【Grant-in-Aid for Scientific Research (S)】
Science and Engineering (Engineering I)

Title of Project : Defect Engineering in SiC and Application to Robust Devices with Ultra-High Blocking Voltage

Tsunenobu Kimoto
(Kyoto University, Graduate School of Engineering, Professor)

Research Area : Engineering

Keyword : Electronic Material

【Purpose and Background of the Research】

In the large electric power conversion systems, about 10% of the converted power is dissipated as heat. This power loss mainly originates from the poor performance of high-voltage silicon (Si) thyristors and PiN diodes. Although Si is an ideal semiconductor for microelectronics applications, the performance of high-voltage Si power devices have faced severe limitations determined by the inherent physical properties of the material. In the typical power transmission line, for example, a high voltage of 6.6 kV has been employed. To regulate the high-voltage power flows, power switching devices as well as power diodes with a blocking voltage over 20 kV are required, but such high blocking voltage cannot be achieved with Si devices.

We have proposed a new wide bandgap semiconductor, silicon carbide (SiC). SiC possesses about ten times higher breakdown field and three times higher thermal conductivity than Si, and the wide-range doping control in both n- and p-types is easily attained by either epitaxial growth or ion implantation. The indirect band structure promises its potentially long lifetime of carriers, indicating the great potential of ultra high-voltage SiC bipolar devices such as PiN diodes, thyristors, and IGBTs. In this project, material science and device physics based on SiC are extensively studied.

【Research Methods】

The major subjects of this study include the elucidation of extended defects and point defects, the defect reduction, the identification of carrier lifetime killers and the lifetime control, the designing and fabrication of ultra high-voltage SiC devices, and characterization of the fabricated SiC devices under extreme conditions such as high voltage, high current density, and high temperature.

By utilizing very thick and high-purity SiC epitaxial crystals grown by an original chemical vapor deposition technique, both extended defects such as dislocations and stacking faults as well as point defects such as vacancies and impurities are systematically investigated. The identification of origins and the defect reduction are realized.

Through characterization of electrical and optical properties of defects, lifetimes of carrier recombination/generation are analyzed, and the lifetime control will be realized.

The original device structures, which are effective for achieving ultra high voltage (> 20 kV) are developed based on the simulation and experiments, and the guideline for high-voltage SiC devices is established.

The fabricated devices are tested under extreme conditions such as high voltage, high current density, and high temperature. The measurement system will be also constructed with unique ideas. The mechanism of breakdown, the dynamic characteristics, and the reliability of ultra high-voltage robust SiC devices are addressed, and the potential of SiC will be demonstrated.

【Expected Research Achievements and Scientific Significance】

Through the fundamental study on extended and point defects in SiC and their engineering, the defect electronics in wide bandgap semiconductors will be established. The designing, fabrication and characterization of ultra high-voltage SiC devices will contribute to the robust electronics.

The present study will also make great contribution to the efficient and highly functional electric power transmission systems such as HVDC, FACTS, and Intelligent Power Networks in the future, with significant energy saving.

【Publications Relevant to the Project】

- T. Hori, K. Danno and T. Kimoto: J. Crystal Growth. **306**, 297-302 (2007).
- T. Hiyoshi, T. Hori, J. Suda, and T. Kimoto: IEEE Transaction on Electron Devices. **55**, 1841-1846 (2008).

【Term of Project】 FY2009-2013

【Budget Allocation】 156,500 Thousand Yen

【 Homepage Address and Other Contact Information】
http://semicon.kuee.kyoto-u.ac.jp/
kimoto@kuee.kyoto-u.ac.jp