

CPP 42: Plasmonics IV (joint session O/CPP)

Time: Wednesday 15:00–17:45

Location: H8

CPP 42.1 Wed 15:00 H8

Switching between sharp Mie and broad plasmonic resonances in phase-change material metasurfaces — ●SOPHIA WAHL, ANDREAS HESSLER, MATTHIAS WUTTIG, and THOMAS TAUBNER — Institute of Physics (IA) RWTH Aachen

Active metasurfaces (MSs) based on phase-change materials (PCMs) enable versatile compact optics like tunable metalenses [1]. PCMs can be rapidly and reversibly switched between their amorphous and crystalline phases which is accompanied by a pronounced non-volatile change in their optical properties [2]. Commonly, PCMs integrated in MSs feature a large change in their positive permittivity.

We present how the phase-change material In_3SbTe_2 (IST) can be used to switch resonators in an infrared (IR) MS between sharp Mie resonances and broad plasmonic resonances. In the IR, the permittivity of IST changes from positive to negative upon crystallization, effectively switching from dielectric to metallic. We demonstrate how this can be used to dramatically change the resonance width and the resonance frequency of IR resonators.

Our work opens up new design concepts for applications like active spectral filters and absorbers, because it could provide tunable bandwidth and operation frequency at the same time.

[1] X. Yin et al., *Light: Science & Applications* 6, e17016 (2017)

[2] M. Wuttig et al., *Nano Photon.* 11, 465 (2017)

CPP 42.2 Wed 15:15 H8

Infrared nanoscopy to unravel the influence of defects in resistive switching of In_3SbTe_2 — ●NIKLAS EICKER¹, MARTIN LEWIN¹, RAIMONDO CECCHINI², SEBASTIAN WALFORTH¹, MATTHIAS WUTTIG¹, MARTIN SALINGA¹, MASSIMO LONGO², and THOMAS TAUBNER¹ — ¹RWTH Aachen - Institute of Physics (IA) — ²CNR - IMM

Phase change materials (PCMs) exhibit at least two stable states at room temperature, one crystalline and one amorphous. Characteristically the different states show a high electrical and optical contrast which can be used for fast, energy efficient and non-volatile nano switches [1]. Thus PCMs are a promising material class for persistent memory devices like PCRAM.

Scattering-type scanning near-field optical microscopy (s-SNOM) in the infrared spectral range can be used to study the differences in local conductivity of both states [2]. Opposed to other techniques like TEM, SNOM allows to study the same system in different states without sample preparation or damaging the PCM.

To investigate the influence of defects on phase change processes in highly scaled PCM devices, we electrically contacted and switched PCM nanowires [3]. With infrared s-SNOM we revealed strong inhomogeneities, which might be linked to a reduced local conduction due to structural defects.

[1] M. Wuttig et al., *Nat. Mater.* 6, 824 (2007)

[2] M. Lewin et al., *Appl. Phys. Lett.* 107, 151902 (2015)

[3] S. Selmo et al., *Appl. Phys. Lett.* 109, 213103 (2016)

CPP 42.3 Wed 15:30 H8

Switchable absorber/emitter based on vanadium dioxide — ●XINRUI LYU^{1,2,3}, TAUBNER THOMAS¹, and YUNZHEN CAO² — ¹Institute of Physics (IA), RWTH Aachen University, 52056 Aachen, Germany — ²Key Laboratory of Inorganic Coating Materials CAS, Shanghai Institute of Ceramics, Chinese Academy of Sciences, Shanghai 200050, PR China — ³University of Chinese Academy of Sciences, Beijing 100049, PR China

We numerically demonstrate a switchable metamaterial absorber/emitter based on vanadium dioxide (VO_2). The absorber consists of three layers, top patterned VO_2 layer, dielectric spacer layer and bottom reflective layer. Perfect absorption can be thermally turned on when the excitation of magnetic resonance is supported with the metallic VO_2 , while switched off with semiconducting VO_2 . The absorption peak can be tuned with different shapes and geometries of patterned VO_2 layer. The absorption bandwidth can be largely broadened when using lossy metallic VO_2 instead of noble metal as reflective layer. The results would facilitate the design of switchable metamaterials for active control in energy and sensing applications.

