BP 2: Biopolymers and Biomaterials (joint session BP/CPP)

Time: Monday 11:00–13:15 Location: ZEU 260

BP 2.1 Mon 11:00 ZEU 260

Radial distribution function for confined semiflexible polymers — •Florian Thüroff, Frederik Wagner, and Erwin Frey — Arnold Sommerfeld Center für theoretische Physik, Ludwig-Maximilians-Universität München

The crowded environment of living cells strongly constrains the conformational degrees of freedom of fluctuating biopolymers. Recent experimental setups achieved to confine single polymers to narrow channels and to directly observe the statistical properties of these chains. We present a theoretical calculation of the radial distribution function of confined semiflexible polymers in the weakly bending limit, for the model case of a parabolic confining potential. Special emphasis has been put on a proper treatment of the boundary conditions. We compare our analytical expressions to numerical data from Monte Carlo simulations and find perfect agreement.

BP 2.2 Mon 11:15 ZEU 260

End-monomer dynamics in semiflexible polymers — •Michael Hinczewski[1,2], Xaver Schlagberger[1], Michael Rubinstein[3], Oleg Krichevsky[4], and Roland R. Netz[1] — [1]Physics Dept., Technical Univ. of Munich, Germany — [2]TUBITAK - Bosphorus Univ. Feza Gürsey Institute, Turkey — [3]Dept. of Chemistry, Univ. of North Carolina, U.S.A. — [4]Physics Dept., Ben-Gurion Univ., Israel

Precise experimental observations over the last few years of end-monomer dynamics in the diffusion of double-stranded DNA have given conflicting results: one study indicated an unexpected Rouse-like scaling of the mean squared displacement (MSD) $\langle r^2(t)\rangle \sim t^{1/2}$ at intermediate times, corresponding to fluctuations at length scales larger than the persistence length but smaller than the coil size; another study claimed the more conventional Zimm scaling $\langle r^2(t)\rangle \sim t^{2/3}$ in the same time range. Spurred by this experimental controversy, we investigate the end-monomer dynamics of semiflexible polymers through Brownian hydrodynamic simulations and dynamic mean-field theory [1]. Both theory and simulation point to a novel intermediate dynamical regime where the effective local exponent of the end-monomer MSD, $\alpha(t) = d\log\langle r^2(t)\rangle/d\log t$, drops below the Zimm value of 2/3 for sufficiently long chains. The deviation from the Zimm prediction increases with chain length, though it does not reach the Rouse limit of 1/2. Anomalously low values of the effective exponent α are explained by hydrodynamic effects related to the slow crossover from dynamics on length scales smaller than the persistence length to dynamics on larger length scales. [1] arXiv:0809.0667, Macromolecules *in press* (2008).

BP 2.3 Mon 11:30 ZEU 260

A liquid state theory for biopolymers — •Jens Glaser and Klaus Kroy — Inst. f. Theoretische Physik, Universität Leipzig, PF 100920, 04009 Leipzig

Solutions of stiff biopolymers, e.g. F-actin, are unique in that the polymers are neither completely rigid nor completely flexible. A successful description of their equilibrium properties is based on the concept that hard-core interactions with the surrounding solution confine each polymer to an effective tube-like cage. The tube radius plays a central role for the phenomenology of stiff polymer solutions. Its scaling behavior with concentration as well as exact prefactors have been derived using mean-field theory and simulation. Generalizing Onsager's ansatz for hard cylinders, we propose a liquid state theory for stiff polymers and derive the fluctuations of the tube radius itself. We obtain length-dependent corrections to the mean-field result as well as a rigorous result for the second cumulant of the distribution of tube radii. The results compare favorably with new dynamical measurements on F-actin networks, obtained using confocal laser scanning microscopy.

