BP 5: Membranes, Vesicles and Synthetic Life-like Systems I

Time: Monday 15:00–16:30 Location: BAR/0205

BP 5.1 Mon 15:00 BAR/0205

Toward programmable microrobots: DNA-based molecular communication between hydrogel microbeads — •Alexandra Bienau, Alexander Wietfeld, Wolfgang Kellerer, and Friedrich C. Simmel — Technical University Munich, Germany

Emerging applications in biomonitoring and smart therapeutics require materials that can sense biochemical cues, process and transfer information, and respond accordingly. In nature, such capabilities are often achieved through chemical communication, for example in bacterial quorum sensing or immune-cell signaling, where diffusing molecules enable coordinated behavior across many units.

DNA-based hydrogels offer a programmable platform for engineering similar functions, supporting sensing, logic operations, and responsive cargo release. Their porous structure enables molecular diffusion and biochemical exchange. Here, we establish DNA-based molecular communication between hydrogel microbeads. Using emulsion-based droplet microfluidics, we fabricate uniformly sized microbeads that can be modularly loaded with molecular cargo. We immobilize photo-initiated transmitter (TX) and fluorescence-based receiver (RX) systems within them. Communication occurs through diffusing DNA strands, and we characterize signal propagation using experiments and a comprehensive modeling framework.

Looking ahead, this platform enables the design of more sophisticated communication protocols and provides a step toward programmable hydrogel microrobots capable of collective information processing and dynamic interaction with biological environments.

BP 5.2 Mon 15:15 BAR/0205

Microfluidic Micropipettes: A Chip-Based Platform for Membrane Mechanics at Scale — •Sebastian W. Krauss[1], Megan Wong[2], Sepideh Razavi[3], Lorenzo Di Michele[1], and Pietro Cicuta[2] — [1]Department of Chemical Engineering and Biotechnology, University of Cambridge, UK — [2]Cavendish Laboratory, University of Cambridge, UK — [3]School of Sustainable Chemical, Biological and Materials Engineering, University of Oklahoma, USA

The mechanical properties of lipid membranes play an important role in diverse processes, from cell interactions to diseases. Established techniques, however, often suffer from low throughput or provide only bulk mechanical readouts, such as overall stiffness, making it challenging to obtain statistically robust measurements of membrane mechanics. Here, we present a microfluidic platform incorporating hundreds of micropipette like confinements on a single chip, enabling parallel mechanical characterisation of giant unilamellar vesicles (GUVs) in a single experiment. The forces acting on the membrane can be precisely tuned via the applied flow rates and the custom channel geometries, allowing well-defined, controllable mechanical testing. The platform also enables in situ exposure of GUVs to membrane-active compounds, such as surfactants, facilitating direct observation of their impact on membrane mechanics, including the dynamics and reversibility of these effects. This high-throughput approach opens the possibility for systematic screening of compound libraries, providing a quantitative framework to study the interactions between solutes and their impact on membranes.

BP 5.3 Mon 15:30 BAR/0205

Supported DPPC/DPPG Bilayers on Oxide Substrates as a Versatile Platform for Protein*Membrane Studies and Future FRET-Based Sensing — •Daniel Saavedra[1], Benjamin Ruz[1], Marcelo Cisternas[2], Susana Rojas[2], and Ulrich Volkmann[1] — [1]Institute of Physics, Pontificia Universidad Católica de Chile, Santiago, Chile — [2]School of Industrial Engineering, University of Valparaíso, Santiago, Chile

We develop a dry-processed supported lipid platform to study how membrane composition and substrate chemistry modulate protein-lipid interactions. Following the dry two-step self-assembly method for DPPC on silicon [1], we prepare DPPC bilayers with gramicidin A on SiO2 and characterize them by temperature ramps using very-high-resolution ellipsometry, AFM, FTIR, and SERS. Ellipsometry resolves DPPC pre- and main-phase transitions and peptide-induced shifts in thermal stability, which correlate with AFM domain morphology and FTIR amide I changes. In parallel, DPPC/DPPG bilayers are deposited on SiO2 and TiO2 and probed by AFM, FTIR, and ellipsometry to disentangle the influence of lipid charge and oxide surface on bilayer continuity and phase behavior, consistent with previous studies on lipid oxide interfaces [2]. Together, these results establish a solvent-free, thermally robust lipid architecture compatible with multimodal read-out and future integration of carbon quantum dots for FRET-based sensing. Acknowledgements: ANID Fellowship (DS) References 1.Cisternas MA et al. Int J Mol Sci. 2020;21:6819. 2.Tero R et al. Proc SPIE. 2007;6769:67690J.

