Viscoelastic phase separation

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Lecture Description: Phase separation is one of the most fundamental phenomena that create spatially inhomogeneous patterns in materials and nature. It has so far been classified into three types: (i) solid, (ii) fluid, and (iii) viscoelastic phase separation [1]. The relevant transport processes are only diffusion for (i), diffusion and hydrodynamic convection for (ii), and diffusion, hydrodynamic convection, and mechanical stress for (iii). Here we discuss the physical mechanism of viscoelastic phase separation. This phase separation takes place universally if there is strong dynamic asymmetry between the components of a mixture. The origin of the dynamic asymmetry is either the size disparity between the components or the difference in the glass transition temperature between the components. For example, viscoelastic phase separation has been observed in polymer solutions, protein solutions [2], colloidal suspensions [3], and membrane systems [4]. Under a deep quench, a transient gel is formed by strong attractive interactions between the slower components. The connectivity of the network acts against phase separation and produces the mechanical stress in it. The coupling between the composition, velocity, and stress fields is the key to this phase separation. We also find phase-separation behaviour accompanying mechanical fracture [5]. Surprisingly, mechanical fracture becomes a dominant coarsening process of the phase separation. The behaviour of viscoelastic and fracture phase separation originates from a strong coupling between the composition and deformation field.

We demonstrate that the same type of coupling between the density and deformation field leads to cavitation of fluid under shear and mechanical fracture of glassy liquids and solids under deformation [6]. We discuss a common physics underlying these apparently unrelated phenomena and a selection principle of the kinetic pathway of pattern evolution. For example, the only difference between phase separation and fracture may stem from whether deformation is produced internally by phase separation itself or externally by loading.

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