O 75: Plasmonics and Nanooptics

Time: Wednesday 18:15–21:00 Location: Poster A

O 75.1 Wed 18:15 Poster A

Control of light-SPP coupling at step edges by local interference — •Alwin Klick[1], Sergio de la Cruz[2], Christoph Lemke[1], Malte Grossmann[1], Hauke Beyer[1], Jacek Fiutowski[3], Jakob Kjelstrup-hansen[3], Horst-Günter Rubahn[3], Eugenio R. Méndez[2], and Michael Bauer[1] — [1]Institute for Experimental and Applied Physics, University of Kiel, Leibnizstr. 19, 24118 Kiel, Germany — [2]División de Física Applicada, Centro de Investigación Científica y de Educación Superior de Ensenada, Carretera Ensenada-Tijuana No. 3918, Ensenada 22860, BC, Mexico — [3]Mads Clausen Institute, University of Southern Denmark, NanoSYD Alsion 2, 6400 Sønderborg, Denmark

A combined experimental and theoretical study on the efficiency of laser-induced surface plasmon polariton (SPP) excitation at defined step edges at a gold-vacuum interface as one of the most basic coupling geometries is presented. As a relevant parameter determining the coupling efficiency we identify the ratio between step height h and excitation wavelength λ [1]. For specific values of h/λ a substantial suppression of laser-SPP coupling is observed arising from destructive interference of the laser field reflected at the two step levels, respectively. Experiment and theory show, furthermore, that the interference affects also the phase of the SPP with respect to the exciting laser field.

[1] De la Cruz, S. et al., 2012. Physica Status Solidi (B), 249(6).

O 75.2 Wed 18:15 Poster A

Super-resonant infrared near-field microscopy — •Denny Lang[1,2], Tino Uhlig[1], Susanne C. Kehr[1], Manfred Helm[2], and Lukas M. Eng[1] — [1]Institut für Angewandte Physik, Technische Universität Dresden, 01069 Dresden — [2]Institut für Ionenstrahlphysik und Materialforschung, Helmholtz-Zentrum Dresden-Rossendorf, 01314 Dresden

Scattering-type scanning near-field optical microscopy (s-SNOM) is an AFM-based technique for achieving nanoscale resolution even at infrared wavelengths [1]. s-SNOM thus is of valuable impact when e.g. investigating low-dimensional conductors or semiconductors. In order to enhance the signal strength we face two options, by either tuning the tip or sample into resonance using appropriate or tunable laser light sources.

In this work we use a CO_2-laser with a tunable center wavelength from 9.7 μm to 11.3 μm as an infrared excitation source in combination with self-prepared AFM particle-tips as probes [2]. The tip particles consist of spherical SiC, Si_3N_4 or SiO_2 nanoparticles with a diameter of $\sim$60 nm. Those materials show phonon resonances in or around the CO_2-laser wavelength range and thus enhance the signal significantly. We explore here the scenario when using both resonant tips and samples, hence resulting in a tip-sample coupled super-resonance. Accordingly, a significantly increased near-field image contrast and resolution is expected in this case.

[1] S.C. Kehr et al., Nat. Commun. 2, 249 (2011).
[2] M.T. Wenzel et al., Opt. Express 16, 12302 (2008).

O 75.3 Wed 18:15 Poster A

Hybrid quantum dot nanoantenna systems: fabrication and characterization — •Manuel Peter, Cody Friesen, and Stefan Linden — Physikalisches Institut, Universität Bonn, Nußallee 12, 53115 Bonn, Germany

This poster will provide an overview of the fabrication and characterization methods we use to investigate hybrid quantum dot nanoantenna systems. We present a two-step electron lithography process for the reliable positioning of colloidal quantum dots in the vicinity of plasmonic nanoantennas with sub-50nm spatial accuracy and a first experiments with such structures In the first lithography step, gold nanoantennas are fabricated with spectral features at the emission wavelength of the used quantum dots (λ=780 nm). Following this, a second layer of PMMA is deposited on the sample. Then a template is written with the electron beam to define the positions for the colloidal quantum dots. After development, the surface of the substrate as well as that of the quantum dots are chemically modified such that a linker molecule can bind the quantum dots to the predefined spots. After removing the PMMA mask, we obtain hybrid nanostructures composed of gold nanoparticles and quantum dots. With our fabrication method, we are able to precisely control all geometrical parameters of the hybrid nanostructures. In this contribution we show an example of a successful coupling of quantum dots and rod nanoantennas. By examining the polarisation of the fluorescence light of the structure, we could confirm that the quantum dots are still functional and interact with the nanoantenna.

