論文の内容の要旨

Non-equilibrium dynamics of chiral liquid crystal
(キラルな液晶の非平衡ダイナミクス)

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In this dissertation, we experimentally studied non-equilibrium dynamics of cholesteric liquid crystal (CLC), which is a chiral phase of liquid crystal (LC) exhibiting helical director field. In spite of increasing understanding on the structure and equilibrium properties of CLC owing to development of microscopy and numerical calculations, the non-equilibrium behaviors have been far from understood due to the complex coupling between the chiral structure and dynamics.

First, we investigated the rotational motion of CLC droplets under a temperature gradient, which is called the Lehmann effect, a long-standing unsolved problem in CLC physics. We controlled the angle between the helical axis of CLC droplets and the direction of the temperature gradient by changing anchoring conditions of LC cells. As a result, we observed that the three types of CLC droplets, one of which we observed for the first time, rotate under a temperature gradient. We found that the rotational velocity of these droplets depends differently on their size. By determining the 3D structures of the droplets using the fluorescence confocal polarizing microscopy (FCPM), we constructed a phenomenological model to describe these rotational behaviors following the basic ideas in a hydrodynamic theory of LC (the Ericksen-Leslie

theory). Our phenomenological model showed that a surface torque induced by a temperature gradient is required to explain the rotational velocity of the three types of CLC droplets.

Secondly, we studied the Marangoni-effect-driven spontaneous swimming motion of CLC droplets dispersed in surfactant solutions. We discovered that a CLC droplet with a helical director field swims in a helical path driven by the Marangoni flow. We also found that the handedness of the helical path is reversed when that of the droplet is reversed by replacing the chiral dopant with the enantiomer. In contrast, we observed that nematic liquid crystal droplets swim in straight paths. Consequently, we concluded that the helical motion of the CLC droplets is induced by chirality of CLC.

Finally, we proposed a phenomenological model of the self-propelled helical motion of the CLC droplets. Our model was constructed by symmetry argument in chiral systems, and it describes the dynamics of CLC droplets with a coupled time-evolution equations in terms of a velocity, an angular velocity and a tensor variable representing the symmetry of the helical director field of the droplet. We found that helical motions appear in our model in addition to other chiral motions. By investigating bifurcation behaviors between each chiral motion, we found that the chiral coupling terms between the velocity and the angular velocity, and the nonlinearity of model equations play a crucial role in the emergence of the helical motion of the CLC droplet.