Materials

Growth of Bulk Single Crystals of Transparent Conductive Oxides

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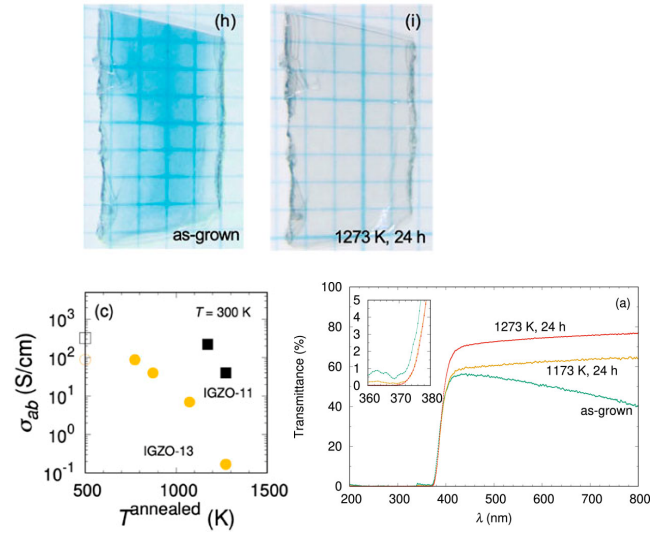
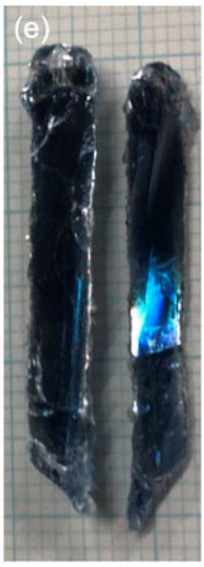
Purpose of Research

In this study, we have successfully achieved the growth of large bulk single crystals of the multicomponent solid solution $(InGaO_3)_m(ZnO)_n$ (IGZO-11), which has long been considered challenging due to its pronounced tendency toward compositional phase separation during crystallization, by employing a pressurized optical floating zone (OFZ) technique. Leveraging this methodology as a platform, we aim to systematically optimize the crystal growth parameters for IGZO-mn and its related oxides, elucidate their carrier transport mechanisms, and ultimately realize the development of transparent, high-performance, multifunctional oxide-based electronic devices.

Summary of Research

Utilizing the **pressurized** optical floating zone (OFZ) method, we have established a reliable approach for the bulk single-crystal growth of IGZO-mn. This advancement has enabled comprehensive physical property evaluations, including not only electrical and thermal transport measurements but also in-depth analyses of electronic structure and defect states. The high-quality bulk single crystals of IGZO-mn (m = 1–2, n = 1–4), along with related oxide crystals developed in this study, are expected to serve as essential platform materials for future investigations into multifunctional oxide electronics.





Comparison with Conventional or Competitive Technologies

・Significant improvements in crystal size and crystallinity.
・Enables the use of IGZO single-crystal substrates.

Expected Applications

・High-speed transparent electrodes
・High-performance display materials
・Novel electronic device materials

Challenges in Implementation

・Elucidation of conduction mechanisms
・Precise control of defect states
・Correlation between composition and physical properties
・Elemental substitution effects

Points

・ Enables fabrication of high-precision crystalline thin films
・Optical transparency can be finely tuned through thermal treatment
・Electrical conductivity can also be flexibly adjusted by annealing

What We Expect from Companies

We welcome collaboration with companies aiming to develop next-generation applications using bulk single crystals—enabling transparent, high-performance, and multifunctional oxide devices beyond the capabilities of a-IGZO.

Future Developments

2025: Establish Sn-substituted IGZO-mn single crystal growth; start device application research; study defect-transport relations.
2026: Develop IGZO-mn bulk single crystal device prototypes.
2027: Design and investigate In-free transparent conductors.

■ Related Programs：JSPS KAKENHI Grant Number JP21K04909
■ Awards：Selected as a *HOT Article* in *CrystEngComm* and as an *Editor's Pick* in *APL*.
■ Intellectual Property Rights：Japanese Patent Application No. 2017-084553
■Samples ：Available（single-crystal sample）

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