O 75.4 Wed 18:15 Poster A

Tuning the Localized Surface Plasmon Resonance: An Annealing Study for Aluminium, Copper, Gold and Silver Nanostructures Prepared by Nanosphere Lithography — •Stefan Moras, Jacek Gasiorowski, Ovidiu D. Gordan, and Dietrich R. T. Zahn — Semiconductor Physics, Technische Universität Chemnitz, D-09107 Chemnitz

Metallic nanostructures attract great interest due to their unusual characteristics. The optical response of such nanostructures differs markedly from bulk material because of the localized surface plasmon resonance (LSPR) of these structures. Optical properties associated with LSPR are determined by shape, size, structure, and the local dielectric environment of the metal nanostructures. Here we present a detailed characterization of the tunability of the LSPR in aluminium, copper, gold, and silver nanostructures by annealing up to 500 °C in nitrogen atmosphere. All structures were prepared by nanosphere lithography (NSL) where self-assembled monolayer of polystyrene particles served as a mask for metal evaporation. UV-vis spectroscopy was used to determine the LSPR of these structures. Changes in morphology were investigated using scanning electron microscope (SEM). Gold and especially silver show pronounced tunability in the visible region due to their change of shape from triangular towards spherical. Copper shows a difference in LSPR which we attribute to a different type of surface oxide whereas aluminium shows no tunability in the temperature range used due to the capping by an aluminium oxide layer.

O 75.5 Wed 18:15 Poster A

Plasmonic Nanoparticles prepared by Nanosphere Lithography for local Excitation of Molecular Aggregates — •Tamam Bohamud[1], Mohammadreza Bahrami[1], Lukas Steffen Rathje[1], J.A.A.W Elemans[2], Ingo Barke[1], and Sylvia Speller[1] — [1]University of Rostock, Institute of Physics, 18051 Rostock, Germany — [2]Institute for Molecules and Materials, RU Nijmegen, NL

Nanosphere lithography (NSL) is an effective technique to fabricate nanoparticles with tailored arrangement and dimensions. We used this method to obtain periodic arrays of silver nanotriangles using beads of polystyrene as a mask on glass and silicon substrates. Periodic hexagonal arrangements of semi-spherical nanoparticles are created by subsequent annealing. Correlation between the morphology of the nanoparticles and their plasmonic signatures indicate different types of resonances depending on size and shape. The utilization of these nanoparticles as an environment to locally excite copper porphyrin aggregates is discussed.

O 75.6 Wed 18:15 Poster A

Studies on the nonlinear optical properties of lithographically fabricated nanoantennas — •jiyong wang[1,2], anke horneber[1], pierre michel adam[2], and dai zhang[1] — [1]Institut für Physikalische und Theoretische Chemie, Eberhard Karls Universität Tübingen, 72076 Tübingen, Deuschland — [2]Laboratoire de Nanotechnologie et d'Instrumentation Optique, Universite de Technologie de Troyes, 10004 Troyes, France

Metallic nanostructures exhibit fascinating linear and nonlinear optical properties when they are excited by incident light. Localized surface plasmons (LSPs) generated by a collective oscillation of electrons in conduction band offer the possibility of enhancing and concentrating electrical field in a subwavelength volume, which enable the nanostructures to act similar to antennas in the microwave or radiowave regime.

In order to explore the dependence of nonlinear optical properties on the LSPs for nanoantennas and their potential applications in the field of enhanced spectroscopy, we fabricated nanoantennas with different geometrical parameters (shape, dimension and gap) and materials by electron beam lithography. These nanoantennas were firstly characterized by far field extinction spectroscopy, which reflects footprints of their LSPs resonances. The nonlinear optical signals including second harmonic generation and two photon photoluminescence were investigated using far-field confocal optical microscopy and scanning near-field optical microscopy. . Gap-, material-, and position-dependent nonlinear optical properties of these nanoantennas will be systematically compared.

