O 38: Nano-optics of metallic and semiconducting nanostructures (experiments I)

Time: Wednesday 15:00–17:30 Location: SCH A216

O 38.1 Wed 15:00 SCH A216

Nanometer scale imaging and spectroscopy of an organic semiconductor film — •Alfred J. Meixner[1], Dai Zhang[1], Ute Heinemeyer[2], Frank Schreiber[2], and Reinhard Scholz[3] — [1]Institute of Physical and Theoretical Chemistry, University of Tübingen — [2]Institute of Applied Physics, University of Tübingen — [3]Walter Schottky Institute, TU-München

The local electronic and optical properties of molecular semiconductors depend sensitively on the local film morphology such as grain boundaries and localized defects. However, quantitative spectroscopic measurements with a resolution matching the molecular morphology of organic semiconductor films has been plagued either by a lack of resolution, contrast or sensitivity. We have investigated an organic molecular semiconductor film (diindenoperylene, DIP) grown by molecular beam deposition on a Si (100) substrate covered with a native oxide layer by tip-enhanced nanometer scale spectroscopic imaging by the use of a novel parabolic-mirror assisted near-field optical microscope. We could for the first time resolve grain boundaries and defects both in the topography and in the near-field optical image and relate them to local PL- and Raman spectra with a spatial resolution on the order of 10 nm.

O 38.2 Wed 15:15 SCH A216

Investigation of Geometry-dependent Dipole Coupling using Near-field Optical Microscopy of Au-nanoantennas — •Kai Braun[1], Dai Zhang[1], Monika Fleischer[2], Dieter P. Kern[2], and Alfred J. Meixner[1] — [1]Institut fuer Physikalische und Theoretische Chemie, Auf der Morgenstelle 8, 72076 Tuebingen — [2]Institut fuer Angewandte Physik, Auf der Morgenstelle 10, 72076 Tuebingen

The plasmon coupling between two dipoles is strongly dependent on their relative positions. Theoretical simulations predicted a red shift of the localized plasmon resonance (LPR) for a dipole top-on-top geometry while a blue shift for a dipole side-by-side geometry[1]. However the corresponding experiments are hard to be realized due to the difficulties of aligning two dipoles into desired configurations. We will use a newly developed parabolic mirror assisted near-field optical microscope (SNOM) to precisely position a gold tip at different positions with respect to a gold cone. By replacing the objective lens with a parabolic mirror, this setup provides the unique possibility of obtaining a 14 times stronger electric field distribution in the longitudinal direction than that of the transversal direction[2]. Since both the gold tip and cone have strong oscillating dipoles in the longitudinal direction, this microscope allows us to study the geometry-dependent dipole coupling more accurately and flexibly. [1] Prashant K. Jain et al (2006), J. Phys. Chem. B, 110 18243-18253 [2] Fleischer M. et al (2008), Applied Physical Letters, 93 1

O 38.3 Wed 15:30 SCH A216

Antenna enhanced Pump-Probe Spectroscopy of Single Metal Nanoparticles — •David Molnar[1,2] and Markus Lippitz[1,2] — [1]Max-Planck-Institut für Festkörperforschung, Stuttgart — [2]4. Physikalisches Institut, Universität Stuttgart

Tailoring a nanoparticle's properties for technological applications requires a profound understanding of its different characteristics compared to those of its bulk material. One arising question is: Down to which lengths can a material be expected to show bulk behaviour?

Acoustical eigenfrequencies of a single gold nanoparticle give insight to its mechanical properties such as density or Young's modulus. A laser induced mechanical oscillation yields a periodical change of the electron density, i.e., a periodically changing plasmon resonance. This change is optically detectable using a pump-probe technique and reveals the dynamics of the particle's oscillation.

As absorption is proportional to the third power of the particle's radius the optical detection of mechanical oscillations of a single metal particle with a diameter of 40nm or less is almost impossible. However using an adequate antenna enhancing the signal oscillations of a single particle, 10nm in size or less, become detectable.

We will show calculations of the signal enhancement by an antenna as well as first experimental results in this field.

