New kinetic pathway of nucleation and growth of the lamellar phase in a lyotropic liquid crystal

— Spontaneous onion nucleation and rapid anisotropic growth —

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我々はリオトロピック液晶である $C_{10}E_3/H_2O$ を用い、そのスポンジ相 (無秩序相) からのラメラ相 (秩序相) の核形成キネティクスについて研究した。その結果特に低濃度の試料において、円盤状のラメラ核が変形して球状のオニオン構造を形成する、新たなオニオン相の自発的形成機構を発見した。これは界面エネルギーと変形の自由度が結合した、ソフトマターに特有の機構と考えられる。更に高濃度の試料では、強い非平衡状態下において、異方的で速い特有の核形成・成長機構が見られた。発表では、セルに閉じ込められた状態における、セル表面での不均一核形成と表面から離れたバルク中での均一核形成の競合も含めて報告する予定である。

Ordering transitions usually occur via a first-order phase transition. In this process domains of the ordered phase are thermally nucleated and then grow. For the nucleation of the ordered phase of hard matter, the energy gain of ordering and the interfacial energy are dominant to the critical radius, domain shape, etc. In soft matter, however, the energy supporting the order is as small as the thermal energy. Therefore the structure of the nucleus of the ordered phase can be coupled to other degrees of freedom such as deformation. This coupling may lead the system to new kinetic pathways of nucleation and growth.

To explore the kinetics of nucleation and growth in soft matter, we use $C_{10}E_3/H_2O$, a lyotropic liquid crystal composed of surfactant bilayers, as a model system. This forms an ordered (lamellar or smectic) phase and disordered (sponge) phase (see Fig. 1(a)). A remarkable feature of this system is its extremely large intermembrane distance d, up to $\sim 0.1\mu$m, which makes it easier to observe with optical microscopy. The large d also makes the characteristic time scale so large that we can observe the nucleation and growth process in real-time.

The lamellar (or smectic) phase is seen in many liquid-crystalline materials. In this study we observed the nucleation and growth of the lamellar phase from the sponge phase upon cooling. In order to observe isolated nuclei, we cool the system from the one-phase (sponge) region just into the sponge-lamellar coexistence region. As a result we found a new kinetic pathway: spontaneous

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onion (multilamellar vesicle[1]) nucleation via the transformation from the discotic nucleus[2] in low concentration up to about 10wt% (Fig. 1(b)(c)). We consider that this new kinetic pathway is caused by the competition between the interfacial energy and elastic energy. Furthermore we found a rapid, anisotropic nucleation and growth process at high concentrations where the system is in far from equilibrium. We also discuss the competition between heterogeneous nucleation on cell surfaces and homogeneous nucleation in the bulk sponge phase in a slit geometry.

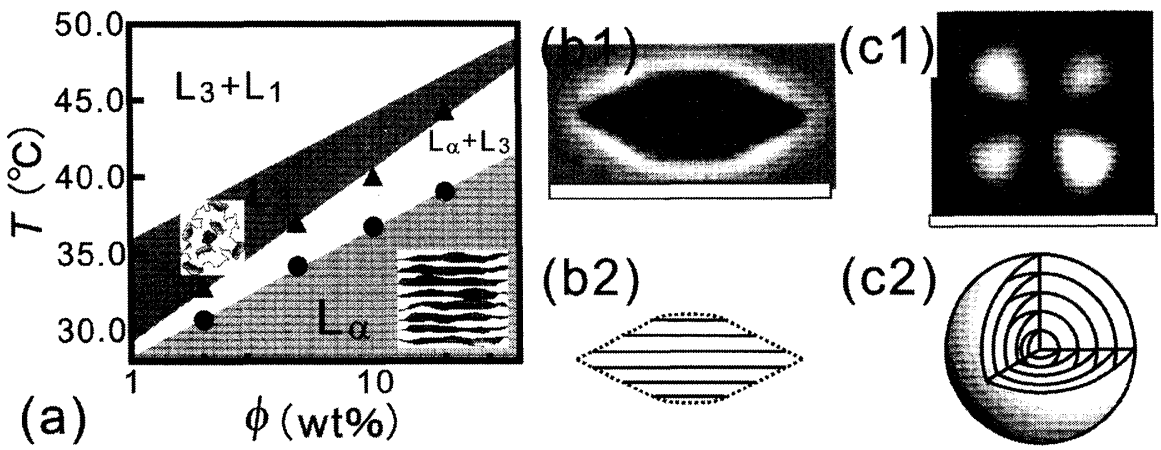

Figure 1: (a)The phase diagram of $C_{10}E_3/H_2O$ including the schematic figures of lamellar and sponge structures. L_α is lamellar, L_3 is sponge and L_1 is micelle phase. (b1)The cross-sectional image of the discotic nucleus formed in $C_{10}E_3$ 4.9wt%. (b2)The schematic lamellar structure in a discotic nucleus. (c1)The onion nucleus in the same concentration observed with polarizing microscopy. (c2)The schematic structure in an onion nucleus. Scale bars correspond to 50 μm.

References

[1] M. Kleman and O. D. Lavrentovich, *Soft Matter Physics: An Introduction* (Springer, New York, 2003).

[2] C. Blanc, Phys. Rev. E **64** (2001), 011702.