BP 5.4 Mon 15:45 BAR/0205

Hexagonal and Lamellar Superstructure in DSPE-PEG1000 Monolayers at the Air/Water Interface — •Issam Assi, Heiko Aherns, and Christiane A. Helm — Institute of Physics, University of Greifswald, Germany

Inspired by diblock copolymer self-assembly, we investigate lipopolymer monolayers at the air/water interface. We studied DSPE-PEG1000 monolayers with alkyl chains in the liquid-condensed phase in dependence of the molecular area. Due to its conformational entropy, the moderately hydrophilic PEG has a larger area requirement than the alkyl chains in all-trans conformation. Small-angle grazing incidence X-ray diffraction (GID) measurements identified a hexagonal superstructure. The ordered alkyl chains form hydrophobic domains that are embedded in dissolved PEG. These domains consist of the alkyl chains of ca. 200 PEGylated lipid molecules. During monolayer compression, the number of alkyl chains in a domain remains constant, while their area fraction increases. At an area fraction of 50%, a transition to a lamellar superstructure occurs. During this transition, the alkyl chain domains merge. This transition is attributed to the entropy loss of the laterally compressed PEG chains. Wide-angle GID reveals that the alkyl chains in the liquid-condensed phase possess the same small cross-sectional area, as those in DSPE monolayers, indicating that PEG has little influence on the liquid-condensed phase. The hexagonal superstructure was confirmed with AFM images.

BP 5.5 Mon 16:00 BAR/0205

Numerical simulation of wetting of biomembranes — •Mokbel Marcel and Aland Sebastian — TU Bergakademie Freiberg

Biological cells utilize membranes and liquid-like droplets, known as biomolecular condensates, to structure their interior. The interaction of droplets and membranes, despite being involved in several key biological processes, is so far little understood. Here, we present a first numerical method to simulate the continuum dynamics of droplets interacting with deformable membranes via wetting. The method combines the advantages of the phase-field method for multiphase flow simulation and the arbitrary Lagrangian-Eulerian method for an explicit description of the elastic surface. The model is thermodynamically consistent, coupling bulk hydrodynamics with capillary forces, as well as bending, tension, and stretching of a thin membrane. Its capabilities are illustrated in several two- and three-dimensional axisymmetric scenarios.

BP 5.6 Mon 16:15 BAR/0205

Theory of Michaelis-Menten kinetics in phase-separated systems — •Gaetano Granatelli[1], Samuel S. Gomez[1], Sudarshana Laha[2], and Christoph A. Weber[1] — [1]Faculty of Mathematics, Natural Science, and Materials Engineering, Institute of Physics, University of Augsburg, Germany — [2]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

Phase-separated systems can regulate chemical reactions through spatial organization. Motivated by their biological relevance, we develop a mean-field theoretical framework for enzymatic kinetics within liquid condensates formed by phase separation. Building on a model that decouples the phase separation dynamics of scaffold components from the chemical kinetics of dilute clients, we generalize the classical Michaelis-Menten theory of enzyme kinetics to spatially heterogeneous systems with coexisting phases. In our framework, the dynamics of client concentrations are governed by scaffold-controlled parameters such as condensate size, partitioning, relative kinetic coefficients, and diffusion. We explore how they modulate the initial reaction rate across regimes set by the interplay of diffusive and reactive timescales, and we derive explicit expressions for the local reaction rate constants in each phase, allowing direct experimental measurement of how condensates

modulate reaction kinetics. We find that, compared to homogeneous conditions, phase-separated liquid condensates can mediate either optimal enhancement or suppression of the initial rate. Our results provide experimentally testable predictions to quantify how phase separation modulates enzymatic activity in living and synthetic systems.