BP 37: Biomaterials

Time: Friday 10:00–13:00 Location: H43

Invited Talk BP 37.1 Fri 10:00 H43

Pearls and Feathers: New Concepts and Inspiration for Plant's Design — •Ingrid Weiss, Eduard Arzt, and Helmut Kirchner — INM - Leibniz Institute for New Materials gGmbH, Campus D2 2, D-66123 Saarbrücken, Germany

Pearls and nacre are at the forefront of understanding the earliest genetic routes towards high-performance composite materials. Also the display function of birdfeathers for sexual attraction implies very specific needs of evolutionary relevance. Our work demonstrates that various functions are achieved by the composite structure of biological materials, which is better than the sum of its parts. While pearls consist of micro- and nano-patterned aragonite with low organic content, the cortex material of feathers, beta-keratin, is homogeneous over about 80% of the length of the rachis. Our ongoing research on chitin in pearls [1,2], and on keratin in feathers [3] aims at understanding what exactly happens in feather follicles under load, and in pearl forming tissue during the process of biomineralization thus creating a basic link between gravity, materials properties, and life. This would as well be relevant for understanding complex structured materials such as plants.

References [1] I.M. Weiss, Jewels in the pearl, ChemBioChem, in press (2010) [2] I.M. Weiss et al., The chitin synthase involved in marine bivalve mollusk shell formation contains a myosin domain, FEBS Lett. 580, 1846-1852 (2006) [3] I.M. Weiss & H.O.K. Kirchner, The peacock's train (Pavo cristatus and Pavo cristatus mut. alba) I. Structure, mechanics, and chemistry of the tail feather coverts, J. Exp. Zool. A, submitted, (2009)

BP 37.2 Fri 10:30 H43

New functional ceramic composits through biomineralisation? — •Katharina Gries[1,2], Malte Launspach[1], Meike Gummich[1], Tanja Dodenhof[1], Andreas Rosenauer[2], and Monika Fritz[1] — [1]Pure and Applied Biomineralisation, Biophysics Institute, Universität Bremen, Germany — [2]Electron Microscopy Group, Solid State Physics, University Bremen, Germany

The biogenic polymer/mineral composite nacre is grown by a self-organisation process, where a few weight percent of organic material governs the specific crystallization of the calcium carbonate polymorph aragonite. The thus developed material shows a dense packing of thin layers (500nm) of mineral platelets interdispersed by a few nanometer of organics, acting like a glue to improve the mechanical properties of this biogenic ceramic by making it non-brittle. In order to be able to make use of this self-organised structure formation for future purposes and applications we have to understand this process, which results in the microstructure with mineralized platelets embedded in bioorganic nanolayers. In direct atomic force microscopy experiments and in crystallization experiments, on the interaction of model polymers and purified proteins with the mineral calcium carbonate, crystal nucleation and inhibition properties of the different polymers and proteins were discovered. We employ SEM (scanning electron microscopy), AFM (atomic force microscopy), precipitation assays, contact angle measurements and theoretical simulations to investigate the interaction processes between organic and inorganic material in the natural and synthetic composites.

BP 37.3 Fri 10:45 H43

The nanostructure of biogenic calcite: a 3D SAXS/WAXS study. — •Christoph Gilow[1], Barbara Aichmayer[1], Chenghao Li[1], Stefan Siegel[1], Oskar Paris[2], Emil Zolotoyabko[3], and Peter Fratzl[1] — [1]Department of Biomaterials, Max Planck Institute of Colloids and Interfaces, Research Campus Golm, 14424 Potsdam, Germany — [2]Institute of Physics, University of Leoben, A-8700 Leoben, Austria — [3]Department of Materials Engineering, Technion - Israel Institute of Technology, Haifa 32000, Israel

Biogenic crystals grow in the presence of organic macromolecules which influence their shape and internal structure, often resulting in superior material characteristics. Calcitic prisms from the shell of the *Pinna nobilis* scatter like single crystals, despite containing significant amounts of intra-crystalline organic macromolecules which cause anisotropic distortions of the calcite unit cells. Individual prisms were investigated by means of 3D wide- and small-angle scattering (SAXS/WAXS) using synchrotron radiation at the μ-Spot beamline, BESSY II, Helmholtz Zentrum Berlin. The SAXS signal was also found to be strongly anisotropic and had a fixed orientation correlation to the WAXS pattern. Additional insights into the nanostructure of calcitic prisms and the organic-mineral interfaces were gained by laboratory SAXS measurements on powdered samples as well as by SEM studies on etched samples. Annealing the prisms at 300°C, a temperature which was chosen to mainly affect the organic macromolecules, led to substantial structure rearrangements on a nano-scale.

