O 46: Plasmonics and Nanooptics IV: Fabrication and Applications

Time: Wednesday 10:30–13:00 Location: MA 042

O 46.1 Wed 10:30 MA 042

Electron-beam-induced synthesis and characterization of random plasmonic gold nanoparticle assemblies — •Kristina Weinel[1,2], Johannes Schultz[2], Daniel Wolf[2], Leonardo Agudo Jácome[1], Axel Lubk[2,3], and Bernd Büchner[2,3] — [1]Federal institute of materials research and testing, Berlin, Germany — [2]Leibniz institute for solid state and materials research Dresden, Dresden, Germany — [3]Institute of solid state and materials physics, Technische Universitaet Dresden (TUD), Dresden, Germany

Several studies have been shown that the electron beam can be used to create nanomaterials from microparticle targets in situ in a transmission electron microscope (TEM). Here, we show how this method has to be modified in order to synthesize plasmonic gold nanoparticles (NPs) on insulating silicon oxide substrate by employing a scanning electron microscope with a comparatively low acceleration voltage of 30 kV.

The synthesized NPs exhibit a random distribution around the initial microparticle target: Their average size reduces from 150 nm to 3 nm with growing distance to the initial Au microparticle target. Similarly, their average distance increases. The synthesized NP assemblies therefore show distinctly different plasmonic behaviour with growing distance to the target, which allows to study consequences of random hybridization of surface plasmons in disordered system, such as Anderson localization. To reveal the surface plasmons and their localization behaviour we apply electron energy loss spectroscopy in the TEM.

O 46.2 Wed 10:45 MA 042

Controlling Nanoparticle Distance by On-surface DNA-origami Folding — •Zhe Liu[1], Zunhao Wang[2], Jannik Guckel[2], Daesung Park[2], Ziba Akbarian[1], Uta Schlickum[1], and Markus Etzkorn[1] — [1]Technische Universität Braunschweig, 38106 Braunschweig, Germany — [2]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany

This study introduces a novel method that combines top-down lithography with bottom-up DNA origami techniques to achieve accurate manipulation of nano-objects on pre-patterned silicon surfaces. Using electron beam lithography, we determined specific sites where DNA origami-nanoparticle hybrid nanostructures can adsorb, enabling precise and controlled arrangement of adsorption patterns in several dimensions. The specific adsorption of the DNA origami leads to controllable deformations if the origami helices are defined by the shape of the pre-patterned adsorption site. This approach also works for origami functionalized with two gold nanoparticles (AuNPs). This unique behavior allows for tunable assembly of plasmonic dimer nanoarrays, showing the ability to manipulate the center-to-center distance of AuNPs dimers on the origami template. The efficiency and precision of this technique were confirmed with Raman spectroscopy of dye molecules coated on the AuNPs. The results show the great potential for creating nanoarrays with precise control over nanoscale dimensions and orientation. This opens up new possibilities for using these nanoarrays in fields such as biomedicine and nano-photonics.

O 46.3 Wed 11:00 MA 042

Comparison of plasmonic and dielectric phase-change materials by modifying magnetic infrared resonances — •Lukas Conrads, Andreas Hessler, Matthias Wuttig, and Thomas Taubner — I. Institute of Physics (IA), RWTH Aachen University

For miniaturized active nanophotonic components, resonance tuning of nanoantennas is a key ingredient. Phase-change materials (PCMs) have been established as prime candidates for non-volatile resonance tuning based on a change in refractive index [1]. Currently, a novel material class of switchable infrared plasmonic PCMs, like In_3SbTe_2 (IST), is emerging. Since IST can be locally optically switched between dielectric (amorphous phase) and metallic (crystalline phase) states in the whole infrared range, it becomes possible to directly change the geometry and size of nanoantennas to tune their infrared resonances [2]. Here, we demonstrate tuning magnetic dipole (MD) resonances of split-ring resonators (SRRs) by modifying the arm length of IST SRRs [3] and by locally addressing the antenna hotspots of aluminum SRRs covered by amorphous $Ge_3Sb_2Te_6$ [4]. Finally, we compare both PCMs by investigating the MD resonance tuning of slit antennas [5]. Our concepts are well-suited for rapid prototyping, speeding up workflows for engineering ultrathin, tunable, plasmonic devices for infrared nanophotonics, telecommunications or (bio)sensing.