O 75.7 Wed 18:15 Poster A

Positioning colloidal nanocrystals next to plasmonic nanostructures using electron-beam lithography — •Marvin Berger[1,3,4], Daniela Wolf[1], Thorsten Schumacher[1], Stuart Earl[2,3], Daniel Gomez[3,4], and Markus Lippitz[1] — [1]Experimentalphysik III, Universität Bayreuth, Germany — [2]School of Physics, The University of Melbourne, Parkville, Victoria, 3010, Australia — [3]The Melbourne Centre for Nanofabrication (MCN), Australian National Fabrication Facility, Clayton, Victoria, 3168, Australia — [4]CSIRO, Materials Science and Engineering, Private Bag 33, Clayton, Victoria 3168, Australia

The plasmon resonance of a nobel-metal nanoparticle leads to an increased optical near-field. This can be used to enhance nonlinear optical effects such as third-harmonic generation or transient absorption. However, this requires that the nonlinear object is positioned in the plasmonic near-field.

We use semiconducting colloidal CdSe nanocrystals, localised within the range of some tens of nanometers to a gold or silver nanorod. Our approach to create such well defined structures is two-step Electron Beam Lithography (EBL). We discuss details of this process, especially the placement of the colloidal nanocrystals. Moreover we will use data from AFM, SEM and optical measurements to characterize our structures.

O 75.8 Wed 18:15 Poster A

Enhanced near-field coupling of plasmonic antennas with few-nm gap sizes fabricated by helium ion beam milling — Heiko Kollmann[1], Xianji Piao[2], Martin Esmann[1], Simon F. Becker[1], Dongchao Hou[1], Henning Vieker[3], André Beyer[3], Armin Gölzhäuser[3], Namkyoo Park[2], •Martin Silies[1], and Christoph Lienau[1] — [1]Carl von Ossietzky-Universität Oldenburg — [2]Seoul National University, Korea — [3]Universität Bielefeld

Metallic nanoantennas are able to localize far-field electromagnetic waves on sub-wavelength scales. Standard fabrication tools such as Electron Beam Lithography and Ga-based Focused Ion Beam (FIB) milling lead to sub-20-nm feature sizes. In the recent past, He-ion based lithography (HIL) has proven to push this limit below 10 nm [1,2]. Here, we combine Ga-based FIB and HIL for the fabrication of gold antennas with variable gap sizes down to a few nanometers. Using polarization-sensitive linear and nonlinear third harmonic (TH) spectroscopy, the linear optical resonances of single gold antennas and the TH emission intensities are analyzed for different feed gap distances. Both the spectral red-shift of the linear emission and the increased TH signal for small feed gaps are taken as a signature for the improved coupling of the antennas. Our experimental findings are strongly supported by FEM calculations and demonstrate that He-ion beam lithography is a highly attractive and promising new tool for the fabrication of plasmonic nanoantennas with few-nanometer feature sizes.

[1] M. Melli et al., Nano Letters 13, 2687-2691 (2013) [2] H. Kollmann et al., Nano Letters 14, 4478-4784 (2014)

O 75.9 Wed 18:15 Poster A

Sphere-based Aperture SNOM: A tool for ultrafast nano-optics — •Michael Hartelt, Cristian González, Anna-Katharina Mahro, Daniela Bayer, Elena Ilin, Deirdre Kilbane, Stefan Mathias, Egbert Oesterschulze, and Martin Aeschlimann — Department of Physics and Research Center OPTIMAS, TU Kaiserslautern, Germany

In traditional aperture Scanning Near-field Optical Microscopy (a-SNOM), the sample is illuminated through a sub-wavelength sized aperture at the apex of a tapered fiber or an Al-coated SiO_2 pyramid. These constructions have a number of drawbacks, such as the metal-metal interaction between tip and sample and the low transmission which causes problems for achieving the high intensities that are required for time-resolved measurements. We developed a new cantilever design, in which a SiO_2-sphere was added at the apex of such a pyramid. Here, we demonstrate the various benefits of this design for the imaging of localized and propagating surface plasmons, as well as ultrafast pump-probe experiments with pulse lengths well below 100 fs. Illuminating with an Optical Parametric Oscillator (OPO) allows us to address a wide spectral range from the UV up to the infrared regime. A setup combining these components provides a versatile tool for the investigation of ultrafast phenomena in nano-optics.

