O 59: Photonics and Nanooptics III: Fabrication and Characterization

Time: Wednesday 15:00–18:15 Location: S051

O 59.1 Wed 15:00 S051

Magnesium for Active Plasmonics in the Visible Wavelength Range — •Florian Sterl, Nikolai Strohfeldt, Ramon Walter, Andreas Tittl, and Harald Giessen — 4th Physics Institute and Research Center SCoPE, University of Stuttgart, Germany

Investigating new materials plays an important role for advancing the field of nanoplasmonics. Here we fabricate nanodisks from magnesium and demonstrate tuning of their plasmon resonance throughout the whole visible wavelength range by changing the disk diameter. Furthermore, we employ a catalytic palladium cap layer to transform the metallic Mg nanoparticles into dielectric magnesium hydride nanoparticles when exposed to hydrogen gas. We prove that this transition can be reversed in the presence of oxygen. The addition of a titanium buffer layer which separates the Mg and Pd layers from each other significantly enhances the (un)loading dynamics of the particles. During the transition from Mg to MgH_2, the plasmon resonance disappears within minutes. When the particles are dehydrogenated, the resonance is fully restored in 10-20 minutes. Large-area samples covered with such nanodisks thus feature an extinction peak that can be repeatedly switched on and off or kept at any intermediate state, which offers new perspectives for active plasmonic metamaterials. Our findings can also contribute to a better understanding of the H_2 diffusion dynamics in Mg, which can lead to new insights for H_2 storage applications. To this end, we use dark field spectroscopy to observe the scattering spectrum of single Mg nanocrystals during (de)hydrogenation, and make first steps to reproduce our observations in numerical simulations.

O 59.2 Wed 15:15 S051

Thermodynamics of Hydrogen in Palladium Nanoparticles — •Nikolai Strohfeldt[1], Ronald Griessen[2], and Harald Giessen[1] — [1]4. Physics Institute and Research Center SCoPE, University of Stuttgart, Germany — [2]Faculty of Sciences, Division of Physics and Astronomy, VU University, Amsterdam, The Netherlands

Palladium-hydrogen is a prototypical metal-hydrogen system, which is well suited for active plasmonics. Upon hydrogenation of Pd to PdH_x, the dielectric function and particle size changes quite severely. These changes can be traced through the plasmonic resonance, in situ, which enables us to optically study microscopic changes in our system. Recently, a lot of attention has been devoted to the ab- and desorption of hydrogen in nanosized plasmonic palladium particles. Here, we show that the large body of data on the thermodynamics of palladium nanostructures available so far in literature exhibits general patterns that lead to unambiguous conclusions about the detailed microscopic processes involved in H absorption and desorption in Pd nanoparticles that can be used as prototypes for active plasmonic elements. On the basis of a remarkably robust scaling law for the hysteresis in absorption-desorption isotherms, we also show that hydrogen absorption in palladium nanoparticles is consistent with a coherent interface model and is thus clearly different from bulk Pd behaviour. However, H desorption occurs fully coherently only for small nanoparticles at temperatures sufficiently close to the critical temperature. For larger particles it is partially incoherent as in bulk, where dilute α-PdH_x and high concentration β-PdH_x phases coexist.

O 59.3 Wed 15:30 S051

Simple, but complicated surface chemistry for Surface Plasmon resonance sensor — Thidarat Wangkam[1], •Toemsak Srikhirin[2], Boonsong Sutapun[3], Kawin Nawattanapaiboon[2], Supaporn Kanjai[1], Armote Somboonkaew[4], and Rathasart Amarit[4] — [1]Department of Industrial Physics and Medical Instrumentation, Faculty of Applied Science, King Mongkut*s University of Technology North Bangkok, Thailand — [2]Materials Science and Engineering Programme, Faculty of Science, Mahidol University, Bangkok — [3]School of Electronics Engineering, Suranaree University of Technology, Thailand — [4]Photonics Technology Laboratory,National Electronics and Computer Technology Center,Thailand

Thin metal planar surface would bring us to the fascinated plasmon resonance phenomena. This characteristic is specified some optical properties on the surface under a penetration depth about 200-300 nm on the metal surface. Surface plasmons resonance sensor has been employed in a wide spectrum of studies ranging from biosensor, electrochemistry, thin film, surface plasmon microscopy and nanoparticles. This work would be shown a variety of surface chemistry which were performed on the surface Plasmon sensor. Multiplexed of gold nanoparticle and magnetic nanoparticle were combined with a variety of biological samples (Protein chip, allergy, biomarkers etc.) for real-time detection on SPR spectroscopy. Moreover, the SPR sensor chip has been designed with simple platform for a complicated body fluids samples for clinical diagnostic further.

