Patentix Inc. Succeeds in Synthesizing Bulk Rutile Germanium Dioxide Crystals

Patentix Inc. has successfully synthesized bulk crystals of rutile germanium dioxide (r-GeO2), a material gaining significant attention as a next-generation power semiconductor. This achievement is a crucial step towards realizing large-diameter, high-quality r-GeO2 bulk substrates, as these synthesized crystals can now be used as seed crystals in crystal growth methods like the Czochralski process.

Background: Power Semiconductors and the Drive for Decarbonization

Power semiconductors are vital components in modern electronics, from home appliances to electric vehicles, facilitating various power conversion circuits. The heat generated during these conversions represents an energy loss, and reducing this loss is a key challenge in achieving a decarbonized society.

Traditional silicon (bandgap 1.12 eV) is reaching its physical limits, leading to a shift towards power semiconductors made from materials with wider bandgaps, such as silicon carbide (SiC, 3.3 eV) and gallium nitride (GaN, 3.4 eV). While SiC offers about a 40% energy-saving effect compared to silicon, **r-GeO2, with an even wider bandgap of 4.68 eV, is expected to provide superior energy-saving benefits.**

Furthermore, r-GeO2 holds an advantage over gallium oxide (Ga2O3), another semiconductor with a similar bandgap, as **r-GeO2 is theoretically predicted to enable p-type doping through impurities, which is difficult with Ga2O3.** This opens up possibilities for a broader range of device applications. To maximize r-GeO2's performance, developing technology for homoepitaxial growth of high-quality r-GeO2 thin films on bulk crystal substrates with minimal defects is essential. However, synthesizing r-GeO2 bulk crystals using melt methods has been challenging, leading to very few reported successes previously [1].

Achievement: Successful Synthesis and Characterization

Patentix Inc. has now successfully synthesized an **r-GeO2 bulk crystal approximately 15 mm in size** (Figure 1).

Figure 1: Photograph of an r-GeO2 bulk crystal

After pulverizing the crystal, X-ray diffraction analysis confirmed that **most peaks were attributed to r-GeO2**. Furthermore, X-ray diffraction analysis of the crystal's facets revealed the primary **facet to be the (110) plane** (Figure 2).

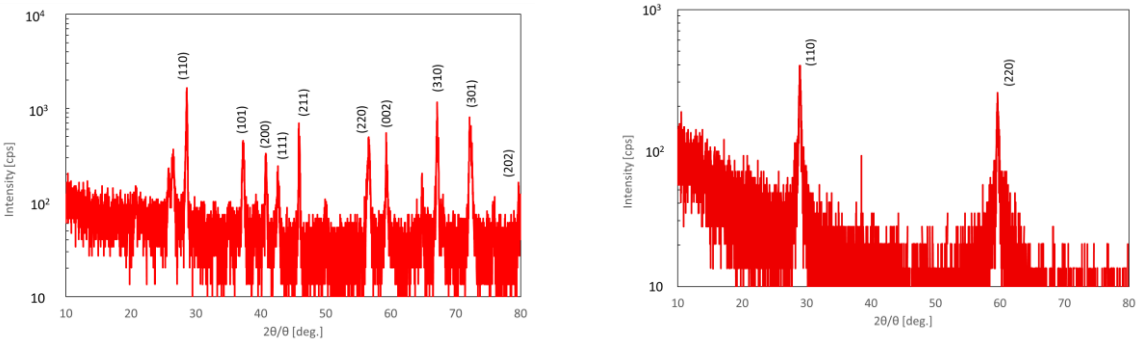

Figure 2: X-ray diffraction profiles of the powdered sample (left)

and the crystal's facet plane

The Vickers hardness of the r-GeO2 bulk crystal's (110) plane was measured at **approximately 1610 HV**. This value indicates that r-GeO2 is harder than Si (1150 HV) but softer than SiC (2500-3000 HV) and GaN (1800-2000 HV) (Figure 3). This suggests that **r-GeO2 is a relatively easy-to-process material.**

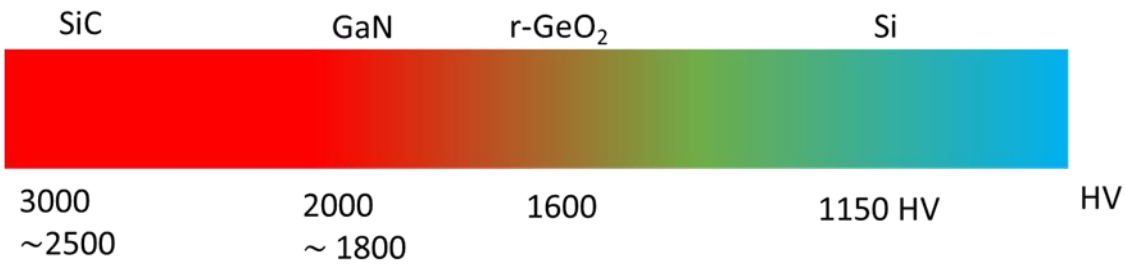

Figure 3: Vickers Hardness of Various Semiconductor Materials

This successful synthesis of r-GeO2 bulk crystals marks a significant step in Patentix Inc.'s goal of contributing to a decarbonized society through this new semiconductor material. The company also plans to present other fundamental physical properties at the 86th Autumn Meeting of the Japan Society of Applied Physics [2].

Future Outlook

Building on this success, Patentix Inc. will accelerate the development of r-GeO2 bulk crystals. While mechanical properties such as Young's modulus, linear expansion coefficient, and Poisson's ratio have primarily been reported for the amorphous phase, the company plans to measure these values for the rutile crystal structure **for use in** stress calculations.

The company will continue its development efforts, aiming to **increase the diameter and improve the quality of the newly synthesized r-GeO2 bulk crystals** by using them as seed crystals, with the ultimate goal of bringing them to market.

This research was supported by a subsidy from the Project for Promoting Policies for Small and Medium Enterprises (the Research and Development Support Project for Growth-Oriented Small and Medium Enterprises). The research and development project name is "Development of Bulk Crystals for the World's First Next-Generation Semiconductor Germanium Dioxide for Practical Use."

References: [1] Z. Galazka, et al., "Bulk Single Crystals and Physical Properties of Rutile GeO2 for High‐Power Electronics and Deep‐Ultraviolet Optoelectronics", *physica status solidi (b)* 2400326 (2024). [2] K. Kawanishi et al., "Evaluation of Physical Properties of r-GeO2 Bulk Crystals", 86th Autumn Meeting of the Japan Society of Applied Physics (2025) (submitted).