Shear-driven Solidification and Nonlinear Elasticity in Epithelial Tissues

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Abstract

Biological processes, from morphogenesis to tumor invasion, spontaneously generate shear stresses inside living tissue. The mechanisms that govern the transmission of mechanical forces in epithelia and the collective response of the tissue to bulk shear deformations remain, however, poorly understood. Using a minimal cell-based computational model, we investigate the constitutive relation of confluent tissues under simple shear deformation. We show that an undeformed fluid-like tissue acquires finite rigidity above a critical applied strain. This is akin to the shear-driven rigidity observed in other soft matter systems. Interestingly, shear-driven rigidity in tissue is a first-order transition and can be understood as arising from the second order critical point that governs the liquid-solid transition of the undeformed system. We further show that a solid-like tissue responds linearly only to infinitesimally small strains and rapidly switches to a nonlinear response, with substantial stress stiffening. Finally, we propose a mean-field formulation for cells under shear that offers a simple physical explanation of shear-driven rigidity and nonlinear response in a tissue.

Biography

Max Bi is a theorist working in soft condensed matter. His broad interests range from the emergent and critical phenomenon in non-living soft materials to the collective behavior exhibited by cells. His group uses analytical methods from statistical mechanics and field theory and numerical computations to understand these problems.

Max received his PhD from Brandeis University in 2012, where his research focused on the origin of rigidity and the nature of the jamming transition in frictional granular materials. He completed his postdoctoral training at Syracuse University and Rockefeller University before establishing an independent research group at Northeastern University in 2017.