ)
- Mu'tah University (Al-Karak, JO)
- Ostbayerische Technische Hochschule (Regensburg, DE)
- Tomas Bata University in Zlín, Centre of Polymer Systems (Zlín, CZ)
- University Olomouc (Olomouc, CZ)

Collaboration with companies

- Crytur, s.r.o. (Turnov, CZ)
- Czech Metrology Institute (Brno, CZ)
- Delong Instruments (Brno, CZ)
- IQS Group holding (Řež u Prahy, CZ)
- Meopta - optika, s. r. o. (Přerov, CZ)
- Nenovision, s.r.o. (Brno, CZ)
- NETWORK Group, s.r.o. (Brno, CZ)
- TESCAN Brno, s.r.o. (Brno, CZ)
- Thermofisher Scientific (Brno, CZ)

EXPECTATIONS

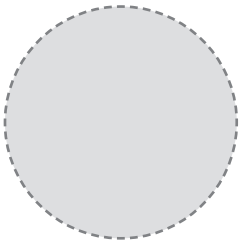
Offers

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.

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



Complex diffractive structure: CGH structures, diffraction gratings and phyllotactic spiral gratings.