

Deformation and flow in disordered materials

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Many important natural and fabricated systems, such as plastically deforming solids, earthquake faults, and even some fluid flows are currently described by phenomenological models. While these models are useful for predicting macroscopic behavior in typical situations, they may fail in extreme situations and provide little insight into the microscopic mechanisms that give rise to the large-scale behavior. Because sheared solids such as foams, colloids, amorphous metals and granular fault gouge are composed of particles in closely-packed, non-crystalline configurations, small-scale mechanisms for deformation in these materials are less well-understood than those in liquids or crystals. I will discuss a mesoscopic model for these disordered solids, the theory of Shear Transformation Zones (STZs), and show that it captures macroscopic features seen in experiments as well as interesting internal dynamics such as shear banding. An important component of this model is the effective temperature, which describes the statistical distributions of particle configurations and governs plastic deformation. Shear banding occurs due to a “frozen”-time instability in the effective temperature field, and one can determine a condition for shear banding based on the initial conditions alone. I will discuss how the STZ formulation can be used as a constitutive law for friction on earthquake faults and includes a mechanism by which the system can dynamically transition from strengthening to weakening with increasing slip.