O 59.4 Wed 15:45 S051

Bottom-up synthesis of large area single-crystalline atomically flat gold flakes with single-crystalline silver cubes as single quantum emitter nanoantennas — •Simon Ristok, Bettina Frank, and Harald Giessen — University of Stuttgart, 4th Physics Institute and Research Center SCoPE, Pfaffenwaldring 57, 70569 Stuttgart, Germany

When using quantum emitters such as NV centers in diamond, quantum dots, or dye molecules as effective photon sources, it is often necessary to control certain characteristics of the emitted radiation, i.e., the emission rate and direction. A promising approach is the coupling of the emitters to a plasmonic nanoantenna. In this work, we fabricate plasmonic nanopatch antennas using exclusively bottom-up methods. The antennas consist of silver nanocubes which are positioned over the atomically flat surface of a gold microplatelet. Both Ag nanocubes and Au microplatelets are single-crystalline and are separated by a dielectric polymer spacer layer. The plasmonic resonance of the antennas can be tuned by varying the size of the Ag nanocubes and the thickness of the nm-thick spacer layer. The further steps include the embedding of fluorescent dye molecules into the gap of the nanopatch antenna, followed by fluorescence enhancement and lifetime measurements. Investigating this system can help us understand the prerequisites to expand the range of emitters also to NV centers and quantum dots.

O 59.5 Wed 16:00 S051

Helium-Ion Milling of Gold Nanoantennas: Toward Plasmonics with Nanometer Precision — •André Beyer[1], Henning Vieker[1], Heiko Kollmann[2], Xianji Piao[3], Namkyoo Park[3], Martin Silies[2], Christoph Lienau[2], and Armin Gölzhäuser[1] — [1]Physics of Supramolecular Systems and Surfaces, Bielefeld University, 33615 Bielefeld — [2]Institute of Physics and Center of Interface Science, Carl von Ossietzky University Oldenburg, 26129 Oldenburg — [3]Photonic Systems Laboratory, School of Electrical Engineering, Seoul National University, 151-742 Seoul, Korea

Plasmonic nanoantennas are versatile tools for coherently controlling and directing light on the nanoscale. For these antennas, current fabrication techniques such as electron beam lithography (EBL) or focused ion beam (FIB) milling with Ga^+-ions routinely achieve feature sizes in the 10 nm range. However, they suffer increasingly from inherent limitations when a precision of single nanometers down to atomic length scales is required, where exciting quantum mechanical effects are expected to affect the nanoantenna optics. Here, we demonstrate that a combined approach of Ga^+-FIB and milling-based He^+-ion lithography (HIL) for the fabrication of nanoantennas offers to readily overcome some of these limitations. Gold bowtie antennas with 6 nm gap size were fabricated with single-nanometer accuracy and high reproducibility. Using third harmonic (TH) spectroscopy, we find a substantial enhancement of the nonlinear emission intensity of single HIL-antennas compared to those produced by state-of-the-art gallium-based milling.

O 59.6 Wed 16:15 S051

Long-range plasmon coupling in self-assembled colloidal monolayers — •Joseph P.S. Fitzgerald, Kirsten Volk, Tobias Honold, and Matthias Karg — Physical Chemistry I, University of Bayreuth, Germany

Localized surface plasmon resonances (LSPRs) of metal nanoparticles show large interaction cross sections with incident light and intense surface near-fields, but with large optical losses and short coherence times. Two-dimensional lattices of plasmonic particles can support high Q-factor collective resonances, with increased intensity, reduced losses, and increased excitation lifetimes. Here, we report on the plasmonic properties of highly-ordered monolayers of metal-hydrogel core-shell particles prepared using an interfacial self-assembly protocol [1].

This method allowed us to produce hexagonal lattices with a range of interparticle spacings 350-550 nm [2]. We found that the resonance peak position, intensity, and width depend strongly on the interparticle spacing. We show that this is due to long-range dipole-dipole coupling between individual nanoparticles using the coupled dipole approximation (CDA). The results are further supported by finite-difference time-domain (FDTD) calculations, allowing detailed analysis of lattice near-fields. The presented approach is an important step toward higher Q-factor plasmonic materials for several nano-optical applications.

[1] T. Honold, K. Volk, A. Rauh, J.P.S. Fitzgerald, M. Karg. J. Mater. Chem. 3 (2015) 11449-11457.

[2] K. Volk, J.P.S. Fitzgerald, M. Retsch, M. Karg. Adv. Mater. (2015).