BP 2.4 Mon 11:45 ZEU 260

Active and Passive Microrheology Probes Reconstituted Intermediate Filament Networks — •Sarah Köster[1,2], Yi-Chia Lin[2], Johannes Sutter[2], and David Weitz[2] — [1]Courant Research Centre Physics, University of Göttingen, Germany — [2]Department of Physics and School of Engineering and Applied Sciences, Harvard University, Cambridge, USA

Intermediate filaments (IFs) are one of the major filament systems of the eukaryotic cytoskeleton. Their remarkable tensile strength and biochemical heterogeneity distinguishes IFs from microfilaments and microtubules and identifies them as a key component for cell mechanics. Here, we study in vitro reconstituted vimentin networks by active and passive microrheology. By tracking individual beads we are able to characterize both the overall network properties as well as the degree of heterogeneity and the effect of crosslinking ions on the network structure and mechanics. This also provides a measure of the pore-size distribution in the network. Active microrheology, using magnetic tweezers, allows us to determine the viscoelastic properties of the network. By exposing the network to several sequential cycles of applied force, we observe changes in the response due to network reorganization.

BP 2.5 Mon 12:00 ZEU 260

Non-affine Deformations in Entangled Networks of Semiflexible Polymers — •Hauke Hinsch and Erwin Frey — Arnold Sommerfeld Center for Theoretical Physics, Ludwigs-Maximilians-Universität, 80333 Munich, Germany

Biopolymers are ubiquitous in nature and play a crucial role for cell mechanics and motility. One prominent example is the semiflexible filamentous actin that constitutes the cytoskeleton by forming large networks with viscoelastic properties that are suited to the cell's need for both rigidity and plasticity.

To characterize these properties we have investigated the modulus of entangled networks of semiflexible polymers. We report on theoretical work and simulation results. While most theoretical descriptions assume the macroscopic deformation to be affinely transmitted to the network constituents, we have developed a model that accounts for local non-affine displacements.

BP 2.6 Mon 12:15 ZEU 260

Fiber Networks: Relationship between Effective Elastic Properties and Morphology — •Susan Sporer[1], Mayhar Madadi[2], Stefan Münster[3], Klaus Mecke[1], Christoph Arns[2], Ben Fabry[3], and Gerd E. Schröder-Turk[1] — [1]Institut für Theoretische Physik, Universität Erlangen-Nürnberg, Germany — [2]Applied Maths, ANU, Canberra, Australia — [3]Center for Medical Physics and Technology, Biophysics Group, Universität Erlangen-Nürnberg, Germany

Elastic properties of disordered 3D fiber networks formed by reconstituted collagen fibers are studied numerically using a two-phase voxel-based finite element method. The fiber network structures are extracted from segmented confocal microscopy image stacks of collagen gels with different concentrations using the medial axis construction [1]. Effective shear moduli are analysed as function of two morphological parameters, fiber thickness and collagen concentration. For these data, the collagen volume fraction is the principal morphological measure that affects the shear modulus, similar to the case of open-cell foam structures. Our quantitative results raise the question if, for the analysis of effective elastic properties, the collagen scaffold can be modelled as a homogeneous body in network shape with locally isotropic elastic moduli – whereas in reality it is a cross-linked network of anisotropic individual fibers.

[1] W. Mickel , S. Münster, L.M. Jawerth, D.A. Vader, D.A. Weitz, A.P. Sheppard, K. Mecke, B. Fabry, G.E. Schröder-Turk, Biophys. J. 95 (12), in print (2008).

