Department of Chemical Engineering, IIT Hyderabad
Scientific Seminar Series 2026

Date: 16-09-2026
Time: 16:00 PM (IST)
Speaker: Dr. Bhanjan Debnath
Affiliation: DST Inspire Faculty, Chemical Engineering, IITH
Title: Aging in Biomolecular Condensates
Venue: LHC-10

Abstract

Biomolecular condensates play important roles in intra- and inter-cellular organization and signaling through maintaining their material properties and spatial morphology. They can undergo striking changes, such as transitioning from a liquid-like state to a gel- or a solid-like aggregate due to changes in molecular interactions in response to changes in the biochemical environment. A progressive loss of condensate fluidity, particularly when associated with irreversible transitions in material properties, is commonly referred to as condensate aging. Aging of condensates is often linked to pathological conditions and diseased states. This talk will be themed around demonstrating plausible mechanistic routes that connect molecular interaction pathways and aging.

The first theme of the talk will address how interaction specificity can emerge from distinct molecular binding-unbinding interaction pathways and how this specificity can regulate condensate fluidity. Such interaction specificity is modeled using a heuristic approach. It is followed by development of a hybrid simulation methodology to predict condensate dynamics over a longer period, bypassing the classical limitation of Molecular Dynamics simulations.

The second part of the talk will show development of a continuum theory for such complex systems to predict dynamics at a larger spatial scale and over a longer time scale. This theory demonstrates how altered molecular interactions lead to a coupled

transition in the mechanical properties and morphology of condensates. An implication of this work is that morphology transition can serve as a readily observable signature of pathological states. In a liquid-like state, condensates continue to coarsen and dissolve under different cellular stress conditions. But, in a diseased state, when elastic memory progressively builds up in condensates, coarsening can be significantly suppressed with persistent arrested structure and altered rheological properties. Therefore, morphology transition can play a role in biomarkers when microrheological measurements are beyond scope and where time-resolved imaging of morphology can provide indirect evidence of a pathological state.

1. **Debnath B**, Katira P, Multi-step binding-unbinding pathways govern properties of biomolecular condensates, Biophysical Journal (2026), **doi:** https://doi.org/10.1016/j.bpj.2026.08.004.

2. **Debnath B**, From Maxwell Fluid to Kelvin Voigt Solid: A Transient Network Model of Condensate Aging and Morphology Transition in Phase Separation, arXiv:2608.23076, (2026) **doi:** https://doi.org/10.48550/arXiv.2608.2307

Biography

Bhanjan Debnath is a Chemical Engineer. He has held visiting positions at University of California-San Diego and San Diego State University after receiving his Masters and PhD from IISc Bengaluru. He was a Dharam Hinduja Scholar from 2009-2015. He has been awarded Prof. NR Kuloor Memorial Gold Medal for best PhD thesis in Chemical Engineering by the Mechanical Sciences division of IISc. His research is about understanding chemical physics of discrete systems, particularly rheophysics of granular flows, biophysics of cell-extracellular matrix interactions, and biomolecular condensates. Apart from research and academics, he likes to Meditate, play Tabla, Chess, sketching, and cooking. He belongs to a Bengali family from Agartala, Tripura nestled in the mountains and greenery in the North-East part of India.