HL 23: Plasmonics and Nanophotonics I (Joint Session with DS/O)

Time: Tuesday 10:30–13:00 Location: H2

HL 23.1 Tue 10:30 H2

Electrochemically tunable photonic metamaterial — •Lihua Shao, Stefan Linden, Matthias Ruther, Jörg Weissmüller, and Martin Wegener — Institut für Nanotechnologie and DFG-Center for Functional Nanostructures (CFN), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

We report experiments to combine two approaches for designing functional nanomaterials. Photonic metamaterials provide a strategy for obtaining unconventional optical response - in the extreme, negative refractive indices - by lithographically structured elements like arrays of split-ring resonators (SRR). Nanomaterials with tunable electronic structure exploit large specific surface area of metal nanostructures to tune the surface properties through the controlled space-charge regions for tuning macroscopic properties. The combination is a photonic metamaterial in which the space-charge at the surface of SRR is controlled via an applied potential, leading to a tunable optical resonance. We report first results support this concept. SRR structures with resonance frequencies in the near infrared are immersed into aqueous electrolytes as working electrode in an electrochemical experiment. Varying the electrode potential, E, induces a space-charge layer at the metal surface as part of the electrochemical double-layer. We find the resonance frequencies vary linearly, reversibly, and reproducibly with E, with a blue shift for negative potential. A tentative explanation is based on the effective thickening of the SRR by the excess electrons, which changes the SRR aspect ratio. The observation of larger frequency shift for thinner SRR's is compatible with this scenario.

HL 23.2 Tue 10:45 H2

Mixing colours like nature — •Mathias Kolle, Maik Scherer, Pedro Cunha, Fumin Huang, Jeremy Baumberg, and Ullrich Steiner — Cavendish Laboratories, University of Cambridge, UK

Biomimetic attempts to produce novel photonic structures have attracted increasing research interest in recent years. Nature offers us an enormous amount of multifunctional micro- and nanostructures, that provide outstanding, distinctive, dynamic and tailored colouration. A "brilliant" example is the indonesian butterfly *papilio blumei*, whose wing scales are covered with 5-10μm wide concavities, that are cladded with a perforated cuticle multilayer. The regularly shaped multilayer structure gives rise to very impressive colour mixing effects, accompanied by controlled change in light polarisation.

We have successfully replicated the intricate photonic structure of *papilio blumei* on the cm^2-scale in four simple steps involving colloidal templating, electrochemical growth and atomic layer deposition. A small conceptual modification of the original photonic structure leads to a completely different optical effect. Any freely chosen colour and its complementary hue can be separated and reflected into different directions while conserving a particular polarisation effect.

Since the procedures are easily up-scaleable, these biomimetic photonic structures have a huge potential for industrial applications in security printing, encoding of information, non-emissive display technology and other fields where distinct colours play an important role.

HL 23.3 Tue 11:00 H2

Optical properties of carpets of randomly grown silicon nanowires on glass — •Gerald Brönstrup and Silke Christiansen — Institut für Photonische Technologien e.V., Abt. Halbleiter-Nanostrukturen, 07745 Jena

Silicon Nanowires [SiNWs] have attracted much attention in the recent years as possible future building blocks for field effect transistors, sensors, photo detectors and solar cells. For the latter SiNWs grown on a cheap substrate like glass is of special interest. To build solar cells with high efficiencies a high absorption is mandatory. We present a study of the influence of the diameter on the reflection, transmission and absorption spectra of carpet like assembly of SiNWs grown on glass.

We grew SiNWs on glass using gold colloids of different fixed diameters to achieve a control over the diameter of the SiNWs. Then we measured the reflection R and transmission T using an integrating sphere. The absorption A was calculated using the simple formula A=1-T-R.

For a better understanding of the underlying physics of the absorption happening in SiNWs with diameters much smaller than the wavelength of the visible light we present a statistical model based on scattering cross sections calculated for single SiNWs using Mie-theory.

