Kyropoulos Growth of a Large SrB_4O_7 Single Crystal

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There is a high demand and urgent necessity to consider new optical materials with high laser-induced damage threshold (LIDT), especially in the deep ultraviolet region (DUV, 200 to 300 nm). Strontium tetraborate (SrB_4O_7, SBO) which exhibits excellent DUV transmission and chemical stability has been considered as a candidate optical material in the DUV region. Previously, we have reported that surface LIDT of a SBO crystal is higher than those of a synthetic silica glass and a CaF_2 crystal [1]. Since the SBO crystals we have produced so far only span for less than 60 mm and weight less than 100 g [2], it is likewise necessary to grow larger crystals in order to produce large-diameter windows. In this study, we worked on the production of a large SBO crystal through the Kyropoulos method by using a large-capacity crucible and a new twin-type stirring blade [3].

SBO crystals were grown through the Kyropoulos method using a six-zone resistance heating furnace. $SrCO_3$ (4N) and B_2O_3 (3N) powders were used to synthesize the raw material with a B-rich self-flux composition (B_2O_3: 67.3%). A platinum crucible with a diameter of 150 mm and a height of 150 mm was then filled with 5.2 kg of the sintered raw material. The growth started at 1002 °C, and the crucible was only rotated at 15 rpm with the *c*-axis-oriented seed crystal being fixed during growth. The stirring blades were inclined with respect to the horizontal direction. When the crucible was rotated clockwise, the liquid flows down the wing at the outer periphery of the crucible and rises to the center of crucible. In order to promote the growth along the vertical direction, we adopted a clockwise rotation for the crucible which seems efficient to provide the raw material to the bottom of the crystal. A transparent SBO crystal with dimensions of 100 mm (*a*) × 30 mm (*b*) × 32 mm (*c*) and a weight of 328.2 g was successfully grown for a period of 25 days. This is the world's largest SBO crystal to date. The crystal exhibits an absorption edge down to 130 nm, high transparency in the DUV and VUV regions. The average growth rate along the *a*-axis is approximately 1.9 mm/day, whereas the average growth rate along the *b*-axis is 0.56 mm/day. In order to produce bulky-shape crystal, we then rotated the seed crystal at 5 rpm, while the crucible was rotated at 15 rpm in the same direction. Under a higher growth rate along the *a*-axis of 2.7 mm/day, a bulk crystal with dimensions of 63 mm (*a*) × 36 mm (*b*) × 39.5 mm (*c*) and a weight of 311.5 g was also grown for a period of 11 days. It suggests that large and bulky SBO crystals can be obtained by optimizing the stirring condition in the solution.

References

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