Magnetic Colloids for Micro-Rheology and Biophysics Applications

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During the last two decades, an extensive body of research has been devoted to the development of newly shaped nanoparticles for materials science and nanomedicine.[1] Because of their high specific surface and reactivity, as-synthesized nanoparticles are sensitive to any change in physico-chemical environment, leading in some cases to their irreversible aggregation, with possibly the loss of their size-related properties. In the present lecture, I will describe an electrostatics-based process in solution that is able to generate nanoparticle aggregates of controlled sizes and shapes. The protocol is versatile and allows adjusting the surface charge, the functionalization as well as the inner colloid structure. Working with 10 nm iron oxide nanoparticles, we managed to synthesize with this method micron-sized wires which lengths range from 1 to 100 µm.[2,3]

The magnetic wires described previously can be remotely actuated with an external magnetic field, and as such they can be used for microrheology. We exploit the technique of rotational magnetic spectroscopy (MRS) in which wires are submitted to a rotational magnetic field as a function of the frequency, and their motion is monitored by time-lapse microscopy.[4-6] The MRS technique was successfully applied to model systems including viscoelastic liquids and soft gel materials, leading to the measure of the shear viscosity and shear elastic modulus.

Finally, the MRS technique was used to address the question of the intracellular rheology, an issue that is relevant to understand how living mammalian cells adapt themselves to their environment, and how they exert forces and torques during locomotion. Cytoplasm viscosity measurements performed on three cells lines, including murine NIH/3T3 fibroblasts, HeLa cervical cancer cells and A549 lung carcinoma epithelial cells were obtained and confirm the viscoelastic character of the cytoplasm. The values of the shear viscosity and elastic modulus were found in the ranges 10 – 100 Pa s and 20 – 200 Pa respectively for the three cell lines.

In contrast to earlier studies, it was concluded that the living cell interior is best described as a viscoelastic liquid similar to a Generalized Maxwell Model, and not as an elastic soft gel.[7] The present work finally demonstrates the potential of the wire-based magnetic rotation spectroscopy as an accurate rheological tool to explore soft matter dynamics and flow.

References:

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