O 24: Plasmonics and Nanooptics: Fabrication, Characterization and Applications

Time: Monday 18:15–20:30 Location: Poster E

O 24.1 Mon 18:15 Poster E

Resonant energy-transfer in plasmonic hybrid arrays — •Julian Sindram, Joseph P. S. Fitzgerald, and Matthias Karg — Physical Chemistry I, University of Bayreuth, Bayreuth, Germany

Energy transfer between plasmonic nanoparticles (NPs) and fluorophores drastically alter the spectral response of the involved species and can be harnessed to create plasmonic nanolasers. Such lasers can be nanoscopic sources of coherent light with high potential for many applications in the field of nano-optics. Energy transfer rates depend on various parameters, including the NP material and size, the optical properties of the fluorophore, the distance between NPs and fluorophores and the concentration of fluorophores. In order to achieve a better understanding of energy transfer processes, a screening of numerous parameter combinations is necessary.

We present a new and efficient approach, allowing us to prepare and analyze large parameter sets on a single substrate. A bottom-up preparation procedure is used to fabricate substrate supported silver NP arrays with a spatial gradient of particle sizes. These plasmonic arrays are embedded in a fluorophore host matrix. Position-dependent steady-state and time resolved fluorescence spectroscopy, as well as extinction spectroscopy, are employed to examine energy transfer.

O 24.2 Mon 18:15 Poster E

Macrocopic self-assembled anisotropic metal-insulator-metal nanoparticles for tunable magnetic modes — •Max Schnepf[1], Martin Mayer[1], Moritz Tebbe[2], Tobias A.F. König[1], and Andreas Fery[1] — [1]Leibniz Institute of Polymer Research (IPF), Institute of Physical Chemistry and Polymer Physics, Hohe Str. 6, 01069 Dresden — [2]Dept. of Physical Chemistry II, University of Bayreuth, Universitätsstr. 30, 95440 Bayreuth

We present the synthesis and optical characterization of anisotropic metal-insulator-metal nanoparticles featuring intrinsic metamaterial properties within the visible wavelength range. The nanoparticle consists of a single crystalline gold nanorod core and a silver/gold hybrid nanobox shell, separated by a dielectric spacer. The magnetic mode can be tailored by distance variations between the nanorod core and the nanobox using a three-step synthesis. To clearly distinguish between the longitudinal and transversal mode, we have incorporated the anisotropic nanoparticle into a stretchable polymer film (polyvinyl alcohol, PVA). Stretching of the polymer film results in macroscopic alignment of the nanoparticles. Using conventional UV/vis scattering and absorption spectroscopy, we were able to identify the absorption dominated magnetic modes. We confirmed the magnetic mode properties with finite-difference time-domain (FDTD) simulations. This simple and rational particle design is capable of enabling bottom-up fabrication of colloidal optical metamaterials on macroscopic areas.

O 24.3 Mon 18:15 Poster E

Coupling of quantum well emission to surface plasmon modes in rolled-up microtubes — •Jan Siebels, Hoan Vu, Tobias Kipp, and Alf Mews — Institut für Physikalische Chemie, Universität Hamburg, Grindelallee 117, 20146 Hamburg, Germany

It has recently been shown that dielectric grating structures with gradually varying effective refractive indices in the direction perpendicular to the periodicity can be utilized for the excitation of surface plasmons in a wide spectral range [1]. This general idea of broad band surface plasmon excitation can be transferred to simple metallic gratings with gradually varying filling-factors. Here, we present the fabrication and optical characterization of silver grating structures positioned in rolled-up microtubes with embedded quantum well heterostructures. Spectrally- and time-resolved photoluminescence spectroscopy shows spectral shifts and changes of the decay lifetime exclusively in those areas of these structures in which calculations indicate an overlap between surface plasmon dispersion and emission energy of the quantum well. Based on these observations we propose and discuss possible coupling mechanisms.

[1] J. Ehlermann et al., Appl. Phys. Lett. 106, 101106 (2015).

O 24.4 Mon 18:15 Poster E

Automatized Optical Switching of Phase Change Material for Mid - Infrared Resonant Structures — •Julian A. Hanss, Martin Lewin, Tobias W.W. Mass, and Thomas Taubner — Institute of Physics (IA) RWTH Aachen

Confinement and local enhancement of electric fields can be achieved by metallic resonant structures. Dimensions and optical properties of the structure and surroundings define the position and strength of the resonance. Optical or thermal switching between different metastable phases of Phase Change Materials (PCMs) with distinct optical properties provide the opportunity of reversible, post - fabrication tuning of such resonances [1]. Focused laser beams change the structural phase of the PCM on a microscale, providing the possibility to switch for example single antennas of an array or write arbitrary structured optical metasurfaces [2].
By automatizing a previously built laser setup, the efficiency of structure modulation is increased facilitating fast investigations of different structures and material combinations. Localized, reversible tuning of resonant structures and and writing of arbitrary patterns can be achieved to create predefined optical responses.

