Poster session #2 / ID# 242

Mass production of enriched $Li_2{}^{100}MoO_4$ crystals at CUP for AMoRE

Ju Kyung Son[a], Cho Rok Byeon[a], Jun Seok Choe[a], Olga Gileva[a], Dae Yeon Kim[a], Yeong Duk Kim[a,b], Cheol Ho Lee[a], Moo Hyun Lee[a,b,*], Douglas Leonard[a], Se Jin Ra[a], Keon Ah Shin[a], Hyo Jin Yeon[a]
[a]Center for Underground Physics, Institute for Basic Science (IBS), Daejeon 34126, Korea
[b]IBS School, University of Science and Technology (UST), Daejeon 34113, Korea

Abstract

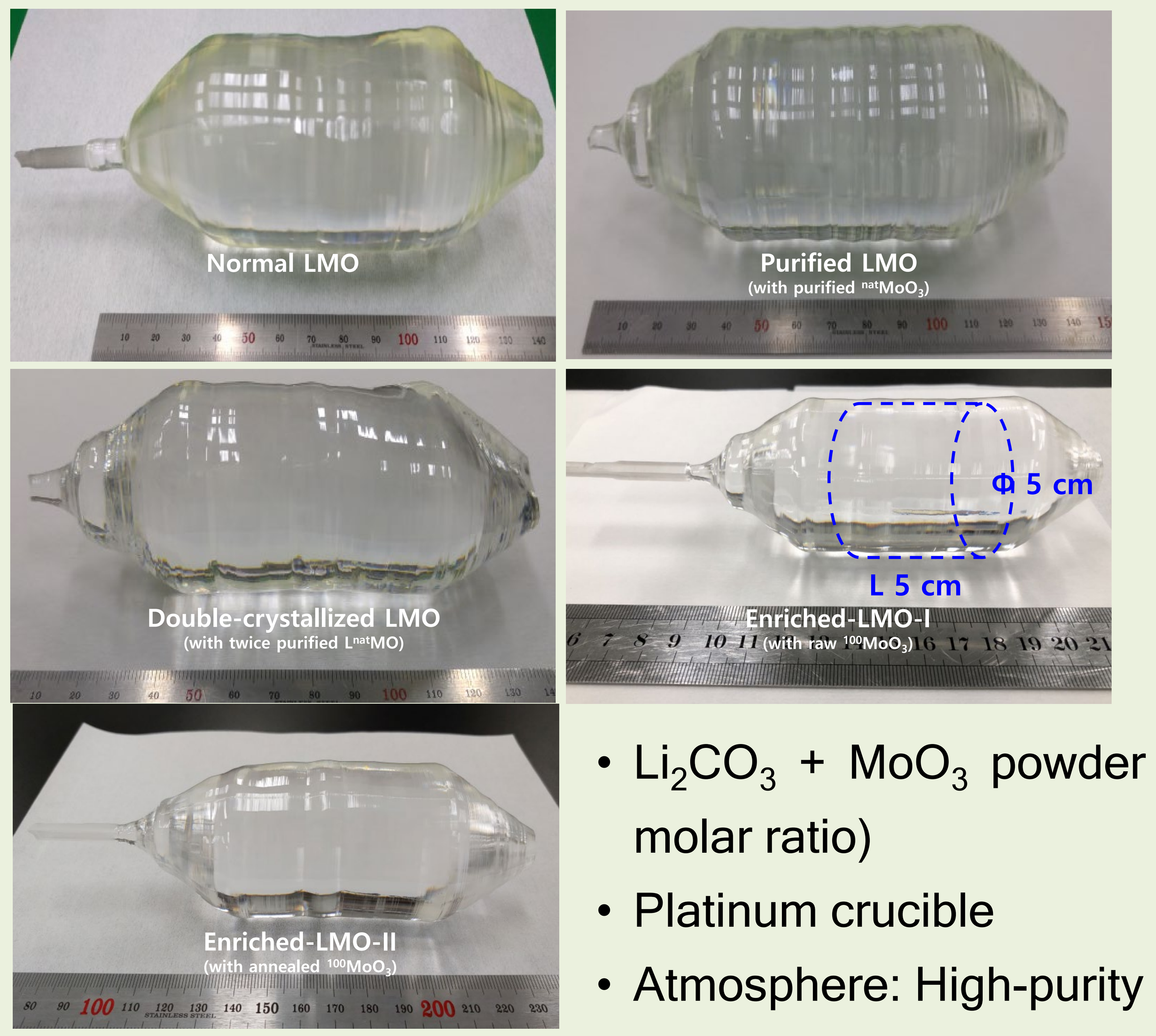
Neutrino oscillation experiments have shown that neutrinos have mass. However, the results haven't provided absolute masses and properties of neutrinos. Many experimental groups have conducted experiments to address these questions. One of the experimental groups is the Advanced Mo-based Rare Process Experiment (AMoRE), which searches for neutrinoless double-beta decay of ^{100}Mo isotopes in scintillation crystals at mK temperatures. Since the decay is very rare, it is extremely important to keep the radioactive background levels of the crystals. The Center for Underground Physics (CUP) at the Institute for Basic Science (IBS) has conducted ultra-pure Li_2MoO_4 (LMO) crystal growth for the AMoRE. After growing natural LMOs of various materials by the Czochralski method, we assessed the purity of each crystal using ICP-MS at CUP. The values of the main impurity elements of the internal crystal to be measured were below the ppb level, and a few major elements were lower than the detection limit of the ppt level. We also investigated natural LMO crystals to determine the optimal growth conditions for CUP facilities. The ingot size of the grown LMO crystals is approximately 50 mm (Ø) × 140 mm (H), and the weight is approximately 600 g in the current facility. With this consistent work, we handle only the body of the ingot, which is used in actual detectors (about 300 g, half the ingot). The remaining parts were reused as the basis for regrowth material. After the crystal growth investigation, mass production of enriched $Li_2{}^{100}MoO_4$ crystals for use in the AMoRE detector started. The crystal ingots cannot be used directly as the detector; they must undergo multiple processing steps in accordance with the detector's design. Minimizing contamination during machining was a key factor in reducing impurities in the final detector. We report on the overall growth and handling of Li_2MoO_4 crystals at CUP for mass production.

