DPG Frühjahrstagung Dresden 19. – 24. März 2016

BIOINSPIRED FUNCTIONAL MATERIALS:

From Nature's Nanoarchitectures to Nanofabricated Designs

Symposium der Fachverbände CPP · BP · MM · DF · DY · MI

EINGELADENE SPRECHER

Silvia Vignolini CAMBRIDGE · Peter Vukusic EXETER
Martin Wegener KARLSRUHE · Thomas Speck FREIBURG
Vladimir Tsukuruk ATLANTA

SYMPOSIUM Tue 9^{30} am HSZ 2 DYMP 1

CPP SITZUNGEN Mon 10^{15} ZEU 114 CPP 4
Mon 15^{00} ZEU 114 CPP 7 · Mon 18^{30} P1C CPP 14

DPG

Dear fellow scientists,

Welcome to the spring meeting of the German Physical Society in Dresden and to the symposium ***Bioinspired Functional Materials: From Nature's Nanoarchitectures to Nanofabricated Designs!***

We are delighted to invite you to attend this joint symposium, organised by six of the DPG's Divisions (CPP, BP, MM, DF, DY, MI) , featuring five top-notch invited speakers on Tuesday morning. We are also delighted to invite you to three associated sessions with additional talks and posters in the CPP program on Monday:

Monday, CPP 4, 10:15 – 13:00, Room ZEU 114: Bioinspired Materials I

with an invited talk by Rumiana Dimova *and 7 contributed talks*

Monday, CPP 10, 15:00 – 18:15, Room ZEU 114: Bioinspired Materials II

with 12 contributed talks

Monday, CPP 14, 18:30 – 21:00, Room P1 : Bioinspired Materials III

with 8 poster presentations … and some refreshments.

Tuesday, Symposium SYBM, 9:30 – 12:15, Room HSZ 2

with invited talks by

Pete Vukusic (Exeter) : *New twists in biological photonics: circular polarisation and beyond*

Thomas Speck (Freiburg) : *Bio-inspired materials & structures for technology & architecture*

Silvia Vignolini (Cambridge) *: Cellulose bio-inspired hierarchical structures*

Vladimir Tsukuruk (Atlanta) *: Flexible Bioenabled Nanocomposites for Sustainable Sensing*

Martin Wegener (Karlsruhe) : *3D laser nano-printing of rationally designed materials*

Check out the following pages for the complete program and abstracts for all sessions, or click here for the online program and personal planer.

We look forward to seeing you in Dresden!

Best wishes,

Gerd Schröder-Turk (Murdoch University Perth)

Robert Magerle (Technische Universität Chemnitz)

Karin Jacobs (Universität des Saarlandes)

CPP 4: Bioinspired Functional Materials I

Monday 10:15–13:00 ZEU 114

Invited Talk CPP 4.1 Mon 10:15 ZEU 114

Membrane nanotube formation in giant vesicles — •Rumiana Dimova — Max Planck Institute of Colloids and Interfaces, Science Park Golm, 14424 Potsdam, Germany

Nanotubes are ubiquitous in cells. Examples for tubular structures are provided not only by organelles such as the Golgi body and the endoplasmic reticulum but also by intercellular connections between different cells. Their geometry and large area-to-volume ratio make them an excellent natural tool for membrane storage, sorting and transport. Such nanotubes can also be formed from synthetic lipid bilayers. Here, we discuss two systems based on giant vesicles, within which lipid nanotubes are generated and stabilized by spontaneous curvature. In the first case, we employ membranes doped with the ganglioside GM1 (Biophys. J. 111:1935, 2016). Upon dilution, the vesicle membrane exhibits asymmetric composition set by the different surface GM1 coverage on the two membrane leaflets. Employing vesicle micromanipulation and electroporation, we could assess the GM1 asymmetry and the associated spontaneous curvature. In the second system, the two leaflets of the bilayer have the same composition, but the solutions in contact with the inner and outer leaflet differ in the concentration of polyethylene glycol (PEG). We show that the spontaneous curvature is now generated by weak adsorption of PEG onto the membranes (ACS Nano 10:463, 2016). The tube shapes, cylindrical or necklace-like, and their diameters can be varied by the membrane composition and bending rigidity. We demonstrate this variation by employing membranes in the liquid-ordered and liquid-disordered phase state.

Talk CPP 4.2 Mon 10:45 ZEU 114

Traction forces of water droplets on superhydrophobic pillar structures — •Schellenberger Frank, Saal Alexander, and Tress Martin — Max Planck Institute for Polymer Research, Mainz, Germany

Surfaces with super-hydrophobic properties play an important role in both nature and science. Thereby, the artificial surfaces typically try to copy the characteristic features of their natural pendants. That is in general, a hydrophobic surface chemistry combined with a structured topography. To investigate the particular impact of these characteristics model surfaces with pillars of varying size, arrangement and surface coating have been employed [1]. While many studies used rigid pillars to maintain a well-defined topography, in the present work flexible pillars are focused. When imaged with a Laser Scanning Confocal Microscope, these flexible pillars act as cantilevers to detect traction forces of a drop resting on their top. By that, the distribution of the forces in parallel to the surface along the contact line is recorded. Especially the traction forces of the receding contact line of an evaporating or advancing drop will be illuminated.

[1] P. Papadopoulos et al. PNAS 9 (2013) 3254

Talk CPP 4.3 Mon 11:00 ZEU 114

Functional biohybrid materials: Centric diatoms with incorporated donor-acceptor laser dye couples — Lukas Selzer, Michael Grimann, and •Thomas Fuhrmann-Lieker — University of Kassel, Institute of Chemistry and Center for Interdisciplinary Nanostructure Science and Technology, 34109 Kassel, Germany

Centric diatoms are unicellular algae with an intricate cell wall of silica that can be described as a photonic crystal slab waveguide. The photonic function can be enhanced by the incorporation of laser dyes, turning the living algae into active fluorescent light-emitters. In order to increase the photoluminescence efficiency, we achieved dual in-vivo-staining with a dye pair for fluorescence resonant energy transfer (FRET). In addition to applications in photonics, this method allows the determination of the acceptor dye concentration in the hybrid material.

