HL 52: Focus: Self-Assembly of Plasmonic Nanostructures (joint session CPP/HL)

Organized by Tobias A. F. König and Markus Lippitz

Time: Friday 9:30–12:30 Location: GÖR 226

Invited Talk HL 52.1 Fri 9:30 GÖR 226

Self-assembled optical metamaterials — •Ullrich Steiner — Adolphe Merkle Institute, Chemin des Verdiers 4, 1700 Fribourg

The self-assembly of block-copolymers gives rise to numerous 2D and 3D morphologies with characteristic pattern sizes on the 10 nm length scale. These polymer structures can be transformed into plasmonic metals to fabricate 2D metasurfaces and 3D metamaterials. These plasmonic replicas have the appropriate structure sizes for the coupling of plasmon resonances to the visible light spectrum, yielding interesting optical materials.

This presentation will review recent progress in manufacturing and studying these materials and highlight interesting current developments.

HL 52.2 Fri 10:00 GÖR 226

In Situ Monitoring of Self-Assembly and Plasmonic Shifts during the Growth of AgCu Alloy Nanostructures — •Matthias Schwartzkopf[1], André Rothkirch[1], Niko Carstens[2], Thomas Strunskus[2], Franziska C. Löhrer[3], Senlin Xia[3], Volker Körstgens[3], Peter Müller-Buschbaum[3,4], Franz Faupel[2], and Stephan V. Roth[1,5] — [1]DESY, Notkestr. 85, D-22607 Hamburg — [2]CAU zu Kiel, Kaiserstr.2, 24143 Kiel — [3]TUM, James-Franck-Str. 1, D-85748 Garching — [4]MLZ, Lichtenbergstr. 1, D-85748 Garching — [5]KTH, Teknikringen 56-58,SE-100 44 Stockholm

While magnetron sputtering is a versatile routine method in industry for the deposition of large area metal and alloy coatings, it can be also used for the preparation of functional nanocomposites with e.g. adjustable optical properties [1]. We investigated in real-time the formation of supported silver, copper, and silver-copper-alloy nanoclusters during sputter deposition on poly(methyl methacrylate) by combining in situ surface-sensitive X-ray scattering with optical spectroscopy [2]. While following the transient growth morphologies, we quantify the early stages of phase separation at the nanoscale, track the shifts of surface plasmon resonances, and quantify the growth kinetics of the nanogranular layers at different thresholds. We are able to extract the influence of scaling effects on the nucleation and phase selection and demonstrate a route to tailor accurately the plasmon resonances of nanosized, polymer-supported clusters. [1] Faupel et al., Adv. Eng. Mater. 2010, 12, 12, 1177-1190. [2] Schwartzkopf et al., ACS Appl. Nano Mater. 2022, 5, 3, 3832-3842.

HL 52.3 Fri 10:15 GÖR 226

What happens to bovine serum albumin in-between two gold nanoparticles and how this biomolecule defines the plasmonic effect? — Nina Tverdokhleb, •Olga Guskova, Ziwei Zhou, Holger Merlitz, and Vladyslav Savchenko — Leibniz-Institut für Polymerforschung Dresden e. V.

In experiments, spherical gold nanoparticles (NPs) covered by bovine serum albumin (BSA) create 1D Au-BSA nanoarrays on a polymer film. The external mechanical strain applied to the film leads to plasmon-coupled circular dichroism (PCCD) enhancement. To explain this phenomenon, we perform all-atom MD simulations of plasmonic nanostructures, representing BSA in-between two gold NPs. The following steps were undertaken: (1) BSA was adsorbed on the gold wall (a model of NP) in implicit water with optimization of its geometry; (2) the second mobile gold wall was approaching adsorbed protein until the distance between NPs reaches the experimentally measured value; (3) mimicking mechanical stretching mentioned above, an external tensile force applied on the second wall has induced the backbone stretching of the initially compressed BSA. This process is accompanied by the crucial growth of BSA dipole moment along the directional deformation, restructuring of the protein secondary structure from helices to coils upon compression (2), the reorientation of the charged amino-acid residues, and subsequent partial back-folding of the secondary structure elements upon stretching (3). We correlate an observed plasmonic effect in the 1D Au-BSA arrays to the changes in dipole moment and chirality of BSA.

HL 52.4 Fri 10:30 GÖR 226

Uniform and sensitive Raman signal by self-assembled plasmonic nanoparticle gratings — •Sezer Seçkin[1] and Tobias A. F. König[1,2] — [1]Leibniz-Institut für Polymerforschung e.V., Hohe Straße 6, 01069 Dresden — [2]Center for Advancing Electronics Dresden (cfaed), Technische Universität Dresden, 01062 Dresden

Despite recent advancements in this field, it is still challenging to manufacture SERS substrates that provide high sensitivity and uniformity over large areas. One can overcome this challenge by employing a colloidal approach such as directed self-assembly of plasmonic nanoparticles into ordered structures [König et al. Advanced Functional Materials 31.36 (2021): 2105054]. Here, we have produced highly ordered 1D plasmonic lattice structures by assembling nanoparticles of various sizes. With the help of the low optical loss of colloidal gratings, we studied the enhancement capabilities of the SERS substrates by the excitation of a fluorescent reporter Rhodamine 6G, at different wavelengths. We conducted the polarization-dependent SERS enhancement by exciting colloidal gratings parallel and perpendicular to the polarization of the excitation lasers. Moreover, we studied the effect of the surface plasmon modes on the SERS enhancement at different orientations using the FDTD simulation. The mapping technique visually interpreted the SERS performances of other substrates, which supports the reproducibility and uniformity of the Raman signals over larger areas. Controlling the particle size while keeping the periodicity constant allows us to tune the SERS enhancement factor, which can be helpful for various sensing applications.

