Hydrodynamical effects in Lamellar Ordering

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Kinetics of lamellar ordering is relevant for many systems in condensed matter. Competition between attractive and repulsive forces often produces lamellar structures. Examples are di-block copolymer solutions, ternary mixtures, supercooled liquids, fluids in Raleigh-Benard experiments above the convective threshold.

Growth properties of these systems are not always well understood. The purpose of our work was to analyse the effects of hydrodynamics in this process. Our model, based on Navier-Stokes and convection-diffusion equations, is particularly appropriate for describing copolymer systems. Lattice Boltzmann Methods coupled with finite difference schemes for the convection-diffusion equation are used. This algorithm allows to overcome usual problems arising in the free-energy approach, as the appearance of spurious terms in the continuum limit of lattice Boltzmann equations. The size of the lattice considered is large enough to minimize finite size effects in the evaluation of the growth laws.

We show that, while at high viscosity the system evolves into frozen configurations, at low viscosities order is reached on large scales and dynamical scaling is verified [1]. The structure factor behaves like $C(\vec{k},t) \sim L(t)^{\alpha} f[(k-k_M)L(t)]$ where k_M is the equilibrium wave number of lamellae, $L(t)$ is a characteristic length calculated by the structure factor, and $\alpha = 1.25$. $L(t)$ first grows as a power law with exponent $z = 0.3$ while, at later times, its behavior changes over to a slower logarithmic growth. This scaling, expected for glassy systems, is a new results for systems without quenched disorder [2]. The motion of grain boundary defects between differently oriented lamellae can explain the evolution of $L(t)$.

We have also considered the effects of shear flow. Our results show that in this case lamellar ordering occurs with power-law behavior at all times. In some cases shear banding with coexistence of phases of differently oriented lamellae has been also observed.

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[2] M. Rao and A. Chakrabarti, Phys. Rev. Lett. v. 71 p. 3501 (1993).