Shear-induced onion formation of complex bilayer membrane systems

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The influence of a triblock copolymer, poly(ethylene oxide)m-b-poly(propylene oxide)n-b-poly(ethylene oxide)m (Pluronic series with different PEO and PPO chain length) on the phase behavior and on the shear induced onion formation in the lyotropic lamellar phase of the nonionic surfactant C10E3 was investigated by means of rheology, small angle neutron scattering (SANS) and small angle light scattering (SALS). At quiescent state, added triblock copolymer significantly shifted the La-L3 phase transition to lower temperatures. Under shear, the onion structure was not stable and easily transformed back into the lamellar phase with increasing polymer concentration and with increasing the polymer chain length, both of m and n. As a typical example of the results we obtained, polymer chain length dependence of the time development of 2D-SANS pattern in the shear-induced lamellar-to-onion formation process is shown in figure 1. Here, only the results on the PPO chain length dependence are shown. At short time region, anisotropic SANS pattern with the Bragg peak in the neutral direction, which was a representative for the parallel oriented lamellae along the flow direction, was observed for every samples. As PPO chain length, m, of triblock copolymer was increased, however, the time development of the onion formation process was remarkably affected. Samples with short PPO chain length showed an isotropic SANS pattern, which is a signal of the onion formation. As the PPO chain length was increased, the isotropic SANS pattern, i.e., the onion formation, was remarkably prohibited, and the sample with the longest PPO chain, m=69, showed no onion formation but the parallel oriented lamellar phase. In the rheology measurements, we found an increase of the critical shear rate for the onset of the shear-thickening, which also indicates the instability of onion in the presence of the triblock copolymer. Suppression of the shear-induced onion formation might be attributed to the enhancement of the effective surface tension, which might be also influenced by added triblock copolymer. These results clearly indicate that not only the hydrophilic polymer chain, PEO, but also the hydrophobic polymer chain, PPO, influences the dynamic properties of the lamellar membranes, which would be controlled by a combination of hydrophilic and hydrophobic chain length. To make clear the effect of guest components on the shear-induced nonequilibrium phenomena, it is necessary to perform experiments with different series of complex lamellar phase and elaborate analysis of structure on the basis of SANS.

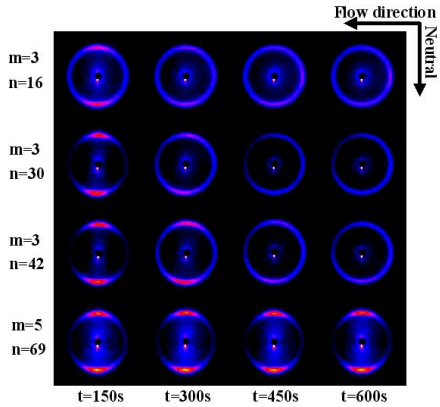

Fig. 1. Hydrophobic polymer chain length dependence of the time development of 2D-SANS patterns for complex lamellar phase in the onion formation process. Polymer mole fraction was fixed at 1mol%. Shear rate was fixed at 10s-1.