Development of Novel Mechanical Devices Using Liquid Crystal Flows

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Liquid crystals are the states of matter between liquids and crystals and exhibits both fluidity and various anisotropic properties such as optical, electrical, thermal properties, and so on. Currently, the major application of the liquid crystals is the display devices in which the optical switching is achieved by controlling the molecular orientation of the liquid crystal. In our work, we aim to explore the dynamic behavior of the liquid crystals and to develop new applications of the liquid crystals, from the fluid dynamics point of view.
Followings are some examples of our works.

1. Liquid crystal linear actuator and motor

Figure 1 illustrates the mechanism of the liquid crystal actuators. Liquid crystals are constituted with the molecules whose shapes are highly anisotropic, such as rod-like or disk-like shapes. The ellipses represent the rod-like molecules, and the liquid crystal is confined between parallel plates. When an electric field is applied on the liquid crystals, the anisotropic molecules tend to align along the electric field. The flow of the liquid crystal is induced during the reorientation process of the molecules, and the shear stress acts on the surface of the plates. For the case that the upper plate is unfixed the movement of the upper occurs.

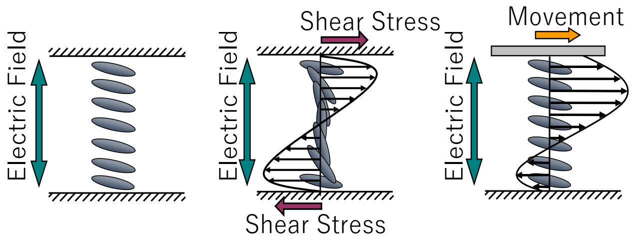

Figure 1

Since the liquid crystals have no unique shapes and thus high shape adaptability, they can drive objects of any shape. Figure 2 shows a picture of a liquid crystal micro-motor on a grain of a rice, whose diameter is 0.1mm. The liquid crystal is confined between concentric cylinders and an electric field is applied between the inner and outer cylinders. The inner cylinder rotates with 30rpm under the application of the electric field.

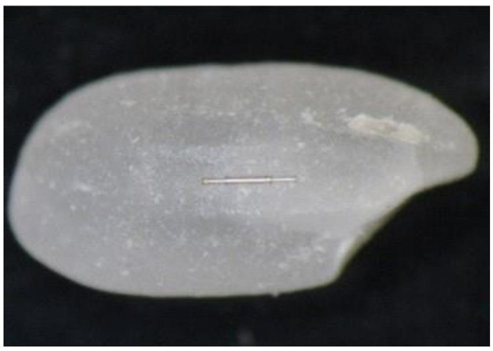

Figure 2

2. Liquid crystal soft-manipulator

Liquid crystal materials exhibit two liquid-like states depending on temperature, which are isotropic liquid and liquid crystal states. By controlling the temperature of the material, an interface between these two states emerges within the material and the position of the interface is also adjustable. The capture and the displacement of micro-objects are possible by using the interfacial force between isotropic liquid and liquid crystal states. Figure 3 shows the capturing of a tungsten particle with 100μm diameter using the interfacial force between isotropic liquid crystal states. Because of the high density of tungsten carbide, the particle rapidly approaches to the interface. Despite the high terminal velocity of this particle, the interfacial force between smectic and isotropic phases was sufficiently strong to decelerate and hold the particle at the interface. In future, the novel device for manipulating bio-cell will be developed using the liquid crystal interface.

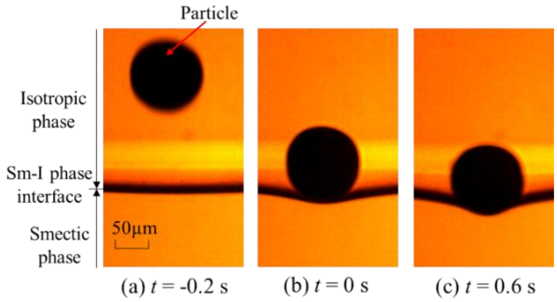

Figure 3