DS 16: Plasmonics and Nanophotonics O-II (jointly with HL and O)

Time: Monday 17:15–19:15 Location: PHY C213

DS 16.1 Mon 17:15 PHY C213

Lithographically defined plasmonic waveguides on semiconductors for on-chip quantum optics applications — •Gregor Bracher, Konrad Schraml, Benedikt Mayer, Birgit Wiedemann, Simon Frédéric, Jonathan J. Finley, and Michael Kaniber — Walter Schottky Institut, Technische Universität München, Am Coulombwall 4, D-85748 Garching, Germany

We present optical investigations on lithographically defined plasmonic waveguides (WG). The metallic WGs are fabricated on GaAs substrates by electron beam lithography and subsequent metallisation. Structural properties are probed by atomic force microscopy and scanning electron microscopy revealing a surface roughness below 3 nm. For the optical characterisation we use a two axis confocal microphotoluminescence setup that enables us to excite and detect plasmons perpendicular and parallel to the sample surface. First measurements show that Au WGs with a thickness of 100 nm and width of 4 μm exhibit a propagation length of 15 μm at $\lambda = 820\ nm$. We clearly observe strong localisation of the excitation at the wire end and the expected polarisation dependence along the WG axis. Using the same technique we prove that plasmons can be excited in lithographically defined Au nanowires with a cross section down to 100x100 nm^2. The deterministic control of the position and shape of the plasmonic nanostructures by means of electron beam lithography combined with near surface self-assembled InGaAs/GaAs quantum dots promises efficient on-chip generation and guiding of single plasmons for future applications in nanoscale quantum optics.

DS 16.2 Mon 17:30 PHY C213

Fabrication of high-quality large-area plasmonic oligomers — •Jun Zhao, Bettina Frank, and Harald Giessen — Universität Stuttgart

Plasmonic structures with a structure size of around 100nm are tremendously important for applications in the visible and near-IR range. Surface-enhanced Raman scattering substrates, localized surface plasmon resonance sensors, narrow resonances using plasmonic induced transparency, and local field concentration in oligomers to create hot spots are among those applications. Key issues in the design and manufacturing of such structures are small gaps in the range of sub-20nm, sharp edges, and narrow resonances. For applications, large fabrication areas in the range of cm^2 and low manufacturing costs are crucial. Here, we present a method that fulfils these requirements. Utilizing tilted-angle-rotation lithography with a polar and azimuthal rotation axis and shutter control together with monolayers of polystyrene spheres we create reproducibly homogeneous structures in 50nm to 200nm range with 10nm gaps over areas of cm^2. We fabricated triangular monomers, dimers, trimers, quadrumers, and pentamers, with open and closed gaps and with different size of nanospheres, and measured their transmittance spectra by FTIR microscopy. The spectra show well modulated resonances which depend sensitively on the incident polarization. We can attribute the various collective modes to the different features of the spectra and observe hybridization effects. This confirms the high quality of our fabrication method.

DS 16.3 Mon 17:45 PHY C213

Plasmonic nanostructures for strong light confinement fabricated using soft-lithography and plasma etching techniques — •Manuel Gonçalves[1], Tobias Paust[1], Fabian Enderle[2], Stefan Wiedemann[2], Alfred Plettl[2], Paul Ziemann[2], and Othmar Marti[1] — [1]Ulm University - Inst. of Experimental Physics, Albert-Einstein-Allee 11, 89069 Ulm, Germany — [2]Ulm University - Inst. of Solid State Physics, Albert-Einstein-Allee 11, 89069 Ulm, Germany

Nanosphere lithography has been commonly used for fabrication of plasmonic nanostructures. Small triangular particles of less than 100 nm size, with sharp corners, can be obtained at low cost. These structures have been used for plasmonic based sensing applications.

