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Three-dimensional pattern formation and synchronization regimes of magnetic rods under rotating fields

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We investigate the three-dimensional collective dynamics of assemblies of rod-shaped magnetic colloids subjected to rotating magnetic fields using molecular dynamics simulations. By systematically varying the field strength, rotation frequency, and rod aspect ratio, we identify distinct dynamical regimes characterized by different degrees of synchronization, aggregation, and structural organization. Depending on the driving conditions, the system exhibits a variety of steady-state patterns, ranging from disordered and clustered states to layered, entangled, and columnar structures. The interplay between dipolar interactions, external driving, and particle anisotropy governs both the rotational dynamics and the resulting three-dimensional organization. Our results provide a unified framework for understanding pattern formation and synchronization in driven suspensions of magnetic rods.

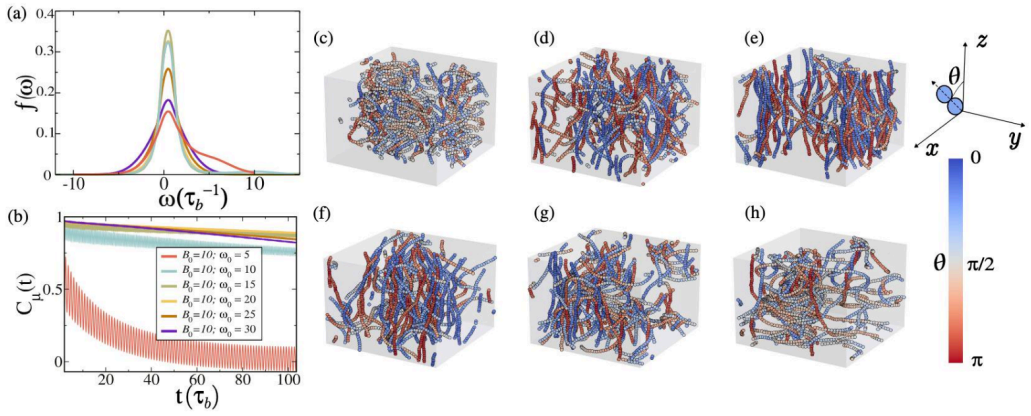

Figure 11: Photographs of (a) millimeter-scale UCST hydrogels containing MNPs, (b) ground UCST hydrogels containing MNPs, and (c) DLS results.

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