DY 6: Soft Matter (joint session CPP/DY)

Time: Wednesday 10:00–12:45 Location: H3

Invited Talk DY 6.1 Wed 10:00 H3

Chemically Fueled Out-Of-Equilibrium Self-Assemblies and Autonomous Material Systems — •Andreas Walther — Department of Chemistry, University of Mainz

Living self-organizing systems operate far-from-equilibrium and maintain functions by constant energy dissipation in feedback-regulated adaptive steady states. In stark contrast, man made self-assemblies are typically oriented towards equilibrium or deep metastable states.

Some of the next steps in self-assembling systems are to approach multicomponent co-assembling systems, and to master temporal behavior as well as complex adaptation mechanisms. The latter require new types of internal control mechanisms, such as kinetic control over opposing reactions (built-up/destruction), the integration of feedback mechanisms, or the use of energy dissipation to sustain structures only as long as a chemical fuel is available. This ultimately goes along with a transition towards out-of-equilibrium complex systems, in which multiple components self-assemble dynamically in a non-linear and adaptive fashion.

In this talk I will present two conceptual pathways towards out-of-equilibrium systems, (i) driven environments and (ii) driven structures, which allow to program self-assemblies and materials with lifetimes and programmable steady state dynamics using feedback mechanisms and conversion dynamics of chemical fuels. This will be showcased for different self-assembling systems (polymers, peptides, DNA), and the connection to hydrogels and photonic materials demonstrates possibilities for new horizons in materials science.

DY 6.2 Wed 10:30 H3

UV-light printing on APTES functionalized SiO2 surfaces: New approach for nanoparticle assembly — •Sergii Snegir[1], Olivier Plichery[2], Thomas Huhn[1], and Elke Scheer[1] — [1]University of Konstanz, Konstanz, Germany — [2]INSP, Sorbonne University, France

The 3-Aminopropyl)trimethoxysilane (APTES) terminated SiO2 surface allows creating self-assembled monolayers (SAMs) of gold nanoparticles (AuNPs). However, further functionalization of AuNPs with thiol-containing molecules leads to their strong aggregation due to the appearance of uncompensated dipole moments on the AuNP. Therefore, we developed a UV-light fixation method, which anchors AuNPs on their initial positions on the APTES surface prior to the process of AuNP functionalization. Herein, we present detailed studies of the passivation efficiency as the function of UV light wavelength, time of exposure, the concentration of O2, N2, O3 gases (1). We have found that the combination of O3 and UV light under ambient atmospheric conditions lead to complete passivation of APTES terminated glass already after 2 min of UV exposure (26.1 mW/cm2). We have tested also the possibility to use the UV-light passivation for printing on APTES terminated surfaces by using different chromium masks. With this method, we can create SAMs of AuNP with different geometry and size (resolution limit several um) on a SiO2 surface (glass/quartz/silicon). 1. S.Snegir, T.Huhn,J. Boneberg, S.Haus, O.Pluchery, E.Scheer, J.Phys.Chem.C, 2020,124(35), 19259-19266.

DY 6.3 Wed 10:45 H3

In situ GISAXS analysis of printed hybrid diblock copolymer thin films containing mixed magnetic nanoparticles — •Christopher Everett[1], Xinyu Jiang[1], Manuel Scheel[1], Huaying Zhong[1], Martin Bitsch[2], Martina Plank[3], Markus Gallei[2], Matthias Schwartzkopf[4], Stephan V. Roth[4,5], and Peter Müller-Buschbaum[1,6] — [1]TU München, Physik-Department, LS Funktionelle Materialien, Garching, Germany — [2]Saarland University, LS Polymer Chemistry, Saarbrücken, Germany — [3]TU Darmstadt, Ernst-Berl-Institut, Darmstadt, Germany — [4]Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany — [5]KTH Royal Institute of Technology, Stockholm, Sweden — [6]Heinz Maier-Leibnitz Zentrum (MLZ), TU München, Garching, Germany

Diblock copolymer (DBC) thin films that form periodic nanostructures are appropriate scaffolds for magnetic nanoparticles (NPs) and have potential for a variety of applications such as highly functional magnetic sensors and in high-density magnetic data storage. In this investigation, ultra-high molecular weight PS-b-PMMA films are used as templates for both ferrimagnetic magnetite NP and ferromagnetic Ni NPs. The thin films, containing up to 6 wt% NPs, are fabricated by a slot-die coating technique and the morphological evolution of the films during the deposition and drying process is monitored in situ with grazing incidence small-angle X-ray scattering (GISAXS). The dry thin films are subjected to solvent vapor annealing and ordered nanostructured hybrid films are obtained. Using a SQUID magnetometer, the resulting magnetic properties are measured.

15 min. break

Invited Talk DY 6.4 Wed 11:15 H3

The quest for robust superhydrophobic surfaces — •Robin Ras — Department of Applied Physics, Aalto University, Espoo, Finland

Nature offers various examples of extreme water-repellency, such as the leaves of Lotus plant and wings of cicada. The water repellency allows plants for efficient photosynthesis even in dusty environments, and allows large-wing insects to fly even in humid conditions. Likewise, our technological society could benefit from surfaces that stay clean and dry in challenging conditions. For example, solar cells on roof tops loose efficiency when they are covered with sand and dust.

The extreme water-repellency, also called superhydrophobicity, is attributed to the combination of micro/nanoscale topography and hydrophobic surface chemistry that allows trapping of a thin air film between the water and the solid substrate. The air film effectively shields the water from the solid by reducing the contact area, leading to very high contact angle and very low adhesion and friction. The required topography, however, also makes these surfaces very fragile.