HL 23.4 Tue 11:15 H2

Suppressed transmission through ultrathin metal films by subwavelength hole arrays — •Julia Braun[1], Bruno Gompf[1], Uwe Huebner[2], and Martin Dressel[1] — [1]1. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart — [2]IPHT Jena, Albert-Einstein-Straße 9, 07745 Jena

If an opaque metal film is periodically perforated by tiny subwavelength holes, extraordinary high transmission is observed [1]. We investigate the transmission through subwavelength hole arrays (SWHA) in ultrathin semitransparent Au films with various periodicities and hole diameters and observe the opposite behavior: less light is transmitted through the pierced metal compared to the closed film. The samples were fabricated by optical interference and electron beam lithography in 12 nm and 20 nm thick Au films with periodicities between 250 nm and 400 nm, and than characterized in the frequency range 4400 cm^{-1} to 37000 cm^{-1} (0.6 eV to 4.6 eV). The optical properties of SWHA cannot be explained by a pure dielectric function, but show a strong $\vec{k}$-dependent behavior. In ultrathin Au films it is marked by the excitation of strongly damped antisymmetric short range surface plasmons. The obtained dispersion curves perfectly agree with this explanation when the altered dielectric function of the ultrathin Au films is taken into account [2].

[1] T.W. Ebessen, H.J. Lezec, H.F. Ghaemi, T. Thio, and P.A. Wolff, *Nature* **391**, 667 (1998).

[2] J. Braun, B. Gompf, G. Kobiela, M. Dressel, *Physical Review Letters* **103**, 203901 (2009)

HL 23.5 Tue 11:30 H2

Manipulation of fluorescence resonance energy transfer in single plasmonic nanoresonators — •Valerie Faessler, Calin Hrelescu, Sergiy Mayilo, Frank Jäckel, and Jochen Feldmann — Photonics and Optoelectronics Group, Department of Physics and Center for Nano Science (CeNS), Ludwig-Maximilians-Universität München, Amalienstrasse 54, 80799 München, Germany;

We show that fluorescence resonance energy transfer (FRET) between two organic chromophores can be manipulated in plasmonic nanoresonators consisting of two spherical gold nanoparticles.The nanoresonators can be tuned by varying the inter-particle distance or the nanoparticle size. This allows us to selectively modify the decay channels of the chromophores. FRET can be supressed if the molecules are placed in the nanoresonator at a certain distance from the nanoparticle surface. Furthermore we observe spectral shaping and intensity modulation of the fluorophore emision in the nanoresonators [1]. Correlated whitelight Rayleigh scattering and fluorescence microscopy data of the hybrid system are discussed in the framework of generalized Mie theory.

[1] M. Ringler, A. Schwemer, M. Wunderlich, A. Nichtl, K. Kürzinger, T. A. Klar, J. Feldmann Phys. Rev. Lett., 100, 203002 (2008)

HL 23.6 Tue 11:45 H2

Optical antenna thermal emitters — •Jon Schuller[1], Thomas Taubner[1,2], and Mark Brongersma[1] — [1]Stanford University, Stanford, CA, USA — [2]1. Physikalisches Institut, RWTH Aachen, Germany

Optical antennas are a critical component in nanophotonics research[1] and have been used to enhance nonlinear and Raman cross-sections and to make nanoscale optical probes [2]. In addition to their receiving properties, optical antennas can operate in broadcasting mode, and have been used to modify the emission rate[3] and direction [4] of individual molecules.

In these applications the antenna must operate at frequencies given by existing light emitters. Using thermal excitation of optical antennas, we bypass this limitation and realize emitters at infrared frequencies where sources are less readily available [5].

Specifically, we show that the thermal emission from a single SiC whisker antenna is attributable to well-defined, size- tunable Mie resonances. Furthermore, we derive a fundamental limit on the antenna emittance and argue theoretically that these structures are nearly ideal black-body antennas.

1. Schuck, P. J. et al., PRL 94, 017402 (2005).
2. Farahani, J. N., et al., PRL 95, 017402 (2005).
3. Kuhn, S., et al., PRL 97, 017402 (2006).
4. Taminiau, T. H., et al, Nature Photon. 2, 234-237 (2008).
5. Schuller, J.A. et al., Nature Photon. 3, 658-661 (2009).

HL 23.7 Tue 12:00 H2

Spatial Resolved Near Field Interference on Nanooptical Bowtie Antennas — •Pascal Melchior, Daniela Bayer, Christian Schneider, Martin Rohmer, Alexander Fischer, and Martin Aeschlimann — Fachbereich Physik and Research Center OPTIMAS, Technische Universität Kaiserslautern, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern, Germany

The response of metallic nanostructures is responsible for interference effects of the electric near field in the vicinity of the structure surface. While the incoming electric field vectors are independent in the far field, spectral interference in the near field can occur since the resulting field vectors are not necessarily perpendicular. On the nanostructure configuration of a Bowtie antenna, we show how the superposition of different plasmonic excitation modes leads to a local enhancement of the effective near field depending on the phase relation between the incoming electric field vectors. Via an interferometric superposition of two laser pulses with cross polarized electric fields the near field interference can be directly observed by means of a photoemission electron microscope (PEEM). Spatial switching of the photoemission yield depending on the relative phase between the two superposed laser pulses will be demonstrated.

