Laboratory for Biologically inspired materials

Playing with Magnetic Janus Particles

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Colloids are chunks of several nm's to several µm in size of some material dispersed in a fluid. Daily life examples include paints, milk, whipped cream and smoke. Colloids make Brownian (thermal) motion and a colloidal system is thus free to reach thermal equilibrium. Light microscopy can visualize their phase behaviour in real-time and real-space. This makes colloidal particles ideal building blocks for self-organizing systems that automatically reach certain phases, such as different crystals that have interesting optical, electrical or mechanical properties. The art of self-organization to produce complex new materials lies in manipulating the interactions between the colloids. When making cheese for instance, one can add enzymes to change the surface chemistry of the protein blobs in milk, change the pH, or add alcohol, to make everything clog together and let the cheese precipitate. In contrast to small molecules, the interactions of engineered colloids are typically uniform or not controlled in which direction an interaction occurs.

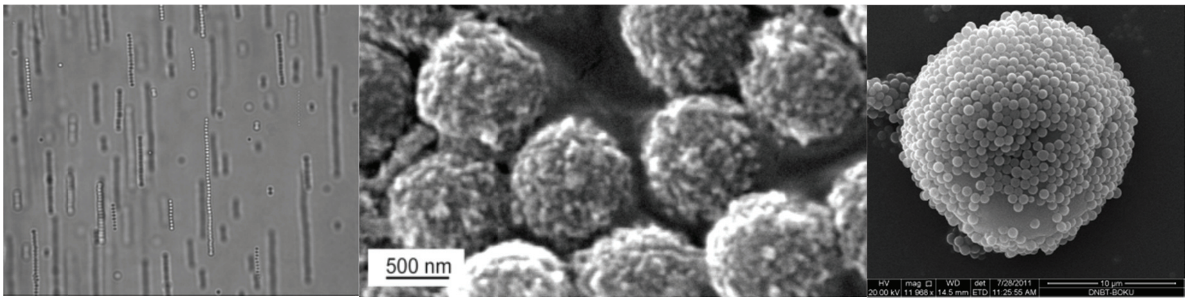

Figure 1. From right to left: 1 µm PS particles lined up in an electric field, magnetic nanoparticles at the surface of PS particles from [3], 870 nm silica particles at the surface of a wax colloidome.

Patchy colloids have different zones, patches, on their surface such that they interact differently in specified directions[1]. This gives rise to interactions analogous to those between atoms and certain molecules such as peptides. Recently these novel interactions gave rise to interesting new phases for colloidal assemblies. The simplest example of patchy colloids is so-called Janus particles that have two different faces, like the Roman god after which they are named.

External fields are another way to manipulate the interaction between colloids. In this case forces between the colloids are induced by external fields such as gravity, radiation pressure from bright light, Coulomb forces in electric fields, dielectric forces in AC fields and magnetic forces.

In our laboratory we mainly work with AC electric fields and magnetic fields. In figure 1 you can see how electric dipoles induced by an AC electric field makes the particles form strings. Colloids can also be made magnetic by decorating their surface with superparamagnetic iron oxide nanoparticles[3]. Such particles will string up when you hold a simple permanent magnet close to the sample[3].

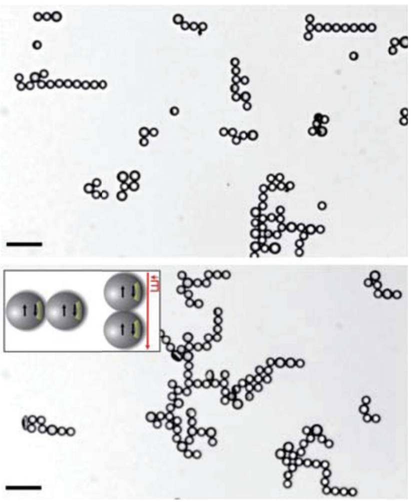

Figure 2. Typical structures for patchy particles in external fields from reference 4. These 2.4 µm particles have 11% of their surface coated with a thin layer of gold. The applied electric field strength was 150 V cm^{-1} and 150 V cm^{-1} respectively at 400 kHz.

Patchy particles in external fields have been proven to show rich phase behaviour, see reference 4, and figure 2. It was shown that Janus Particles, where one half of the surface is metallic and responds particularly strong to external fields, form intriguing structures in electric fields. The metal and the dielectric material house two oppositely oriented dipoles

In this project you will combine patchy, directional, interactions with magnetic and electric fields. In particular you will use the symmetry breaking at an oil-water interface to selectively coat one half of your micron sized PS particles with superparamagnetic nanoparticles, see the wax colloidosome in figure 1. After this you will learn to apply electric and magnetic fields and combinations thereof to dispersions of these particles to vary the interactions between the particles. Although the Fe_3O_4 particles will not be touching, the conductivity is such that they respond strongly to electric fields. You will foremost use electron microscopy and confocal light microscopy to characterize the particles and their assembly behaviour (kinetics and structure). You will be mesmerized by the structures the particles form!

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