Press Release

January 18, 2023

FLOSFIA has solved a long-standing challenge on Gallium Oxide " P-type semiconductor"

World's first-ever achievement of verifying Junction barrier effect by integrating Ultra-Wide bandgap P-type semiconductor "Iridium Gallium Oxide" into the Gallium Oxide Power Device.

~Significant milestone to realize the ultimate SEMI-ecology™ which enables a new-sustainable future~

【Key Points of this Research and Development】

FLOSFIA Inc., headquartered in Kyoto, Kyoto prefecture, Japan, is a spin-off from the research of Kyoto University. FLOSFIA commits to contributing to realizing a new sustainable future through comprehensive ecological activities under "SEMI ecology™" (1) initiative, which has three pillars, "Low Energy Loss" to reduce energy loss, "Low Process Loss" to reduce the loss in the manufacturing process, and "Low Material Loss" to reduce the loss of finite Global resources. FLOSFIA has been working on deploying a cutting-edge power semiconductor (2) using corundum Gallium Oxide(α-Ga_2O_3) (3) into the market as its business activity.

In order to realize the "SEMI ecology™" initiative by unlocking the material potential of Gallium Oxide, FLOSFIA believes it is vital to have a high-quality P-type semiconductor to be used in combination with Gallium Oxide.

Figure1. Comparison between Gallium Oxide-Alone Power Device vs Combination of P-type and Gallium Oxide Power device.

	Power Device by Gallium-Oxide Alone	Power Device by Combination of P-type and Gallium Oxide
The perspective of material potential	**Unable** to unlock the material potential.	**Able** to unlock the material potential.
Key feature of Power Device	・Low current density, unable to operate high current by small Chip. ・Difficult to achieve low-cost Power Device.	・High current density, able to operate high current by small Chip. ・Promising solution to achieve low-cost Power Device.

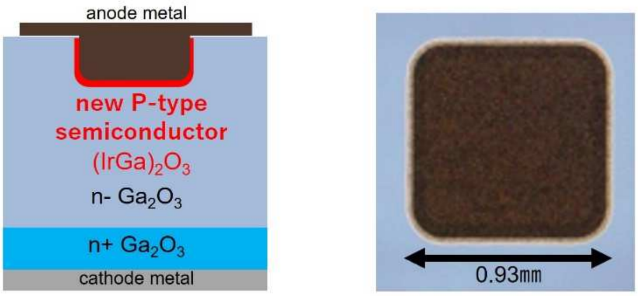
FLOSFIA has been working on device-level demonstration using P-type semiconductor since FLOSFIA successfully developed a new P-type semiconductor, "Iridium Oxide (α-Ir_2O_3)" which has an equivalent crystal structure with Gallium Oxide in collaboration with Kyoto University in 2016. This time, FLOSFIA successfully demonstrated leakage current suppression by the junction barrier effect (Figure 2 and 3). FLOSFIA has applied the JBS structure (4), which is used in State-of-the-art Silicon Carbide (SiC) Diode, and successfully grown the Iridium Gallium Oxide [α-$(IrGa)_2O_3$] (5) thin layer as an embedded P-type semiconductor.

Indium Gallium Oxide used in this achievement is Ultra-wide bandgap semiconductor (6) material with an extremely large bandgap of approximately 5eV and a high hole concentration $1\times10^{19}cm^{-3}$. This material property indicates that Iridium Gallium Oxide would be applicable to a wide range of power device designs with a high electric field. Furthermore, by combining Gallium Oxide Power Device and this promising Gallium Iridium Oxide P-type, Gallium Oxide Power Device can maximize its device performance at various products portfolio such as SBD, MOSFET, IGBT, and achieve High current density on a small chip. Furthermore, FLOSFIA expects to reduce the device cost through this R&D achievement, which is a significant milestone to realize the ultimate SEMI-ecology™, which enables a new-sustainable future.

【Achievement of this Research and Development】

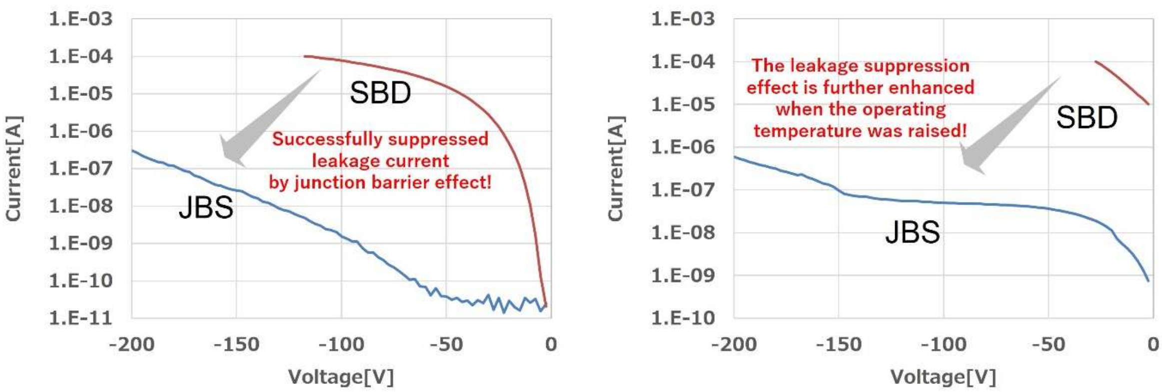
First, FLOSFIA fabricated a trench structure in a part of Gallium Oxide n- layer, and grew crystal by embedding new P-type semiconductor (Figure 2). FLOSFIA's unique core technology MIST DRY™ (7) is applied for crystal growth, and chip size is approximately 0.9mm, and Line-and-Space of trench structure is 1µm each.
Then, FLOSFIA applied reverse current to the fabricated JBS structure Chip and verified the leak current suppression effect by the embedded Iridium Gallium Oxide. （For comparison, FLOSFIA fabricated normal structure SBD on the same wafer）. Furthermore, FLOSFIA confirmed that the leakage suppression effect is further enhanced when the operating temperature was raised from 25℃ to 125℃.