[1] A. Michel et al., Nano Lett., 13(8), pp 3470-3475 (2013)
[2] Q. Wang et al., arXiv: 1508.03818 [physics.optics]

O 24.5 Mon 18:15 Poster E

Plasmonic gradient structures: Nanorod arrays with high spectral tunability — •Matthias Böhm[1], Susan Derenko[1], Vera Fiehler[1], Fabian Patrovsky[1], Stephan Barth[2], Hagen Bartzsch[2], Peter Frach[2], and Lukas M. Eng[1] — [1]Institut für Angewandte Physik, Technische Universität Dresden, 01062 Dresden, Deutschland — [2]Fraunhofer-Institut für Organische Elektronik, Elektronenstrahl- und Plasmatechnik Dresden (FEP), 01277 Dresden, Deutschland

Nanorod arrays are fabricated for instance by anodizing aluminum thin films with acidic solutions such as sulfuric acid or oxalic acid [1]. When altering the anodization conditions, different pore sizes and inter-pore distances are achieved, hence leading to plasmonic nanorod arrays that offer a broad range of spectral tunability when filling the pores with e.g. gold or silver. It is well known that the plasmonic resonance properties strongly depend on the aspect ratio (length-to-diameter) of individual particle antennas [2]. However, when fabricating antenna arrays, the distance between adjacent rods becomes crucial and thus needs to be controlled by the fabrication method and conditions.

Our study here presents a experimental and theoretical analysis of how the geometrical parameters must be varied in order to achieve antenna gradient structures within one sample that allows spectral tunability over several hundred nanometers in the optical wavelength range.

[1] M. Wang, Y. Liu, and H. Yang, Electrochim. Acta 62, 424 (2012).
[2] S.W. Prescott and P. Mulvaney, J. Appl. Phys. 99, 123504 (2006).

O 24.6 Mon 18:15 Poster E

Controlled growth of high aspect-ratio single-crystalline gold-platelets — •Enno Krauss[1], René Kullock[1], Guilherme Stein[1], Peter Geisler[1], and Bert Hecht[1,2] — [1]NanoOptics & Biophotonics Group, Experimentelle Physik 5, Physikalisches Institut, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [2]Röntgen Research Center for Complex Material Systems (RCCM), Am Hubland, 97074 Würzburg, Germany

Advances in nano-fabrication increase the need for high-quality single-crystalline gold-substrates that combine large areas to enable lithographic methods with low and tunable thickness. We present a simple recipe to chemically grow high quality single-crystalline gold-platelets with thicknesses of less than 20 *nm* combined with edge lengths up to 0.2 *mm*. The reactants are tuned and their impact on the growth-velocities of height and lateral size is statistically investigated. By varying the chemical environment during growth, the thickness can be tuned independently of the lateral size.

O 24.7 Mon 18:15 Poster E

Construction of a tip-enhanced Raman spectroscopy system and gold tip fabrication — •Marcel Weinhold[1], Thomas Sander[1], Jalmar Tschakert[2], Thomas Göddenhenrich[2], André Schirmeisen[2], Sangam Chatterjee[1], and Peter J. Klar[1] — [1]Justus-Liebig-Universität Gießen, I. Physikalisches Institut, Heinrich-

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Raman spectroscopy is a powerful technique for analyzing molecular vibrations as well as lattice dynamics in bulk materials. However, Raman signals are of an weak intensity and the scattering volume probed is rather large, roughly about $(500\ \text{nm})^3$. Metallic Scanning Probe Microscope (SPM) tips acting as nanoantennas enhance the signal in a small area (hot-spot) by several orders of magnitude. The phenomenon is known as tip-enhanced Raman spectroscopy (TERS). Due to the fact that reliable tip preparation is still challenging, we fabricated suitable tips by etching a gold wire, sputtering a thin layer of gold on standard Si AFM-tips, and by using an Au e-beam resist. These tips were analyzed with respect to surface roughness, apex radius, and enhancement factor. The latter investigations were carried out on the TERS-system constructed by us and compared with studies on a commercially available one.

O 24.8 Mon 18:15 Poster E

Surface potential studies on nanostructured plasmonic films under monochromatic illumination — •Ömer Akay[1], Eser M. Akinoglu[1,2], Klaus Schwarzburg[3], and Michael Giersig[1,3] — [1]Freie Universität Berlin, Department of Physics, Berlin, Germany — [2]Max-Planck-Institut für Kolloid- und Grenzflächenforschung, Potsdam-Golm Science Park, Potsdam, Germany — [3]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Institut Nanoarchitekturen für die Energieumwandlung, Berlin, Germany

Recently, surface potential changes were observed when plasmon active and optically thin metal films with periodic perforations on the nanoscale are illuminated with monochromatic light in the range of the plasmon resonance of the studied nanostructured film. This effect is described as a plasmoelectric effect that could convert optical energy into electrical potential differences in absence of semiconductors. An applied fabrication method to obtain plasmon active nanostructured metallic films with hexagonally ordered perforations is nanosphere lithography (NSL) in conjunction with plasma etching and physical vapour deposition. We present the characterisation of our systems with optical spectroscopy, atomic force microscopy (AFM) and we study the impact of monochromatic light on plasmon active optically thin and nanostructured metallic films via surface potential measurements using Kelvin probe force microscopy (KPFM) under simultaneous illumination in the energy range of the plasmon resonance peak of our system towards observing plasmoelectric effects.

