Title	Shear Banding of Complex Fluids(New Frontiers in Colloidal Physics : A Bridge between Micro- and Macroscopic Concepts in Soft Matter)
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Citation	物性研究 (2007), 89(1): 33-33
Issue Date	2007-10-20
URL	http://hdl.handle.net/2433/110963
Right	
Type	Departmental Bulletin Paper
Textversion	publisher

Shear Banding of Complex Fluids

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Complex fluids can develop shear-induced instabilities that lead to non-uniform flow profiles and pattern formation. Two different types of banding instabilities can be distinguished : gradient banding and vorticity banding.

The gradient-banding transition will be discussed on the basis of a relatively simple constitutive equation, where the standard expression for the stress tensor is extended to include the next higher order derivative in its formal Taylor expansion with respect to gradients in the fluid flow velocity. This term is necessary in order to capture the large spatial gradients of the velocity within the interfaces that connect the shear bands. The kinetics of the gradient-banding transition is formally very similar in structure to the Cahn-Hilliard model for spinodal gas-liquid demixing. In the initial stages of band formation there is a most rapidly growing wavelength, while at larger times coarsening occurs. The microscopic origin for the gradient-banding instability for suspensions of rods will be discussed in connection with the critical point in the shear-rate versus concentration phase diagram.

The vorticity-banding transition is experimentally observed for suspensions of rods to occur only inside the two-phase paranematic-nematic region in the shear-rate versus concentration plane. Experiments on the kinetics of this banding transition will be discussed as well as experiments on the internal structure of the vorticity bands. Particle-tracking experiments indicate that the vorticity bands are in weak, internal rolling motion. This is an indication that normal stresses along the gradient direction are responsible for the instability. A mechanism will be proposed for the vorticity-banding instability which is similar to the well-known elastic instability for polymers (the Weissenberg effect), where the role of polymers is played by inhomogeneities formed due to paranematic-nematic phase separation.

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