O 59.7 Wed 16:30 S051

Efficient Surface Plasmon Excitation via Inelastic Electron Tunneling — •Eric Jehnes and Lukas M. Eng — Institut für Angewandte Physik, TU Dresden, Deutschland

Surface plasmon polaritons (SPPs) can be described as electromagnetic waves that are localized at metal-dielectric interfaces. Such surface-bound fields are caused by electron-density oscillations that may be excited by both photons and electrons. While current research mostly focuses on light-excited SPPs, the interaction with charged particles such as electrons is often neglected.

This contribution concentrates on the excitation of SPPs via inelastic electron tunneling in metal-insulator-metal and metal-insulator-semiconductor junctions. Such tunneling junctions emit visible light [1] of a specific wavelength and polarization, clearly depending on the nanoscopic structure of the metal electrode. Far-field imaging and spectroscopic measurements were used to characterize the fabricated samples. The conversion from electrical to optical signal is limited only by the tunneling time itself and enables high bandwidths, which is of relevance for telecommunication and optical interconnect applications. With current lithographic techniques at hand, nanoscopic light emitting tunneling junctions can easily be integrated into opto-electronic devices.

[1] J. Lambe and S. L. McCarthy, Phys. Rev. Lett. 37, 923 (1976)

O 59.8 Wed 16:45 S051

Plasmonic Coupling in Core/Satellite Nanoclusters — •Christian Kuttner[1,2], Roland Höller[1,2], Martin Dulle[3], Sabrina Thomä[2], Martin Mayer[1], Stephan Förster[3], Andreas Fery[1,2], and Munish Chanana[2,4] — [1]Nanostructured Materials, Leibniz Institute of Polymer Research, 01069 Dresden, Germany — [2]Physical Chemistry II, University of Bayreuth, 95440 Bayreuth, Germany — [3]Physical Chemistry I, University of Bayreuth — [4]Institute of Building Materials, ETH Zürich, 8093, Zürich, Switzerland

We present the fundamental coupling scenarios in core/satellite nanoclusters prepared from colloidal assembly of small spherical gold or silver NPs (as satellites) onto larger gold NPs (as cores). The resulting dispersions exhibit high colloidal stability and allowed for the precise characterization of the core/satellite architecture in dispersion by small-angle X-ray scattering (SAXS).
Strong near-field coupling between the building blocks results in distinct regimes of dominant satellite-to-satellite and core-to-satellite coupling. High robustness against satellite disorder was proved by UV/Vis diffuse reflectance (integrating sphere) measurements. Generalized multi particle Mie theory (GMMT) simulations were employed to describe the electromagnetic coupling within the nanoassemblies.

Roland P. M. Höller *et al.*, **2015** (submitted).

O 59.9 Wed 17:00 S051

Improved anodisation of aluminium thin films through reactive sputtering — •Fabian Patrovsky[1], Vera Fiehler[1], Susan Derenko[1], Matthias Böhm[1], Stephan Barth[2], Hagen Bartzsch[2], Peter Frach[2], and Lukas M. Eng[1] — [1]Institut für Angewandte Physik, TU Dresden, Deutschland — [2]Fraunhofer-Institut für Organische Elektronik, Elektronenstrahl- und Plasmatechnik FEP, Dresden, Deutschland

Anodised aluminium oxide (AAO) templates are widely used to fabricate plasmonic nanorod and nanowire arrays as well as sophisticated meta-materials [1]. However, manufacturing those structures on a substrate has always proven to be very difficult; either an elaborate membrane transfer is necessary [2] or previously deposited aluminium layers (CVD or PVD) have to be anodised directly, which often leads to poor results [3].

In this study we present a method which greatly improves anodisation of sputtered aluminium thin films. By introducing oxygen into the sputtering plasma, we create a highly amorphous aluminium layer that exhibits a very low defect density after anodisation, while yielding highly reproducible results. This approach enables us to reliably fabricate plasmonic nanorod arrays with improved optical properties.

