

O 42: Plasmonics and Nanooptics III: Infrared Microscopy

Time: Tuesday 14:00–16:00

Location: H4

O 42.1 Tue 14:00 H4

Determination of local variations in charge carrier concentrations of doped nanowires using infrared near-field microscopy — ●LENA JUNG¹, ROBERT UKROPEC^{1,2}, FABIAN HAAS², HILDE HARDTDEGEN², THOMAS SCHÄPERS², and THOMAS TAUBNER¹ — ¹I. Institute of Physics (IA), RWTH Aachen University, 52056 Aachen, Germany — ²Peter Grünberg Institut 9, Forschungszentrum Jülich, 52425 Jülich, Germany

In scattering-type scanning near-field optical microscopy (s-SNOM), optical near-fields are generated at the apex of a sharp illuminated tip. The near-fields interact with the part of the sample in close proximity to the tip, therefore the back-scattered light contains information about the optical properties of the sample with a resolution only limited by the sharpness of the tip. We use this high resolution for the investigation of local variations in the charge carrier density of doped semiconductor nanowires (NW). Since the SNOM signals are related to the dielectric function of the sample material, which in turn can be connected to charge carrier density and mobility for doped semiconductors by applying the Drude model, it is possible to determine these important quantities from the spectroscopic SNOM signals. Measurements on partly doped Si-NW will be presented as well as on contacted InAs-NW. With a sample holder that allows contacting the sample, which was specifically designed for this sample system, we were able to perform SNOM measurements of these NW by at the same time applying a source-drain voltage and a backgate to the nanowires. This allows for the investigation of the direct influence of gating on the NW.

O 42.2 Tue 14:15 H4

Experimental investigation of the depth-dependent near-field coupling in subsurface s-SNOM imaging. — ●MIKE PRÄMASSING, MARTIN LEWIN, and THOMAS TAUBNER — Institute of Physics (IA) RWTH Aachen

Scattering-type Scanning Near-field Optical Microscopy (s-SNOM) is based on a laser-illuminated metal-coated tip being scanned over the sample. Due to the localized tip sample interaction, the optical properties of the sample can be analysed on the nm-scale. Since the tip probes high spatial frequencies, s-SNOM is capable of imaging buried structures via evanescent waves [1]. We could distinguish between amorphous and crystalline regions of AgInSbTe even below 100 nm of capping layer [2]. The found complex material contrasts can be explained by theoretical calculations taking into account the layered structure of the sample [3]. At the sample surface, the tip predominantly probes spatial frequencies in the range of the inverse tip radius. Here we investigate the tip-sample-coupling for different burying depth and spatial frequencies. High quality gold gratings are employed to produce well defined spatial frequencies. The Depth dependence of the coupling of the tip to these spatial frequencies is investigated by measuring the gratings buried below PMMA layers of varying thickness.

[1] Taubner et al., Opt. Express 13, 8893 (2005)

[2] Lewin et al., Appl. Phys. Lett., 107, 151902 (2015)

[3] Hauer et al., Opt Expr. 20, 13173 (2012)

O 42.3 Tue 14:30 H4

Amplitude-modulated scattering cross-section in near-field infrared microscopy (s-SNIM) — ●FREDERIK KUSCHEWSKI¹, S.C. KEHR¹, N. AWARI², B. GREEN², S. KOVALEV², M. GENSCH², and L.M. ENG¹ — ¹Institut für Angewandte Photophysik, TU Dresden, 01062 Dresden, Germany — ²Helmholtz-Zentrum Dresden-Rossendorf, Institut für Strahlenphysik, 01314 Dresden, Germany

Scattering-type scanning near-field optical microscopy (s-SNIM) was applied to investigate the local infrared-optical properties of Ge, Si and SiGe thin films in a pump-probe experiment below the diffraction limit. The combination of s-SNIM with pump-probe techniques allows for studying electron-excitation processes at an ultimate temporal resolution, and for investigating their decay behavior.