O 75.10 Wed 18:15 Poster A

Plasmonic nanostructure fabrication based on FIB milling of high-quality monocrystalline gold flakes and transfer — •Xiaofei Wu[1,2], Peter Geisler[1], Enno Krauss[1], René Kullock[1], and Bert Hecht[1] — [1]Nano-Optics and Biophotonics Group, Experimentelle Physik 5, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [2]Present address: Experimentalphysik III, Universität Bayreuth, Universitätsstraße 30, 95447 Bayreuth, Germany

Good fabrication techniques are vital for successful experiments because they not only make it possible to obtain structures with expected performance, but also significantly boost the working efficiency and success rate. Moreover, a novel fabrication technique also inspires new experimental ideas. Therefore it is always important to keep developing advanced fabrication techniques. Here we present our developments in preparing high-quality chemically synthesized monocrystalline gold flakes on substrates and their use in plasmonic nanostructure fabrication with focused ion beam (FIB) milling. To make the FIB-fabricated nanostructures available for substrates that are not suitable for FIB milling as well, we have developed approaches to transfer the nanostructures with 100% efficiency. A few typical applications based on these techniques are also presented.

O 75.11 Wed 18:15 Poster A

Implantation of gold into pure and silver containing glass by means of ArF-excimer laser irradiation — Maximilian Heinz[1], Manfred Dubiel[1], •Jörg Meinertz[2], and Jürgen Ihlemann[2] — [1]Institute of Physics, Martin Luther University of Halle-Wittenberg, Halle, Germany — [2]Laser-Laboratorium Göttingen e.V., Göttingen, Germany

The generation of plasmonic Au/Ag nanostructures in glass surfaces showing a tunable surface plasmon resonance in a wide range of wavelengths should be realized by laser implantation of gold by means of excimer laser irradiation. These are promising materials for optoelectronics and nanoplasmonics. Thin films of Au were applied to the glass surface and then Au species were incorporated by means of intense UV radiation using fluences below the ablation threshold of the glass. The formation of Au and Au/Ag nanoparticles with surface plasmon resonances between 500 and 620 nm could be verified by optical spectroscopy. These results demonstrate that such procedures enables the space-selected generation of plasmonic Au/Ag structures in glass surfaces by excimer laser irradiation.

O 75.12 Wed 18:15 Poster A

Periodic plasmonic nanoparticle arrays with controllable interparticle distances and plasmon resonance coupling — •Kirsten Volk and Matthias Karg — Physical Chemistry I, University of Bayreuth, Universitätsstr. 30, 95447 Bayreuth, Germany

Surface plasmons (SPs) are light induced collective oscillations of the electron liquid in respect to the crystal lattice at a metamaterial-dielectric interface with permittivities of different signs. When employing nanoparticles with a size smaller than the sink depth, optical fields can penetrate its entire volume and drive localized surface plasmon oscillations. The plasmon resonance wavelength of metallic nanoparticles is highly dependent on the size, shape and the material of the nanoparticle. Additionally the localized surface plasmon resonance (LSPR) is sensitive to the dielectric environment and the interparticle distance in nanoparticle arrays. Varying these two parameters significant changes of the optical properties of the system due to coupling can be achieved.

In this contribution we show how to make use of the dielectric environment and interparticle distance dependence of LSPRs to create functional materials with tailored optical properties. As particular building blocks we employed silver nanoparticles, which are coated by a polymer shell. The particles are then self-assembled into highly ordered hexagonally packed monolayers by a floatation approach. The interparticle distances can be exactly tuned by the dwell-time of the particles at the liquid-air interface. By placing the monolayers on substrates with high refractive indices the optical properties of the system can be further enhanced.

