# CPP 45: P10: Colloids and Complex Liquids

Time: Wednesday 10:00–13:00 Location: Poster A

CPP 45.1 Wed 10:00 Poster A

**Early stage of liquid-liquid phase separation in protein solutions studied by USAXS** — •Fajun Zhang[1], Stefano Da Vela[1], Michal Braun[1], Michael Sztucki[2], and Frank Schreiber[1] — [1]Institut für Angewandte Physik, Universität Tübingen, 72076 Tübingen — [2]ESRF, Grenoble, France

We present new results on the early stage of liquid-liquid phase separation (LLPS) in protein-salt solutions using the improved USAXS beamline (ID2, ESRF). We use our model system of bovine serum albumin (BSA) with $YCl_3$ [1,2], which shows LLPS and a lower critical solution temperature (LCST) phase behavior and can be rationalized using an ion-activated patchy-colloid model [3]. The USAXS data of sample solutions after a temperature jump exhibit a peak that grows in intensity and shifts to lower q values with time. The characteristic length scale obtained from this scattering peak increases with time as $t^{0.3}$, which will be further discussed for different temperature jumps as well as sample compositions. The method established in this work can be used to study the arrested spinodal decomposition in protein and colloid systems covering both the correlation length and the local structure. [1] F. Zhang, et al. Phys. Rev. Lett. 101, 148101 (2008) Proteins 78, 3450-3457 (2010). [2] F. Zhang, et al. Soft Matter 8, 1313-1316 (2012) and Faraday Discuss. 159, 313-325 (2012) [3] F. Roosen-Runge, et al. Sci. Rep. 4, 7016 (2014)

CPP 45.2 Wed 10:00 Poster A

**Dynamics of a rigid particle near a deformable interface in a viscous flow** — •Abdallah Daddi-Moussa-Ider, Achim Guckenberger, and Stephan Gekle — Biofluid Simulation and Modeling, University of Bayreuth, Germany

Using computer simulations, we study the parallel motion of a rigid particle moving close to a deformable elastic membrane. We use a completed double layer boundary integral formulation to solve the Stokes equation in the limit of low Reynolds numbers. The interface deformability is treated in the linear response framework where its elastic energy is locally stored in a shear deformation and dilatation. A bending resistance has been included in order to account for the strong local curvatures. By dragging the rigid particle parallel to the elastic interface, we evaluate the drag coefficient for several distances from the surface. An elasto-hydrodynamic coupling between the flow and the wall deformation plays an important role for the particle dynamics. We find that the drag coefficient and the rotation about the axis parallel to the interface are largely dependent on the interface rigidity. We compare our numerical results for high stiffness values with the analytically exact solutions in the hard wall limit.

CPP 45.3 Wed 10:00 Poster A

**Phase Unwrapping of two-dimensional interferograms - Preparations for the DCMIX-3 experiment on board the ISS** — •Thomas Triller and Werner Köhler — Physikalisches Institut, Universität Bayreuth, 95440 Bayreuth, Germany

The DCMIX project is an international effort to investigate diffusive transport in ternary fluid systems in the presence of a temperature gradient. In certain systems these processes are prone to gravitational instability. Therefore, experiments have been designed in a microgravity environment on board the ISS with SODI (Selectable Optical Diagnostics Instrument). SODI is a variation of a Mach-Zehnder interferometer and thus generates two-dimensional interferograms of a thermodiffusion cell. To analyse these interferograms and extract transport coefficients (e.g. the Soret coefficients of the diffusing components), the image information has to be processed with the Phase Unwrapping method. Such image processing is necessary, because the phase information $\psi(t)$ in the images is wrapped into the range $(-\pi, \pi]$: $\psi(t) = \varphi(t) + 2\pi k(t)$ with $k(t)$ an integer function. The full phase $\varphi(t)$ has to be reconstructed with proper algorithms. As preparations for the DCMIX-3 experiment (the system Water/Ethanol/Triethylene-glycol), several algorithms for Phase Unwrapping have been implemented and compared.

