K035-P001 Time: May 30 17:00-18:30

Synthesis of large high-quality olivine single crystals, and its significance

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Comprehensive and conclusive understanding of the anisotropic upper mantle relies on the physical property measurements on high-quality homogeneous specimens of various crystallographic directions. Such specimens are ultimately prepared from one large single crystal. Large olivine single crystals were synthesized for use in property measurements and laboratory experiments including anisotropic studies. We are capable of producing large homogeneous single crystals over 50 mm diameter and 200 mm length.

Olivine is the most abundant phase of the Earth's mantle. Synthesis of high-quality large olivine single crystals is essential to understand physical properties of the mantle. Particularly in the upper mantle, many geophysical observations show anisotropic physical properties. To study anisotropies in seismic velocity, elasticity, anelasticity, viscoelasticity, rheology, electrical conductivity, and thermal property, it is essential to determine the properties of mantle minerals along various crystallographic directions. For systematic anisotropy measurements, it is important to prepare homogeneous specimens cut for various crystallographic directions from one large single crystal. High-quality forsterite single crystals have been successfully grown by the Czochralski-pulling (CZ) method. However, the crystal size (20-30 mm long) was not large enough to conduct various physical property measurements. To date, large olivine single crystals are not constantly produced yet. We report synthesis of large high-quality olivine single crystals for use in physical property measurements at high pressure and temperature.

We synthesized olivine single crystals by the CZ method with a pure-iridium crucible. A wide furnace space of the new CZ apparatus used in this study allows to mount a large Ir-crucible to about 90 mm diameter and 90 mm height. The CZ apparatus is equipped with the automatic diameter control (ADC) system, which automatically maintains uniform crystal diameter. The major impurities in the crystals come from starting reagents and stoichiometry. We used high-purity MgO and SiO2 reagents (both in 99.99 wt.%) and natural olivine crystals for synthesis of forsterite and olivine single crystals, respectively. Up to 1500 grams were mounted in the crucible, and heated up under N2 atmosphere. A rotating seed crystal (10-20 rpm) is attached to the melt surface, and then slowly pulled up at a rate of 5 mm/hour. The melt is solidified by touching to the seed, and a growing olivine single crystal follows up the pulling seed.

We will show as-grown crystals of forsterite and olivine. Careful preparations (weighing and mixing) of starting reagents enable us to create a high-quality crack-free forsterite specimen. Owing to the new ADC system, the present crystals have uniform diameter, and their cross sections are nearly perfect circle. In contrast, previously grown crystals had rough surfaces and irregular cross sections; practical sample volume used for the experiment might be less than a half of the crystal volume. Many homogeneous olivine specimens of various crystallographic directions and various sizes will be obtained from one large single crystal. The samples are large enough to conduct, e.g., systematic deformation experiments for various crystallographic directions.

A thick long crystal can be produced by using a large volume crucible. Ultimately, we will be capable of producing specimen size to over 50 mm diameter and to 200 mm length, by using a crucible of 90 mm diameter and 90 mm height. Large high-quality single crystals will be successively supplied for use in property measurements and laboratory experiments.

The authors thank the Material Design and Characterization Laboratory of the Institute for Solid State Physics of the University of Tokyo for the CZ facilities. This work was supported by grants from the Earthquake Research Institute of the University of Tokyo (2001-A-18).