O 75.13 Wed 18:15 Poster A

Characterization of Single Gold Nanoparticles Using Confocal Interference Microscopy in Combination with Cylindri-

cal Vector Beams — •Otto Hauler, Frank Wackenhut, Tina Züchner, and Alfred J. Meixner — 1Eberhard-Karls-Universität Tübingen, Institut für physikalische Chemie, 72076 Tübingen, Germany

By using confocal interference microscpoy in combination with cylindrical vector beams it is possible to directly image the orientation and to detect the shape of single metal nanoparticles, with sizes well beyond the diffraction limit [1,2]. Metal nanoparticles can be imaged by detecting both their luminescence and the elastically scattered light. In the scattering detection mode the visualized pattern strongly depends on the local environment, e.g. the refractive index of the surrounding medium [3]. By shifting the resonance of the particles via coupling e.g. to a flat gold film and simultaneously measuring the luminescence and the elastic scattered signal we can further analyze the scattering properties. [1] A.V. Failla, H. Qian, H. Qian, A. Hartschuh, A. J. Meixner (2006), Nano Lett. 6, 1374. [2] T. Züchner, A. V. Failla, A. J. Meixner (2008), J. Microsc. 229, 337. [3] T. Züchner, A. V. Failla, M. Steiner, A. J. Meixner (2008), Opt. Expr. 16, 14635.

O 75.14 Wed 18:15 Poster A

Nanodiamonds with singe nitrogen vacancy centres in laser-written microstructures — •Bernd Sontheimer[1], Qiang Shi[2], Johannes Kaschke[2], Tanja Neumer[1], Joachim Fischer[2], Andreas W. Schell[1], Martin Wegener[2], and Oliver Benson[1] — [1]AG Nanooptik, Humbodt-Universität zu Berlin, Germany — [2]DFG-Center for Functional Nanostructures, Karlsruhe Institute of Technology (KIT), Germany

Hybrid integration of nano-sized quantum emitters in photonic structures can be achived by random methods or by nanomanipulation techniques. We report on our recent progress using another approach. In our method, the nanodiamonds are embedded in a photoresist, which is subsequently structured [1]. This allows for fabrication of a variety of different structures, such as resonators and waveguides coupled to single emitters. By pre-characterizing the emitter's properties and position, such structures can be fabricated in a highly controlled way [2].

[1] Schell et al.. Sci. Rep. 3, 1577 (2013)
[2] Schell et al., Appl. Phys. Lett. (accepted)

O 75.15 Wed 18:15 Poster A

Sputter deposition of Ag on PDMS thin films for flexible SERS substrates — •Gonzalo Santoro[1], Isabel M. Ochando[2], Torsten Boese[1], Ralph Döhrmann[1], Peng Zhang[1], and Stephan V. Roth[1] — [1]DESY, Notkestr. 85, D-22607 Hamburg, Germany — [2]Institute of Polymer Science and Technology, ICTP-CSIC, Juan de la Cierva, E-28006 Madrid, Spain

Silver (Ag) nanoclusters present excellent plasmonic properties that can be exploited for Surface Enhanced Raman Scattering (SERS) based sensors. To optimize the sensitivity of SERS substrates, it is crucial to achieve a profound understanding of the Ag nanocluster growth kinetics and to correlate the thin film morphology with its functionality [1].

This work presents in-situ time-resolved Grazing Incidence Small Angle X-ray Scattering (GISAXS) [1-3] results concerning the evolution of the nanostructures developed during the RF-sputtering of Ag on semiconductor (SiOx) and polydimethylsiloxane (PDMS) thin films, a highly flexible and stretchable silicone widely used for microfluidics. The SERS activity of the prepared thin films and the correlation of morphology and sensitivity are also presented.

[1] Santoro et al. Appl. Phys. Lett. 104, 243107 (2014); [2] Yu et al. J. Phys. Chem. Lett. 4, 3170 (2013); [3] Schwartzkopf et al. Nanoscale 5, 5053 (2013).