A quest for soft matter single crystals: complex self-assembling materials cooked to perfection with lasers

Project goal

The project explores the mechanisms of a fascinating phenomenon of spontaneous organization of simple chemical units (molecules and nanoparticles) into more complex structures called *self-assembly*. Unfortunately, soft materials typically self-assemble into structures with a high density of structural defects that diminish their application potential. The goal of our project is to find an effective way of controlling this process, limit the undesired formation of defects, and correct them once they appear. We are studying three important classes of self-assembling materials: block copolymers, nanoparticle-liquid crystal conjugates, and nature-inspired DNA-guided nanoparticle superlattices. We propose to use laser light to accelerate and guide their self-assembly to structural perfection in a controllable way by monitoring this process in action by x-ray scattering and microscopic observations.

Motivation

In contrast to their hard matter counterparts *e.g.*, inorganic crystals of sodium chloride or silicon single crystals, soft materials such as polymers, foams, and colloids typically lack the so-called long-range order due to the easy formation of structural defects in these systems. Nonetheless, the idea of imposing long-range order in soft self-assembling materials is very attractive and has resonated in the scientific community, motivated by their prospective applications *e.g.*, as highly-selective filtration membranes, elastic electronics, and photonic materials. We propose to look into the mechanisms of self-assembly *in action* by developing a laser-heating setup for real-time structural studies by small-angle x-ray scattering and optical microscopy. This approach will enable finding more efficient materials' processing routines by engineering the pathway of their self-assembly. We believe that our method will also allow laser-light driven corrections of structural defects in these materials, further improving their order and functional performance.

Expected results

Although our studies will have a character of basic research *i.e.*, with the objective of gaining new knowledge about the physical mechanisms of self-assembly, the expected results will also contribute to the development of time-efficient processing protocols of defect-free complex nanomaterials and benefit their future applications.