universität wien

**Faculty of Physics**
**Computational and Soft Matter Physics**

### Master's thesis topic

# Magnetoactive Polymers

**Supervisors: Lucio Isa (ETH), Jan Smrek/Christos Likos (Uni Vienna)**

**Background:** Active matter consists of components that spend the energy from own or external sources and convert it to forces or nonequilibrium fluctuations typically used for self-propulsion. Examples range from swimming whales, through bacteria, down to the protein motors dragging on the molecule of life DNA. Particularly on the microscopic level, the out-of-equilibrium nature of the constituents generate interesting phenomena that are not yet fully understood, and, besides their biological relevance, possess the features to be harnessed for future active adaptable and switchable materials. For example, computer simulations show a liquid made of polymer rings with active segment can glassify when the activity is turned on [1]. However, to create such a material in reality presents a significant challenge on various levels. One of

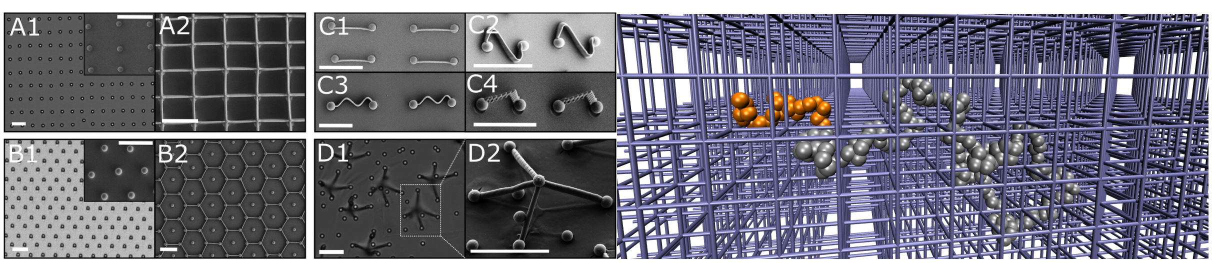


**Figure 1.** Left: range of structures fabricated by CAPA with 2PP-DLW, scale bar 10 micrometers, adapted from [2]. Right: Simulation snapshot of polymer with active segment (orange) in a lattice of obstacles.

them is the experimental manufacturing of long and flexible polymers that allow for activation of a segment. A recent progress in this direction has been achieved on a colloidal scale by joining the methods of capillarity-assisted particle assembly (CAPA) and two-photon polymerization direct laser writing (2PP-DLW) [2]. The methods allow for precise structured placement of colloids on a template and subsequent linking them to form flexible superstructures (Fig. 1 left), however to achieve sufficient length and flexibility for the fabrication of colloidal-polymers requires further development. The method also allows the incorporation of superparamagnetic colloidal particles, which would enable activation by an external magnetic field. On the theoretical side, the challenge is the understanding of the dynamics of such a polymer with magnetically responsive segments in a crowded environment. On the one hand, the activity enhances the mobility of the particles, fluidizes the system, but, on the other hand, higher mobility also increases entanglement between chains, which, in contrast, strongly decreases mobility. The idea is that space-time dependent magnetic fields can be employed to highlight one feature or the other allowing for a control of the properties.

**The goal** of the master thesis is to overcome the challenges using experiments and simulations. The candidate will fabricate systems of linear active colloidal polymers and study their dynamics in free space and in an array of micropillars (obstacles) under the action of randomly fluctuating and oscillating magnetic fields. The micropillars emulate the presence of other chains with which the polymer can entangle.
The candidate will also run and analyze corresponding molecular dynamics simulations of the magnetoactive polymers to scan the response to differently modulated magnetic field.

The successful completion of the thesis not only opens a way for a novel adaptive switchable materials, but also touches on a deep biophysical questions of the conformations and the dynamics of DNA fibers that are subject to nonequilibrium fluctuations due to driving by molecular motors in crowded environment of the living cell nucleus.

The topic is suited for a curious hard working candidate willing to acquire a broad expertise, both in experiments and in simulations.

[1] J Smrek, I Chubak, C N Likos, K Kremer, Active topological glass, Nat. Commun. 11 (2020)
[2] S van Kesteren, X Shen, M Aldeghi, L Isa, Printing on Particles: Combining Two-Photon Nanolithography and Capillary Assembly to Fabricate Multimaterial Microstructures, Adv. Mater. 35, (2023)

**Practical Info:**

- The stay at ETH (~6moths) will be supported by the stipend 1100CHF/mo that can typically cover student’s accommodation costs.
- The stay at Uni Vienna - possibility to apply for a scholarship ~ 550EUR/mo.

**Contact:** For further details, please contact Lucio Isa or Jan Smrek