Crystal growing equipment

◇ Crystal growers and mass production
- Three Czochralski crystal growers in a 10,000-class clean room.
- Temperature: up to 2200 ℃ (Ir crucible), up to 1500 ℃ (Pt crucible)
- Pulling speed: 0.1 ~ 10 mm/h - Seed rod rotation: 0 ~ 30 rpm
- High resolution 'Load cell' (for weighing)

Fig. 1. Photographs of Czochralski growers in the clean room

Grown LMO Crystals at CUP

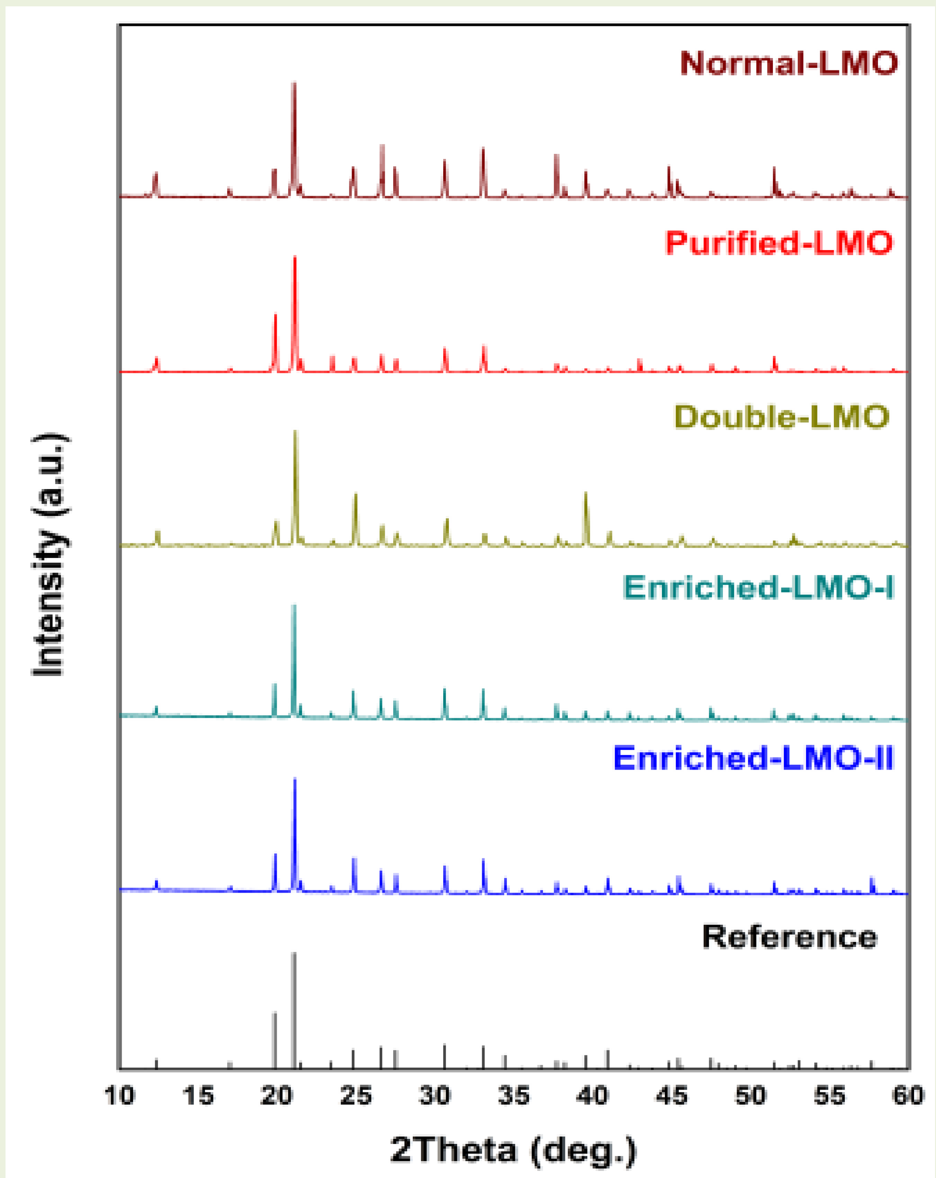


- Li_2CO_3 + MoO_3 powder (1:1 molar ratio)
- Platinum crucible
- Atmosphere: High-purity air
- D ~5 cm × H ~14 cm, ~ 600 g
- $^{100}MoO_3$ powder (^{100}Mo ratio > 95%) from the ECP, Russia.

Fig. 2. Grown LMO crystals at CUP

XRD results

- XRD results are well matched with reference data.



※ Ref.: Kolitsch U., Zeitschrift fuer Kristallographie, 216, 449, (2001)

Crystal treatment

❖ The crystal is grown under the specified conditions.
❖ The grown crystal is removed from the grower and annealed.
❖ The top and bottom parts of the grown crystal are cut off to obtain the body for use as an actual detector.
❖ The crystal for the actual detector should be cylindrical; the coring process is performed using a milling machine due to the uneven surface.
❖ After all machining is complete, the crystal is polished on one side of the flat surface, leaving no scratches.