Talk CPP 4.4 Mon 11:15 ZEU 114

DNA based assembly of plasmonic nanoantennas — •Mathias Lakatos[1], Hanna Brunner[1], Darius Pohl[2], Andreas Heerwig[1], Bernd Rellinghaus[2] und Michael Mertig[1] — [1]TU Dresden, Physikalische Chemie, Mess- und Sensortechnik, 01062, Dresden — [2]IFW, Institut für Metallische Materialien, 01171 Dresden

Based on the ability of DNA to self-assemble into complex 2D and 3D structures with defined dimensions and structure specification at the nanometer scale, optical active nanostructures were synthesized and characterized. The preparation of the DNA template structures was done according to the so-called DNA origami method, where a long single-stranded DNA, the scaffold strand, is folded into a previously designed form by short single-stranded oligonucleotides. The incorporation of specific binding sites enables the local positioning of functional elements. For the construction of plasmonic active nanoantennas, complementary functionalized AuNR were used. Depending on the DNA template structures and the gold nanoparticles, nanoantennas of about 100 nm up to 300 nm size have been realized. Low-loss electron energy loss spectroscopy measurements were carried out using monochromated scanning transmission electron microscopy (STEM) on individual structural elements to gain insight into the localization of different plasmonic modes.

15 min break

Talk CPP 4.5 Mon 11:45 ZEU 114

Vesicles-on-a-chip : A universal microfluidic platform for the assembly of liposomes and polymersomes — •Julien Petit[1], Ingmar Polenz[1], Laura Thomi[2], Frederik Wurm[2], Jean-Christophe Baret[3], Katharina Landfester[2], Stephan Herminghaus[1], and Oliver Bäumchen[1] — [1]Max Planck Institute for Dynamics and Self-Organization (MPI-DS), 37077 Göttingen, Germany — [2]Max Planck Institute for Polymer Research (MPI-P), 55128 Mainz, Germany — [3]Centre de Recherche Paul Pascal (CRPP), CNRS, Université de Bordeaux, 33600 Pessac, France

One key challenge nowadays for a "bottom-up" approach in synthetic biology relies on the fabrication of compartments such as vesicles that can be viewed as model membranes. Nevertheless, the development of reliable methods for the high-throughput production of vesicles in an easy and well-controlled manner is still in progress. In this context, we propose a versatile method for producing monodisperse liposomes as well as polymersomes on the exact same PDMS-based microfluidic platform from double-emulsions [J. Petit et al., EPJE 39: 59 (2016)]. The size of the vesicles obtained with this technique can be varied over at least one order of magnitude and they are stable for more than 3 months under ambient conditions. Furthermore, we demonstrate the versatility of this microfluidic platform by producing polymersomes composed of functionalized block-copolymers. We characterize the successful functionalization by fluorescent labeling and measure the specific adhesion of polymersomes on dedicated surfaces using a micropipette force sensor technique.

Talk CPP 4.6 Mon 12:00 ZEU 114

Passive Polymer Translocation Through Membranes: An Edwards Model Based Guideline — •Marco Werner[1,2], Jasper Bathmann[3], Vladimir Baulin[1], and Jens-Uwe Sommer[2] — [1]Universitat Rovira i Virgili, Tarragona, Spain — [2]Leibniz-Institut für Polymerforschung Dresden, Dresden, Germany — [3]Technische Universität Dresden, Dresden, Germany

We propose a theoretical framework for examining translocation of flexible polymers through amphiphilic membranes: A generic model for monomer-membrane interactions is formulated and the Edwards equation is employed for calculating the free energy landscape of a polymer in a membrane environment. By the example of homopolymers it is demonstrated that polymer adsorption and the symmetry of conformations with respect to the membrane's mid-plane trigger passive polymer translocation in a narrow window of polymer hydrophobicity. We demonstrate that globular conformations can be taken into account by means of a screening of the external potential, which leads to excellent agreement of predicted translocation times with dynamic lattice Monte Carlo (MC) simulations. The work opens a theoretical roadmap on how to design translocating flexible polymers by referring to universal phenomena only: adsorption and conformational symmetry. As confirmed by MC simulations on amphiphilic polymers, promising candidates of translocating polymers in practice are short-block amphiphilic copolymers, which in the limit of small block sizes resemble homopolymers on a coarse grained level.

Talk CPP 4.7 Mon 12:15 ZEU 114

The Bicontinuous Gyroid-Phase in Purely Entropic Self-Assembly of Hard Pears — •Philipp Schönhöfer[1,2], Laurence Ellison[3], Matthieu Marechal[2], Douglas Cleaver[3], and Gerd Schröder-Turk[1] — [1]School of Engineering and Information Technol-

ogy, Murdoch University, Murdoch, Australia — [2]Institut für Theoretische Physik I, Universität Erlangen-Nürnberg, Erlangen, Germany — [3]Materials and Engineering Research Institute, Sheffield Hallam University, Sheffield, UK

We investigate a model of tapered hard particles reminiscent of pears forming the bicontinuous Ia3d structure by entropic self assembly. Based on the observations of Barmes et al. and Ellison et al. a phase diagram for particles with an aspect ratio $k = 3$ in relation to the degree of tapering k_θ and the tapering angle $\theta = 2\arctan(\frac{1}{2k_\theta})$, respectively, around the gyroid phase is generated. Additionally, the mechanism of interdigitating sheets of pears in these systems to create surfaces with negative Gauss curvature, which is needed to form the gyroid minimal surface is investigated in detail. We show that this mechanism differs from systems, which occur in nature (lipid bilayers) and synthesized materials (di-block copolymers) and where the formation of the gyroid is energetically driven, as for single hard pears do not follow Steiner*s theorem. This behaviour is investigated by Voronoi tessellation, whereas both shape and volume of the Voronoi cells in regard to the gauss curvature of the gyroid surface is determined.