CPP 42.4 Wed 15:45 H8

Tip-enhanced Raman spectroscopy of ultrathin ZnO layers on

$\text{Ag}(111)$ — ●SHUYI LIU¹, MARTIN WOLF¹, and TAKASHI KUMAGAI^{1,2} — ¹Department of Physical Chemistry, Fritz-Haber Institute of the Max-Planck Society, Faradayweg 4-6, 14195 Berlin, Germany. — ²JST-PRESTO, 4-1-8 Honcho, Kawaguchi, Saitama 332-0012, Japan.

Tip-enhanced Raman spectroscopy (TERS) is a powerful nanoscale vibrational microspectroscopy combining high-spatial resolution of SPM with chemical sensitivity of surface enhanced Raman spectroscopy [1, 2, 3]. We report the TERS measurement of the ultrathin ZnO layers epitaxially grown on a $\text{Ag}(111)$ surface. The enhancement mechanisms were examined in detail by a combination of STS and STM-induced luminescence spectroscopy with the TERS measurements. We found a clear correlation between the TERS signal and the plasmonic properties of the STM junction. It was also revealed that the TERS intensity increases exponentially with decreasing the tip-surface distance and the decay constant is largely different inside and outside the tunneling regime. Our results provide a detailed insights into the TERS mechanism and the plasmonic properties relevant for field enhancement and confinement in nanoscale cavities. References [1] *Annu. Rev. Phys. Chem.* 63, 379 (2012). [2] *Chem. Rev.*, 117, 4961-4982 (2017) [3] *Chem. Soc. Rev.*, 46, 4020 (2017).

CPP 42.5 Wed 16:00 H8

Dependence of graphene photoluminescence blinking on the local field enhancement — MARKUS PFEIFFER¹, ●MO LU¹, BORIS V. SENKOVSKIY², DANNY HABERER³, FELIX R. FISCHER³, FAN YANG², KLAUS MEERHOLZ¹, YOICHI ANDO², ALEXANDER GRÜNEIS², and KLAS LINDFORS¹ — ¹Department of Chemistry, University of Cologne, Luxemburger Str. 116, D-50939, Köln, Germany — ²II. Physikalisches Institut, University of Cologne, Zùlpicher Strasse 77, 50937 Köln, Germany — ³Department of Chemistry, University of California at Berkeley, Tan Hall 680, Berkeley, CA 94720, USA

Armchair-edge graphene nanoribbons (AGNRs) are novel one-dimensional semiconductors with well-defined structure and promising optoelectronic properties. Their nanometer-sized dimensions and versatile electronic properties make them the ideal candidate for future optoelectronics. By coupling GNRs to plasmonic nanoantennas array, we obtain an enhancement of photoluminescence and Raman scattering intensity [1]. In the hotspots of the antennas, we observe the blinking of emission from AGNRs, which is a typical characteristic of a single quantum emitter [2]. Here we study the influence of the local field enhancement on the blinking process and find that the amplitude of the blinking events strongly correlates with the enhancement.

Reference:

[1] M. Pfeiffer, et al. *2D Materials*, 5, 045006 (2018)

[2] M. Pfeiffer, et al. *Nano Lett.* 18, 7038-7044 (2018)

CPP 42.6 Wed 16:15 H8

Electrochemistry on Copper Nanostructures for Active Plasmonics — ●ANNETTE BÖHME, FLORIAN STERL, ELINOR KATH, MONIKA UBL, and HARALD GIESSEN — 4th Physics Institute and Research Center SCoPE, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Applications of active plasmonics include the development of advanced plasmonic color displays and switchable metasurfaces. We aim to fabricate plasmonic nanostructures that can be switched electrochemically by applying a voltage.

Copper is a suitable material for this attempt as it can easily be switched electrochemically between copper (Cu) and copper oxide ($\text{CuO}/\text{Cu}_2\text{O}$) [1]. We have developed a manufacturing process to fabricate high-quality inverse copper nanostructures that exhibit well-modulated plasmonic resonances. We use these samples to perform cyclic voltammetry in order to switch them electrochemically, and at the same time we perform spectral reflectance measurements in the visible wavelength range. Thereby, we demonstrate that the resonances can be reversibly shifted by as much as 80 nm. The wavelength shift becomes stronger after several cycles of voltammetry which we attribute to the modification of the copper surface with repeated oxidation and reduction.

