

# Crucible-free growth of bulk Sn-doped Ga<sub>2</sub>O<sub>3</sub> single crystals by pulling from a cold container technique

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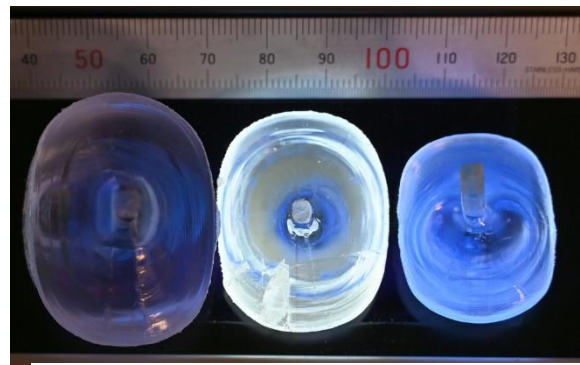
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In recent years,  $\beta$ -Ga<sub>2</sub>O<sub>3</sub> has attracted the attention of researchers as a wide-band-gap semiconductor material. Also, both non-activated and activated by some ions Ga<sub>2</sub>O<sub>3</sub> single crystals demonstrated interesting scintillation properties. The primary methods for growing such crystals are Czochralski (Cz), Bridgman and Edge-defined film-fed growth (EFG) techniques. Unfortunately, these methods require the use of expensive crucibles made of precious metals. Moreover, the gallium oxide melt in a non-oxidizing gas atmosphere is very aggressive to iridium, from which crucibles for the Czochralski and EFG methods are mainly made. Using crucible-free growth methods, relatively small Ga<sub>2</sub>O<sub>3</sub> crystals were grown only by the Floating zone (FZ) method.

Recently, our group used a crucible-free method to grow Gd<sub>3</sub>Al<sub>2</sub>Ga<sub>3</sub>O<sub>12</sub> and (La,Gd)<sub>2</sub>Si<sub>2</sub>O<sub>7</sub> crystals [1,2]. In the method used, the melt is held in a water-cooled copper basket and crystal growth is performed by pulling it upward using a seed, like in the Cz method. This combined method has no limitations on the size of the crystals grown or the growth atmosphere used.



*Ga<sub>2</sub>O<sub>3</sub> single crystals with different Sn<sup>2+</sup> concentration under 254 nm UV light*

In this work, we studied the possibility of growing large single crystals of  $\beta$ -Ga<sub>2</sub>O<sub>3</sub> activated by Sn<sup>2+</sup> ions using this crucible-free technique in an oxidizing atmosphere. Previously, such small crystals were grown using the FZ method and demonstrated interesting scintillation properties [3]. We have successfully grown high-quality Ga<sub>2</sub>O<sub>3</sub> crystals up to 40 mm in size with various Sn<sup>2+</sup> concentrations. The features of growing activated gallium oxide crystals using the developed combined method, along with their optical and scintillation properties, will be discussed.

1. A. Yoshikawa et al. "Bulk single crystal growth of Ce/Gd<sub>3</sub>(Al,Ga)<sub>5</sub>O<sub>12</sub> from melt without a precious metal crucible by pulling from a cold container", Cryst. Growth Des. 23, 2048-2054 (2020)
2. Y. Shoji et al. "Growth of (La,Gd)<sub>2</sub>Si<sub>2</sub>O<sub>7</sub> crystals by the Czochralski method and crucible-free pulling from cold container techniques for scintillator applications", J. Cryst. Growth, 649, 127950 (2025)
3. Y. Usui et al. "Scintillation and optical properties of Sn-doped Ga<sub>2</sub>O<sub>3</sub> single crystals", J. Phys. Chem.Solids,117, 36-41 (2018)