[1] F. Barmes et al., Phys. Rev. E 68, 021708 (2003)
[2] Ellison et al., Phys. Rev. Lett. 97, 237801 (2006)

Talk CPP 4.8 Mon 12:30 ZEU 114

Probing Adhesion with Mechano-Responsive Polymers — •Jens W. Neubauer[1], Longjian Xue[2], Johann Erath[3], Dirk-M. Drotlef[4], Aránzazu del Campo[5], and Andreas Fery[1,6] — [1]Leibniz-Institut für Polymerforschung Dresden e.V., Germany — [2]Wuhan University, China — [3]University of Bayreuth, Germany — [4]Max-Planck-Institut für Polymerforschung, Mainz, Germany — [5]Leibniz-Institut für Neue Materialien, Saarbrücken, Germany — [6]Technische Universität Dresden, Germany

We use mechano-responsive polymers to elucidate adhesion. In gecko-inspired micropillar adhesives, for instance, a significant impact of the pillar contact geometry on the adhesion was found. Fundamental differences in their contact stress distributions were predicted by theory. We applied a mechano-responsive polyelectrolyte brush to determine the contact stress distributions of the micropillars. The mechano-response is based on the quenching of a labeled dye so that local tensile and compressive stresses affect the local fluorescence intensity. It was read out with high spatial resolution utilizing confocal laser scanning microscopy.

J.W. Neubauer, L. Xue, J. Erath, D.-M. Drotlef, A. del Campo, A. Fery *ACS Appl. Mater. Interfaces* **8** (2016), 17870-17877.

Talk CPP 4.9 Mon 12:45 ZEU 114

Theoretical quantification of nano carrier loading and release rates — •Richard Schwarzl[1], Fang Du[2], Rainer Haag[2], and Roland R. Netz[1] — [1]Freie Unversität Berlin, Fachbereich Physik, Arnimallee 14, 14195 Berlin — [2]Freie Unversität Berlin, Institut für Chemie und Biochemie, Arnimallee 14, 14195 Berlin

Macromolecular nanostructures that are used as drug carriers are characterized by their loading and release kinetics. Release studies commonly employ the dialysis method, in which a cellulose membrane separates the solution of released drug from the nanocarrier solution. In order to extract the nano carrier release rate, it is necessary to take the effect of the dialysis membrane on the release kinetics into account. Using a theoretical two-step approach, consisting of the analysis of a calibration experiment of drug diffusion through the dialysis membrane in the absence of nanocarriers, and of an experiment in the presence of nanocarriers, one is able to determine all kinetic rates and in particular to disentangle kinetic dialysis membrane properties from kinetic nanocarrier properties.

CPP 10: Bioinspired Functional Materials II

Monday 15:00–18:15 ZEU 114

Talk CPP 10.1 Mon 15:00 ZEU 114

Extreme refractive index wing scale beads cause the bright colors of pierid butterflies — •Bodo Wilts[1], Bas Wijnen[2], Ullrich Steiner[1], and Doekele Stavenga[2] — [1]Adolphe Merkle Institute, University of Fribourg, Switzerland — [2]University of Groningen, Groningen, the Netherlands

Butterflies feature strong, vivid colours due to photonic structures on their surface. Butterflies of the family Pieridae are brightly colored, ranging from white to red, caused by various pterin pigments concentrated in scattering spheroidal beads in the wing scales. Given the sparsity of the beads in the wing scales, the high brightness suggests a scattering strength of the beads that significantly surpasses that of typical cuticular chitin beads with the aereal density found in the wing scales. To elucidate this apparent contradiction, we have analyzed the optical signature of the pierids* highly saturated pigmentary colors by using Jamin-Lebedeff interference microscopy combined with Kramers-Kronig theory and light scattering modeling. We show that extreme pterin pigment concentrations cause a very high refractive index of the beads with values above 2 across the visible wavelength range, thus creating one of the most highly light scattering media thus far discovered in the animal kingdom.

Talk CPP 10.2 Mon 15:15 ZEU 114

Actuated Self-(Un)rolling Silk Microstructures: Rings, Tubules, and Hhelical Tubules — •Chunhong Ye[1,2], Svetoslav V Nikolov[3], Ren Geryak[2], Rossella Calabrese[4], Alexander Alexeev[3], David L Kaplan[4], and Vladimir V Tsukruk[2] — [1]Institute of Physical Chemistry and Polymer Physics, Leibniz Institute of Polymer Research, Dresden, 01169 Germany — [2]School of Materials Science and Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332 USA — [3]Woodruff School of Mechanical Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332 USA — [4]Department of Biomedical Engineering, Tufts University, 4, Colby street, Medford, MA 02155 USA

We demonstrated facile, reversible, fast self-rolling biopolymer microconstructs using sandwiched active-passive, silk-on-silk morphology. We experimentally showed and theoretically confirmed that the shape of individual sheets effectively controls biaxial stresses within these sheets which can self-roll themselves into distinct 3D structures including microscopic rings, tubules, and helical tubules. This is a unique example of tailoring self-rolled 3D geometries though shape design without changing the inner morphology of active bimorph nanomaterials. Furthermore, the self-rolling direction, percentage shape, and diameter of the silk microtubes can be readily controlled over the geometry of the 2D microsheets, such as lateral dimension, thickness and aspect ratio. The microstructrues indicated highly reversible rolling/unrolling by alternating the external pHs, attributed to the significant swelling/deswelling of silk active layer at different pHs.