[1] A. Eftekhari, Nanostructured Materials, Wiley-VHC, (2008)

[2] Z. Zhan and Y. Lei, ACS Nano 8, 3862 (2014)

[3] M. Es-Souni and S. Habouti, Frontiers in Metamaterials 1 (19), (2014)

O 59.10 Wed 17:15 S051

Seed-Mediated Growth of Bimetallic Plasmonic Nanostructures and their Use for Chemical Reaction Sensing — •Domenico Paone, Nikolai Strohfeldt, Florian Sterl, and Harald Giessen — 4th Physics Institute and Research Center SCOPE, University of Stuttgart

Plasmonic nanostructures show unique optical properties by focusing down light into the sub-wavelength scale. These properties can be used in several practical applications like e.g. gas or chemical sensing. The resonance behavior of such nanoparticles is strongly size and shape dependent. Therefore, it is essential to develop methods for growing nanostructures in various geometries at high yield and low costs. In this work, we present a seed-mediated growth method for gold nanorods that enables the variation of the rodlength using CTAB-capping. We characterize these nanorods optically with ensemble UV-Vis spectroscopy. To study the properties and quality of individual nanorods, we also employ single-particle dark-field spectroscopy. Furthermore, we synthesize Pd overcoated Au nanorods to investigate optically the hydrogen diffusion into extremely small, but well defined palladium structures. We find pronounced spectral shifts upon exposure to different hydrogen concentrations.

O 59.11 Wed 17:30 S051

Controlled Living Nanowire Growth: Precise Control over the Morphology and Optical Properties of AgAuAg Nanowires — •Martin Mayer[1], Leonardo Scarabelli[2], Katia March[3], Thomas Altantzis[4], Moritz Tebbe[5], Mathieu Kociak[3], Sara Bals[4], F. Javier García de Abajo[6], Luis M. Liz-Marzán[2], and Andreas Fery[1] — [1]Leibniz Institute of Polymer Research, Dresden, Germany — [2]CIC biomaGUNE, Donostia, Spain — [3]Laboratoire de Physique des Solides, University Paris-Sud, Orsay, France — [4]EMAT, University of Antwerp, Antwerp, Belgium — [5]Physical Chemistry II, University of Bayreuth, Bayreuth, Germany — [6]Institut de Ciencies Fotoniques, Barcelona, Spain

Inspired by the concept of living polymerization reaction, we are able to produce bimetallic noble metal nanowires with a precise control over their morphology and plasmonic properties. By establishing a constant silver deposition rate on the tips of pentatwinned gold nanorods used as seed cores, the lengths of the AgAuAg nanowires increases linearly in time with nanometer control.

Due to the extraordinary low polydispersity of the resulting nanowires, plasmonic modes up to the 8th order can clearly distinguished in UV–vis/NIR spectroscopy of colloidal solutions.

We analyze the spatial distribution and the nature of the plasmons on the single nanowire level by electron energy loss spectroscopy and obtain excellent agreement between measurements and electromagnetic simulations. This procedure opens up new possibilities for the exploitation of plasmon resonances in the near and mid IR regions.

O 59.12 Wed 17:45 S051

Complete analysis of plasmon transmission through top-down fabricated monocrystalline nanowires — •Enno Krauss[1], Gary Razinskas[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

Exact quantitative understanding of plasmon propagation along nanowires is mandatory for designing and creating functional devices. We investigate plasmon transmission through top-down fabricated single crystalline gold nanowires on a glass substrate. We show that the transmission through finite length nanowires can be described by Fabry-Pérot oscillations that beat with free-space propagating light launched at the incoupling end. Using this extended Fabry-Pérot model, experimental and simulated length dependent transmissions

agree quantitatively with a fully analytical model.

O 59.13 Wed 18:00 S051

3D chiral metamaterials made by direct laser writing — •Ioanna Sakellari[1], Xinghui Yin[1], Maxim Nesterov[1], Andre Radke[1], Konstantina Terzaki[2], Aggelos Xomalis[2], Maria Farsari[2], and Harald Giessen[1] — [1]4th Physics Institute and Research Center Scope, University of Stuttgart, Stuttgart, Germany — [2]Institute of Electronic Structure and Laser - Foundation for Research and Technology Hellas (IESL-FORTH), Heraklion, Greece

Direct Laser Writing (DLW) by two photon absorption has proven to be a versatile technique for the creation of arbitrary solid 3D polymer nanostructures for photonics, biomedical and microfluidic applications. By employing laser intensities that are only slightly above the nonlinear polymerization threshold, structures with submicron resolution can be fabricated.

In this work, we combine DLW and subsequent electroless silver plating to experimentally and theoretically study the plasmonic version of a 3D chiral meta-atom, which comprises of a loop-wire structure or the so-called twisted omega particle. In this case, the metallic wire of finite length supports an electric dipole, whereas the loop acts as a split ring resonator which exhibits a magnetic dipole resonance leading to the separation of right handed circularly polarized light (RCP) and the left-handed one (LCP). FTIR spectroscopy is utilized to electromagnetically characterize the fabricated structures for both circular and linearly polarized waves demonstrating strong CD response in the IR region in accordance with theoretical predictions.