TUT 4: Nanofabrication and 3D Printing with Submicron Resolution (joint session CPP/TUT)

3D printing or additive manufacturing witnessed one of the most revolutionizing progresses in the last decade. Traditionally used for macro-scale prototyping, 3D printing currently finds applications in large-scale industrial manufacturing, medical technology, education and scientific research. More astonishingly, the resolution of lithography-free 3D printing technologies has reached to microns, pushing the borders of nanoscale and pioneering the miniaturisation of diverse tools to smallest-ever dimensions. This tutorial will present an overview on submicron 3D printing technologies and nanofabrication tools, their novel applications, and recent scientific progress in the area. Organised by: Regine v. Klitzing (TU Darmstadt) and Cagri Üzüm (Grace GmbH, Worms).

Time: Sunday 16:00–18:15 Location: HSZ 304

Tutorial TUT 4.1 Sun 16:00 HSZ 304

3D laser nanoprinting — •Martin Wegener — Institute of Applied Physics and Institute of Nanotechnology, Karlsruhe Institute of Technology, 76128 Karlsruhe, Germany

This tutorial follows a recently published review and perspectives article on 3D laser nanoprinting (V. Hahn et al., Opt. Photon. News 30(10), 28-35 (2019)).

I will review the underlying physical principles, describe the state-of-the art in the context of many other alternative 3D additive manufacturing approaches, and emphasize two challenges: (i) Substantially faster and scalable 3D printing with sub-micrometer voxel sizes, and (ii) multi-material 3D nanoprinting.

(i) I will present (unpublished) results on rapid multi-focus 3D laser nanoprinting leading to printing rates around 10^7 voxels/s at sub-micrometer voxels sizes. For example, this has led to 3D mechanical metamaterials with more than 100 thousand unit cells and more than 300 billion voxels total. Furthermore, I will sketch our ideas to go well beyond this by introducing light-sheet 3D laser nanoprinting.

(ii) I will discuss three different approaches towards multi-material architectures: (a) integrated microfluidic chamber, (b) stimuli-assisted 3D laser nanoprinting, and (c) meta-inks.

This work has been supported by the Excellence Cluster "3D Matter Made to Order".

Tutorial TUT 4.2 Sun 16:45 HSZ 304

3D printed microoptics: State of the art and future challenges — •Harald Giessen — 4. Physikalisches Institut, Universität Stuttgart

3D printing using femtosecond lasers gives submicron resolution when polymerizing plastics by two-photon absorption. The small voxel size well below the diffraction limit and the combination with high-speed scanners and high-precision piezo stages allows for the creation of millimeter-sized 3D optics with unprecedented design freedom. We will demonstrate that such complex optics with aspherical and freeform surfaces without rotational symmetry can lead to novel miniature optics with wavefront aberrations as small as lambda/10. Multiple materials can be combined with different refractive indices and dispersions, thus allowing for Fraunhofer-type achromats. Diffractive optics can be 3D printed as well, and stacking several Fresnel-type surfaces leads to aplanatic imaging systems. Hybrids that combine diffractive and refractive surfaces as well as transparent and opaque materials enhance the imaging capabilities even further. When combined with imaging fibers or CMOS imaging sensors, an entire new class of miniature optical devices can be created which will revolutionize augmented and virtual reality as well as self-driving cars. Fiber-based optical trapping, side-looking OCT endoscopes, the smallest imaging endoscope in the world, as well as applications in quantum technology pave the way towards future functionalities and applications [1-2].

[1] T. Gissibl et al., Nature Communications 7, 11763 (2016). [2] T. Gissibl et al., Nature Photonics 10, 554 (2016).

Tutorial TUT 4.3 Sun 17:30 HSZ 304

Nanofabrication and 3D printing with submicron resolution — •Michael Huth — Goethe University, Frankfurt am Main, Germany

Focused electron beam induced deposition (FEBID) is a direct-write method for the fabrication of nanostructures whose lateral resolution rivals that of advanced electron beam lithography but is in addition capable of creating complex three-dimensional (3D) nano-architectures. Over the last decade several new developments in FEBID and focused electron beam induced processing (FEBIP) in general have led to a growing number of scientific contributions in solid state physics and materials science based on FEBID-specific materials and particular shapes and arrangements of the employed nanostructures. In this tutorial talk I will give an introduction to the most relevant aspects of FEBID with a particular focus on the creation of 3D functional structures. I will discuss simulation-assisted approaches to FEBID based on effective models for the reliable growth of complex 3D shapes and will briefly allude to microscopic modeling attempts that aim to go beyond growth rate and shape prediction. During the talk I will show different examples of 3D FEBID materials used in nano-magnetism, superconductivity, single-electronics and scanning probe microscopy.