Single Crystal Growth of Inorganic Salts in a Magnetically Levitated Aqueous Droplet Using Small Permanent Magnets

*Yasuhiro Ikezoe, Tomoaki Suzuki, Tomoya Naito

Department of Applied Chemistry, Nippon Institute of Technology

Using the microgravity environment inside the space station, numerous important studies are being conducted that are difficult to achieve on Earth. In particular, for protein crystal growth, the microgravity environment suppresses convection caused by density differences within liquids, enabling the formation of high-quality crystals. This has stimulated extensive research into potential applications in the medical and biological fields. However, in addition to the enormous cost of conducting experiments in space, there are various limitations in terms of human resources, available time, and experimental equipment. Therefore, several technologies have been explored to reproduce microgravity-like environments on Earth, one of which is diamagnetic levitation. In general, diamagnetic levitation requires large superconducting magnets and thus has not become a highly versatile technique. However, we have recently discovered that placing two pairs of small permanent magnets in a specific configuration makes it possible to levitate diamagnetic substances such as water and sodium chloride [1].

In this study, we levitated an aqueous solution of an inorganic salt and carried out its recrystallization by evaporating the solvent (water). As a result, it was found that controlling the crystallization conditions makes it possible to grow only a single crystal. In the experiment, small plate-shaped magnets (depth 5 mm, width 1 mm, height 10 mm; Type A) and cylindrical magnets (diameter 1 mm, length 3 mm; Type B) were fixed in pairs (Fig. 1-(a)). Under conditions of room temperature (24.6 °C) and 10% humidity, microdroplets of a 4.5 M NaCl solution generated by an ultrasonic humidifier were introduced into an acrylic case through a silicon tube. The microdroplets slowly fell inside the case and gathered at levitation points in the narrow valley between the Type A magnets, forming droplets with a diameter of about 100 μm. As the solvent evaporated, seed crystals formed at the bottom of the droplets, and the crystals grew as the water evaporated (Fig. 1-(b)). When the water completely evaporated, transparent cuboid crystals remained levitated. Similar results were obtained using a KCl solution, and it was found that the timing of seed crystal formation could be controlled.

This method offers extremely low initial and operating costs, minimal restrictions on experimental time, space, and energy consumption, and broad applicability. In the future, this method is also expected to find applications in protein crystallization and in experiments involving supercooled melts.

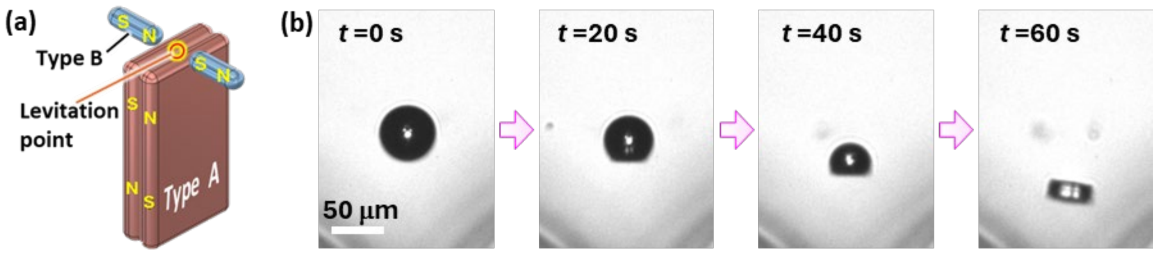

Figure 1. (a) Schematic illustration of the magnet configuration. Magnetic levitation of objects is observed in the narrow valley between the Type A magnets. (b) A series of photographs showing the recrystallization process. During evaporation of the levitating aqueous droplet, nucleation occurred, resulting in the growth of a single transparent cuboid crystal of sodium chloride.

[1] T. Naito et al., *Appl. Phys. Lett.* 125, 264102 (2024)