Controlled anisotropy in bijels.

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The cooling of buildings requires an enormous amount of energy, and due to a warming climate the cooling needs will increase over the coming decades [1]. Passive radiative cooling of a building could be achieved by optimizing the optical properties of the walls and roof. Indeed, if a surface radiates more energy (by way of infrared radiation) than that it absorbs energy from solar irradiation, the surface will cool down [2]. The white scarab beetle achieves high reflectance by means of a microscopic structure on its shell, composed of an interwoven scaffold (see Figure 1i) [3]. Computer simulations have shown that the anisotropy of this scaffold enhances the reflectivity [4]. Can we synthesize such an interwoven and anisotropic scaffold ourselves in the laboratory?

In our group a similar interwoven structure is extensively studied (Figure 1ii). The structure that forms during spinodal phase decomposition can be kinetically trapped through the adsorption of nanoparticles to the interface, forming a bicontinuous interfacially jammed emulsion gel (bijel) [5, 6]. In practice we make a mixture of 3 liquids, an oil, water, and an alcohol, add some nanoparticles and bring this dispersion in a bath of oil. The diffusion of alcohol into the oil bath induces the spinodal decomposition [6]. The typical length-scale in this material can be as low as hundreds of nanometers [7], perfect for interactions with light.

Figure 1: i. (a,c), Images of *Cyphochilus* and *Lepidiota stigma* beetles, respectively. (b,d), Scanning electron micrographs (SEM) of the cross-section of the scales of the respective species. Image taken from ref. [3]. ii. Confocal images from a bijel prepared without monomer. The interwoven structure is similar to the structure in part i of the figure. Image taken from ref. [7]. iii. Ternary phase diagram, with the binodal curves plotted for two systems. In green water, 1-propanol and diethylphthalate, in purple water mixed with acrylamide, 1-propanol and diethylphthalate. Plait points are indicated by a star. Clearly, addition of the acrylamide in water changes the binodal curve.

In this project we want to study the potential of introducing controlled anisotropy in a bijel. To achieve this we aim to polymerize one of the phases of the bijel with an elastic polymer and subsequently stretch the material. As the phases are normally inaccessible after preparation, we need to introduce the monomer before the spinodal phase decomposition. However, the introduction of
another chemical changes the composition at which the spinodal phase decomposition is triggered (Figure iii). As such, in this project we hope to answer the following questions:

1. What is the phase diagram and plait point of a mixture that includes a certain amount of monomer?
2. How is the surface tension between the oil and water influenced by the presence of monomer in the water?
3. What is the best composition of a mixture that includes a monomer to achieve a bijel?
4. How does the polymerization affect the bicontinuous structure?
5. How does stretching the polymerized material affect the bicontinuous structure and its anisotropy?

During the project we will find quantitative answers for the research questions. To do so we will leverage the use of the pendant drop method to measure surface tension, and confocal microscopy and electron microscopy to analyze bijel structures. Part of the project can be to set up a (semi-)automatic analysis pipeline to analyze the generated images.

References