BP 37.4 Fri 11:00 H43

The ordered arrangement of secondary osteons in long bones — •Carolin Lukas[1], Ron Shahar[2], John Dunlop[1], Sharon Papo[2], and Richard Weinkamer[1] — [1]Max Planck Institut of Colloids and Interfaces, Potsdam — [2]The Hebrew University of Jerusalem, Rehovot, Israel

Bone remodeling, the renewal process of bone, leads in compact bone to the formation of cylindrical structures called osteons. In the central cavity (haversian canal) of the osteon a blood vessel is responsible for the supply of nutrients to the bone cells. This work aims (i) to quantify the order in the arrangement of haversian canals and (ii) to use a simple model to explain the measured order. Using microscopy we studied different long bones (radius, metacarpal) from horses and dogs at different anatomical locations. The spatial arrangement of osteons was quantified by the use of the autocorrelation function (ACF) and by the shortest distance distribution (SDD) which describes how far away bone is from its nearest haversian canal. In our model the arrangement of osteons is created by a random sequential addition process. Each osteon is characterized by an haversian canal surrounded by a circular exclusion zone within which the creation of another osteon is prohibited (cherry-pit model). The radii of the exclusion zone are assumed to be normally distributed. The analysis of the microscopic images showed that the ACFs and SDDs are independent of the anatomical location in the horse radius, but not in the metacarpal bone. These differences could be explained by the model, by either increasing the mean value of the exclusion radius or the standard deviation.

BP 37.5 Fri 11:15 H43

Bioactive surfaces from polymeric films aiming at near IR-light triggered cellular response — •Dmitry Volodkin[1,3], Andre Skirtach[1], Narayanan Madaboosi[1], Jenifer Blacklock[1], Regine von Klitzing[3], Andreas Lankenau[2], Claus Duschl[2], and Helmuth Möhwald[1] — [1]MPIKG, Am Mühlenberg 1, 14476 Potsdam-Golm, Germany — [2]IBMT, Am Mühlenberg 13, 14476 Potsdam-Golm, Germany — [3]TU Berlin, Strasse des 17. Juni 124, 10623 Berlin, Germany

The layer-by-layer (LbL) polymer self-assembly based on consecutive polymer adsorption has emerged as a powerful and versatile strategy to engineer surface films for bio-applications. Here we present composite LbL-assembled dynamic films possessing high loading capacity, remote release functionalities, and controlled cellular response. The film has been formed using two biopolymers, namely hyaluronic acid (HA) and poly-L-lysine (PLL). The film able to embed material of different nature (from flexible macromolecules such as DNA and proteins to nano- and microparticles) in extremely high amounts (tens of mkg per cm2) that is related to spontaneous "polymer doping". Here we present remote release of film-entrapped material by "biofriendly" near-infrared light. Composite HA/PLL film with embedded gold nanoparticles and biomacromolecules or microcapsules hosting biomolecules can be activated by infrared light resulting in biomolecules* release. The films can be constructed to be cell (fibroblasts) adhesive or cell resistant depending on its intrinsic properties. Light-triggered DNA transfection to individual cell is demonstrated.

15 min. break

BP 37.6 Fri 11:45 H43

The Effect of Large Strain Deformations on the Non-linear Material Properties of Collagen — •Stefan Münster[1,2], Louise Jawerth[2], David Weitz[2], and Ben Fabry[1] — [1]Department of Physics, University Erlangen-Nuremberg, Germany — [2]Department of Physics, Harvard University, Cambridge, USA

Collagen is the most abundant protein in vertebrates, and its mechani-

cal properties govern the structure and function of many tissues. When subjected to large strain, collagen shows strain-stiffening behavior typical for biopolymers. Here, we investigate how the strain-stiffening response of collagen changes as the material undergoes repeated large strain oscillations. We shear *in vitro* reconstituted collagen gels in a plate-plate rheometer by applying sinusoidal strain oscillations, and analyze the non-linear stress-strain relationship. With each cycle, the maximum stress and the linear modulus of the material decrease, and the strain-stiffening response occurs at higher strains. Surprisingly, the shape of each stress-strain response is similar to that observed during the previous cycle, only shifted towards larger strain values. Upon addition of covalent crosslinks by incubating the polymerized collagen gels with 2% glutaraldehyde solution, the stress-strain relationship becomes independent of the loading history. We hypothesize that the microscopic mechanism responsible for the history dependence is intra-fibrillar slip of adjacent collagen monomers, which increases the rest lengths of previously strained fibers. A simple visco-elastic model which takes the fibrillar structure of the gels into account shows remarkable similarity with our experimental data.