HL 52.5 Fri 10:45 GÖR 226

Investigating Charge Transfers in Colloidal Photonic Crystal Slabs — •Swagato Sarkar[1] and Tobias A. F. König[1,2] — [1]Leibniz-Institut für Polymerforschung Dresden e.V., Institute of Physical Chemistry, Hohe Str. 6, 01069 Dresden, Germany — [2]Center for Advancing Electronics Dresden (cfaed), Technische Universität Dresden, Helmholtzstraße 18, 01069 Dresden

The challenges of large-scale and low-loss plasmonic charge transfers are systematically investigated by optical designs with colloidal 1D plasmonic lattice structures. These plasmonic lattices are used as couplers to confine the incident energy into the underlying titanium dioxide layers, thus acting as colloidal photonic crystal (cPhC) slabs. Conventionally, photodetection is possible at energy levels close to the semiconductor bandgap; however, with the observed plasmonic-photonic hybrid modes, the extended solar spectrum can be used for energy harvesting. The photo-amplified current is measured locally with simple two-point contact on the centimeter-sized nanostructure by applying a bias voltage. The optical concepts for metallic grating composed of nanobars are extended for the first time to colloidal self-assembled gold nanoparticle (AuNP) chains to make large-scale charge injection accessible at a reasonable cost. Further, the possibility of photodetection by electric field vectors lying both along and perpendicular to the grating lines can be achieved by tuning the plasmonic grating periodicities.

HL 52.6 Fri 11:00 GÖR 226

Self-assembled plasmonic metasurfaces for sensing and photocatalysis — •Olha Aftenieva[1] and Tobias A.F. König[1,2] — [1]Leibniz-Institute for Polymer Research Dresden, Hohe Straße 6, 01169 Dresden, Germany — [2]Center for Advancing Electronics Dresden (cfaed), Technische Universität Dresden, 01062 Dresden, Germany

Self-assembly of colloids allows for robust and tunable manufacturing over centimeter-scaled areas. Here we present the soft lithographic approach for creating plasmonic lattices and demonstrate their usage for sensing applications and photocatalysis. First, a particular case of collective out-of-plane resonant coupling is considered. Such resonances are excited solely under oblique illumination with transverse magnetic polarization and provide field enhancement in the area above the metasurface that is easily accessible to an analyte and is particularly sensitive to the changes in the refractive index. On the other hand, we realize imprinting of such periodic plasmonic lattices on functional substrates, including glass, silicon wafers, carbon, gold, semiconductor, or polymer thin films, illustrating the versatility of the colloidal approach. In particular, the combination of titanium dioxide thin waveguiding layers and plasmonic metasurface gives rise

to narrow-bandwidth guided plasmon-polariton modes. Moreover, it induces the generation of hot charge carriers and enhances photocatalytic processes. Thus, colloidal self-assembly of plasmonic metasurfaces presents an application-oriented approach that is of potential use for optical sensors, photonic circuit applications, or hybrid device manufacturing.

15 min. break

Invited Talk HL 52.7 Fri 11:30 GÖR 226

Simulating quantum systems with plasmonic waveguide arrays — •Stefan Linden — Physikalisches Institut, Universität Bonn, 53115 Bonn

Coupled waveguides provide a powerful platform to simulate the evolution of quantum mechanical tight-binding systems in a classical wave environment. The basis for this is the mathematical equivalence between the time-dependent Schrödinger equation and the paraxial Helmholtz equation. In this presentation, we report on the observation of the Wannier-Stark ladder and Bloch oscillations in arrays of plasmonic waveguides with a propagation constant gradient acting as an effective external potential. Moreover, we show that Floquet engineering is a powerful method to tailor the topological properties of plasmonic waveguide arrays. In this context, we demonstrate that time-periodic modulation of dissipation can restore transport quantization in fast Thouless pumps and report on the observation of the anomalous Floquet topological π-mode at optical frequencies.

Invited Talk HL 52.8 Fri 12:00 GÖR 226

single molecule detection on a smartphone microscope enabled by DNA origami biosensors — •Philip Tinnefeld — Department of Chemistry and Center for NanoScience, Ludwig-Maximilians-Universität München, Butenandtstr. 5-13, 81377 München, Germany

DNA nanotechnology and especially the DNA origami technique allow well-defined assembly of optically active components and sensing units for novel biosensing approaches. We here demonstrate single-molecule detection on a battery driven smartphone microscope enabled by fluorescence enhancement with DNA origami nanoantennas. As further examples, we show DNA origami membrane sensors for curvature and membrane potentials. Finally, DNA origamis are used for a novel superresolution approach combining graphene energy transfer, pMINFLUX and DNA PAINT that enables nanometric 3D superresolution close to the coverslip.