We show how nanosphere lithography can be extended for fabrication of more complex structures as arrays of holes on corrugated dielectrica and arrays of metal-dielectric pillars, using in combination soft-lithography and reactive ion-etching techniques (ICP-RIE). Surface plasmon modes can be easily excited on metal coated periodic dielectric structures using light. On the other hand, geometrical singularities lead to strong localized surface plasmons. The fabricated structures can be used for plasmonic effects as enhanced optical transmission, light confinement and surface enhanced Raman spectroscopy, due to their geometrical and optical properties. Confocal microscopy and angle-resolved spectroscopy were used for study of far-field transmittance and reflectance. The near-fields were investigated by SNOM and confocal Raman microscopy. Simulations were carried out to obtain the near-fields and optical resonances.

DS 16.4 Mon 18:00 PHY C213

Light Localization Effects in Commensurate Gratings — •Aude Barbara[1,2], Jerôme Le Perchec[3], Stéphane Collin[4], Camille Maxime[1,2], and Pascal Quémerais[1,5] — [1]Institut Néel, CNRS-UJF, Grenoble, France — [2]IAPP, TU Dresden, Germany — [3]CEA, Grenoble, France — [4]LPN, Marcoussis, France — [5]MPI-PKS, Dresden, Germany

We present a study in which infrared light localization phenomena are induced in commensurate gratings made of deep sub-wavelength metallic grooves. We combined the effects of light trapping within active sites (the deep cavities) with the properties of self-similar arrangements (commensurate gratings). We show that as the degree of commensuration tends to an irrational number new light localization states are produced. Interestingly, these have properties close to that reported for hot spots on disordered surfaces. In particular they present a very high sensitivity to the variation of the exciting field (wavelength and incident angle). We also experimentally demonstrated the existence of these new resonances and measured their dispersion diagrams. We observed selective light localization within the cavities, transition from localized to delocalized modes and modifications of the mode coupling with the incident light leading to the generation of black modes. The theoretical analyze is in full agreement with the experiments.

A. Barbara et al. *Opt. Exp.* **16**, 19127 (2008)
A. Barbara et al. *Opt. Exp.* **18**, 14913 (2010)

DS 16.5 Mon 18:15 PHY C213

Parallel nanostructuring of fused silica exploiting local near fields — •Sören Maag, Rodica Morarescu, Frank Träger, and Frank Hubenthal — Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany

In modern nanotechnology, there is an ongoing interest to decrease the dimensions of surface structures below the diffraction limit. Furthermore, parallel structuring of surfaces with light induced processes is of particular interest. Along these lines we are using nanosphere lithography to create highly ordered triangular gold nanoparticle arrays and exploit their localized optical near field to overcome locally the ablation threshold of fused silicia. Therefore, the nanoparticle arrays were irradiated with a single ultrashort laser pulse (35 fs), at a central wavelength of 790 nm. Depending on the polarization and the fluence of the laser light holes, grooves, or channels, with dimensions well below the diffraction limit have been created. For example, for a polarization along the bisector of the triangular nanoparticles, nanogrooves with a depth of 14 nm, a width at its waist of 45 nm, and a length of 290 nm have been generated, if fluences near the ablation threshold were applied. In contrast, tiny spherical nanoholes with diameters of only 23 nm can be achieved, for fluences significantly below the ablation threshold. The obtained structures can be explained by the enhanced electromagnetic near fields, which overcome locally the ablation threshold of fused silica in the vicinity of the irradiated nanoparticles.

DS 16.6 Mon 18:30 PHY C213

Mapping infrared antenna resonances of particle arrays fabricated by nanosphere lithography — •Jens Richter[1], Andrea Hartung[1], Jón Mattis Hoffmann[1], Xinghui Yin[2], and Thomas Taubner[1,2] — [1]1st Institute of Physics, RWTH-Aachen University, Sommerfeldstrasse 14, 52074 Aachen, Germany — [2]Fraunhofer Institute for Laser Technology, Steinbachstr. 15, 52074 Aachen, Germany

Infrared vibrational spectroscopy is sensitive to characteristic molecule absorption bands, yielding a "fingerprint" spectrum of the molecules involved. The sensitivity of infrared spectroscopy has been increased by several orders of magnitude with optical antennas [1-3]. Arrays of hexagonal sorted triangular metallic infrared antennas created by Nanosphere lithography (NSL) have already been shown to exhibit IR resonances [4].