These results provide a basis for the future development of pixelated active plasmonic devices.

[1] Ye Wan, Yundian Zhang, Xianle Wang, and Qing Wang, *Electrochem. Commun.* 36, 99 (2013).

CPP 42.7 Wed 16:30 H8

How Metal Nanoantennas' Optical Properties Affect Surface Enhanced Infrared Absorption — ●MICHAEL TZSCHOPPE, CHRISTIAN HUCK, JOCHEN VOGT, FRANK NEUBRECH, and ANNEMARIE PUCCI — Kirchhoff Institute for Physics, Heidelberg University, Germany

Surface enhanced infrared absorption (SEIRA) is known as a powerful tool to study tiny amounts of molecules on the basis of enhanced vibrational signals. In order to further increase the enhancement, the impact of the structures' geometry as well as their interaction have been intensively investigated within the last decade.^{1,2} We present an experimental study with focus on the impact of the nanoantennas' metal-optical properties on SEIRA sensitivity. Various aspect ratios of nanoantennas made of the metals gold, silver, copper, aluminum, and iron, respectively, were inspected. From the measured fundamental plasmonic resonance spectra the contributions of the intrinsic damping (electron scattering) as well as the radiative damping (light scattering) were evaluated. The SEIRA enhancement factors were determined for a thin organic probe layer. These investigations finally yield the correlation between the ratio of intrinsic damping and radiation damping with the SEIRA enhancement, which clearly shows the maximum enhancement when both damping mechanisms contribute equally.³

[1] Neubrech *et al.* Chem. Rev. **2017**, 117 (7), 5110

[2] Dong *et al.* Nano Lett. **2017**, 17 (9), 5768

[3] Tzschoppe *et al.* J. Phys. Chem. C **2018**, 122 (27), 15678

CPP 42.8 Wed 16:45 H8

Watching a single fluorophore molecule walk into a plasmonic hotspot — LING XIN^{1,2}, ●MO LU³, STEFFEN BOTH⁴, MARKUS PFEIFFER³, MAXIMILIAN J. URBAN^{1,2}, CHAO ZHOU^{1,2}, HAO YAN⁵, THOMAS WEISS⁴, NA LIU^{1,2}, and KLAS LINDFORS³ — ¹Max Planck Institute for Intelligent Systems, Heisenbergstrasse 3, 70569 Stuttgart, Germany — ²Kirchhoff Institute for Physics, Heidelberg University, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany — ³Department of Chemistry, University of Cologne, Luxemburger Straße 116, 50939 Köln, Germany — ⁴4th Physics Institute and Stuttgart Research Center of Photonic Engineering, University of Stuttgart, 70569 Stuttgart, Germany — ⁵Department of Chemistry & Biochemistry, Biodesign Institute, Arizona State University, Tempe, AZ 85287-5601, USA

Plasmonic nanoantennas allow for enhancing the spontaneous emission, altering the emission polarization, and shaping the radiation pattern of quantum emitters. A critical challenge for the experimental realizations is positioning a single emitter into the hotspot of a plasmonic antenna with nanoscale accuracy. We demonstrate a dynamic light-matter interaction nanosystem enabled by the DNA origami technique. A single fluorophore molecule can autonomously and unidirectionally walk into the hotspot of a plasmonic nanoantenna along a designated origami track. Successive fluorescence intensity increase and lifetime reduction are in situ monitored using single-molecule fluorescence spectroscopy. Our scheme offers a dynamic platform, which can be used to develop functional materials, investigate intriguing light-matter interaction phenomena as well as to serve as examine theoretical models.

