BP 12: Biopolymers and Biomaterials (joint session BP/CPP)

Time: Wednesday 9:30–13:00 Location: TOE 317

BP 12.1 Wed 9:30 TOE 317

Interaction of laminin and brain cells with ion implanted titania nanotube scaffolds — •Jan Frenzel[1,2,3], Astrid Kupferer[1,2], and Stefan Mayr[1,2] — [1]Leibniz Institute of Surface Engineering (IOM), 04318 Leipzig, Germany — [2]Division of Surface Physics, Faculty of Physics and Earth Sciences, Leipzig University, 04103 Leipzig, Germanyany — [3]Research Group Biotechnology and Biomedicine, Faculty of Physics and Earth Sciences, Leipzig University, 04103 Leipzig, Germany

Brain-machine interfaces enable symptomatic treatment of neurodegenerative diseases by modulating neural activities and enjoy great popularity when brain tissue is assessed ex vivo. However, current-use interface materials are troubled by numerous challenges concerning loss of long-term adhesion, rejection reactions, and glial scarring. We show that ion-implanted titania nanotube scaffolds (TNS) are a promising candidate for dealing with these issues because they combine high biocompatibility with adequate electrical conductivity. Based on our experiments, we explain how changes in the adsorption of laminin and the viability/adhesion of neurons and glial cells caused by ion implantation can be described by alterations in surface characterisics. The high neuron viability observed on all TNS, but suppressed glial cell formation on implanted TNS, demonstrates the potential as a future interface material. We acknowledge funding by SMWK (100331694). Reference: Frenzel et al., Nanomaterials 2022, 12, 3858. https://doi.org/10.3390/nano12213858

BP 12.2 Wed 9:45 TOE 317

Fiber-based femtosecond 3D printing — •Claudia Imiolczyk[1], Andy Steinmann[1], Moritz Flöss[1], Zhen Wang[1], Michael Heymann[2], Andrea Toulouse[3], and Harald Giessen[1] — [1]4th Physics Institute, Research Center SCoPE, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Institute of Biomaterials and Biomolecular Systems, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [3]Institute of Applied Optics, Research Center SCoPE, University of Stuttgart, Pfaffenwaldring 9, 70569 Stuttgart, Germany

Ultrashort laser pulses are often used in medical applications, for instance for soft-tissue surgeries. However, the progress on using such laser pulses for tissue structuring is rather marginal so far. Therefore, we aim to realize an endoscopic fiber-based femtosecond 3D printer to minimally invasively surgically repair organ damage on a micrometer scale. For this, high-power femtosecond laser pulses are required, in order to 3D print desired geometries with a microfluidic bio-ink using two-photon-lithography. We utilize ruled reflective diffraction gratings to pre-chirp laser pulses, as dispersion in optical fibers broadens these femtosecond laser pulses. We report on measurements of pulse duration, spectrum, compression, and nonlinear effects. These resulting 3D printed structures should be colonized with endogenous cells, analogous to the extracellular matrix. This could open a new area of endoscopic 3D printing of biomaterials inside the human body to revolutionize plastic micro-surgery, such as repairing defects in the heart of embryos or even repairs behind the eardrum at the auditory ossicles.

BP 12.3 Wed 10:00 TOE 317

DNA-encoded viscoelastic matrices for cell and organoid culture — •Elisha Krieg — Leibniz-Institut für Polymerforschung Dresden e.V. — Technische Universität Dresden

The recent advances in mechanobiology and the physics of life have driven an immense interest in mechanically programmable viscoelastic materials for cell and organoid culture. Here I describe a class of soft hydrogels based on novel DNA libraries that self-assemble with synthetic polymers.[1] This dynamic DNA-based matrix (DyNAtrix) provides computationally predictable, systematic, and independent control over key cell-instructive properties by merely changing DNA sequence information without affecting the compositional features of the system. This approach enables: (1) thermodynamic and kinetic control over network formation; (2) adjustable heat activation for the homogeneous embedding of mammalian cells; and (3) dynamic tuning of stress relaxation times to precisely recapitulate the mechanical characteristics of living tissues. DyNAtrix is self-healing, printable, exhibits high stability, cyto- and hemocompatibility, and controllable degradation. DyNAtrix-based 3D cultures of human mesenchymal stromal cells, pluripotent stem cells, canine kidney cysts, and placental organoids exhibit high viability, proliferation, and morphogenesis over several days to weeks. DyNAtrix thus represents a programmable and versatile precision matrix, paving the way for advanced approaches to biomechanics, biophysics, and tissue engineering.