[1] Wuttig et al., *Nat. Photon.* **11**, 465 (2017) [2] Heßler et al., *Nat. Commun.* **12**, 924 (2021) [3] Heßler, Conrads et al., *ACS Photon.* **9**, 5 (2022) [4] Conrads et al., *Adv. Opt. Mat.* **11**, 17 (2023) [5] Conrads et al., *ACS Nano* submitted

O 46.4 Wed 11:15 MA 042

Towards a Dynamic and Switchable All-Optical Image Processing Device — •Dominik Ludescher[1], Lukas Wesemann[2], Lincoln Clark[2], Mario Hentschel[1], Ann Roberts[2], and Harald Giessen[1] — [1]4th Physics Institute and Research Center SCoPE, University of Stuttgart, Germany — [2]School of Physics, the University of Melbourne, Melbourne, VIC 3010, Australia

The urge for all-optical image filtering without the need for postprocessing is increasing with the requirement for fast operation, reliability, and robustness. This study unveils a fascinating new approach towards switchable image filtering devices drawing inspiration from the concept of a Salisbury screen. This novel method paves the way to real-time dynamic image processing holding immense potential in various fields of applications such as microscopy, facial recognition, or biological imaging. The general concept is based on the possibility of altering the properties of a conducting polymer by driving its inherent electrochemical redox reaction. By simply changing the applied voltage, the material properties such as the refractive index can be adapted. This change in the refractive index can be directly utilized to adapt the functionality of devices such as an optical filter. Besides turning the operation of a system fully on and off, a gradual change of the refractive index can be used to continuously vary the performance of the image processing device. Combining this approach with the concept of Fourier filtering certain spatial frequencies known from static approaches such as the Salisbury screen generates the possibility of working our way towards devices with adaptive properties.

O 46.5 Wed 11:30 MA 042

Accelerating Plasmonic Hydrogen Sensors by Transformer-Based Deep Learning — •Viktor Martvall[1], Henrik Klein Moberg[1], Athanasios Theodoridis[1], David Tomeček[1], Pernilla Ekborg Tanner[1], Sara Nilsson[1], Giovanni Volpe[2], Paul Erhart[1], and Christoph Langhammer[1] — [1]Department of Physics, Chalmers University of Technology, Gothenburg, Sweden — [2]Department of Physics, University of Gothenburg, Gothenburg, Sweden

Fast and accurate H_2 sensors are needed for H_2 technologies to address safety concerns associated with the high flammability of H_2-air mixtures. Plasmonic optical hydrogen sensors, monitoring H_2 through changes in the localized surface plasmon resonance peak of metallic nanoparticles absorbing hydrogen, shows promise. In idealized H_2-vacuum conditions, they have met the US department of energy's target of a response time < 1 s for concentrations < 0.1 vol.% H_2. However, further advances are required to meet this target in a realistic environment, where the presence of other molecules slows down the sensor response. Here, we accelerate sensor response by developing a deep learning (DL) model to predict the H_2 % from the time-dependent extinction spectrum. We apply the DL model to a $Pd_{70}Au_{30}$ alloy plasmonic sensor in Ar carrier gas. Compared to the conventional analysis, collapsing each spectrum to a single spectral descriptor related to the H_2 % via a power law, our model demonstrates up to a 40 times faster sensor response time during rapid H_2 pulses. Also, we illustrate that it can faster discern and quantify gradual changes in H_2 %.

O 46.6 Wed 11:45 MA 042

Mie voids for all-optical sizing and counting of microplastics — •Mario Hentschel[1], Julian Karst[1], Lukas Wesemann[2], and Harald Giessen[1] — [1]4th Physics Institute and Research Center SCoPE, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]3ARC Centre of Excellence for Transformative Meta-Optical Systems, School of Physics, The University of Melbourne, Victoria 3010, Australia

Manipulating light on the nanoscale has become a central challenge in metadevices, resonant surfaces, nanoscale optical sensors and many more, and it is largely based on resonant light confinement in dispersive

and lossy metals and dielectrics. In contrast, Mie void resonances observed in air-filled cavities in dielectric host materials have been shown to resonantly confine light in air, thus circumventing this loss and dispersion. One of the key benefits afforded by the Mie void concept is the full access to the model volume inside the air-filled void. This allows for maximised interaction of the modal intensities with analytes and other systems of interest, consequently allowing to maximise sensitivities. We demonstrate this potential for nanophotonic sensing and show that Mie voids are ideal sensors for the detection and sizing of nano- and micro-sized particles. We utilize Mie voids of different size and depth for the characterization of ensembles of polystyrene beads as model system for micro- and nanoplastic. We demonstrate that our ansatz allows for the all-optical sizing and counting of micro- and nanoplastic samples, thus being of large environmental importance.