Here I will present the progress made during previous decade, including different strategies for enhancing the mechanical durability. Recently, in collaboration with the group of Xu Deng, we developed an extremely durable superhydrophobic surface, by making use of a microstructured armor that protects the otherwise fragile nanostructures. I will present the concept, and steps that we are taking towards commercialization.

DY 6.5 Wed 11:45 H3

Calculating Magnetization Fields in Magnetoactive Elastomers: A Cascading Mean-Field Approach — •Dirk Romeis and Marina Saphiannikova — Leibniz Institute of Polymer Research Dresden, Germany

We consider the application of an external magnetic field to a composite of a non-magnetizable elastomer matrix with embedded magnetizable particle inclusions. The resulting interactions are determined by the magnetization field which is generated not only by the external magnetic field but also by the magnetic fields arising due to surrounding inclusions. A comprehensive description requires knowledge about the magnetization of individual particles and of macroscopic portions of the composite. Accordingly, a precise calculation becomes elaborate for a specimen comprising billions of particles. We present a greatly simplified, but accurate approximation for the computation of magnetization fields in such composites. Based on the dipole model, we introduce the cascading mean-field description [1] by separating the magnetization field into three contributions on the micro-, meso-, and macroscale. It is revealed that the contributions are nested into each other, as in the Matryoshka's toy. Our description allows for an efficient and transparent analysis of such composite materials under rather general conditions.

Financial support by DFG, SPP 1713, is gratefully acknowledged.

[1] D. Romeis and M. Saphiannikova: A cascading mean-field approach to the calculation of magnetization fields in magnetoactive elastomers. Polymers, 13(9):1372, 2021.

DY 6.6 Wed 12:00 H3

Magnetostrictive effects in soft magnetic gels and elastomers — •Lukas Fischer and Andreas M. Menzel — Institut für Physik, Otto-von-Guericke-Universität Magdeburg, Magdeburg, Germany

Our work focuses on magnetic gels and elastomers, also known as magnetorheological elastomers or ferrogels, that feature a soft elastic matrix enclosing magnetizable particles. These materials react to an applied external magnetic field mainly in a twofold manner: by changing their overall mechanical properties (magnetorheological effect) and by overall macroscopic deformations (magnetostriction).

We have developed a mesoscopic theory to describe the latter effect. For this purpose, we analytically solve the linear elastic problem, linking the particle scale to the scale of overall deformation. To adjust the deformational response, we modify the initial positioning of the particles inside the material, relative to the magnetic field direction [1].

Specific spatial arrangements of the magnetizable particles inside the elastic medium favor specific magnetostrictive modes of deformation, for example torsion [2]. Targeted modification of the particle size can likewise serve to adjust the magnetostrictive response [3]. Our work supports the construction of magnetically controlled soft actuators that are tailored to requested deformational tasks.

[1] L. Fischer, A. M. Menzel, *J. Chem. Phys.* **151**, 114906 (2019).
[2] L. Fischer, A. M. Menzel, *Phys. Rev. Research* **2**, 023383 (2020).
[3] L. Fischer, A. M. Menzel, *Smart Mater. Struct.* **30**, 014003 (2021).

DY 6.7 Wed 12:15 H3

Perturbed Jamming transitions — Moumita Maiti[1] and •Michael Schmiedeberg[2] — [1]Institut für Physikalische Chemie, Westfälische Wilhelms-Universität Münster, 48149 Münster, Germany — [2]Institut für Theoretische Physik 1, Friedrich-Alexander-Universität Erlangen-Nürnberg, 91058 Erlangen, Germany

By minimizing the interaction energy in a soft sphere system without crossing energy barriers the discontinuous athermal jamming transion can be observed at a packing fraction of about 0.64 in 3D [1]. However, if perturbations like thermal fluctuations [2] or an active self-propulsion [3] are added, the transition becomes continuous and the transition packing fraction might occur at a different density. For example, in case of thermal fluctuations, the transition packing fraction approaches 0.55 in case of small thermal fluctuations [2]. We show that the thermal jamming transition lies within the universality class of directed percolation. As a consequence, athermal jamming is a (singular) limit of a much wider class of perturbed jamming transitions that can also be understood as dynamical transitions [2,4]. Therefore, perturbed jamming transitions open up a large variety of amorphous packings and insights how these packings are related to glassy dynamics.

[1] C.S. O'Hern et al., Phys. Rev. Lett. 88, 075507 (2002), Phys. Rev. E 68, 011306 (2003).
[2] M. Maiti and M. Schmiedeberg, Scientific Reports 8, 1837 (2018).
[3] M. Maiti and M. Schmiedeberg, EPL 126, 46002 (2019).
[4] L. Milz and M. Schmiedeberg, Phys. Rev. E 88, 062308 (2013); S. Wilken et al., Phys. Rev. Lett. 127, 038002 (2021).

DY 6.8 Wed 12:30 H3

Fluidity models for amorphous glassy materials — •Robin Lautenschlager and Thomas Voigtmann — Institut für Materialphysik im Weltraum, Deutsches Zentrum für Luft- und Raumfahrt (DLR), 51170 Köln

Different rheological models are proposed to describe the complex flow properties of amorphous glassy materials, such as granular materials or colloidal glasses, intermediate between a solid and liquid behavior. These systems show a strong non-linearity due to stresses and strain rates, as well as time-dependent ageing effects. The materials are hence described by a time-dependent local fluidity as a main rheological quantity. Spatial non-localities are quantified by a characteristic cooperativity length that describes the extent over which neighboring material regions influence their flow behavior.

We compare three different approaches of such fluidity models and discuss their key features regarding the complex flow properties and how they try to reproduce the time-dependent effects of such a flow. We probe the models in a pressure driven two-dimensional-channel-flow and compare their long-time numerical results to analytically estimated steady state solutions for this test case. We will discuss how the models respond to different flow properties to evaluate their usability in applications.