[1] Peng et al. bioRxiv 2022, DOI:10.1101/2022.10.08.510936

Invited Talk BP 12.4 Wed 10:15 TOE 317

Materials properties of bacterial biofilms. — •Cécile M. Bidan — Max Planck Institute of Colloids and Interfaces, Department of Biomaterials, Potsdam, Germany

As bio-sourced materials are raising interest for their sustainability, using bacteria to produce biofilms made of a protein and polysaccharide matrix has become a new strategy to make engineered living materials with various functionalities. Our group contributes to this emerging field by clarifying how bacteria adapt biofilm materials properties to the environment. For this, we culture E. coli producing curli amyloid and phosphoethanolamine-cellulose fibers on nutritive agar substrates with varying physico-chemical properties and study the growth, morphology and mechanical properties of the resulting biofilms. We demonstrated that changing the properties of the agar substrate with polyelectrolyte coatings or by varying the water content the bulk properties of the agar affects E. coli biofilm growth, morphology and mechanical properties. We also used E. coli producing only amyloid fibers and focus on the matrix structural and functional changes at the molecular scale. To assess the contribution of each matrix component to the macroscopic biofilm materials properties, we compared the characteristics of biofilms produced by a collection of E. coli mutants differing in the matrix they produce. The results indicate that E. coli biofilm matrix is a composite made of rigid and brittle curli amyloid fibers assembled within a mesh of soft and adhesive phosphoethanolamine-cellulose fibers. Finally, we explored how treating biofilms with ionic solutions can help tuning further their properties.

BP 12.5 Wed 10:45 TOE 317

The migration and search behavior of immune cells — Reza Shaebani and •Franziska Lautenschläger — Saarland University, Saarbrücken

Immune cells have a variety of tasks in the body. For example, dendritic cells act as the *sentinels* searching for pathogens. For this search, the cells need to scan a certain area in an effective way. Here, we investigate how cells optimize the search of such area. We have shown before that all cell types show a correlation of migration speed and persistence [1]. We later found that cells which strongly correlate these two parameters are particularly good at searching objects [2]. Interestingly, we found that cells do not keep the memory of their speed as long as the memory of their persistence [3]. Now, we investigate how we can disturb this migration and search behavior, preferable by altering the cytoskeleton [4].

1.*Maiuri, P., et al., Actin flows mediate a universal coupling between cell speed and cell persistence. Cell, 2015. 161(2): p. 374-86. 2.*Shaebani, M.R., et al., Persistence-Speed Coupling Enhances the Search Efficiency of Migrating Immune Cells. Phys Rev Lett, 2020. 125(26): p. 268102. 3.*Shaebani, M.R., M. Piel, and F. Lautenschläger, Distinct Speed and Direction Memories of Migrating Cells Diversify Their Possible Search Strategies. arXiv. 4.*Shaebani, M.R., et al., Vimentin provides target search efficiency and mechanical resilience for dendritic cell migration. bioRxiv, 2020: p. 2020.12.18.423401.

BP 12.6 Wed 11:00 TOE 317

Molecular motors from a 3D perspective: how do kinesins organize microtubules? — •Laura Meissner[1], Jonas Bosche[2], Ludger Santen[2], and Stefan Diez[1,3,4] — [1]B CUBE - Center for Molecular Bioengineering, TU Dresden, Dresden, Germany — [2]Center for Biophysics, Department of Physics, Saarland University, Saarbrücken, Germany — [3]Cluster of Excellence Physics of Life, TU Dresden, Dresden, Germany — [4]Max Planck Institute of Molecular Cell Biology and Genetics, Dresden, Germany

Kinesins are ubiquitous motor proteins that are essential for intracellular transport processes. In addition, several kinesins act within the mitotic spindle by sliding and crosslinking microtubules. Some of those kinesins not only move longitudinally on the microtubule filament but

also display an axial component in their motion. So far, the effect of this axial motion on motility and force generation within the mitotic spindle has not been explored deeply. Using a 3D motility assay, we show that the antagonistic motor proteins kinesin-5 and kinesin-14 drive the rotation of microtubules around each other. We characterize their motility parameters, including velocity and pitch. Further, we determine the extension of the motors, which reveals the conformation of the motors in microtubule overlaps. To investigate the rotational force (torque) that the motors could produce during microtubule sliding, we developed a microtubule coiling assay. Here, both kinesin-5 and kinesin-14 bent and coiled microtubules, indicative of the generation of significant torque. We hypothesize that this behavior serves to organize spindle fibers and to provide robustness to the spindle.