O 38.4 Wed 15:45 SCH A216

A Simple Fabrication of Nanoantennae over Large Areas — •Reto Giannini[1], Arda Kristopuryan[1], Yasin Ekinci[1], Pratap K. Sahoo[2], and Jörg F. Löffler[1] — [1]Laboratory of Metal Physics and Technology, Department of Materials, ETH Zurich, 8093 Zurich, Switzerland — [2]Laboratory of Micro- and Nanotechnology, Paul Scherrer Institute, 5232 Villigen, Switzerland

Metallic nanoparticles are very promising candidates for the creation of nanoantennae. Such nanoantennae can be used to excite flourophores more efficiently or to increase the emission of molecules and quantum dots leading to applications in biosensing, nanophotonics and Raman-/fluorescence spectroscopy. The basis of using metallic nanoparticles as nanoantennae is their capability to create a huge electromagnetic enhancement. This enhancement is a consequence of the resonant excitation of charge density oscillations, known as surface plasmons. A further significant increase of the enhancement can be achieved by coupling of two closely-spaced nanoparticles (dimers). Reproducible and cost-effective methods, applicable to large areas, are readily available for single nanoparticles, whereas well-defined dimers are difficult to obtain with comparable simple methods. We have fabricated gold and silver nanoantennae using colloidal lithography and thermal evaporation providing nanoparticle dimers with small gaps over large areas. We measured the plasmon resonances of individual gold and silver dimers with different structural parameters and performed surface-enhanced Raman spectroscopy to determine the relative near-field enhancement factors of the fabricated nanoantennae.

O 38.5 Wed 16:00 SCH A216

Three-dimensional metal photonic nanostructures using direct laser writing and electrodeposition — •Justyna Kinga Gansel[1], Michael Thiel[1], Klaus Bade[2], Volker Saile[2], Georg von Freymann[1], Stefan Linden[1], and Martin Wegener[1] — [1]Institut für Nanotechnologie, Forschungszentrum Karlsruhe; DFG-Center for Functional Nanostructures (CFN) and Institut für Angewandte Physik, Universität Karlsruhe (TH) — [2]Institut für Mikrostrukturtechnik, Forschungszentrum Karlsruhe

An interesting part of the field of photonic nanostructures are metamaterials. Particularly, three-dimensional (3D) structures like 3D negative index metamaterials [1] or optical cloaking devices [2] attract increasing attention. Yet, few techniques for the fabrication of true 3D metamaterials exist [3, 4]. Here we present a method for the fabrication of 3D metal nanostructures. A positive or negative photoresist layer can be structured by direct laser writing, facilitating a wide amount of structure designs. The template is backfilled with gold using electrodeposition, where an ITO-layer below the photoresist acts as a cathode. After removal of the resist, free-standing gold nanostructures emerge. A structure design that can be realized using this method are 3D gold spirals. Corresponding simulations have shown that these structures possess interesting chiral properties.

[1] J. Valentine et al., Nature **455**, 376 (2008)
[2] J. B. Pendry et al., Science **312**, 1780 (2006)
[3] M. S. Rill et al., Nature Mater. **7**, 543 (2008)
[4] N. Liu et al., Nature Mater. **7**, 31 (2008)

O 38.6 Wed 16:15 SCH A216

Fabrication and optoelectronic properties of individual gold nanostructures — •Monika Fleischer[1], Sebastian Jäger[2], Marcus Sackrow[2], Dai Zhang[2], Rudolf Ehlich[3], Catrinel Stanciu[2], J.K. Heinrich Hörber[3], Alfred J. Meixner[2], and Dieter P. Kern[1] — [1]Institut für Angewandte Physik, Eberhard Karls Universität Tübingen, Deutschland — [2]Institut für Physikalische und Theoretische Chemie, Eberhard Karls Universität Tübingen, Deutschland — [3]H.H. Wills Laboratory, University of Bristol, England

When interacting with the electromagnetic field of a focused laser beam, individual gold nanostructures can act as optical antennas. For efficient excitation, the shape and size of the nanostructures need to be adjusted to the applied laser mode and wavelength. Cone structures e.g. are particularly well suited for excitation with a radially polarized beam [1]. In a process based on electron beam lithography and ion milling, individual gold nanostructures are fabricated in a range of different shapes, whose critical dimensions are varied systematically. The structures are characterized by means of confocal microscopy, NSOM, SEM, AFM and STM. Results of these studies are presented together with spectra indicating the shape and size dependent resonance fre-

quencies of the gold structures.
[1] M. Fleischer et al., Appl. Phys. Lett. 93, 111114 (2008).

O 38.7 Wed 16:30 SCH A216

20 nm Optical Resolution Using Gold Nanospheres as Near-Field Probes — Hadi Eghlidi, Kwang Geol Lee, Xuewen Chen, Mario Agio, •Stephan Götzinger, and Vahid Sandoghdar — Laboratory of Physical Chemistry and optETH, ETH Zürich, CH-8093 Zürich, Switzerland

Apertureless Scanning Near-Field Optical Microscopy (SNOM) has reported spatial resolution below 20 nm in isolated cases. However, researchers have confronted considerable difficulties in reproducing tips that deliver this performance. Several years ago, we developed reliable and reproducible near-field probes consisting of single gold nanospheres attached to the end of glass tips. It has been also shown that such probes can act as resonant dipole nanoantennas to enhance the fluorescence of single molecules by more than 25 times [1, 2]. We report on experimental images of single molecules obtained using different gold nanoparticle probes with diameters between 40 nm and 100 nm. Resolutions as high as 20 nm were demonstrated at a high yield and with different particle sizes. Furthermore, fluorescence enhancements greater than 30 times were observed. For very small gold particles, the competition between quenching and enhancement of the molecular fluorescence becomes important because the ratio of the absorption to the scattering cross section inverses. We discuss this paradigm shift and its implications for ultrahigh resolution SNOM.

