SCATTERING-TYPE SCANNING NEAR-FIELD OPTICAL MICROSCOPY (S-SNOM) AS A VERSATILE TOOL FOR OPTICAL IMAGING AND SPECTROSCOPY WITH NANOSCALE SPATIAL RESOLUTION

Aina Reich

neaspec GmbH, 85540 Haar, Germany

EMail: aina.reich@neaspec.com

Near-field methods are a means of optical investigation without the spatial resolution limitations that are conventionally determined by the diffraction limit of light[1] which is a tremendous benefit for the investigations of nanostructures with radiation in the IR to THz region. This talk will show how we implemented the method in our neaSNOM microscope and give an overview of applications that were realized in different fields. We implement nearfield imaging as an s-SNOM with broadband reflective optics that admit illumination light from the visible to THz. Our interferometric detection method allows us to detect both optical amplitude and phase at the same time and efficiently suppress background[2]. Applications range from the monochromatic chemical mapping of fillers distributions in polymer composites[3] to the imaging of polariton modes[4]. Broadband sources can be employed for nano-FTIR spectroscopy, combining the chemical identification of soft matter nanoscale structures – e.g. the compositions of a human hair or polymer blends[6] – with a spatial resolution <20 nm. Other applications include the characterization of charge carrier densities in semiconductor devices[7]. In addition, the beam-path design easily allows for the implementation of pump–probe experiments and THz–TDS and studies have been performed on sub-picosecond dynamics of charge-carriers in single nanowires.[8] Another important field of research with s-SNOM is the investigation of graphene plasmon polariton, which can be made visible though near-field IR imaging[9,10]

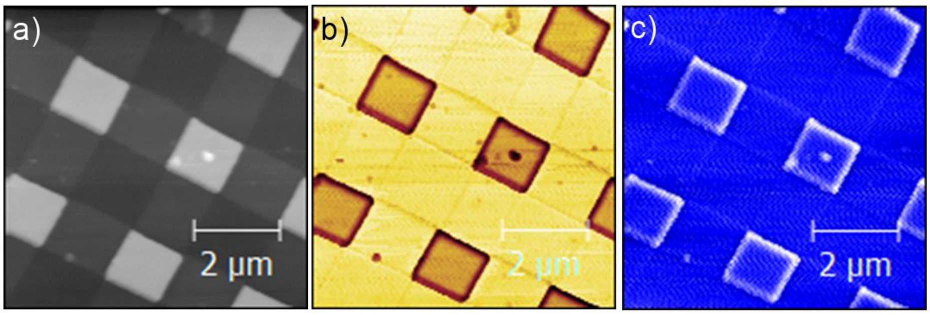

Fig. 1: a) AFM topography and b) near-field amplitude and c) phase measured at 8.5 K sample temperature. The images demonstrate the high stability of the setup.

Finally, this talk will introduce our latest breakthrough in the field of near-field optics: cryogenic near-field optical microscopy using our closed-cycle-cooled cryo-neaSNOM. With this new approach it is possible to investigate materials at temperatures <10 K which opens up exciting new opportunities to study low-energy surface processes (fig.1[11]).

1. F. Keilmann, R. Hillenbrand, "Near-field microscopy by elastic light scattering from a tip" *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 362, pp. 787–805, 2004
2. N.Ocelic, A. Huber and R. Hillenbrand, "Pseudoheterodyne detection for background-free near-field spectroscopy" *Applied Physics Letters* **89**, pp.27–29, 2006
3. M- Etxeberria-Benavides, O. David, T. Johnson et al., "High performance mixed matrix membranes (MMMs) composed of ZIF-94 filler and 6FDA-DAM polymer" *Journal of Membrane Science* **550,** pp. 198–207, 2018
4. F. Hu, Y. Luan, M. Scott et al. "Imaging exciton-polariton transport in $MoSe_2$ waveguides" *Nature Photonics* **11**, pp. 356–360, 2017
6. I. Amenabar, S. Poly, M. Goikoetxea et al., "Hyperspectral infrared nanoimaging of organic samples based on Fourier transform infrared nanospectroscopy" *Nature Communications* **8**, pp. 14402, 2017
7. A. J. Huber, F. Keilmann, J. Wittborn et al. "Terahertz Near-Field Nanoscopy of Mobile Carriers in Single Semiconductor Nanodevices" *Nano Letters* **8**, pp. 3766–3770, 2008
8. M. Eisele, T. Cocker, M. Huber et al. "Ultrafast multi-terahertz nano-spectroscopy with sub-cycle temporal resolution" *Nature Photonics* **8**, pp.841–845, 2014
9. J. Chen, M. Badioli, P. Alonso-González et al. "Optical nano-imaging of gate-tunable graphene plasmons" *Nature* **487**, pp. 77-81, 2012
10. Z. Fei, A. S. Rodin, G. O. Andreev et al. "Gate-tuning of graphene plasmons revealed by infrared nanoimaging" *Nature* **486**, pp. 82-85, 2012
11. *www.neaspec.com*