Our goal is the systematic variation of the NSL fabrication parameters in order to tune the antenna resonance over the whole mid-IR spectrum. We fabricate antenna arrays on different IR-transparent substrates and vary the particles lateral size and height. Using a Fourier-Transform-Infrared-Microscope (FTIR) we determine the plasmon resonance position of each sample. Applications of those structures to surface enhanced IR-Spectroscopy (SEIRA) will be discussed.

[1] R. Adato et al.; PNAS, 106, 19227 (2009)
[2] F. Neubrech et al.; PRL 101, 157403 (2008)
[3] R. Bukasov et al.; Analyt. Chem. 81, 4531 (2009)
[4] C. Haynes et al.; J. Phys. Chem. B, 105, 5599 (2001)

DS 16.7 Mon 18:45 PHY C213

Plasmonic oligomers: the role of individual particles on collective behavior — •Mario Hentschel[1,2], Na Liu[3], and Harald Giessen[1] — [1]4th Physics Institute and Research Center SCoPE, University of Stuttgart, D-70569 Stuttgart, Germany — [2]Max-Planck-Institute for Solid State Research, Heisenbergstr. 1, D-70569 Stuttgart, Germany — [3]Department of Chemistry, University of California, Berkeley, and Materials Science Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA

We theoretically and experimentally study the transition from isolated to collective modes in plasmonic oligomers which consist of a six-particle outer ring around a single center particle. The inter-particle gap distance plays a key role for the formation of collective modes. The plasmon hybridization method is applied to analyze the optical properties of plasmonic oligomers. The interference between a subradiant and a superradiant mode leads to a pronounced Fano resonance [1]. Furthermore we demonstrate the possibility to switch on and off the Fano resonance by the presence or absence of the central nanoparticle without breaking the system symmetry [2]. We also study the optical response upon modifications such as the introduction of defects by shifting the inner particle from the center position and the variation of the number of individual discs. The ability to observe and tune the collective resonances in metallic nanostructures will allow for the creation of a rich new set of artificial plasmonic molecules with a wide range of controlled optical properties. [1] B. Lukyanchuk et al., Nature Mat. 9, 707 (2010) [2] M. Hentschel et al., Nano Lett. 10, 2721 (2010)

DS 16.8 Mon 19:00 PHY C213

Fabrication of nanocone arrays for high sensitivity biosensing — •Monika Fleischer, Christian Schäfer, Andreas Horrer, Katharina Broch, Dominik Gollmer, Frank Schreiber, and Dieter P. Kern — Institut für Angewandte Physik, Eberhard Karls Universität Tübingen, Auf der Morgenstelle 10, D- 72076 Tübingen

Plasmonic nanostructures, when resonantly interacting with an electromagnetic field, act as optical antennas focusing light to nanoscale volumes. Extremely high near-field enhancement is observed in the direct vicinity of the nanostructure surface, in particular at edges, corners, or tips. A process was developed for the fabrication of metallic nanocones with tip radii on the order of 10 nm. The cones are demonstrated to be efficiently excited by electric field components polarized parallel to the cone axis [1,2]. A narrow spot of high electric field strength is created near each cone apex due to the occurrence of localized surface plasmon resonances. Both serial and parallel methods for the fabrication of regular arrays of nanocones made from e.g. gold, silver, and copper are presented. Dense arrays of metal cones constitute a highly favorable system for high sensitivity sensing of biological or other organic molecules. For molecules located near a cone apex, strong Raman intensity enhancement is observed, similar to the effect of tip-enhanced Raman spectroscopy. This is demonstrated by the example of pentacene molecules [3] on gold cones.

[1] M. Fleischer et al., Nanotechnology 21, 065301 (2010)
[2] M. Fleischer et al., Appl. Phys. Lett. 93, 111114 (2008)
[3] A. Hinderhofer et al., J. Chem. Phys. 127, 194705 (2007)