O 46.7 Wed 12:00 MA 042

High-refractive Index Nanodisk Arrays with Hyperuniform Disorder — •Davy Tesch, Koundinya Upadhyayula, Bodo Fuhrmann, Alexander Sprafke, and Ralf Wehrspohn — Martin Luther University Halle-Wittenberg, 06120 Halle, Germany

Light-scattering metasurfaces with tailored disorder, especially Hyperuniform disorder (HuD), have recently garnered interest within the photonics community. HuD promises various properties that, until now, have only been associated with either periodic or random structures. The combination of strong diffraction from periodic structures and the spectrally broadband response of disordered structures holds promise for light scattering.

In this work, we experimentally investigate HuD nanodisk arrays made of amorphous silicon (a-Si). The high refractive index of a-Si enables the excitation of pronounced Mie resonances in the nanodisks. However, the optical response of the nanodisk array is significantly impacted by the arrangement of the nanodisks, namely the structure factor. The interaction between the form factor and HuD structure factor is central to our investigations. We employ a scalable fabrication process to experimentally prepare HuD nanodisk arrays using a-Si optimized for low absorption as the nanodisk material. Our results indicate a substantial impact of HuD on the optical response of the system. Furthermore, we also examine more complex systems, such as HuD nanodisk arrays at a defined distance above metallic mirrors.

O 46.8 Wed 12:15 MA 042

A numeric analysis of the angular distribution of dielectric Mie void structures — •Benjamin Reichel[1], Michelle Pfahl[1], Serkan Arslan[1], Adrià Canós Valero[1], Mario Hentschel[2], Thomas Weiss[2], and Harald Giessen[1] — [1]4th Physics Institute and Research Center SCoPE, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Institute of Physics, University of Graz, and NAWI Graz, Universitätsplatz 5, Graz 8010, Austria

Controlling the behavior of light at the nanoscale is a significant challenge in various applications such as metadevices, diffraction gratings and resonant surfaces. The confinement of light is one of the typical interactions used in such devices. Recently, Mie voids have emerged as a promising platform for confining electromagnetic waves, possibly extending down to ultraviolet wavelengths in air. Therefore understanding and theoretical modeling the electromagnetic scattering behaviour of Mie voids are crucial for their effective use. In this study, we conduct a numerical study of the scattering behaviour for a periodic dielectric Mie void metasurface, alongside simulations for single Mie voids using widely used commercial software, COMSOL Multiphysics, and an in-house MATLAB code. These insights will be important in the development of resonant meta-structure designs. Finally leveraging the full resolution of electromagnetic fields within the void will open avenues for novel spectroscopy and active manipulation strategies, for example for coupling single quantum emitters via Mie voids to directed radiative modes.

O 46.9 Wed 12:30 MA 042

Dissipation-engineered plasmonic ratchet — •Anna Sidorenko[1], Jan Mathis Giesen[2], Sebastian Eggert[2], and Stefan Linden[1] — [1]Physikalisches Institut, Universität Bonn, Kreuzbergweg 24, 53115 Bonn, Germany — [2]Physics Department and Research Center OPTIMAS, University of Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

A ratchet effect is an ability to convert periodic drive into directed motion without a bias force. The working principle of a ratchet relies on the breaking of space- and time-reversal symmetry that would otherwise not allow a directed current. Based on the quantum-optical analogy, we propose a new design of a plasmonic ratchet. Our implementation features a trimerized lattice where losses are periodically varied while hopping amplitudes and on-site potentials are kept constant. The plasmonic structures were fabricated by means of two-step electron beam lithography. In the produced arrays, the spatial evolution of surface plasmon polaritons (SPPs) was recorded by leakage radiation microscopy. We observe both in numerical calculations and in our measurements a directional transport of SPPs in such an array in a single preferred direction. Control of directionality purely by tailored dissipation distinguishes our system from a simple combination of directional couplers. We examine the effect of different dissipation strengths and durations on the efficiency of transport.

O 46.10 Wed 12:45 MA 042

Very thin plasmonic films for optical mirrors: influence of the dielectric function on the spectral properties — •Manuel Gonçalves — Ulm University - Inst. of Experimental Physics, Albert-Einstein-Allee 11, 89081 Ulm, Germany

Metallic thin films combined with dielectric layers allow a large variety of optical effects, as broadband high reflectivity, narrow spectral dips due to surface plasmon resonances and almost total absorption by surface nanostructuring.

In this contribution, it is shown that very thin films of few nanometers thickness can produce broadband resonances with high contrast in the vis-NIR reflectance spectrum, when interacting with an underlying high reflectance mirror. However, the design of such colored mirrors cannot employ the classical dielectric function of the bulk material. Several effective medium theory (EMT) models have been proposed for quasi-percolated thin films. A study of these models and their application in the design of the reflectance spectra is presented.