15 min. break

BP 12.7 Wed 11:30 TOE 317

3D stimulated Raman spectral imaging of water dynamics associated with pectin-glycocalyceal entanglement — •Moritz Floess[1], Tobias Steinle[1], Florian Werner[1], Yunshan Wang[1], Willi L. Wagner[2], Verena Steinle[2], Betty S. Liu[3], Yifan Zheng[3], Steven J. Mentzer[3], and Harald Giessen[1] — [1]4th Physics Institute, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Department of Diagnostic and Interventional Radiology, University Hospital of Heidelberg, Im Neuenheimer Feld 420, 69120 Heidelberg, Germany — [3]Laboratory of Adaptive and Regenerative Biology, Brigham & Women's Hospital, Harvard Medical School, Boston MA

Pectin, a heteropolysaccharide, is an ideal biomaterial for medical applications such as serosal wound healing and visceral tissue repair. It forms strong mechanical bonds with the underlying tissue. The extraordinary adhesive properties of pectin on organ surfaces are highly water-dependent and most likely result from a microstructural entanglement of pectin polysaccharide chains with the similarly textured glycocalyx, a glycoprotein coat, covering mammalian cell surfaces. We employ label-free 3D stimulated Raman scattering (SRS) microscopy to investigate the hydrophilicity of pectin hydrogel without the altering effects of sample fixation, dehydration, or tissue staining. In particular, we quantify the time scales, on which two different hydration mechanisms take place. Furthermore, the transition zone between pectin and porcine serosal tissue is imaged to obtain quantitative insights into the entanglement between pectin and mammalian glycocalyx.

BP 12.8 Wed 11:45 TOE 317

Quantifying optomechanical properties of phase separated protein condensates — •Timon Beck[1], Lize van der Linden[2], Raimund Schlüssler[2], Kyoohyun Kim[1], Simon Alberti[2], and Jochen Guck[1] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Biotec TU Dresden, Dresden, Germany

The organization of intracellular material is a complex task and cells have different strategies for compartmentalization. One way is the formation of membraneless organelles that are involved, for example, in metabolic control and DNA repair. The underlying process of phase separation and percolation is tightly controlled by many parameters as temperature, ion and protein concentration, as well as crowding conditions. Changes in these parameters have an impact on the intermolecular interactions and accordingly tune optical and viscoelastic characteristics of the condensates. Despite the dynamic development of the research field in the last years, there is a lack of tools to quantitatively measure such physical properties. A combination of Brillouin microscopy with quantitative phase imaging, providing information about refractive index and density, gives access to a set of optical and mechanical quantities and in particular the longitudinal modulus. By varying temperature and ion conditions, we were able to tune intermolecular interactions within phase separated protein droplets and found that the introduced variations are reflected in the optomechanical properties of the condensates.

BP 12.9 Wed 12:00 TOE 317

Confinement-induced fractionation and liquid-liquid phase separation of polymer mixtures — •Arash Nikoubashman[1] and Miho Yanagisawa[2] — [1]Institute of Physics, JGU Mainz, Germany — [2]Graduate School of Science, The University of Tokyo, Japan

The formation of (bio)molecular condensates via liquid-liquid phase separation in cells has received increasing attention, as these coacervates play important functional and regulatory roles within biological systems. However, the majority of studies focused on the behavior of pure systems in bulk solutions, thus neglecting confinement effects and the interplay between the numerous molecules present in cells. To advance our knowledge, we perform simulations of binary polymer mixtures in droplets, considering both monodisperse and polydisperse molecular weight distributions for the longer polymer species. We find that confinement induces a spatial separation of the polymers by length, with the shorter ones moving to the droplet surface. This partitioning causes a distinct increase of the local polymer concentration in the droplet center, which is more pronounced in polydisperse systems. Consequently, the systems exhibit liquid-liquid phase separation at average polymer concentrations where bulk systems are still in the one-phase regime.