Talk CPP 10.3 Mon 15:30 ZEU 114

Shear-induced transformation of polymer-rich lamellar phases to micron sized vesicles investigated by small-angle scattering — •Sören Grosskopf[1], Miriam Siebenbürger[2], Oliver Wrede[1], Yvonne Hertle[1], and Thomas Hellweg[1] — [1]Bielefeld University — [2]Helmholtz-Zentrum Berlin

The influence of adding an amphiphilic triblock copolymer to a cationic microemulsion results on the one hand in an increasing viscosity and on the other hand in complexer phase behavior with an enhanced lamellar phase. This is a common feature of amphiphilic block copolymers related to the *efficiency boosting effect*. The aim of this work was to fabricate multi-lamellar-vesicles (MLV) out of a triblockcopolymer-rich lamellar phase applying stress and their identifaction via small angle scattering. The system consists beside the the polymer of a polar and apolar component and an cationic co-surfactant. Such large vesicles are of potential interest for the usage as drug delivery systems. Different *rheo*-small-angle scattering techniques were used to investigate structures while applying shear stress: With neutrons the change in the bilayer spacing can be investigated. For the research of larger structures depolarized rheo-small-angle light scattering (*rheo*-SALS) was used. The *rheo*-SALS experiments shows an inverse dependency of the applied shear-rate on the size of the MLVs. Beside the small-angle scattering experiments different microscopy techniques (polarized light, difference interference contrast microscopy) was used to obtain real space pictures of the resulting particles.

Talk CPP 10.4 Mon 15:45 ZEU 114

Carbon-Nanotube Membranes from Self-Assembly in Lipid Bilayers — •Martin Vögele, Jürgen Köfinger, and Gerhard Hummer — Max-Planck-Institut für Biophysik, Frankfurt am Main

Carbon nanotube (CNT) pores in lipid membranes are a promising candidate for applications as molecular filters and in drug delivery. The similarity of such pores to cylindrical membrane proteins raises the question whether they can self-assemble to a thin membrane with a high density of pores in a manner similar to protein 2D crystallization. We apply fully atomistic and large-scale coarse-grained molecular dynamics simulations to explore the hypothetical formation of such a material and to guide future experiments.

We find that indeed carbon nanotubes self-assemble to large clusters in lipid membranes. As the up-right carbon nanotubes induce very strong annular lipid shells around themselves, those clusters include trapped lipids between the CNTs. This trapped state is advantageous as it softens boundaries between otherwise incompatible local crystallization nuclei.

Our simulations suggest that the lipid composition is less important for the experimental procedure to produce such membranes but it will need a very subtle fine-tuning of the CNT properties. If this can be mastered, there is a broad field of applications, e.g. in desalination or dialysis, with many possibilities to tune the desired properties of the material.

Talk CPP 10.5 Mon 16:00 ZEU 114

The impact of surface curvature on growing tissues — •Sebastian Ehrig[1], Alan West[1], Cecile M. Bidan[2], Karen Lam[1], Philip Kollmannsberger[3], Pavel Tomancak[4], Peter Fratzl[1], and John W.C. Dunlop[1] — [1]MPIKG, Potsdam, Germany — [2]CNRS, Université Grenoble Alpes, France — [3]University of Würzburg, Germany — [4]MPICBG, Dresden, Germany

Biological tissues continuously undergo shape changes that effect the development and regeneration of tissues and organs. These changes are regulated by cells confined within a complex environment of mechanical and biochemical constraints. Cells not only respond to the geometry of their local environment but also modify it, through the production of extracellular matrix. How these cells are able to form complex tissue structures over large distances, however, is still elusive. Motivated by the observation that tissues grown on substrates of controlled curvature in-vitro are strongly influenced by the local curvature, we have performed tissue culture experiments on surfaces of constant mean curvature and are able to show that the mean curvature has a strong impact on the rate of tissue growth and on the organization of the cellular structures. We can show that on long time scales the tissue surface behaves like a viscous fluid with an equilibrium shape governed by the Laplace-Young-law. Cells on these surfaces display liquid-crystal like behaviour leading to remarkably symmetric stress patterns that closely resemble geodesics. The emergence of such patterns is a result of the intrinsic surface curvature and can partly be explained by minimizing the free energy of the cells director-field.

Talk CPP 10.6 Mon 16:15 ZEU 114

Colloid Clusters in Confinement: Observation, Modelling and Simulation — •Junwei Wang[1,2], Michael Engel[2], and Nicolas Vogel[1] — [1]Institute of Particle Technology, Friedrich Alexander Universität, Erlangen, Germany — [2]Institute of Multiscale Simulation, Friedrich Alexander Universität, Erlangen, Germany

Natural materials evolve to maximize performance from a limited choice of simple building blocks. Structural coloration is one example where nature utilizes ordered nanostructures to create vivid color. Colloidal particles are ideal building blocks to mimic this design principle, as their sizes match with wavelength of visible light. Colloids assemble upon increase of volume fraction into crystals, driven by entropy. Recent studies show that for colloids in spherical confinement, entropy favors icosahedral symmetry. Here we experimentally realize and geometrically model highly ordered icosahedral colloid assemblies. We discuss and compare stabilization mechanisms. Our study demonstrates the ability to create sophisticated colloid assemblies via confinement, which may find use as templates, photonic materials, and building blocks for hierarchical assembly.

15 min break

Talk CPP 10.7 Mon 16:45 ZEU 114

Nonclassical Crystallization in vivo et in vitro: origin and mimesis of a fundamental and nanoscale process-structure-property relationship of biominerals — •Stephan E. Wolf — Friedrich-Alexander-University Erlangen-Nürnberg, Erlangen, Germany; Juniorprofessor for Biomimetic Materials and Processes

Hidden within their structural wealth, a distinct nanogranular fine structure is shared by nearly all biominerals. This structural dichotomy of universality vs. diversity roots in a common nanoparticle-mediated growth, i.e. nonclassical crystallization, which underlies the formation of these nanogranular biominerals. This reveals a fundamental process-structure-property relationship of biominerals since the nanoscale organic-inorganic composite design affects multiple properties of the bioceramic. The mimesis of such a nanogranular material can be readily accomplished by exploitation of an in vitro mineralization route which involves accretion of amorphous colloids and their subsequent solid-amorphous to solid-crystalline phase transformation. This model system allows an unpreceded view on the mineral phase transformation and allows further the mimesis of crystal lattice tilting and twisting as observed in biogenic minerals. We discuss the origin of this peculiar crystallographic feature and demonstrate that crystal lattice bending represents a powerful, yet unexploited means to design and dynamically control anisotropic properties of a crystalline material. Revelation of the underlying mechanisms may pave the way to new classes of gradient materials and provide a new view on crystallographic design of solid state materials.