CPP 42.9 Wed 17:00 H8

Surface-enhanced infrared absorption spectroscopy for in-vitro detection of the polypeptide monolayer conformation on a single gold nanoantenna — ●ROSTYSLAV SEMENYSHYN^{1,2}, FLORIAN MÖRZ^{1,2}, FRANK NEUBRECH^{1,3}, and HARALD GIESSEN^{1,2} — ¹4th Physics Institute and Research Center SCoPE, University of Stuttgart — ²Center for Integrated Quantum Science and Technology, IQST — ³Kirchhoff Institute for Physics, University of Heidelberg

In our present work, we demonstrate the capability of surface-enhanced infrared absorption spectroscopy for ultra-sensitive in-vitro detection of the secondary structure of polypeptides monolayer. We utilized a

monolayer of thiols as a bonding spacer for deposition of poly-L-lysine (PLL) molecules onto the gold surface [1]. We tuned the length of nanoantennas to be resonant at the frequency of the amide-I band of PLL and performed SEIRA measurements in the D₂O environment using a specially designed transmittance flowcell. To measure an optical response of a *single* nanostructure, we pushed our system towards the diffraction limit and therefore applied a light source with higher brilliance, namely specifically designed broadband tunable laser [2]. Then, we compare our results to a global, as well as a synchrotron, which are well-known FTIR light sources. With further advances it might become possible to scale the process down to a few or even single proteins.

[1] R. Semenyshyn, M. Hentschel, C. Stanglmair, T. Teutsch, C. Tarin, C. Pacholski, H. Giessen, and F. Neubrech, Nano Lett. (2018); doi: 10.1021/acs.nanolett.8b02372 [2] T. Steinle, F. Mörz, A. Steinmann, and H. Giessen, Opt. Lett. **41**, 4863 (2016)

CPP 42.10 Wed 17:15 H8

Optical Nanoplasmonic CO₂ Detection in the Visible by Polyethylenimine — ●POHL TOBIAS, STERL FLORIAN, STROHFELDT NIKOLAI, and GIESSEN HARALD — 4th Physics Institute and Research Center SCOPE, University of Stuttgart, 70569 Stuttgart, Germany

In industrial production and other technologically relevant processes CO₂ is a common byproduct that must be monitored to keep up a high efficiency. Most of the currently available CO₂ detection systems use an electrical readout. This poses in environments with explosive or flammable gases a major risk of spark ignition. The available optical solutions, which circumvent this risk altogether, rely on the characteristic infrared absorption of CO₂. While being very specific this method requires a large sensing volume. In our contribution, we introduce a cheap and compact nano-optical gas detection scheme for CO₂ based on a plasmonic perfect absorber structure combined with the polymer polyethylenimine. The polymer acts as the gas sensitive part as it changes its refractive index by absorbing CO₂, which is then translated by the absorber to a resonance shift. By tracking the plasmon resonance we studied the time, concentration, and temperature dependence, as well as possibilities to enhance the response and aging effects. Furthermore we will show that this sensing scheme also works with a much simpler setup consisting only of a LED, a photodiode, and appropriate electronics.

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three-dimensional plasmonic nanostructure design for boosting photoelectrochemical — ●RUI XU, HUAPING ZHAO, MAX SOMMERFELD, and YONG LEI — Institut für Physik & IMN MacroNano, Technische Universität Ilmenau, 98693, Ilmenau, Germany

Plasmonic nanostructures have been widely incorporated into different semiconductor materials to improve solar energy conversion. An important point is how to manipulate the incident light so that more light can be efficiently scattered and absorbed by the semiconductors. Here, by using a tunable three-dimensional Au pillar/truncated-pyramid (PTP) array as a plasmonic coupler, a superior optical absorption of about 95% within a wide wavelength range is demonstrated from an assembled CdS/Au PTP photoanode. Based on incident photon to current efficiency measurements and the corresponding simulations, it is concluded that the enhancement is mainly attributed to an appropriate spectral complementation between surface plasmon resonance modes and photonic modes in the Au PTP structure over the operational spectrum. Because both of them are wavelength dependent, the Au PTP profile and CdS thickness are further adjusted to take full advantages of the complementary effect and subsequently, an angle independent photocurrent with an enhancement of about 400% was obtained. The designed plasmonic PTP nanostructure of Au is highly robust and it could be easily extended to other plasmonic metals equipped with semiconductor thin film for photovoltaic and photoelectrochemical cells.