BP 2.7 Mon 12:30 ZEU 260

Encapsulation of carbon nanotubes within the microtubules — •Melinda Varga[1,2], Nitesh Ranjan[1], Wolfgang Pompe[1], and Michael Mertig[1] — [1]Institute for Materials Science and Max Bergmann Center of Biomaterials, Dresden University of Technology, D-01062 Dresden, Germany — [2]Institut for Genetics, Dresden University of Technology, D-01062 Dresden, Germany

Manipulation and local defined positioning of carbon nanotubes (CNTs) is one of the main challenges in CNT-based nanotechnology. Here we report the encapsulation of single-walled carbon nanotubes (SWCNT) into the lumen of microtubules with the aim to accomplish a biological functionalization of the CNTs and to elucidate motor-driven active transport of these one-dimensional wires. The encapsulation is obtained by self-assembly of microtubules from tubulin dimers in the

presence of CNTs. To this end, a two-step procedure was developed including dispersion of single-walled CNT with tubulin dimers and subsequent polymerization of the protein tubes [1,2]. The obtained products were characterized by various scanning probe and electron microscopy methods. The presence of CNTs within the microtubules was proven by electrostatic force measurements (EFM).

[1] M. Varga, Master thesis: "The interaction of tubulin dimers with carbon nanotubes", Dresden University of Technology (2006). [2] N. Ranjan, Ph.D. thesis: "Dielectrophoretic formation of nanowires and devices", Dresden University of Technology (2008).

BP 2.8 Mon 12:45 ZEU 260

Mineralization kinetics and heterogeneity of mineral content in bone — •Carolin Lukas[1], Harald Engel[2], Peter Fratzl[1], Paul Roschger[3], Klaus Klaushofer[3], and Richard Weinkamer[1] — [1]Max Planck Institute of Colloids and Interfaces, Department of Biomaterials, Potsdam, Germany — [2]TU Berlin, Germany — [3]Ludwig Boltzmann Institute of Osteology, Vienna, Austria

An important factor for the mechanical behaviour of bone at the material level is the amount and the distribution of mineral. The heterogeneous distribution of the bone mineral is due to the continuous remodelling of bone and the consecutive mineralization process. Bone mineralization increases the stiffness of each bone packet by increasing its mineral content. The mineralization kinetics is characterized by the mineralization law which describes the increase in the mineral content in a bone packet as a function of time. Remodelling and mineralization lead to a patchwork of bone elements with different mineral contents. Their frequency distribution, called the bone mineralization density distribution (BMDD), can be measured experimentally and modelled using a continuity equation [1, 2]. Extending the theoretical framework the influence of changes in the mineralization kinetics due to administration of drugs or disease on the BMDD can be described, which is of fundamental interest to medicine. We will present model predictions and compare them to experimental data.

[1] D. Ruffoni et al., Bone, 40(5), 2007.
[2] D. Ruffoni et al., JBMR 2(6), 2008.

BP 2.9 Mon 13:00 ZEU 260

Leg joints of the lobster H. americanus: An example of cuticle modification for specific functions — •Helge Fabritius[1], Torsten Fischer[1], Sabine Hild[1,2], and Dierk Raabe[1] — [1]Max-Planck-Institut fuer Eisenforschung, Duesseldorf , Germany — [2]Institut fuer Polymerwissenschaften; JUK Linz, Austria

The exoskeleton of crustaceans is a structural entity which has to be replaced frequently by the organisms in order to grow. Its various morphologically distinct parts have to fulfill a multitude of different functions like providing mechanical stability to the body, acting as a barrier to the environment, enable movement through the formation of joints and bearing both external loads as well as internal loads caused by attached muscles. To adjust the mechanical properties to the required task, the animals vary the basic cuticle structure through modifications in microstructure like number and thickness of the chitin-protein fibre layers and the amount of incorporated biomaterials as well as the use of different proteins with distinct properties. This study focuses on articulations in the limps of H. americanus, where elaborate joint structures between segments provide mobility to enable locomotion. Joint structures require different mechanical properties than simple load bearing cuticle parts or the soft arthrodial membranes. We chose hinge and pivot joints in the claws to investigate their microstructure, composition and mechanical properties using electron microscopy, Energy-Dispersive X-Ray Analysis, Raman spectroscopy and SFM. The results are compared to previous studies conducted on mineralized cuticle and arthrodial membranes of H. americanus.