Varity of phase separation patterns induced by a propagating trigger

A pattern is formed when a phase separation in two component mixtures occurs. A bicontinuous network pattern is formed when the concentration of the two phases are symmetry to the phase separation line. Meanwhile, when there is a high degree of asymmetry, the minority phase can appear as droplets, with random droplet size and spatial distribution. It is also known that the pattern formation can be different in polymer solutions. The majority phase (the solvent phase) appears as droplets and the polymer rich phase transiently forms a network. The two phases usually have different physical properties such as mechanical property, heat conduction, and so on. Thus control of the pattern formation is important not only for academic interest but also for industrial science.

Fig. 1. Right : Random droplet pattern. Center : Concentric circle pattern. Left : Dendritic pattern

Here we performed numerical simulations to investigate new pattern formation mechanisms during phase separation. We propagate a trigger, which induces a phase separation, radially from a point. We observed different pattern formation from the structures reported in classical studies. We found that the pattern can be controlled with changing the propagation speed. When the speed is much faster than the time scale of the phase separation, the pattern becomes random structure. Meanwhile, we can observe a concentric circles (CC) if the propagation speed is comparable. When the propagation speed is much slower, a dendritic (DD) pattern can be observed (Fig. 1).

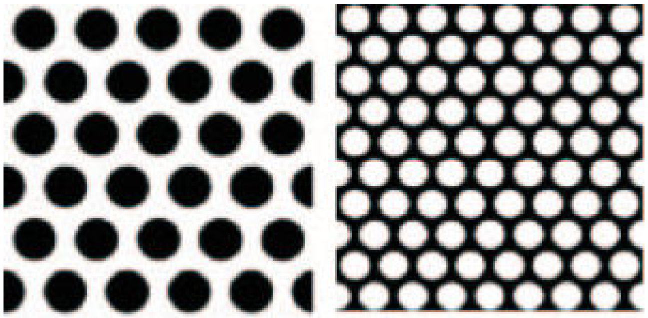

Fig. 2. Right : the minority phase is arranged in the hexagonal order. Left : the majority phase is arranged in the hexagonal order. The simulation conditions for both images are the same except a distance between the cores.

We also investigated pattern formation with multiple propagated triggers. The propagating triggers are initiated simultaneously from points arranged in a hexagonal pattern with a spacing. At the beginning of the phase separation, the CC pattern is formed at every point where the triggers start to propagate, as shown in Figure 2. At the later stage, the hexagonal pattern with extremely long range is created by the coarsening. We also found that the phase at the boundary of the neighboring CC pattern is not changed with time, while the phase at the core oscillates. Due to this feature, we can select the phase at the lattice point even though it is the minority phase. Furthermore we observed the bicontinuous pattern even in the asymmetric composition with multiple triggers propagating though the system.

This pioneering research show that pattern formation can be significantly influenced by changing the speed of the propagation of the trigger and the arrangement of the triggers. Those patterns are strongly related with unique physical properties. Those results motivate more experiments and understanding of the physics of pattern structure and formation.

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