Quantitative Imaging that Makes Magnetic Rotational Spectroscopy with Nanorods a Tool for Characterization of Nanoliter Droplets and Thin Films

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Materials scientists often need to perform optical microscopy and simultaneously measure and characterize fluids of varied viscosity and volumes. *In situ* rheological characterization of minute volumes of complex liquids, such as surfactants, biopolymers, and salt solutions, can be achieved using the Magnetic Rotational Spectroscopy (MRS), introduced by our group. Magnetic nanorods are attractive materials that enable the assembly, ordering, control, and reconfiguration of different magnetic lattices within milliseconds. MilliTesla magnetic fields are sufficient to manipulate these nanorods. This talk will introduce Magnetic Rotational Spectroscopy (MRS), where remote-controlled rotation of magnetic nanorods coupled with advanced image processing provides a new nanoscale tool to probe different properties of liquids and solids at the micrometer scale. We introduced a novel optical microscope stage design that contains five magnetic coils and a microTesla rotating magnetic field applied within the focal plane of the microscope objective. The optical microscope stage allows to achieve on-demand cancellation of the Earth's 3D magnetic field and other ambient bias fields to more precisely analyze samples; create a minimized magnetic gradient and uniform magnetic field; and control or maintain sample exposure to environmental factors like gas content and humidity in an environmental chamber.

Significant challenges arise, however, when using this technique to measure and characterize volatile and low-viscous nanodroplets and thin films that are significantly influenced by small changes within their immediate microenvironments. The nanorod tracking protocol was developed to follow the probe rotation in real-time and to relate it with the viscosity of the host liquid. Using this magnetic stage, a method for measuring mPa·s-level viscosity of nanoliter droplets and micron-thick films in a 10-20 second timeframe becomes possible.

As an example, an MRS analysis of clotting of insect blood will be demonstrated and new discoveries on the strategy that insects developed over millions of years of evolution will be presented. If time allows, I will show the MRS applications for analyses of the gelation processes in polymers and sols and formulate the image processing challenges that need to be addressed to make further progress toward commercialization of this technology.

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