Talk CPP 10.8 Mon 17:00 ZEU 114

Gyroid Optical Metamaterials: Termination-Induced Anisotropy — •Matthias Saba[1], James A. Dolan[2,4], Raphael Dehmel[2], Angela Demetriadou[1], Ilja Gunkel[5], Yibei Gu[3], Ulrich Wiesner[3], Timothy D. Wilkinson[4], Ullrich Steiner[5], Jeremy J. Baumberg[2], Bodo D. Wilts[5], and Ortwin Hess[1] — [1]Department of Physics, Imperial College, Prince Consort Road, London SW7 2BB, UK — [2]Department of Physics, University of Cambridge, J.J. Thomson Avenue, Cambridge CB3 0HE, UK — [3]Department of Materials Science and Engineering, Cornell University, 214 Bard Hall, Ithace, NY 14853-1501, USA — [4]Department of Engineering, University of Cambridge, J.J. Thomson Avenue, Cambridge CB3 0HE, UK — [5]Adolphe Merkle Institute, Ch. des Verdiers 4, 1700 Fribourg, Switzerland

Inspired by gyroid photonic crystals that are found in the wing-scales of several butterfly species, metallic gyroids fabricated via self-assembly constitute the first example of a truly three dimensional optical metamaterial. Gyroid metamaterials (GMMs) are known for their unique optical properties, such as linear and circular dichroism.

We here demonstrate experimentally and theoretically that (a) short range order GMMs essentially behave similar to isotropic nanoporous gold and can effectively be modeled by a Bruggeman approach, and that (b) the strong linear dichroism observed for long range order GMMs stems from a distinct plasmonic response at the GMM surface that breaks the cubic symmetry of the gyroid and is extremely sensitive to the specific surface termination.

Talk CPP 10.9 Mon 17:15 ZEU 114

Immobilization Strategies for Photoactive Metal-Complexes on Carbon Nanomembranes — Maria Küllmer[1], Patrick Endres[2], Christof Neumann[1], •Andreas Winter[1], Andreas Winter[2], Benjamin Dietzek[1,3], Ulrich Schubert[2,4], and Andrey Turchanin[1,4] — [1]Institute of Physical Chemistry, Friedrich Schiller University Jena, 07743 Jena — [2]Institute of Organic Chemistry, Friedrich Schiller University Jena, 07743 Jena — [3]Leibniz Institute of Photonic Technology, 07745 Jena — [4]Jena Center for Soft Matter, Friedrich Schiller University Jena, 07743 Jena

The investigation of artificial molecular photo catalysts plays an important role in the development of novel energy sources. In this respect, the incorporation of photoactive compounds into nanomembranes is a promising approach for such applications in the field of light harvesting and electron transfer. Ruthenium-complexes are well-known photosensitizers and photocatalysts, which facilitate the utilization of light energy by electron transfer to/from the actual catalyst. The preparation of photoactive nanomembranes requires selective immobilization of these species on the nanomembrane surface. Here we present various immobilization strategies of ruthenium-II-photosensitizers on 1 nm thick carbon nanomembranes (CNMs). We use thiol-ene click reactions and amide-bond formation via active esters to couple the complexes to the CNM. Alternatively the metal-capturing unit was formed intrinsically by the crosslinked self-assembled monolayer units. The functionalized CNMs have been characterized by means of X-ray photoelectron spectroscopy as well as atomic force and optical microscopy.

Talk CPP 10.10 Mon 17:30 ZEU 114

Bio-inspired photonic structures as blueprints for compact polarization converters — •Xia Wu[1], Fernando Luis Rodríguez Gallegos[2], Marie-Christin Angermann[3], Bertram Schwind[1], Helge-Otto Fabritius[4], Georg von Freymann[3], and Jens Förstner[2] — [1]Department of Chemistry, University of Paderborn, Warburger Straße 100, D-33098, Paderborn, Germany — [2]Theoretical Electrical Engineering, University of Paderborn, Warburger Straße 100, 33098 Paderborn, Germany — [3]Physics Department, University of Kaiserslautern, Erwin-Schroedinger-Strasse, 67663 Kaiserslautern, Germany — [4]Max-Planck-Institut für Eisenforschung GmbH, Max-Planck-Straße 1, 40237 Düsseldorf, Germany

Polarization conversion is often needed in many optical applications. In nature, many species of insects have evolved photonic structures can convert the polarization state of light upon reflection[1,2]. We reveal a new type of biological polarization converter found in the scales of weevil Entimus imperialis. We show that the D-structures in (and only in) the green domains of scales (i.e. {001} lattice plane parallel to scale surface) can act as a linear polarization converter. Furthermore we show that the D-structures in green domains preserve the handedness of the incident circularly polarized light upon reflection. Inspired by this finding, we synthesized woodpile structures by direct laser writing. We show that the well-known woodpile structure has very similar polarization conversion effect like that of D-structure. References: [1] K. Zhang et al., RSC Adv. (2014) 4, 51865-51871 [2] P. Vukusic et al., Nature (2000) 404, 457

Talk CPP 10.11 Mon 17:45 ZEU 114

Soft and Tough as well: Morphology and Functional Structure of Spider Silk — A. Markus Anton and •Friedrich Kremer — Institute of Experimental Physics I, University of Leipzig, Germany

Spider dragline silk exhibits remarkable characteristics, such as exceptional biocompatibility or high tensile strength combined with great elasticity. Its mechanical properties are based on a refined architecture on the molecular scale: Proteins with highly repetitive core motifs aggregate into nanometer-sized crystals, rich on alanine in β-sheet secondary structure, surrounded by an amorphous glycine-rich matrix. During spinning the amorphous parts are elongated, which orients both substructures and gives rise to an inherent non-equilibrium state. Thus, external stress is directly transferred to the nanocrystals, while the tendency to contract is counterbalanced by surrounding fiber structure, as demonstrated by FTIR experiments in combination with uniaxial stress [1] or hydrostatic pressure [2].