O 24.9 Mon 18:15 Poster E

Plasmonically enhanced perovskite solar cells for photovoltaics — •Jonas Schwenzer[1], Domenico Paone[1], Justus Back[2], Sabine Ludwigs[2], and Harald Giessen[1] — [1]4th Physics Institute and Research Center SCOPE, University of Stuttgart, Germany — [2]Institut für Polymerchemie, Universität Stuttgart, Germany

Perovskite solar cells are the most promising alternative to silicon solar cells. Their record efficiency has increased from 9% to over 20% within the last three years. Further improvements are only possible if the photon to electron conversion efficiency can be increased. Here, we incorporated gold nanoparticles into the alumina scaffolding layer of perovskite solar cells to excite localized surface plasmon resonances. We investigated the short circuit current, open circuit voltage, external quantum efficiency, and power conversion efficiency in dependence of the gold nanoparticle concentration. A decrease in voltage was compensated by an increased current for optical densities below 0.1. Hence, the efficiency could be increased by 53% and 32% for optical densities of 0.05 and 0.1, respectively. Higher nanoparticle concentrations lead to decreased voltages and currents. Thus, we conclude that low concentrations of gold nanoparticles can be used to increase the current and thereby the performance of perovskite solar cells.

O 24.10 Mon 18:15 Poster E

Nonlinear holography using plasmonic metasurfaces — •Bernhard Reineke[1], Guixin Li[2], Shumei Chen[2], Franziska Zeuner[1], Nitipat Pholchai[3], Polis Wing Han Wong[4], Edwin Yue Bun Pun[4], Kok Wai Cheah[2], Shuang Zhang[2], and Thomas Zentgraf[1] — [1]Department of Physics, University of Paderborn, Warburger Straße 100, 33098 Paderborn — [2]School of Physics and Astronomy, University of Birmingham, Birmingham B15 2TT, UK — [3]Department of Industrial Physics and Medical Instrumentation, King Mongkuts University of Technology North Bangkok, 1518 Pibulsongkram Road, Bangkok 10800, Thailand — [4]Department of Electronic Engineering, City University of Hong Kong, 83 Tat Chee Avenue, Hong Kong

Recently it was shown that high-resolution holograms can be realized by using plasmonic metasurfaces. Combining nonlinear metasurfaces and holography can lead to new highly unconventional and versatile optical devices.

Here, we show a way to generate nonlinear holograms in the visible spectral range by using Second Harmonic Generation. For this purpose we fabricated a plasmonic nonlinear metasurface consisting of plasmonic nanoantennas. The desired phase for the hologram is hereby encoded in the arrangement and orientation of the antennas. By imaging the nonlinear second harmonic signal from the sample when illuminated with RCP or LCP short laser pulses we can reconstruct the image. Furthermore, we demonstrate that multiplexing of holographic images can be obtained.

O 24.11 Mon 18:15 Poster E

Large-area olasmonic devices for hydrogen sensing — •Ramon Walter, Nikolai Strohfeldt, Florian Sterl, Jonas Schwenzer, and Harald Giessen — 4th Phsics Institute and Research Center SCOPE, University of Stuttgart

Hydrogen has the potential to be a source of clean energy when used in fuel cells. However, it also poses potential hazards. A sensitive and reliable sensor can reduce this risk. Plasmonics can serve as an ideal building block for such sensor devices. By changing the optical properties of such a device under hydrogen exposure, the plasmon resonance shifts depending to the amount of hydrogen.

An ideal plasmonic material is gold. Due to the fact that gold nanoparticles are not reacting to hydrogen, it is necessary to cover these particles with a dielectric film consisting of hydrogen sensitive and transparent films, like Titaniumdioxide and zinc oxide.

We present the feasibility of such devices, using TiO2. By using a combination of directional argon-ion-beam-etching and colloidal lithography we produce gold nanodisks on a large-area scale. By spincoating we deposit a thin film of TiO2 on top and finally add a thin palladium catalyst layer. The resulting device shows a well modulated resonance with low transmission. By changing from pure nitrogen atmosphere to a hydrogen content of 5 %, the resonance shifts to longer wavelengths and the transmission increases.

The sensitivity of our design can optimized by tailoring thickness of the dielectric layer, leading to industrially viably hydrogen sensor coatings for a multitude of practical applications.