CPP 45.4 Wed 10:00 Poster A

**Density functional theory for the bulk phases of a colloid-polymer mixture** — •Mostafa Mortazavifar and Martin Oettel — Institut für Angewandte Physik, Uni Tübingen, Tübingen, Germany

We propose to treat gas, liquid, and crystal phases of the Asakura-Oosawa model (AO) for a colloid-polymer mixture within the framework of Fundamental Measure Theory. In AO model the polymers are an ideal gas, but colloid-colloid and colloid-polymer interactions are of hard sphere type. A new expression is derived for the excess part of the free energy. The bulk free energy and liquid-gas transition are calculated for various values of polymer reservoir packing fraction, $\eta_p^r$, and colloid-polymer size ratios, $q = \frac{2R_g}{\sigma}$; $\sigma$ is the diameter of colloid particles and $R_g$ is the gyration radius of polymers. By a self consistent full minimization scheme the free energy of the fcc solid and the solid-liquid phase transition is calculated for different values of $q$ and $\eta_p^r$. In the limit of $\eta_p^r$ to zero, the problem reduces to the pure hard sphere case. By increasing the reservoir packing fraction of polymers, the fluid-solid coexistence region broadens compared to pure hard spheres.

CPP 45.5 Wed 10:00 Poster A

**Contribution to a benchmark test on thermodiffusion in an organic ternary mixture** — •Matthias Gebhardt and Werner Köhler — Physikalisches Institut, Universität Bayreuth, D-95440 Bayreuth, Germany

The knowledge of diffusive mass transport in liquid mixtures is important for several natural and technological processes. Especially in the presence of a temperature gradient, where the local composition of a mixture is linked to an inhomogeneous temperature field. In the last decades binary mixtures were investigated in detail and a significant data base has been established. Today, experiments are going one step further and are challenging ternary mixtures. However, first results of multicomponent experiments performed by different groups and methods have shown the difficulties and complexity of this scientific subject. Furthermore, gravity can have a destabilizing effect on many of these diffusion experiments. Therefore, an international community has decided to establish benchmark values for the diffusion, thermodiffusion and Soret coefficients of the organic ternary mixture 0.8/0.1/0.1 (mass fraction) of 1,2,3,4-tetrahydronaphthalene, isobutylbenzene and n-dodecane in microgravity environment aboard the International Space Station (ISS) and on ground. We are presenting our contribution to this benchmark test by means of a two-color optical beam deflection technique.

CPP 45.6 Wed 10:00 Poster A

**Resolving high-speed colloidal dynamics beyond detector response time via two-pulse speckle contrast correlation** — •Sooheyoung Lee[1], Wonhyuk Jo[1,2], Hengsub Wi[1], Christian Gutt[3], Jan Verwohlt[3], and Geunwoo Lee[1] — [1]Korea Research Institute of Standards and Science, Daejeon, Republic of Korea — [2]Department of Physics, Soongsil University, Seoul, Republic of Korea — [3]Department Physik, Universität Siegen, Germany

We report an alternate light scattering approach to measure the intermediate scattering function and structures of colloidal suspensions by using two-pulse speckle contrast correlation analysis. By systematically controlling time-delays between two laser pulses incident on the sample, we are able to monitor transient evolution of coherent diffraction pattern, from which particle dynamics at different length and time scales are obtained simultaneously. Our result demonstrates the feasibility of utilizing a megapixel detector to achieve sufficient data statistics in a short amount of time while enabling microsecond time-resolution. Ultimately, this method provides means to measure high-speed dynamics well beyond the time response limit of a large area two-dimensional (2D) detector.

CPP 45.7 Wed 10:00 Poster A

**Increasing the bending modulus of AOT based microemulsions by the addition of polymer** — •Ann-Kathrin Grefe, Björn Kuttich, and Bernd Stühn — Experimental Condensed Matter Physics, TU Darmstadt, Germany

Being a highly versatile system, microemulsions are applied in many different fields from medical science to oil production. In order to make such implementations accessible, an extensive understanding of the interactions in microemulsions, especially in the presence of additives, is essential. Microemulsions with added polymers represent a suitable

simplified model system to study these interactions.