Until recently it was not possible to artificially recreate this exceptional architecture [3]. We show that wet spinning and post-treatment of a novel biomimetic protein results in fibers with a similar nanostructure and comparable toughness as the natural template [4].

[1] P. Papadopoulos et al., *Eur. Phys. J. E* **24** (2007) 193–199; [2] A. M. Anton et al., *Macromolecules* **46** (2013) 4919–4923; [3] A. Heidebrecht et al., *Adv. Mater.* **27** (2015) 2189–2194; [4] A. M. Anton et al., *Manuscript in preparation*

Talk CPP 10.12 Mon 18:00 ZEU 114

Hyperbolic surface decorations and novel materials — •Myfanwy Evans — Mathematics Institute, TU Berlin, Berlin, Germany

Hyperbolic surfaces form the basis of a wide array of biological structure. This talk explores the mathematical construction of secondary structures, or symmetric decorations, on these surfaces as a way to construct complex entangled materials with novel physical behaviour.

CPP 14: Poster: Bioinspired Functional Materials

Monday 18:30–21:00 P1C

Poster CPP 14.1 Mon 18:30 P1C

Rethinking superhydrophobicity — •Schellenberger Frank, Encinas Noemí, Vollmer Doris, and Butt Hans-Jürgen — Max Planck Institute for Polymer Research, Mainz, Germany

To a certain degree, it is possible to control the macroscopic wetting properties of a surface by its nano- and microstructure. In particular, super liquid-repellant-surfaces have received interest due to their many potential applications, such as anti-fouling for for example. Super liquid-repellency can be achieved by nano- and microstructuring a low energy surface in a way, that the structure can entrap air underneath the liquid. The common criteria for super liquid-repellency are a high apparent advancing contact angle and a low contact angle hysteresis. For a better understanding of how a drop advances and recedes on such a structured surface, we imaged the motion of a water drop on a superhydrophobic array of micropillars by laser scanning confocal microscopy (LSCM). With LSCM, we imaged an advancing water front on a superhydrophobic surface at a resolution of 1 *m. The results give a qualitatively new picture of how water advances on the microscopic scale. We demonstrate that in contrast to traditional goniometer measurements, the advancing contact angle is close to 180° or even higher. In contrast, the apparent receding contact angle is determined by the strength of pinning. We propose that the apparent receding contact angle should be used for characterizing super liquid-repellent surfaces [1,2].

[1]F. Schellenberger et al., Phys. Rev. Lett. 116, 096101 (2016) [2]P. Ball, Nature Materials 15, 376 (2016)

Poster CPP 14.2 Mon 18:30 P1C

3D depth profiles of tip–sample interaction on type I collagen fibrils in humid air — •Robert Magerle[1], Manuel R. Uhlig[1], Diana Voigt[1], Martin Dehnert[1], and Anke Bernstein[2] — [1]Fakultät für Naturwissenschaften, Technische Universität Chemnitz — [2]Orthopädie und Traumatologie, Universitätsklinikum Freiburg

The water content and intermolecular crosslinks between collagen fibrils are important factors that determine the mechanical properties of type I collagen fibrils. With atomic force microscopy (AFM) we study reconstituted type I collagen fibrils (without crosslinks) and native fibrils from sheep tendon (with crosslinks). The water content in the fibrils is controlled via the relative humidity of air in the AFM. We measure force–distance (FD) curves and amplitude–phase–distance (APD) curves and reconstruct from this data three-dimensional (3D) depth profiles of the tip–sample interaction. This reveals the contributions of the attractive capillary interaction, the adhesive interaction as well as the repulsive viscoelastic response of the hydrated collagen fibrils. Furthermore, the 3D depth profiles of the tip–sample interaction allow for accurate measurements of the fibrils' shape and the fibrils' swelling behavior with increasing water content. We compare this with the related changes in the fibrils' elastic modulus and discuss the role of water content and intermolecular crosslinks in collagen fibrils.

Poster CPP 14.3 Mon 18:30 P1C

Study of the ion channels insertion in artificial membranes — Marcelo Cisternas[1,2], Vanessa Zepeda[1,2], Maria Jose Retamal[1,2,5], Tomas P. Corrales[3], Nicolas Moraga[1,2], Diego Diaz[1,2], Rodrigo Catalan[1,2], Sebastian Gutierrez[4], Tomas Perez-Acle[4], Patrick Huber[6], and •Ulrich G. Volkmann[1,2] — [1]Instituto de Fisica, P. Univ. Catolica de Chile (UC), Santiago, Chile — [2]CIEN-UC, P. Univ. Católica de Chile (UC), Santiago, Chile — [3]Facultad de Fisica, UTFSM, Valparaiso, Chile — [4]DLab, Fundacion Ciencia y Vida, Santiago, Chile — [5]Facultad de Quimica, P. Univ. Catolica de Chile (UC), Santiago, Chile — [6]Institute of Materials Physics and Technology, TUHH, Hamburg, Germany

The study of artificial membranes is important, because these model-membranes represent the behavior of its biological analogs, with a similar structure, composed of a series of phospholipids and proteins, altering their behavior when exposed to physical and chemical stimulations. This motivates possible applications, for example in the detection and transduction of molecular signals, a very important step in the development of biosensors. In this research we measured the change in the capacitive response of a system, composed by a DPPC bilayer on a thin layer of Chitosan (CH) deposited on a silicon substrate. The system was immersed into a protein solution of gramicidin and the study of the change of the capacitive response confirms the ion channel formation in the bilayer. Acknowledgements: MJR: Fondecyt postdoc 3160803. UGV: Fondecyt 1141105 y CONICYT-PIA ACT 1409. TPC: Fondecyt Iniciación 11160664, MC: CONICYT scolarship.

