Deck the Walls with Colloids in Confined Liquid Crystals

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Energy landscapes embedded in soft matter can dictate dynamics and (multi)stable states of colloidal assemblies. We exploit this concept to develop paradigms to define colloid dynamics, metastable states and equilibria, including alignment, migration path, interaction strengths and ranges, assembly geometry, and docking sites. We study colloids as mobile inclusions that deform a soft matter host; the energy associated with these deformations drive the colloids to interact and assemble. By confining the host within a vessel, a global energy field is defined. Example hosts include nematic liquid crystals, fluid interfaces, and lipid bilayer membranes. Since the energy fields depend on the configuration of these soft matter hosts, they are inherently reconfigurable. These fields depend on the surface chemistry, size, and topology of the colloids and geometry of the vessels. However, they do not depend on the colloid material composition. Thus, these concepts can be applied across wide ranges of materials, with opportunities to control, reconfigure and manipulate structures for desired mechanical and optical response, or to define active agents that respond to the system’s state.

Here we focus on confined liquid crystals (LCs) in vessels with wavy walls that distort the LC director field, defining a global energy landscape. Colloids deform the LC and form (meta)stable topological companion defects that allow them to sense and interact within this landscape. By appropriate boundary design, we embed stable sites to which colloid paths converge, and unstable sites from which colloids diverge, allowing colloids to be propelled by stored energy into the domain. The embedded energy landscapes can be exploited in conjunction with other external stimuli (e.g. applied electromagnetic fields, reconfigurable boundaries) to trigger transitions between multi-stable states. Anisotropic colloids and complex vessel boundaries provide additional degrees of freedom. The colloids’ companion defects are important features. A metastable companion defect can transform to a stable form, changing the strength and range of colloid interactions. These companion defects can also collect molecules and nanoparticles, allowing the colloids to sense within the domain. Thus, the colloids can act as distributed sensors, actuators, and elements for data storage that respond to the system’s configuration. Our vision is to develop these phenomena as tools to design devices with responsive internal microstructures, broadly applicable for reconfigurable (meta)materials and robotics.