Figure2 Applying Iridium Gallium Oxide to JBS Structure



（a） Cross-sectional view of JBS structure （b） Micrograph from the top

Figure3 Reverse current characteristics



（a） Electric characteristics at 25° C （b） Electric characteristics at 125° C

【Next step and future prospects】

The JBS structure, achievement of this research and development, is subject to apply to the 2nd Generation Diode product among FLOSFIA Corundum Gallium Oxide (α-Ga2O3) Power Device, GaO™ Power Device. Lowering Vf (Forward voltage drop) by reducing rising voltage will enable FLOSFIA to expand 2nd generation of GaO™ Power Device SBD from the high-frequency operation application to a wide range of the application, including Inverter used under 100kHz as well as the wide range of Power supply.

Subsequently, we aim to apply new P-type Semiconductor, "Iridium Gallium Oxide" to transistors such as MOSFET and IGBT. Examples of power conversion equipment are Power Supply (such as AC Adaptor), Operating circuits of Robotics, Electric Vehicle, White goods (such as Air conditioners and refrigerators), and power conditioners for Solar Cells. The adoption of GaO™ power device aims to break through "The limits of power conversion equipment miniaturization and cost reduction" (8). For instance, the degree of power conversion equipment downsizing can be several tens of times greater, and the cost reduction effect is expected to be as much as 50% of the entire power conversion equipment, depending on the type of equipment and its operating conditions (FLOSFIA estimate).

【Acknowledgment】

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【Glossary】

※1「SEMI ecology™」

FLOSFIA commits to contribute to realizing a new sustainable future through comprehensive ecological Activities under "SEMI ecology™" initiative, which has the three pillars, "Low Energy Loss" to reduce energy loss, "Low Process Loss" to reduce the loss in the manufacturing process, and "Low Material Loss" to reduce the loss of finite Global resources, not only semiconductors but also in the peripheral circuit and end user's systems.

※2「Power Semiconductors」

A semiconductor used in power conversion, where it carries higher voltages and larger currents than general semiconductors. They are used as power devices such as transistors, diodes, and thyristors.

※3「Gallium Oxide（Ga_2O_3）」

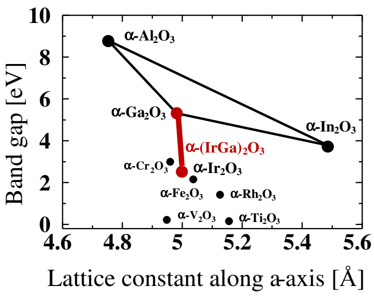
New material which is attracting large attention as a power semiconductor material. It has various crystal structures such as corundum structure (alpha structure), beta-gallia structure (beta structure) , and the others. Beta-gallia structure is a special crystal structure that only gallium oxide can form, while corundum structure is a crystal structure that exists at various material not only Gallium Oxide but also other Corundum family such as sapphire and indium oxide. The existence of various material belonging to this family has led to expectations for the growth of crystals in hetero stack and their use in devices.

※4「JBS Structure」

Junction barrier Schottky Diode structure. The depletion layer spreading from the embedded new P-type semiconductor layer mitigates the electric field strength at the Schottky interface to reduce leakage current.

※5「(α-$(IrGa)_2O_3$)」

Mixed crystal with a corundum structure consisting pf Gallium, Iridium, and Oxygen.



※6「Ultra-Wide Bandgap Semiconductor」

SiC and GaN, which have a band gap of about 3 eV, are called wide bandgap semiconductors, while gallium oxide, diamond, and AlN, which have even larger band gaps (generally 4 eV or higher), are called ultra-wide bandgap semiconductors.

※7「MIST DRY™」

FLOSFIA's unique core technology, which improved Mist CVD method developed by Prof. Shizuo Fujita and his research group at Kyoto University. FLOSFIA applies this MIST DRY™ to grow gallium oxide and to control its impurity concentration.

※8「The limits of power conversion equipment miniaturization and cost reduction」

Higher operating frequency is considered necessary to reduce the size and cost of power converters. When silicon (Si) is used, it is difficult to miniaturize power conversion equipment because the conversion loss increases when operating at high frequencies, requiring additional heat dissipation material. In addition, when silicon carbide (SiC) is used as a new semiconductor material, high-frequency operation is possible and power conversion equipment can be downsized, but the special crystal growth method and process technology are considered to limit the cost reduction.

【About FLOSFIA】

FLOSFIA

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