Poster CPP 14.4 Mon 18:30 P1C

AFM study of evaporated phospholipidic bilayer on thin film chitosan in liquid environment — Rodrigo Catalan[1,3], Maria Jose Retamal[1,2,3], Diego Diaz[1,3], Marcelo Cisternas[1,3], Nicolas Moraga[1,3], Tomas P. Corrales[4], Marco Soto-Arriaza[2], Patrick Huber[5], and •Ulrich G. Volkmann[1,3] — [1]Instituto de Fisica, P. Univ. Catolica de Chile (UC), Santiago, Chile — [2]Facultad de Quimica, P. Univ. Catolica de Chile (UC), Santiago, Chile — [3]CIEN-UC, P. Univ. Catolica de Chile (UC), Santiago, Chile — [4]Facultad de Fisica, UTFSM, Valparaiso, Chile — [5]Institute of Materials Physics and Technology, TUHH, Hamburg, Germany

Self-assembly of artificial biological membranes on solid substrates has gained importance due to the potential applications in the field of BioNanotechnology. Particularly important are phospholipidic membranes, e.g. DPPC, which interact with proteins that regulate the flow of ions across the membrane. In a previous work we have shown that DPPC forms a bilayer on silicon, which can serve for biosensoric applications. We have extended this concept to other phospholipids to explore their interactions with proteins. We present a thermal and morphological study of three phospholipidic thin-films: DODAB, DSPC and DMPC. These films are fabricated by Physical Vapour Deposition (PVD) on silicon and analyzed with Atomic Force Microscopy (AFM) in liquid at various temperatures. We show that these phospholipids do not decompose during PVD. Acknowledgements: MJR: Fondecyt postdoc 3160803. UGV: Fondecyt 1141105 y CONICYT-PIA ACT 1409. TPC: Fondecyt Iniciación 11160664, MC: CONICYT scolarship.

Poster CPP 14.5 Mon 18:30 P1C

Optical characterisation of single setae of the Saharan silver ant — •Bertram Schwind[1], Helge-Otto Fabritius[2], Thorsten Wagner[1], and Xia Wu[1] — [1]Department of Chemistry, University of Paderborn, Warburger Straße 100, 33098 Paderborn, Germany — [2]Max-Planck-Institut für Eisenforschung GmbH, Max-Planck-Straße 1, 40237 Düsseldorf, Germany

The Saharan silver ant (*Cataglyphis bombycina*) is adapted to extreme hot environmental conditions of the sahara desert [1]. The body of the ant is covered with a dense array of triangular shaped setae [2]. These setae not only reflect the incoming solar radiation by internal total reflection [3], but also enhance radiative cooling [2].

To deepen our understanding on the optical properties of the setae, we measured transmission spectra of single setae by FTIR from the MIR to visible range. Both the chemical composition and the orientation of the setae may have an influence on the shape of the transmission spectra. The absorption bands in the MIR region identify the composition of the setae. The relationship between the structure of the setae (orientation, shape, size, surface morphology) and scattering is investigated by transmission experiments combined with FDTD simulations.

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Poster CPP 14.6 Mon 18:30 P1C

Simulation of the Cuticular Photonic Crystals Evolved by the Neotropic Weevil Entimus Imperialis — •Fernando Luis Rodríguez Gallegos[1], Xia Wu[2], and Jens Förstner[1] — [1]Theoretical Electrical Engineering Group, Paderborn University, Germany — [2]Department of Chemistry, Paderborn University, Germany

We analyze the reflectance within the visible spectrum of the photonic crystals found in the scales of the neotropic weevil Entimus Imperialis. Our simulations show that the reflected signal at certain frequencies is cross polarized with respect to the excitation source. We present details of our simulation procedure, explain the underlying mechanism using a reduced equivalent structure and finally show the agreement to our experimental results.

Poster CPP 14.7 Mon 18:30 P1C

Actin stress fiber dynamics under lateral constraint —

•Andreas Müller and Tilo Pompe — Universität Leipzig, Institute of Biochemistry, Johannisallee 21-23, 04103 Leipzig

Cells at interfaces experience inhomogeneous mechanical environments, including spatial constraints, even down to 1D confinement, e.g., on single fibers in reconstituted in vitro fibrous scaffolds and also in various tissues in vivo. Previously, we found a bimodal distribution of actin stress fibers in cells under varying lateral constraint, indicated by the distinct formation of exterior and interior stress fibers and their respective spacing. We now investigated the dynamics of stress fiber formation and the correlated cell traction forces.

We use micro-patterned hard substrates and polyacrylamide hydrogels with fibronectin for subsequent culture of cells on stripe-like patterns. Cells are analyzed for several hours using SiR-Actin probes, focusing on actin cytoskeleton pattern, overall cell characteristics, and cell traction forces. We show that the magnitude of traction forces does correlate weakly with lateral constraint while actin cytoskeleton morphology and directionality of traction forces are strongly correlated and governed by the degree of confinement. Furthermore, time resolved actin stress fiber patterns are investigated in relation to cell dynamics.

With our setup, we are able to determine the mechanical and morphological response of cells in spatially constraining environments in a time-resolved manner.

Poster CPP 14.8 Mon 18:30 P1C

Dissipative bio-inspired supramolecular materials — •Marta Tena-Solsona, Benedikt Reiss, and Job Boekhoven — Technische Universität München

Synthetic self-assembled supramolecular materials have enormously developed during last decades. Applications of them are found in healthcare opto-electronics, and a wide range of fields. Although the behavior of these man-made materials is well-known, they are far from competing with biological counterparts. Especially, concerning spatio-temporal control, responsiveness, or adaptivity against external stimuli. The main differences between both type of systems lie in the energy balance. While most artificial assembled materials operate close to the thermodynamic equilibrium, many of the more advanced biological machineries are kinetically governed by self-assembly processes. These processes require a constant input of energy in order to be sustained, and to continuously dissipate energy. This dissipative mode of self-assembly requires specific design rules which are not fully understood in chemically driven man-made materials. Therefore, the design of these dissipative self-assembled systems remains challenging and the number of man-made examples is still limited. Our work focuses on translating the interesting properties biology offers, to the fully synthetic dissipative assemblies. We have designed a chemical reaction network based on small molecules that forms transient, far from-equilibrium materials, by consuming a chemical fuel. The dissipative nature of our system allows us to spatio-temporary control these assemblies which are of colloidal nature or hydrogels.