Pump excitation is exhibited in our setup with different NIR laser systems, while near-field probing was carried out either by using a cw CO₂ or the tuneable free-electron-laser at the Helmholtz-Zentrum Dresden-Rossendorf. The periodic optical excitation of the sample induces sidebands to the higher-harmonics in our s-SNIM setup, that contain

the pure pump-induced information [1]. Using a special demodulation technique, the existence of these new frequencies was proven up to the 10th sideband. The investigated samples show a time-variable pump-effect in the near-field when being probed at $\sim 10 \mu\text{m}$ wavelength. Image scans clearly proof the resolution far beyond the diffraction limit. Our experiment proves that ultra-fast phenomena may elegantly be probed in the near field with a superb sub-diffraction resolution.

[1] F. Kuschewski. et al., *Scientific Reports* 5, 12582 (2015).

O 42.4 Tue 14:45 H4

Exploring local-scale phase transitions by low-temperature scattering scanning near-field optical microscopy — ●JONATHAN DÖRING, SUSANNE C. KEHR, and LUKAS M. ENG — IAPP, Technische Universität Dresden

Using a low-temperature ($T \geq 4 \text{ K}$) scattering scanning near-field optical microscope (LT-s-SNOM) in conjunction with infrared photon excitation from a tunable free-electron laser (FEL) source, we are able to explore phase transitions in various systems down to the 1-nm length scale.

In LT-s-SNOM, the light scattered off an atomic force microscopy tip is strongly dependent on the tip-sample near-field interaction. Hence, recording this local light scattering enables imaging of optical properties with a resolution several orders of magnitude below the diffraction limit. The FEL laser light source provides high power densities and is precisely spectrally tunable from 4 to 250 μm . The unique combination of LT-s-SNOM and FEL thus allows for investigating a manifold of phonon-resonant phase transitions between 4 - 300 K by both nano-imaging and nano-spectroscopy. We report here on such studies for different systems; ferroelectric barium titanate [1] and doped lanthanum manganites [2]. Our LT near-field studies are backed-up by complementary piezo-response force microscopy (PFM) and Kelvin probe force microscopy (KPFM) performed in-situ with one and the same AFM.

[1] J. Döring et al., Appl. Phys. Lett. 105, 053109 (2014).

[2] E. Beyreuther et al., Phys. Rev. B 80, 075106 (2009).

O 42.5 Tue 15:00 H4

Characterization of Thin Organic Layers using Synchrotron-based nano-FTIR Spectroscopy with adapted Storage Ring Optics — ●PETER HERMANN¹, ARNE HOEHL¹, BERND KÄSTNER¹, C. MAGNUS JOHNSON², PIOTR PATOKA³, GEORG ULRICH³, JÖRG FEIKES⁴, MARKUS RIES⁴, TOBIAS GÖTSCH⁴, BURKHARD BECKHOFF¹, ECKART RÜHL³, and GERHARD ULM¹ — ¹Physikalisch-Technische Bundesanstalt (PTB), 10587 Berlin, Germany — ²School of Chemical Science and Engineering, KTH, SE-100 44 Stockholm, Sweden — ³Physikalische und Theoretische Chemie, Institut für Chemie und Biochemie, Freie Universität Berlin, 14195 Berlin, Germany — ⁴Helmholtz-Zentrum Berlin (HZB), 12489 Berlin, Germany

Near-field techniques such as infrared scanning near-field optical microscopy (SNOM) and nano-FTIR spectroscopy enable imaging and spectroscopic characterization of samples at the nanoscale. However, the spectroscopic characterization of thin organic films and monolayers requires additionally highly stable radiation sources with a broad emission spectrum in the mid-IR range, e.g. thermal and synchrotron based sources. In order to exploit the full potential of this approach, we report on the adaption of storage ring optics at the Metrology Light Source (MLS). This results in a significantly reduced size of the electron bunches. In combination with appropriate spectral filters the sensitivity of synchrotron-based near-field spectroscopy can be increased even further, thus enabling also the spectroscopic characterization of organic samples. This is demonstrated by performing nano-FTIR spectroscopy and nano-imaging on biological model systems.