This work focuses on the analysis of AOT based w/o microemulsions in the droplet phase, modified by the water soluble polymer polyethylene glycol (PEG). The polymer is confined to the water core of the droplets where it is expected to adsorb at the surfactant shell. Due to the adsorption the bending modulus of the shell changes, which in turn affects the phase diagram of the microemulsion.

Samples with different amounts of polymer are examined by dielectric spectroscopy to find their percolation and phase separation temperatures. Temperature resolved small angle X-ray scattering allows the determination of the water droplet sizes. In doing so, a dependence of the droplet radius on the molar ratio of water and surfactant as well as on the temperature is found and quantified. Both are significantly influenced by the presence of polymer. Combining dielectric and scattering experiments the bending modulus of the surfactant shell can be deduced and a stiffening of the shell due to the polymer is found.

CPP 45.8 Wed 10:00 Poster A

**Clusters formation of patchy particles** — •Reint Hieronimus and Andreas Heuer — Westfälische Wilhelms-Universität Münster, Institut für physikalische Chemie, Corrensstrasse 30, 48149 Münster, Germany

A system of patchy particles can aggregate in different ways to clusters. The aggregation behaviour is determined by the particle geometry and the type of patch interaction. In order to estimate the probability of finding clusters of different sizes we calculated their free energy. This was done by performing Monte-Carlo simulations in combination with thermodynamic integration. Our method is independent of the chosen potential and can be used for any particle geometry. As a verification, we compared the simulation results to analytic results for a one-dimensional system using the well-known model by Kern and Frenkel.

CPP 45.9 Wed 10:00 Poster A

**The influence of Brownian motion on sheared nanocomposites: New experimental results and a revision of Peclet-time as a characteristic time scale** — •Rick Dannert, Roland Sanctuary, and Jörg Baller — University of Luxembourg, Laboratory for the Physics of Advanced Materials, Grand-Duchy of Luxembourg

Oscillatory shear tests performed on concentrated and semi-diluted suspensions of spherical silica nanoparticles in Diglycidyl Ether of Bisphenol A (DGEBA) have revealed a low-frequency relaxation process. The latter was interpreted as Brownian stress relaxation resulting from strain-induced perturbations of the isotropic filler distribution [1]. To cover a broader concentration range we have extended the rheological investigation of the low-frequency anomaly to ultra-diluted DGEBA/silica suspensions. We illustrate that the Brownian relaxation process depends in a complex manner on the volume concentration: For very dilute systems, the relaxation frequency increases with the concentration, whereas for semi-dilute or concentrated systems, the opposite behaviour can be observed. This non-monotonic dependency of the relaxation frequency can no longer be modelled by classical Peclet frequencies. Therefore we show that modified Peclet-frequencies including a structural, concentration dependent length scale viz. the mean particle distance lead to an accurate description of the Brownian relaxation process for all concentrations.

[1] R. Dannert, R. Sanctuary, M. Thomassey, P. Elens, J.K. Krüger, J. Baller, Rheologica Acta, 53 (2014) 715-723.

CPP 45.10 Wed 10:00 Poster A

**Rheological study of anisometric pigment particle suspensions** — •Yong Geng, Alexey Eremin, and Ralf Stannarius — Otto-von-Guericke-Universität Magdeburg, FNW/IEP/ANP, Postfach 4120, 39016 Magdeburg, Germany

Rheological properties of colloidal suspensions formed by nanometer size rod-shaped pigment particles dispersed in a non-polar solvent are studied. Experiments have shown that these suspensions possess unusual properties such as liquid crystalline behaviour at high dispersant concentration, field-induced phase separation at low and intermediate concentrations, switching in electric fields, and a reversible response to the adsorbing light affecting current transients in sandwich cells.1,2 By doping with small amounts of ferrofluid these pigment dispersions can form a basis for magneto-responsive materials. A strong magneto-optical effect has been confirmed. In our studies, we demonstrate a strong shear-induced birefringence and shear thinning behaviour in pure dispersions. We also discuss the effects of magnetic fields on the rheological properties of the pigment/ferrofluid mixtures. This helped to get a deeper insight into the properties of these suspensions and understand the mechanisms of the structural changes under external field such as electric, magnetic and flow.