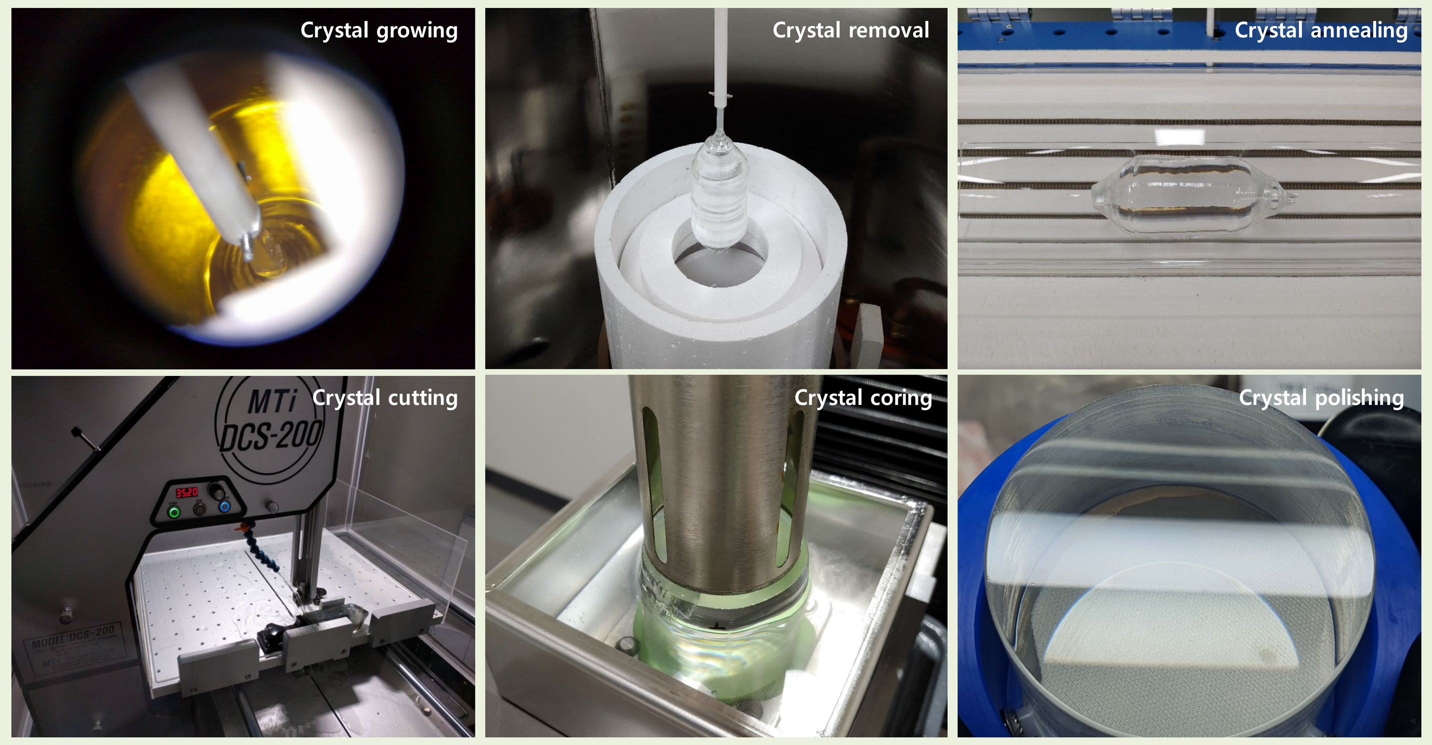


Fig. 3. The whole process from crystal growth to crystal polishing

ICP-MS results

- After confirming the purities of natural Li_2MoO_4 crystals via ICP-MS measurements, we have grown $Li_2{}^{100}MoO_4$ using enriched $^{100}MoO_3$ powder (^{100}Mo > 95%), which can serve as an actual crystal detector for the AMoRE experiment.
- The grown Li_2MoO_4 crystals at CUP have low impurity levels, as shown in Table 1; many elements are below the detection limit of ICP-MS at CUP.

Table 1. ICP-MS results of enriched $L^{100}MO$ & natural LMO

Unit : ppt

Crystal #	K	Sr	Ba	Pb	Th	U
Natural LMO	347,302	< 15	5,445	< 300	< 15	< 16
Purified LMO	39,000	< 50	6,300	< 100	< 8	< 8
Double-crystallized LMO	< 30,000	< 50	4,744	< 100	< 8	< 8
Enriched LMO-I	< 40,000	< 31	6,820	< 225	< 6	< 6
Enriched LMO-II	< 60,000	< 80	1,757	< 100	< 8	< 8