BP 37.7 Fri 12:00 H43

Using microtubules to measure actin viscoelasticity — Felix Zörgiebel[1], •Marcel Bremerich[1], Frederick C. MacKintosh[2], and Christoph F. Schmidt[1] — [1]III. Physikalisches Institut, Georg-August-Universität, 37077 Göttingen — [2]Department of Physics & Astronomy, Vrije Universiteit, 1081 HV Amsterdam

In conventional active and passive microrheology techniques, micron-sized particles are embedded in biological samples for probing their viscoelastic properties. These methods are not always well suited for investigating the interior of living cells because the probe particles can perturb their neighborhood and because surface interactions can occur. Such problems can be elegantly circumvented by using natural constituents of the cellular system as local probes. The thermal bending fluctuations of microtubules, for instance, intrinsically carry information about the mechanical properties of the surrounding medium. It turns out that one can investigate local shear moduli and stress fluctuations in biopolymer networks by a detailed analysis of the spatial and temporal bending fluctuations of just one point of a microtubule, largely without introducing probe artifacts. To test this new method, we sparsely seeded an in vitro network of filamentous actin with microtubules which were again sparsely labeled with nanometer-sized gold particles. The displacements of these particles were then tracked by laser interferometry using an optical trap. Knowing the microtubule elastic properties, the observed bending dynamics allowed us to estimate the complex shear modulus of the surrounding actin network.

BP 37.8 Fri 12:15 H43

Micromechanical Properties and Structure of the Pericellular Coat of Living Cells — •Heike Böhm[1], Tabea Mundinger[1], Valentin Hagel[1], Uwe Rauch[2], Jennifer Curtis[3], and Joachim Spatz[1] — [1]Max-Planck-Institute for Metals Research, Department New Materials & Biosystems & University of Heidelberg, Department of Biophysical Chemistry, Heisenbergstr. 3, 70569 Stuttgart, Germany — [2]Vessel Wall Biology, Department of Experimental Medical Science, Biomedical Center, Lund University, 221 84 Lund, Sweden — [3]School of Physics, Georgia Institute of Technology, 837 State Street, Atlanta, GA

Most mammalian cells are enveloped by a coat of polysaccharides and proteins, the pericellular coat (PCC). It plays a vital role in biological processes such as adhesion and proliferation. The PCC's backbone is composed of hyaluronan (HA), a highly hydrated polysaccharide that anchors the coat to the cell membrane. The molecular interaction of hyaluronan with different HA binding proteins determines the architecture of the PCC. Their mesoscopic arrangement influences not only the cell's perception of its environment but also its ability to withstand compression. This is especially important for our cells of interest: chondrocytes living and maintaing the load-bearing cartilage. In order to study the mesoscopic strucutre of the PCC, we employ a toolbox of different biophysical techniques, including confocal microscopy, particle tracking microrheology [1] and adhesive nanostructured surfaces. T [1] H. Boehm, T. A. Mundinger, C. H. J. Boehm, V. Hagel, U. Rauch, J. P. Spatz, J. E. Curtis, Soft-Matter 2009, DOI: 10.1039/B905574F.

BP 37.9 Fri 12:30 H43

Linker Induced Actin Network Formation under Cell-Sized Confinement — •Florian Huber, Sebastian Ehrig, Carsten Vogt, Dan Strehle, and Josef Käs — Division of Soft Matter Physics, Department of Physics, University of Leipzig, Linnéstr. 5, D-04103 Leipzig, Germany

Cross-linked actin networks are decisively involved in the overall mechanical properties of cells. The networks' architecture ranges from densely packed bundles to networks with high crossing angles and is typically assigned to specific linker proteins. Recently, however, it was found that weak cross-linkers give rise to both extended networks and bundles. We used multivalent ions as model-linkers to study actin filament aggregation in cell-sized geometries. Small droplets filled with actin filaments are sealed by a thin oil film to control droplet evaporation. At a critical concentration of multivalent ions their potential turns attractive. This implies a phase transition from isotropic or nematic f-actin solutions to cross-linked actin networks.

In addition to the well-known bundle formation, we obtained regularly spaced networks of star-like astern patterns. These networks display many features of cellular networks in the actin cortex and may serve as a model system for the cortical actin layer. Moreover, by altering the linker properties it was possible to switch between different network architectures. Observed phase transitions are fast (seconds to few minutes) which is of high interest concerning the known ability of living cells to quickly modify their morphology.

BP 37.10 Fri 12:45 H43

Active polar gels in a Taylor Couette Geometry — •Matthias Mussler and Albrecht Ott — Biologische Experimentalphysik, Universität des Saarlandes, Saarbrücken

The Taylor Couette Geometry is a well researched system for polymer-suspensions and many other inactive fluids.Our experimental approach starts with the assumption that, if a fluid or suspension has active components, the critical Taylor Number is influenced by these active processes, i.e. filament de-/polymerisation, and the phase diagram will change. This is observable by the formation of Taylor Vortices or other flow figures and calculable by the stimulus in relation to the flow variation. For these experiments we use an extract of Xenopus Oocytes as an example for acellular but nonetheless active fluid and Macrophages as an example for highly active living cells in a coaxial cylinder geometry in a commercial rheometer. The calculus of these experiments is based on the theory of active polar gels described by Kruse et al. This theory describes an active fluid with several components. It takes into account polar order and considers the case when one component is viscoelastic.