HL 23.8 Tue 12:15 H2

Interaction effects of gold nanoantenna arrays in the infrared — •Daniel Weber[1], Frank Neubrech[1], Dominik Enders[2], Tadaaki Nagao[2], and Annemarie Pucci[1] — [1]Kirchhoff Institute for Physics, University of Heidelberg, Germany — [2]National Institute for Materials Science, Tsukuba, Japan

Gold nanoantennas are of great interest for applied spectroscopy due to their tuneable plasmonic properties including local electromagnetic (EM) field enhancement (FE). Excited resonantly by EM radiation, they are able to strongly enhance the local EM field. In the past, we exploited this strong effect for surface-enhanced infrared spectroscopy (SEIRS) with gold nanoantennas. We want to further improve the sensitivity of SEIRS by making use of nanoantenna coupling. Coupling may increase local FE but also strongly modify the spectral distribution of the FE, which provides further options for optimum resonance tuning as necessary for specific sensor applications.

We report on the IR optical properties of gold-nanoantenna arrays with different gap sizes and show the relation between plasmonic resonances and geometrical arrangement on the substrate. Stripe-like, polycrystalline gold nanoantennas (nanorods) with rectangular cross-sections were produced by electron beam lithography on silicon wafers. IR measurements were performed by micro-spectroscopy in our laboratories and at the synchrotron light source ANKA (Karlsruhe Institute of Technology). Special focus is on the preparation of very small gaps between the tip ends of nanorods, where the highest local FE is expected.

HL 23.9 Tue 12:30 H2

Structural and Optical Properties of Gold and Iron Nanowires — •Piotr Patoka[1,2], Georgios Ctistis[3], Michael Hilgendorff[1], and Michael Giersig[1] — [1]Freie Universität Berlin — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH — [3]University of Twente, MESA+ Institute & Dept. of Science and Technology, Complex Photonic Systems (COPS), Enschede, The Netherlands

Plasmonic nanostructures gained a tremendous interest during the last decade due to their structural and optical properties, which make them promising materials for opto-electronic as well as bio-sensing-applications.

Here we will present results on gold and iron nanowires prepared by means of nanosphere lithography as a cheap method of preparation of large areas of such nanostructures. The 30nm thick lines with 440nm in periodicity have been characterized with atomic force microscopy and scanning electron microscopy. The investigation showed strong influences of the preparation steps to the final structure. For optical investigation UV-VIS-NIR spectrometry and scanning near field optical microscopy have been used showing extraordinary light transmission.

HL 23.10 Tue 12:45 H2

Surface Plasmon Resonance Coupling on Magnetically Capped Gold Nanorods — •Gillian Doyle and Dominic Zerulla — Plasmonic and Ultrafast Optics Group, School of Physics, University College Dublin, Belfield, Dublin 4, Ireland

Nanorods compared to their spherical counterparts exhibit enhanced sensitivity and are used for a wide variety of applications from biosensing to solar cells. The presence of two resonance peaks in their scattering spectra allows their two geometrical axes, the longitudinal and transverse axes to be separately distinguished. In this research we use iron capped gold nanorods with geometrical dimensions in the range of 60 x 700 nm. Coupling of the surface plasmons between the two axes is investigated both in multiple particle and single particle experiments and the effect of the proximity of particles to each other and their associated coupling is considered. In the single particle experiments a 532 nm laser beam is used to optically trap and manipulate a nanorod, while coupling white light to the setup allows Mie Scattering Spectroscopy (MSS) to be performed on a single particle. Large sample MSS experiments provide more intense signals for detection and give an insight into phenomena occurring at the surface of the nanoparticle [1]. In addition, the intensity of the scattering cross section by these nanorods is examined by magnetically manipulating the particles themselves and opening a novel method of optimum signal detection of SP resonances on nanorods.

[1] G Doyle, D. Zerulla, Applied Physics A, Vol 89, No. 2, 2007