BP 11: Bioinspired Functional Materials: From Nature's Nanoarchitectures to Nanofabricated Designs (Joint Symposium CPP/BP/MM/DF/DY/MI)

Tuesday 09:30–12:15 HSZ 02

Invited Talk BP 11.1 Tue 9:30 HSZ 02

New twists in biological photonics: circular polarisation and beyond. — •Pete Vukusic, Luke McDonald, and Ewan Finlayson — University of Exeter, Exeter, UK.

The evolution of structural colour mechanisms in many biological systems has given rise to many specialised and often highly functional optical effects both in animals and in plants. Recent scientific works yielded several examples that are being developed for use across technology. Among many thousands of biological systems, a distinctive example involving circular polarisation (CP) was described by Michelson himself: the scarab beetle Chrysina resplendens. Its exoskeleton has a bright, golden appearance that reflects both right-handed and left-handed CP light. The chiral nanostructure responsible for this is a helicoid comprising twisted birefringent dielectric planes. This presentation revisits the C. resplendens beetle, correlating details of its CP reflectance spectra directly with detailed analysis of its morphology that includes a chiral multilayer configuration comprising two chirped, left-handed, helicoids separated by a birefringent retarder. The system's optical behaviour is modelled using a scattering matrix simulation, where the optical roles of each component of the morphological substructure are elucidated. The C. resplendens' model is presented here, alongside summaries of other inspirational biological structural colour generation strategies, as a key example of highly adapted optical design.

Invited Talk BP 11.2 Tue 10:00 HSZ 02

Bio-inspired materials and structures for technology and architecture — •Thomas Speck — Plant Biomechanics Group & Botanic Garden, University of Freiburg

Biological structures and materials are typically multi-layered, hierarchically structured, finely tuned and highly differentiated based on the combination of a few basic molecular components. This leads to materials and structures that are characterized by multiple networked functions and (often) possess excellent mechanical properties, a pronounced adaptability to changing environmental conditions and manyfold self-x-properties.

During the last decades biomimetics, i.e. using living organisms as inspiration for technical developments products, has attracted increasing attention as well from basic and applied research as from various fields of industry. Biomimetics has a high innovation potential and offers the possibility for the development of sustainable technical products and production chains. On the one hand, novel sophisticated methods for quantitatively analyzing and simulating the form-structure-function-relationship on various hierarchical levels allow new fascination insights in multi-scale mechanics and other functions of biological structures, materials and surfaces. On the other hand, recent developments in computational design and simulation together with new production methods enable for the first time the transfer of many outstanding properties of the biological role models into innovative biomimetic products for reasonable costs which makes them interesting for applications in many fields of technology and building construction.

Invited Talk BP 11.3 Tue 10:30 HSZ 02

Cellulose bio-inspired hierarchical structures — •Silvia Vignolini — Lensfield Road Cambridge CB2 1EW UK

Nature's most vivid colours rely on the ability to produce complex and hierarchical photonic structures with lattice constants on the order of the wavelength of visible radiation. A recurring strategy design that is found both in the animal and plant kingdoms for producing such effects is the helicoidal multilayers. In such structures, a series of individual nano-fibers (made of natural polymers as cellulose and chitin) are arranged parallel to each other in stacked planes. When distance between such planes is comparable to the wavelength of light, a strong polarised, colour selective response can be obtained. These helicoidal multilayers are generally structured on the micro-scale and macroscopic scale giving rise to complex hierarchical structures.

Biomimetic with cellulose-based architectures enables us to fabricate novel photonic structures using low cost materials in ambient conditions. Importantly, it also allows us to understand the biological processes at work during the growth of these structures in plants. In this talk the route for the fabrication of complex bio-mimetic cellulose-based photonic structures will be presented and the optical properties of artificial structures will be analyzed and compared with the natural ones.

15 min break

Invited Talk BP 11.4 Tue 11:15 HSZ 02

Strong Flexible Bioenabled Nanocomposites for Sustainable Sensing — •Vladimir Tsukuruk — School of Materials Science and Engineering, Georgia Institute of Technology, Atlanta, USA

I discuss recent results from our research group on designing flexible and strong responsive polymer and biopolymer nanocomposite materials and structures for advanced flexible sensing and electronic applications. Ultrathin silk fibroin proteins and chemically modified cellulose nanocrystals were assembled in order to control intimate assembly with graphene oxide sheets with controlled surface chemical composition on planar and curved substrates. We demonstrated flexible laminated bionanocomposites with developed biointerphases that facilitate extremely high elastic modulus, bending flexibility, and toughness. Both experimental and computational methods were undertaken to address silk fibroin adsorption at heterogeneous surfaces of graphene oxide with different degrees of oxidation. Graphene oxide and reduced graphene oxide sheets at various levels of oxidation were compared with silicon dioxide (SiO2) as a benchmark substrate. We concluded that silk fibroin readily forms single molecule proto-nanofibrils with β-sheet structures on oxidized graphene oxide surfaces but aggregated globular structures on the hydrophobic surfaces. Finally, electrochemical-assisted photolithography has been utilized for high spatial resolution conductive patterning of these nanocomposites with high local electrical conductivity, sharp boundaries, and optical transparency. Some peculiar features of these flexible bionanocomposites can be explored for tactile recognition, remote sensing, and low-noise SERS substrates.

Invited Talk BP 11.5 Tue 11:45 HSZ 02

3D laser nano-printing of rationally designed materials — •Martin Wegener — Karlsruhe Institute of Technology, Karlsruhe, Germany

Broadly speaking, 3D structures and materials can be designed by using the human brain, computer-based (topology) optimization, or inspiration from nature. Regardless of how a 3D blueprint has been obtained, it eventually needs to be manufactured. 3D laser printing on the micro- and nanometer scale has become a versatile and reliable workhorse for accomplishing this task. Here, we review recent examples from our group. This includes micropolar metamaterials with behavior beyond ordinary continuum mechanics, metamaterials with effectively negative thermal expansion from positive constituents, and electrical metamaterials with unusual direction and sign of the Hall voltage.