BP 15: Biopolymer Solutions and Networks

Time: Tuesday 15:15–17:15 Location: H44

BP 15.1 Tue 15:15 H44

Protein Network Formation and Manipulation in Microfluidic Devices — •Heather Evans, Enkhtuul Surenjav, Craig Priest, Ralf Seemann, Stephan Herminghaus, and Thomas Pfohl — Max Planck Institute for Dynamics & Self-Organization, 37073 Goettingen

Microfluidic structures are particularly well-suited for controlled investigations of protein bundle and network formation. In addition to their ease of preparation and micrometer length scales, the myriad geometries and flow fields in such microdevices enable time-dependent investigations of non-equilibrium phenomena. We present studies of the blood clotting protein fibrin, a three-dimensional network formed from the enzymatic cleavage of fibrinogen monomers by the protein thrombin. Fibrin is a vital component of blood clots, and has been implicated in a variety of diseases. Real-time high resolution fluorescence microscopy and x-ray micro-diffraction are used to quantify supramolecular assembly and provide snapshots of the evolution of fibrin network formation. These techniques complement one another, providing information about fibrin assembly on length scales ranging from nanometers to micrometers. Specially designed microfluidic devices are also able to mechanically deform the fibrin networks within enclosed compartments. In this context, we report the influence of parameters, such as enzyme concentration and flow velocity, on fibrin network properties.

BP 15.2 Tue 15:30 H44

Contours and Thermal Fluctuations of Individual F-actin Filaments in Entangled Networks — •Marta Romanowska[1,2], Bernd Hoffmann[1], Norbert Kirchgessner[1], Margret Giesen[1], and Rudolf Merkel[1] — [1]Institute of Bio- and Nanosystems: Biomechanics, Research Centre Jüllich, 52425 Jülich, Germany — [2]Marian Smoluchowski Institut of Physics, Jagiellonian University Krakow, Reymonta 4, 30-059 Krakow, Poland

Recently significant scientific interest has been focused on the contours and fluctuations of isolated actin filaments. Moreover, rheological properties of F-actin solutions were characterized in detail. However, studies of the behavior of individual filaments within F-actin solutions are scarce.

To fill this gap, we analyze F-actin filaments in entangled networks by means of Confocal Laser Scanning Microscopy. From real-time observations of the Brownian motion time-averaged filament contours and the fluctuations around them are determined. Our system comprises of fluorescently labelled and phalloidin-stabilized reporter filaments embedded in a 3-D solution of unlabelled ones. Hence, the polymer conformations are determined by a competition of intrinsic filament stiffness and steric constraints induced by surrounding filaments. We investigate the effect of actin concentration as a parameter representing the strength of the confinement. Furthermore, we evaluate some static equilibrium properties of the filaments and compare our findings to theoretical results based on the wormlike chain model and the tube concept.

BP 15.3 Tue 15:45 H44

Dynamic Properties of individual F-Actin Filaments in 3D Networks — •masashi degawa, bernd hoffmann, rudolf merkel, and margret giesen — Forschungszentrum Juelich IBN4, 52425 Juelich Germany

The rigidity and dynamical properties of the cell cytoskeleton are determined by a 3D network of polymerized one-dimensional protein filaments, one of which is the actin filament (F-actin). The understanding of the thermodynamics of F-actin filaments is crucial for cell biophysics, specially within such a network. Whereas isolated F-actin is well described by the worm-like chain model [1], knowledge of thermodynamic properties of F-actin in networks is still scarce. Here we present first studies of F-actin within a 3D network where the presence of other filaments serves as an entropic constraint. We used partially TRITC-labeled networks of different concentration. The fluctuations of the labeled filaments were visualized with line-scan confocal scanning microscopy time images with a time resolution of 1 ms. We measure the time dependence of the filament fluctuations, which yield a concentration dependence of the crossover time in the time correlation function from isolated to constrained behavior of the individual F-actin. [1] L. Le Goff, O. Hallatschek, E. Frey, F. Amblard, Phys. Rev. Lett. 89, 258101 (2002)

BP 15.4 Tue 16:00 H44

Tube Radius in Entangled Networks of Semiflexible Polymers — •Hauke Hinsch, Jan Wilhelm, and Erwin Frey — Arnold Sommerfeld Center und CeNS, Department of Physics, Ludwig-Maximilians-Universität München

The mechanical properties of the cytoskeleton play an important role in many cellular functions like locomotion or adhesion. One of the cytoskeleton's dominant constituents is a network structure composed of the semiflexible polymer F-Actin. To connect the single polymer properties to the macroscopic behavior of the network, a single polymer is considered to be constrained to a tube established by neighboring filaments. Here we focus on the tube's diameter in entangled networks. While scaling laws for the tube diameter are well established, the absolute value is still under debate and different theoretical concepts and experimental measurements exist.

