Time-dependent magnetic forcing: new routes to tunable self-assembly and rheology

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Abstract:

Magnetorheological materials are usually described as field-responsive suspensions in which magnetizable particles form chain-like structures under steady magnetic fields, producing large and reversible changes in rheological properties. Although this picture has been highly successful, it also limits the accessible structural landscape and often leads to kinetically trapped, defect-rich aggregates.

In this lecture, I will discuss how time-dependent magnetic forcing provides new routes to program magnetic soft matter. Toggled and biaxial fields can modify the kinetics of colloidal self-assembly by combining magnetic aggregation with relaxation or orthogonal perturbations, allowing defect reduction, compact aggregate formation, and tunable anisotropy and percolation. These changes in magnetic history can also reinforce field-induced networks and enhance the rheological response.

I will then show how triaxial time-dependent fields allow effective particle interactions to be programmed. Depending on the Mason number, structures either follow the instantaneous field or respond to time-averaged interactions, enabling architectures not accessible under steady fields, including periodic layers and compact networks. These field-programmed structures can also be frozen during hydrogel gelation, imposing anisotropy, spatial confinement and directional cues in soft living matrices.

Finally, I will briefly discuss how time-dependent magnetic gradients can generate directed transport in nonlinear fluids through ratchet-like mechanisms. Overall, the talk will present time-dependent magnetic forcing as a route to expand magnetorheology from field-responsive materials towards field-programmable magnetic soft matter.