

Insights from far-from-equilibrium phenomena at interfaces

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ABSTRACT

In far-from-equilibrium systems, the interfaces between two fluids or between a solid and a fluid are often the place where unique patterns and behaviors emerge. When phase change is involved, these interfacial processes give rise to complex physicochemical–hydrodynamic behaviors with important engineering and ecological consequences. For instance, during dropwise condensation, interactions between condensing droplets lead to in-plane contact-line motion. A non-wetting surface, on the other hand, can interact with the expanding liquid bridges formed during coalescence and propel the merged droplets out of plane, with implications for heat transfer efficiency or pathogen dispersal in plants.

Not all such emergent dynamics are driven by a temperature gradient, as evident in granular materials. To illustrate this, we will place non-cohesive micrometer- to millimeter-sized glass beads at a liquid interface to form a self-assembled monolayer and apply an in-plane compressive stress. Under compression, granular rafts form wrinkles like elastic sheets. Changes in the fluid or the particles can cause individual particles to eject rather than a system-scale buckling, defying traditional continuum understanding.

In this talk, I will show how experiments and theoretical derivations grounded in a physical, first-principles understanding can lead to a model that captures the composite behavior of particle-laden fluid interfaces. The generalized model can help design materials with tunable properties.

ABOUT THE SPEAKER

Dr. Ranit Mukherjee received his Ph.D. in Engineering Mechanics from Virginia Tech in 2021, followed by a postdoctoral assistantship in the Department of Mechanical Engineering at the University of Minnesota. His primary interest lies in designing soft-matter experiments to understand natural far-from-equilibrium systems. He has collaborated with various academic and industrial research groups, including Virginia Tech's Plant Pathology department and Rolls-Royce Research. Dr. Mukherjee has investigated the role of the dew cycle in plant pathogen dispersal, discovered a mechanism by which spontaneous electrification in ice can control frost growth, and developed a generalized model for particle-laden interfaces. His work on frost electrification resulted in a National Science Foundation GOALI grant in 2021. His research has been published in leading journals such as Joule, PNAS, ACS Nano, Advanced Functional Materials, and Soft Matter, and has been featured on popular science platforms. Before transitioning to experimental research, he worked as a process design engineer for fired heaters at Thermax in Pune.