[1] S. Kühn et al., Phys. Rev. Lett. 97, 017402 (2006).
[2] S. Kühn et al., Mol. Phys. 106, 893 (2008).

O 38.8 Wed 16:45 SCH A216

Near-Field Investigation of Plasmonic Nano-Wire Eigenmodes — •Jens Dorfmüller[1], Ralf Vogelgesang[1], and Klaus Kern[1,2] — [1]Max Planck Institute for Solid State Research, 70569 Stuttgart, Germany — [2]Ecole Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland

We use apertureless Scanning Near-Field Optical Microscopy (aSNOM) with cross-polarization of the excitation and scattered radiation, which allows us to map nearly unperturbed eigenmodes of plasmonic nanostructures. We study optical wire antennas produced by electron beam lithography. In contrast to far-field measurements, aSNOM allows us to compare plasmon resonances of many individual single wires simultaneously on a relatively small substrate area. We show measured amplitude and phase maps of the z-component of electromagnetic near-fields around these nano-structures.

Our amplitude images show lobes which indicate a strong z-component of the electromagnetic field and neighbouring lobes show a phase difference of 180° in the phase image. Depending on their size, the wires show multipolar resonances. The dipolar resonance is observed at a wire length $\approx \lambda_{\mathrm{vac}}/5.6$ and higher order resonances at odd multiples of the dipolar resonance length. Higher multipole orders, show less near-field intensity but a broader resonance in the wire-length domain.

We show that it is possible to break the symmetry of the exciting electromagnetic field by turning the sample and excite the otherwise symmetry forbidden even modes.

O 38.9 Wed 17:00 SCH A216

Nanostructure Symmetry Induced Surface Plasmon Propagation Guiding and Polarisation Twisting — •Brian Ashall and Dominic Zerulla — UCD Dublin, School of Physics, Dublin 4, Ireland

In a recent letter [1], we have demonstrated that symmetry properties of tailor designed nanostructures have a well defined impact on propagation characteristics of Surface Plasmon Polaritons (SPPs) excited on the nanostructured arrayed surfaces. Highlighted, were the SPP excitation, propagation and wave-guiding processes on the nanostructured arrays.
Building on these findings, more recent experiments have focused on the ability of 120° symmetric nanostructures to predictably twist the polarisation of the reemitted light with respect to the illumination polarisation.
This effect has been both, directly observed through polariser - analyser experiments, and indirectly observed as a shift in the polarisation at which the most efficient SPP confinement on the nanostructured surface occurs. The degree by which the polarisation can be twisted is a function of the geometry of the nanostructures, and as such is an initial free design parameter. The only apparent restriction for the efficiency of the polarisation twisting effect for a given nanostructured array are the SPP excitation conditions.

[1] B. Ashall, M. Berndt, D. Zerulla, Appl. Phys. Lett. 91, 203109 (2007).

O 38.10 Wed 17:15 SCH A216

Observations of selective near-field focusing on three-fold symmetric, mesoscopic surface patterns - measured with PEEM — •Michael Berndt[1,2], Brian Ashall[1], Martin Rohmer[3], Christian Schneider[3], Martin Aeschlimann[3], and Dominic Zerulla[1] — [1]University College Dublin, School of Physics, Belfield, Dublin 4, Ireland — [2]MPI of Molecular Cell Biology and Genetics, 01307 Dresden, Germany — [3]Technische Universität Kaiserslautern, Fachbereich Physik, 67663 Kaiserslautern, Germany

Optically active, structured surfaces, which provide strong localisation of excitation energies in certain "hot-spots" on their surface are required for many applications.
We examine the modification and polarisation dependence of optical near-fields on the surface of an array of three-fold symmetric, mesoscalic, silver-coated structures produced by e-beam lithography. For mapping the spatially resolved near-fields and examining the influence of polarisation of the excitation light, we use a photoelectron emission microscope (PEEM). We find that the presented structures show strong increase of the near-field intensity in certain "hot-spots" in a polarisation dependent manner. Hence we demonstrate that breaking of symmetry can provide additional centres of "hot-spots", which will be employed as the basis of an improved structure design to gain highly efficient near-fields focusing.