BP 12.10 Wed 12:15 TOE 317

Branching morphogenesis in the silica cell wall of diatoms — •Iaroslav Babenko[1,2,3], Benjamin M. Friedrich[1,2], and Nils Kröger[1,3] — [1]Cluster of Excellence Physics of Life, TU Dresden, 01062 Dresden, Germany. — [2]Center of Advancing Electronics Dresden, TU Dresden, 01062 Dresden, Germany. — [3]Center for Molecular and Cellular Bioengineering, 01307 Dresden, Germany.

Diatoms live in a glass house: these common single-celled algae fascinated evolutionary biologists, chemical engineers and inspired artists for their ability to produce intricately nano- and micropatterned silica schells. The valve of the cell wall is formed in a planar intracellular compartment termed silica deposition vesicles (SDVs). The physical mechanism that guides the self-assembly of species-specific silica patterns is unknown. Here, we address this question by studying the formation of the silica rib patterns in the cell wall of the model diatom *Thalassiosira pseudonana* by combining theory and electron microscopy of nascent silica valves. We propose a minimal model of branching morphogenesis based on a non classical Turing reaction-diffusion system to quantitatively account for the time course of experimentally observed rib patterns. We introduce a novel mechanism of branching morphogenesis, which relies on a transition from soluble to insoluble silica phases inside the SDV and the concurrent release of an inhibitor that hinders this transition. Moreover, our minimal model is capable of producing a wide range of rib patterns, suggesting that this model may be applicable for describing branching morphogenesis in other diatom species and potentially, in other organisms.

BP 12.11 Wed 12:30 TOE 317

Reimplementing the formation and dispersal of transcriptional clusters with synthetic DNA-nanomotifs and Langevin-dynamics simulations — •Aaron Gadzekpo[1], Xenia Tschurikow[1], Mai Tran[2], Rakesh Chatterjee[3,4], Vasily Zaburdaev[3,4], Kerstin Göpfrich[2], and Lennart Hilbert[1] — [1]Karlsruhe Institute of Technology — [2]Max Planck Institute for Medical Research — [3]Max Planck Zentrum für Physik und Medizin — [4]Friedrich-Alexander Universität Erlangen-Nürnberg

Spatial organisation of the genome is emerging as a crucial aspect of gene transcription. In pluripotent cells, self-interacting molecular factors, such as RNA polymerase II, form microphase-separated domains, which become increasingly dispersed due to amphiphilic effects of newly transcribed genes. To understand the principles that lead to this behaviour, we designed synthetic DNA-nanomotifs that form droplets due to self-interaction and allow for the addition of an amphiphilic tail of thymines. Time-lapse microscopy, titration experiments and analysis of the resulting distributions of droplet properties demonstrate that the synthetic system reproduces the dispersal of phase-separated domains found for increasing transcription levels. Simulations based on Langevin-dynamics equally reproduce this behaviour after tuning interaction strengths and number ratios. Our findings illustrate how model-guided design of DNA-based systems can elucidate the mechanisms that control spatio-temporal compartmentalisation in cells.

BP 12.12 Wed 12:45 TOE 317

Partition complex structure can arise from sliding and bridging of ParB dimers — •Lara Connolley[1], Lucas Schnabel[2], Martin Thanbichler[2], and Sean Murray[1] — [1]Max Planck Institute for Terrestrial Microbiology, Marburg, Germany — [2]University of Marburg, Marburg, Germany

Chromosome segregation is vital for cell replication and in many bacteria is controlled by the ParABS system. A key part of this machinery is the association of ParB proteins to the parS-containing centromeric region to form the partition complex. Despite much work, the formation

and structure of this nucleoprotein complex has remained unclear. It was recently discovered that CTP binding allows ParB dimers to entrap and slide along the DNA, as well as leading to more efficient condensation through ParB-mediated DNA bridging. Here, we use semi-flexible polymer simulations to show how these properties of sliding and bridging can explain partition complex formation. We find that transient ParB bridges can organise the DNA into either a globular state or into hairpins and helical structures, depending on the bridge lifetime. Upon coupling with stochastic sliding simulations to form a unified sliding and bridging model, we find that short-lived ParB bridges do not hinder ParB sliding and the model can reproduce both the ParB binding profile and the condensation of the nucleoprotein complex. Overall, our model clarifies the mechanism of partition complex formation and predicts its fine structure.