We present a new approach to the problem and have conducted extensive computer simulations to check the validity of our assumptions. A model of independent rods is used to describe the confinement of a single semi-flexible polymer in the network environment. A self-consistency approach allows us then to derive an absolute tube radius for the network as a function of several parameters and compare our results to experimental measurements.

BP 15.5 Tue 16:15 H44

Mechanics of bundled semiflexible polymer networks — •Oliver Lieleg[1], Mireille Claessens[1], Claus Heussinger[2], Erwin Frey[2], and Andreas Bausch[1] — [1]Lehrstuhl für Biophysik E22, Physik-Department, Technische Universität München, D-85747 Garching, Deutschland — [2]Arnold Sommerfeld Zentrum für Theoretische Physik und CeNS, Physik-Department, Ludwig-Maximilians-Universität München, D-80333 München, Deutschland

Cell shape, mechanics and motility are mainly determined by cross-linked and bundled actin networks. Despite their importance, the mechanical function of cross-linking molecules is not well understood. As in living cells many different actin binding molecules are used simultaneously, it is necessary to study their effect in in vitro systems. As we present here, above a critical concentration of the actin binding protein fascin, a solution of actin filaments organizes into a network of bundles. This structural transition is characterized by the competition between confinement energy and binding enthalpy. The mechanical response of the bundled network can be fully understood in terms of cross-linked bundles that consist of loosely coupled filaments and undergo non-affine bending undulations. Moreover, the mechanical properties of actin/fascin bundle networks can be described by a single pair of master curves over almost eight orders of magnitude in rescaled frequency. This remarkable finding can be attributed to the coarsening, self-similar network-structure.

BP 15.6 Tue 16:30 H44

Random Networks of Semiflexible Polymers — •Panayotis Benetatos and Annette Zippelius — Institut für Theoretische Physik der Universität Göttingen

We consider a fluid of semiflexible polymers modelled as identical wormlike chains with an excluded-volume interaction which prevents the system from collapsing. We introduce permanent cross-links which fix the tangent vectors of the corresponding filament segments to be parallel, and we treat them as quenched disorder which follows the Deam-Edwrads distribution. We present a semimicroscopic replica field theory of the formation of a random network. We show that, upon increasing the cross-link density in the fluid, an isotropic amorphous solid phase emerges in which the orientations of the chains are frozen in random directions. At a higher cross-link density, a different transition to an orientationally ordered phase is also possible.

BP 15.7 Tue 16:45 H44

Active and passive microrheology — •Daisuke Mizuno[1,2], Fredrick MacKintosh[1], and Christoph Schmidt[1,2] — [1]Department of Physics and Astronomy, Vrije Universiteit, Amsterdam, The Netherlands — [2]III. Physikalisches Institut, Fakultät f. Physik, Georg-August-Universität, Göttingen, Germany

We have developed active and passive, 1- and 2-particle microrheology (MR) using micron-sized colloidal particles as probes. Two laser beams focused through a microscope objective serve to both detect probe motion and exert controlled forces on the probes. Both active and passive MR can be done in a frequency range of 0.1Hz to 100 kHz. We compare results on model systems and discuss pros and cons of both technologies.

BP 15.8 Tue 17:00 H44

Modelling Non-Brownian Fluctuations in Stress Fiber Networks — •Claus Metzner, Carina Raupach, Daniel Paranhos-Zitterbart, and Ben Fabry — Biophysics Group, University of Erlangen, Germany

Microbeads attached to the intracellular actomyosin network show spontaneous fluctuations of non-thermal origin. Their motion is characterized by a transition from sub- to superdiffusive mean square displacement (MSD) with increasing lag time. This signature, associated with qualitative changes of the turning angle distribution, is reminescent of a particle diffusing in a potential well with slowly drifting minimum position. By solving this drifting well model analytically, we show that the complex statistical properties of the observed bead trajectories are captured by a small number of parameters.

Next we demonstrate numerically that a dynamic stress fiber network is a biologically plausible realization of drifting well behaviour. Essential features of the network include the formation of new fibers by actin polymerization, the building up of prestress by myosin cross-bridges, the elastic properties of the established fibers, and the reverse processes of fiber degradation. Here, noise caused by myosin activity represents the non-thermal driving force of the diffusion. Established fibers, adhering to the bead surface and connecting radially to the remaining network, form an elastic cage and create a plateau in the MSD. The occasional formation or degradation of bead-linked fibers gives rise to superdiffusive and directed motion on longer time scales.