Rheology in Two Dimensions

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The dynamics of fluid/fluid interfaces control a wide range of phenomena of technological and biological interest. These include flow-induced deformation of blends, emulsions and foams, and cell division in biology. In many applications, amphiphiles can collect at these interfaces and strongly and render the interfacial rheology non-Newtonian. As a result, the fluid mechanical response of films as thin as a monolayer can be highly nonlinear. This paper presents experimental results combining mechanical and optical measurements to reveal the microstructural origins of a variety of phenomena.

Several examples are presented in this paper: the problem of order-disorder in a two-dimensional liquid crystal, the non-Newtonian fluid mechanics of a high molecular weight, flexible polymer chain laying flat on an interface, and the dynamics of two-dimensional suspensions. In the first example, it is demonstrated that many monolayer systems spontaneously order into liquid crystalline domains due to the extra constraints that pin molecules to the interface. It is demonstrated that both thermotropic and lyotropic order-disorder transitions can occur. This is accomplished using a combination of mechanical and optical measurements of orientation. The experiments involving a flexible polymer amphiphile involve surface flows through contractions and demonstrate that these monolayer systems undergo highly nonlinear flow phenomena that are reminiscent of their 3D counterparts. Finally, the dynamics of two-dimensional suspensions are examined. These systems are formed from monolayers of monosized latex spheres pinned at either the air/water or oil/water interfaces. Under appropriate conditions highly organized, two-dimensional crystals are formed that are subjected to both shear and extensional flows. These are examined using flow-microscopy methods as well as interfacial stress rheometry.