CPP 92: Focus: High-resolution Lithography and 3D Patterning II (joint session KFM/HL/CPP)

Chair: Robert Kirchner (TU Dresden)

Time: Thursday 9:30–12:20 Location: TOE 317

CPP 92.1 Thu 9:30 TOE 317

Curvilinear Magnetism: Fabrication and characterization — •Denys Makarov — Helmholtz-Zentrum Dresden-Rossendorf e.V., Institute of Ion Beam Physics and Materials Research, 01328 Dresden, Germany

Extending 2D structures into 3D space has become a general trend in multiple disciplines including electronics, photonics, and magnetics. This approach provides means to enrich conventional or to launch novel functionalities by tailoring curvature and 3D shape. We realize 3D curved magnetic thin films where new fundamental effects emerge from the interplay of the geometry of an object and topology of a magnetic sub-system [1]. The application potential of 3D magnetic architectures is explored for the realization of mechanically shapeable magnetoelectronics [2] for virtual and augmented reality appliances [3,4]. To advance in this research field, we develop novel theoretical methods [5-7], fabrication [1,8,9] and characterization techniques [8-11]. These topics will be addressed in the presentation.

[1] R. Streubel et al., J. Phys. D: Appl. Phys. 49, 363001 (2016). [2] D. Makarov et al., Appl. Phys. Rev. 3, 011101 (2016). [3] S. Cañón et al., Nature Electronics 1, 589 (2018) & Science Adv. 4, eaao2623 (2018). [4] J. Ge et al., Nature Comm. 10, 4405 (2019). [5] O. Volkov et al., PRL 123, 077201 (2019). [6] O. Volkov et al., Sci. Rep. 8, 866 (2018). [7] V. P. Kravchuk et al., PRL 120, 067201 (2018). [8] K. S. Das et al., Nano Let. 19, 6839 (2019). [9] M. Nord et al., Small 1904738 (2019). [10] R. Streubel et al., Nature Comm. 6, 7612 (2015). [11] T. Kosub et al., Nature Comm. 8, 13985 (2017).

CPP 92.2 Thu 9:50 TOE 317

3D printing of complex submillimeter-sized wide angle objectives — •Zhen Wang[1], Ksenia Weber[1], Simon Thiele[2], Alois Herkommer[2], and Harald Giessen[1] — [1]4th Physics Institute and Research Center SCoPE, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Institute of Technical Optics and Research Center SCoPE, University of Stuttgart, Pfaffenwaldring 9, 70569 Stuttgart, Germany

Compact image sensors with a variety of focal lengths, fields of view, and other optical parameters, will be the enabling technology of integrated devices for industry 4.0. In order to miniaturize the imaging devices from currently several mm^3 to below 1 mm^3, and to achieve diameters of the optics below 1 mm, 3D printing with femtosecond laser pulses is the method of choice. Here, we present several multi-lens designs as well as printed objectives with fields of view that range from 60° to 95°, and focal lengths in the range of 200-300 μm, with diameters around 800 μm, which allow for wide-angle imaging. We characterize their performances and report how to overcome some issues when printing such challenging designs. In the future, those objectives can be directly printed onto CMOS imaging chips which will enable very compact image sensors.

CPP 92.3 Thu 10:10 TOE 317

Additive technology for X-ray optical applications — •Adam Kubec, Frieder Koch, and Christian David — Paul Scherrer Institut

X-ray optics are used in many setups connected to materials analysis. Due to very different properties of X-rays as compared to visible light different challenges, have to be tackled in order to manufacture optics. The refractive index has only a small difference to unity. This results in a relatively small optical power. This makes it challenging to manufacture refractive lenses. A successful concentration of X-ray using refractive lenses could only been shown in 1996 using a set of individual refractive lenses.

Today refractive lenses for X-rays are commercially available and are widely used in many synchrotron radiation sources. However, it is still challenging to manufacture aberration free lenses for X-rays. Therefore, custom-made radially symmetric corrector phase plates are used to reduce the aberrations. Spiral phase plates can generate X-ray beams carrying orbital angular momentum of various topological charges.

Additive technology can now also used in order to manufacture refractive lenses directly. Due to the versatility of 3D printed geometries, it is possible to manufacture lenses adapted specifically to improve measuring techniques, such as Ptychography.

We will also see further applications of 3D printing for X-ray applications such as 3D resolution pattern (Siemens Star). These can be can be used to quantify the quality of X-ray tomography setups.

CPP 92.4 Thu 10:30 TOE 317

Mass-producible microoptical elements by injection compression molding and focused ion beam structured titanium molding tools — •Simon Ristok[1], Marcel Röder[2], Simon Thiele[3], Mario Hentschel[1], Thomas Günther[2], André Zimmermann[2], Alois Herkommer[3], and Harald Giessen[1] — [1]4th Physics Institute and Research Center SCoPE, University of Stuttgart, Germany — [2]Hahn-Schickard, Stuttgart, Germany — [3]Institute of Applied Optics and Research Center SCoPE, University of Stuttgart, Germany

Injection molded polymer is the material of choice for micro-optics used in mass producible devices such as smartphones or optical sensors. For feature sizes on the micrometer scale the molding tools are usually fabricated by nickel electroplating on a silicon master, which was previously structured by electron beam lithography and subsequent etching. In total, two inversion steps are necessary to transfer the structure from the silicon master to a plastic polymer part. Here, we introduce an alternative method that requires only a single inversion step. An extremely robust titanium molding tool is directly structured with high precision by focused ion beam milling. We demonstrate the fabrication of Fresnel lenses with 100 μm diameter and a maximum structure height of 1 μm. The inverse Fresnel lens structured into the titanium is transferred to polymer by injection compression molding, enabling rapid mass replication. We show that the optical performance of the molded Fresnel lenses is in good agreement with simulations, rendering our approach suitable for applications which require compact and high quality optical elements in large numbers.