O 42.6 Tue 15:15 H4

Surface-enhanced infrared chemical imaging — ●FRANK NEUBRECH¹, LUCCA KÜHNER¹, MARIO HENTSCHEL¹, UTE ZSCHIESCHANG², HAGEN KLAUK², and HARALD GIESSEN¹ — ¹Physics Institute and Research Center SCoPE, University Stuttgart, Stuttgart — ²Max Planck Institute for Solid State Research, Stuttgart

Infrared (IR) chemical imaging provides laterally resolved spectroscopic information of molecular species based on their material-specific vibrational bands. Nowadays, this powerful method is applied in

medicine and pharmacy to identify different drugs or to differentiate between healthy and diseased tissues. However, the method suffers from the relatively low excitation cross-sections of the IR vibrations. To overcome this limitation, we combine surface-enhanced infrared spectroscopy (SEIRA), which enables the detection of minute amounts of molecules down to attomolar concentrations, and chemical imaging to map heterogeneous molecular layers of nanometer thickness. More specifically, we evaporated 30 nm thick areas of pentacene as well as C_{60} using shadow mask lithography on highly homogeneous nanoantenna arrays fabricated by electron beam lithography. The acquired chemical maps demonstrate a significantly improved detection limit in comparison to conventional chemical imaging.

O 42.7 Tue 15:30 H4

Terahertz spectroscopy of individual donors in silicon by low temperature s-SNOM — •DENNY LANG¹, STEPHAN WINNERL¹, HARALD SCHNEIDER¹, JUERONG LI², STEVE CLOWES², BEN MURDIN², JONATHAN DÖRING³, SUSANNE C. KEHR³, LUKAS M. ENG³, and MANFRED HELM¹ — ¹Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany. — ²University of Surrey, Guildford, UK. — ³Technische Universität Dresden, Germany.

Isolated atoms or ions, typically confined in traps, are ideal systems for studying fascinating coherent quantum effects such as photon echoes. Likewise, isolated donor impurity atoms in semiconductors like silicon show a hydrogen-like spectrum, shifted to the far infrared due to the small effective mass and high dielectric constant [1]. Excited Rydberg states are of particular interest for quantum information, because they allow one to prepare long-living microscopic polarization states.

In contrast to previous far-field spectroscopic studies which probed ensembles of many impurities, we aim here at studying individual im-

purity centers. To this end, low-temperature scattering-type scanning near-field optical microscopy (s-SNOM) is employed and a free-electron laser is used as a precisely tunable terahertz source [2]. Our silicon samples contain different donors (P, Bi) with different defect densities, respectively, and are pre-characterized by conventional Fourier transform infrared spectroscopy.

[1] Greenland et al., *Nature* 465, 1057 (2010).

[2] Döring et al., *Appl. Phys. Lett.* 105, 053109 (2014).

O 42.8 Tue 15:45 H4

Terahertz responses of a metal with sub-nm gap — •TAE YUN KIM¹, SANG JUN PARK¹, DAI-SIK KIM², and CHEOL-HWAN PARK¹ — ¹Center for Theoretical Physics and Department of Physics, Seoul National University, Seoul 08826, Korea — ²Center for Atomic Scale Electromagnetism and Department of Physics, Seoul National University, Seoul 08826, Korea

Recent developments have shown that the characteristic length scale of a plasmonic system can reach a few angstroms. In a recent experiment, it was observed that the tunneling of electrons through quantum barriers can restrict the funneling of terahertz waves through sub-nm gaps in the extremely non-linear, high-intensity regime [1]. In this contribution, we calculate and discuss the responses of a metal with sub-nm gaps in the terahertz regime further based on a recent theoretical study [2].

[1] Young-Mi Bahk, Bong Joo Kang, Yong Seung Kim, Joon-Yeon Kim, Won Tae Kim, Tae Yun Kim, Taehee Kang, Jiyeah Rhie, Sanghoon Han, Cheol-Hwan Park, Fabian Rotermund, and Dai-Sik Kim, *Phys. Rev. Lett.* 115, 125501 (2015).

[2] Sang Jun Park, Tae Yun Kim, Cheol-Hwan Park, and Dai-Sik Kim, unpublished.