Title: Soft and active matter to understand and mimic living systems

Manoj Kumar

Abstract

Several living organisms around us collectively self-organise (at different length scales) into fascinating dynamic structures, e.g., school of fish, flock of birds, trails of ants, bacterial swarms. Some living organisms, e.g., flagellated bacteria, filamentous California blackworm, exhibit interesting changes in their direction of motion, dynamics and shapes due to chemical and physical changes in their surrounding environments. But the living systems are very intricate and are difficult to tweak under experimental settings. My research interests are in creating the synthetic, soft and active systems that not only replicate the properties of living systems (sense, move, fold, morph, compete, cooperate and evolve), but also in developing new functional materials (1D, 2D and 3D) for their applications, such as shape changing metamaterials, foldable material, active colloidal membranes/bilayer, soft micro-robotics, micromachines, cargo delivery, multi-component and muti-stimuli drug delivery systems.

In my talk, I will describe a system of freely-jointed active polymers made of self-propelled droplets as monomeric units, and show that self-shaping chemo-hydrodynamic interactions within the polymer result in novel dissipative structures and steady-states. My experiments show that the interaction between the monomeric droplets gives rise to the ballistic propulsion of active polymers, and is associated with rigidity and stereotypical shapes of the polymers. These traits, quantified by the curvatures and speeds of the active polymers, vary systematically with the chain-length. Using simulations of a minimal model, we establish that the emergent propulsion and rigidity are a generic consequence of quasi two-dimensional confinement and auto-repulsive chemical interactions between the freely jointed active droplets. This work highlights the emergent organization of extended active objects due to self-shaping interaction landscapes. Further, I will discuss the limitations of such systems and additional modifications that could be made to use them as an interesting model for unravelling the rules of folding in RNA and proteins. Finally, I will demonstrate a thermally responsive droplet system that I have synthesized as a first step towards developing a multi-stimuli responsive, multi-cargo delivery system.

Brief Bio:

Dr. Kumar obtained his masters in Chemistry from Shimla university, Himachal Pradesh. He went to CSIR NCL, Pune to obtain his Ph. D. in chemical sciences under the supervision of Dr. Guruswamy Kumaraswamy (currently prof. at IIT Bombay). He worked on understanding the rules that govern the curvature in lipid membrane using hydrophilic polymers as a proxy for proteins, applications in the field of pharmaceutics and agrochemical delivery. For his work, he received a best research scholar award from CSIR-NCL. Dr. Kumar is currently a postdoctoral fellow in Dr. Shashi Thutupalli's lab at NCBS-TIFR, Bengaluru. His current research interests are on active soft matter, directed colloidal assemblies, understanding the pathogen uptake by the immune cells using synthetic systems for designing effective vaccine delivery system.