20 min. break

Invited Talk CPP 92.5 Thu 11:10 TOE 317

3D Printing with Electrons - Advances and Opportunities — •Harald Plank — Institute of Electron Microscopy, Graz University of Technology, Graz, Austria

Since the advent of additive manufacturing, this technology class made tremendous progress. While achievable feature sizes continuously decreased from cm's over mm's towards the sub-micron range their 3D possibilities became increasingly powerful. Naturally, there is a strong interest to push 3D printing into the nano-scale, to take advantage of nanoscale effects. Within the small pool of relevant technologies at that scale, Focused Electron Beam Induced Deposition (FEBID) is a highly promising candidate, as it allows additive, direct-write manufacturing of even complex 3D architectures with feature sizes down to 20 nm on most materials and practically any given surface morphology. Together with an increasing availability of precursors with different functionalities, 3D-FEBID has advanced from a trial-and-error laboratory method to a predictable 3D nano-printing technology. In this talk, the audience is first introduced to the basic principles of 3D-FEBID, complemented by recent advances, which strongly increased precision, predictability and reliability. We then present software solutions for the comfortable upfront design of 3D objects and review several application examples, which strongly benefit from the here presented 3D nanofabrication appraoch. To highlight the industrial relevance of 3D-FEBID, we present concepts of advanced nano-probes for application in scanning probe microscopy. We close the talk with a view on current activities, remaining challenges and future opportunities.

CPP 92.6 Thu 11:40 TOE 317

Perfluorinated amidinate compounds for focused electron beam induced deposition (FEBID) — •Katarzyna Madajska and Iwona Szymańska — Faculty of Chemistry, Nicolaus Copernicus University in Toruń, Gagarina 7, 87-100 Toruń, Poland

FEBID is a direct maskless nanolithography technique, based on the local dissociation of adsorbates upon the irradiation with electrons.[1][2] Silver pentafluoropropionate was applied in the FEBID process yielding 2D and 3D deposits containing up to 70 at. % Ag. [3][4]

Here we report on our study of silver and copper complexes with perfluorinated amidines (CnF2n+1C(=NH)NH2), which are similar in structure to carboxylates but they differ in donor atoms (N,N-donor).

Thermal analysis, EI MS spectrometry, sublimation experiments and temperature variable infrared spectra analysis were carried out to determine the volatility of compounds and their thermal decomposition mechanism. The compounds selected, as based on the results of the volatility, were examined for their sensitivity to the electron beam, using an electron microscope (SEM, TEM).

[1] Utke and A. Gölzhäuser, Angewandte Chemie Int. Ed. 49 (2010) 9328-9330. [2] D. Belić, M. M. Shawrav, E. Bertagnolli, H. D. Wanzenboeck, Beilnstein J. Nanotechnol, 2017, 8, 2530-2543. [3] L. Berger, K. Madajska, I. B. Szymanska, K. Höflich, M. N. Polyakov, J. Jurczyk, C. Guerra-Nuñez, I. Utke, Beilstein J. Nanotechnol., 2018, 9, 224-232. [4] K. Höflich, J. M. Jurczyk, K. Madajska, M. Götz, L. Berger, C. Guerra-Nuñez, C. Haverkamp, I. Szymanska, I Utke, Beilstein J. Nanotechnol., 2018, 9, 842-849.

CPP 92.7 Thu 12:00 TOE 317

Synthetic strategies towards FEBID precursors — •Iwona Szymańska and Katarzyna Madajska — Faculty of Chemistry, Nicolaus Copernicus University in Toruń, Gagarina 7, 87-100 Toruń, Poland

The choice of the precursor is crucial for the success of focus electron beam induced deposition (FEBID) because its physicochemical features determine the composition of the deposit.[1] The applied compounds should effectively generate volatile metal carriers, which can be transport over a surface substrate. In the next stage adsorbed molecules should clearly decompose upon electron beam irradiation forming nanostructures. Additionally, the FEBID precursors should be air stable, easy handling, low cost, and safe. Research was focused on the coordination compounds of copper(II) and copper(I), silver(I) and rhenium(III) with N- and O-donor ligands, which seems to be promising for a FEBID process. The influence of structural features such as: 1) the kind of the central atom and its oxidation state; 2) the coordination sphere composition, 3) the modifications of the ligand substituents by fluorination or branching, were observed. [2,3]

Acknowledgements: Nicolaus Copernicus University in Toruń (Statute Research no.103) for the financial support.

References [1] I. Utke et al., J. Vac. Sci. Technol. B, 2008, 26, 1197. [2] L. Berger et al., Beilstein J. Nanotechnol., 2018, 9, 842. [3] K. Höflich et al., Beilstein J. Nanotechnol., 2018, 9, 842.