

SEMINAR
SERIES

DEC 06

10:00 - 11:00 AM
COLBURN LAB
ROOM 102“PHASE MECHANICS” OF ARRESTED
COLLOIDAL GELS: A NEW PARADIGM FOR
NON-EQUILIBRIUM PHASE TRANSITIONS IN
SOFT MATTER

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ABSTRACT

In colloidal gels and glasses, kinetically-arrested phase transitions exert a remarkable influence on material behavior, yet their structure-property relationships remain challenging to model. The physical and chemical similarities between molecular systems and interparticle colloidal attractions led to the development of colloidal phase diagrams, where metastable and unstable phase separation closely parallels that seen in molecular systems. Thus, colloids have long been viewed as paradigmatic model systems for molecular phase transitions where the vast separation of timescales between colloidal and solvent particles provides a means by which to “slow down” relaxation processes and study phase behavior. However, colloidal gels represent “arrested” states of phase separation, where the same interparticle attractions that promote phase separation also inhibit it, freezing colloids into a non-equilibrium microstructure that forms a viscoelastic network. Despite attempts to place them on equilibrium phase diagrams, such gels do not belong there; rather, temporal evolution is required to describe their “state”. We show that when interparticle bonds are $O(kT)$, thermal fluctuations enable ongoing particle migration and a (logarithmically) slow march toward full phase separation. Our work reveals the surprising result that gel yield can occur with the loss of fewer than 0.1% of particle bonds and no network rupture; instead, localized re-entrant liquid regions permit yield and flow. Analysis of the evolving osmotic pressure and potential energy reveals the interplay between bond dynamics and external stress that underlies mechanical yield and provides a

compelling connection to stress-activated phase separation. I will show that external forces open a pathway of escape from arrest toward equilibrium, and propose a non-equilibrium phase diagram as the foundation for “phase mechanics,” a new view of states of arrested colloidal matter.

BIOGRAPHY

Roseanna N. Zia is an Assistant Professor of Chemical Engineering at Stanford University. She received her Ph.D. from the California Institute of Technology in Mechanical Engineering in 2011 with Professor John F. Brady, for development of theory in colloidal hydrodynamics and microrheology. Zia subsequently conducted post-doctoral study of colloidal gels at Princeton University, in collaboration with Professor William B. Russel. Zia began her faculty career at Cornell in January 2013, then subsequently moved her research group to Stanford University in 2017. Dr. Zia’s body of work in colloidal hydrodynamics includes developing micro-continuum theory for structure-property relationships of flowing suspensions, elucidating the mechanistic origins of the colloidal glass transition, and microscopic modeling of reversibly bonded colloidal gels, which resulted in discovery that gel aging is actually ongoing but very slow phase separation and the finding that mechanical yield of colloidal gels is actually a non-equilibrium phase transition, triggered by changes in osmotic pressure. More recently she is developing models of biological cells, examining biological processes orchestrated by colloidal-scale forces. Dr. Zia’s work has been recognized by several awards, including the NSF BRIGE Award, the NSF CAREER Award, the Publication Award from the Society of Rheology, the Office of Naval Research (ONR) Young Investigator award, the ONR Director of Research Early Career Award, the Engineering Sonny Yau (’72) Teaching Award, and the PECASE Award. In addition, Zia serves as an Associate Editor for the Journal of Rheology, and on the Advisory Board of the journal Physics of Fluids.