Heat-driven micro turbines with cholesteric droplets

Jun Yoshioka* and Yuka Tabe
Faculty of Science and Engineering, Waseda University, Tokyo, Japan
*E-mail: jyoshioka27@gmail.com

In typical steam turbines, rotative power is obtained by two energy conversion processes: first, the heat is converted to vapor flow by boiling water, and second, the flow is converted to mechanical rotations when the steam blows through a propeller. Here we show the mechanism similar to the steam turbine appears in chiral liquid crystalline systems. Figure 1 shows a cholesteric (Ch) droplet dispersed in an isotropic (I) liquid. When the temperature gradient is applied to this system, the texture on the droplet rotates unidirectionally [1,2]. On the other hand, if we prepare the bulk Ch phase and apply the temperature gradient, the rotational motions are hardly induced. This suggests being I-Ch coexistence state is essentially required to induce the unidirectional rotation in the Ch droplets. To verify this hypothesis, we made the system where isotropic droplets were dispersed in the Ch liquid crystal and tried to induce the unidirectional rotation under the temperature gradient. Heating the sample from the Ch phase, we made the isotropic droplets in the Ch liquid crystal. Observing them with polarized microscopy, we found spiral texture appeared as shown in Fig.2. Moreover, when the temperature gradient was applied to this system, the texture rotated unidirectionally. Here, the rotational direction was opposite from the direction in the case of the Ch droplets as shown in Figs.1 and 2. To clarify the physical origin of the rotation, we analyzed the flow-field in the system using photo-bleaching method. As a result, we found convective structures were induced in both the system with the Ch and the isotropic droplets when the temperature gradient was applied. Here, in these systems, the direction of the convection was opposite from each other. This result indicates the rotation is driven by the coupling between the chiral structure of the Ch liquid crystal and the material flow induced by the temperature gradient. Steady flow is induced by heating and cooling the working fluid, and the propeller with the chiral structure rotates owing to the flow; we consider the heat-driven rotations in the I-Ch coexistence system is induced by the mechanism just like the steam turbines.

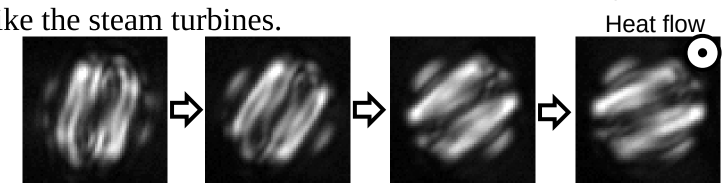

Fig. 1. Heat-driven rotation in cholesteric droplet dispersed in isotropic phase (interval:6sec)

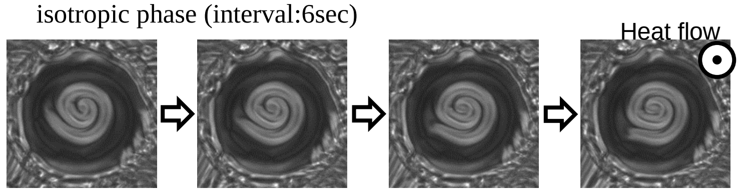

Fig. 2. Heat-driven rotation in the system where isotropic droplet is dispersed in cholesteric phase (interval:3sec)

References

[1] P. Oswald and A. Dequidt, “Measurement of the continuous Lehmann rotation of cholesteric droplets subjected to a temperature gradient,” *Phys. Rev. Lett.*, **100**, 217802 (2008).
[2] J. Yoshioka, F. Ito, Y. Suzuki, H. Takahashi, H. Takizawa and Y. Tabe, “Director/Barycentric rotation in cholesteric droplets under temperature gradient,” *Soft Matter,* **10**, 5869 (2014).

Speaker Biography

Jun Yoshioka received B.S., M.S. and Ph.D. degrees from Kyoto University in 2008, 2010 and 2013, respectively. He joined Faculty of Science and Engineering in Waseda University as a researcher in 2013, and an Assistant Professor from 2014 to 2016, and he moved Center for Emergent Matter Science in Riken as a researcher in 2016. His research interests are structural formations and dynamics in complex softmatter systems, and his paper about the heat-driven dynamics in the cholesteric droplets received an Award from Japan Liquid Crystal Society in 2015.