1. Eremin, Alexey, et al., Adv. Funct. Materials 21.3 (2011): 556-564. 2. Greasty, Robert J., et al., Phil. Trans. Roy. Soc. A 371.1988 (2013): 20120257.

CPP 45.11 Wed 10:00 Poster A

**Fundamental Measure Theory for Liquid Crystals** — •René Wittmann, Matthieu Marechal, and Klaus Mecke — Institut für Theoretische Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstraße 7, 91058 Erlangen, Germany

Fluids of hard spherocylinders exhibit a rich phase behavior including isotropic, nematic and smectic-A phases. A density functional for anisotropic hard bodies can be constructed in terms of tensorial weighted densities (FMT) which depend on geometry and position of only one single oriented particle [1]. Within a new geometric method to derive the exact low-density functional we introduce a mixed measure of two bodies which can be expanded to the original tensor series. We compare this Fundamental Mixed Measure Theory (FMMT) to approximated results and Monte-Carlo simulations.

The isotropic–nematic interfacial tension remarkably improves on earlier, only qualitatively correct predictions for director dependence and density profile [2]. For the first time we obtain a phase diagram of hard spherocylinders, including a stable smectic phase [3], which can be quantitatively compared to simulations. To verify the consitency of the different FMT approaches, we study the the phase behavior of parallel spherocylinders and the elasticity of the nematic phase analytically.

[1] H. Hansen-Goos and K. Mecke, Phys. Rev. Lett. **102**, 018302 (2009).
[2] R. Wittmann and K. Mecke, J. Chem. Phys. **140**, 104703 (2014).
[3] R. Wittmann, M. Marechal and K. Mecke, J. Chem. Phys. **141**, 064103 (2014).

CPP 45.12 Wed 10:00 Poster A

**Defect topolgies in chiral blue phases confined to mesoscopic channels** — Sergej Schlotthauer[1], •Robert Skutnik[1], Tillmann Stieger[1], and Martin Schoen[1,2] — [1]Technische Universität Berlin, Berlin, Germany — [2]North Carolina State University, Raleigh (NC), USA

Soft matter confined to volumes of nanoscopic extent constitutes an interesting class of systems. In particular a lot of work has already been invested to study confined liquid crystals. The focus of this study is the orientational order of liquid-crystals and especially their deformation. In the case of non-chiral nematic liquid crystals one immediately may think of the twisted-nematic cell where the nematic director rotates between the substrates and a quasi-cholesteric helix evolves. The more recent research focuses on confined chiral phases, e.g. cholesteric or blue phases. If the introduced substrates are separated by a distance which is not equal to a multiple of half pitches transitions between the inherent defects of blue phases may be observed. Two-dimensional confinement (i.e. circular or rectangular mesochannels) of liquid crystals has been less far studied to date. In the late 1970s and early 1980s theoretical studies focused on the orientational order of nematic phases in tubular spaces. However, to the best of our knowledge there is no systematic study of chiral phases confined in two dimensions up to date. In our study we focus on two-dimensional confinement of chiral liquid crystals where we observe a host of novel topological defects. Furthermore, the geometry of the chosen channel and its surface anchoring determines the defect structure.

CPP 45.13 Wed 10:00 Poster A

**Self-assembling nanoparticles systems: influence of particles shape and concentration** — •Elena Pyanzina — Ural Federal University, Lenin av. 51, Ekaterinburg, 620000, Russia

The process of self-assembly is a key to design and control various systems, and as such it has recently become a subject of interest in physics, chemistry and biology [M. Nakata et al., Science, 2007]. Self-assembling building blocks might be of different nature and size might also form clusters of almost arbitrary topology. In the present study we focus on one two type of building blocks: superquadrics (namely, elongated spherocylinders) and discs, that can form different type of clusters. We present the analytical model for calculation structural properties and investigate them as functions of particles shape and concentration. Our conclusions are supported by an extensive comparison of the theoretical predictions to the results of computer simulations.