Contribution ID: **149**

Type: **Poster**

#5-149 Evaluation of high temperature tolerance of BGaN detectors for in-core nuclear instrumentation systems for high temperature gas-cooled reactors

Tuesday, June 10, 2025 4:35 PM (5 minutes)

The High Temperature Gas-cooled Reactors (HTGRs), which have been developed as a next-generation nuclear reactor, have an in-core temperature of about 900 oC. The ultra-high temperatures make it difficult to use conventional nuclear instrumentation systems, and novel neutron detectors with high temperature tolerance are expected to be realized. Neutron detection using BGaN semiconductor is a novel neutron detection system expected to allow the development of neutron-imaging sensors. BGaN is a mixed alloy semiconductor of BN and GaN and is a group-III nitride semiconductor, which is a kind of wide bandgap semiconductor. Wide-bandgap semiconductor detectors using SiC and diamond have been developed as radiation detectors for operation in high-temperature conditions. However, the high temperature tolerance of BGaN has not been evaluated, and the investigation of its radiation detection characteristics at high temperatures is require. In this report, the characteristics of the BGaN detector at high temperature conditions were evaluated as a verification of the in-core nuclear instrumentation system for HTGR.
The BGaN films were grown on an α-Al2O3 substrate using metal-organic vapor phase epitaxy (MOVPE). After growing pin BGaN structure, pin-type BGaN diodes were fabricated by using each device process. The electrical and radiation detection characteristics of the pin-type BGaN and GaN detectors were evaluated. For electrical characteristics, CV measurement, and IV measurement were performed from room temperature to 600 oC. 241Am α-particle source was used for radiation detection and measurement. The distance between the α-particle source and the detector was set for the incident energy to be 2.3 MeV. The α-particles energy spectra were measured from room temperature to 450 oC.
Group-III nitride semiconductor detectors were used to measure the energy spectrum of 241Am α-particles at each temperature. In case of a pin-BGaN diode detector, the α-particles spectrum was detected at 300 oC, but it was difficult to discriminate the detection signal from the noise signal at 350 oC. In case of a pin-GaN detector, the α-particles spectra were detected under 450 oC, which is the measurement limit for this experimental setup. Furthermore, X-ray diffraction crystallinity evaluation has confirmed that BGaN crystals are less crystalline than GaN crystals. These results indicated that crystal defects in BGaN are one cause of the device's performance temperature being reduced. It is indicated that the pin-GaN detector is operated at even higher temperatures.
The temperature dependence of the peak position for each detector was evaluated. In the case of a BGaN detector, the peak position was confirmed to be constant at over 100 oC. In the case of a GaN detector, a low channel shift at the peak position was confirmed over 100 oC. These results indicate that the depletion layer thickness, the sensitive layer, decreased with rising temperature. It was confirmed that reducing the thick sensitive layer has a more significant effect on high-temperature tolerance.
Furthermore, the temperature dependence of the leakage current of each detector was evaluated. The leakage current of the BGaN detector was confirmed to be larger than that of the GaN detector. The increase in leakage current is due to crystal defects. The significant degradation of breakdown voltage at high temperatures with large initial leakage currents suggests that crystal quality affects high-temperature tolerance.
In this study, the high-temperature tolerance of BGaN detectors was evaluated as an in-core nuclear instrumentation system for HTGR. The results of the initial study indicate that a BGaN detector, which is a group-III nitride semiconductor, has the potential to detect neutrons at high temperatures. Further development of the BGaN detector is expected to lead to nuclear instrumentation technology that can be used for HTGR.

Primary author: NAKANO, Takayuki (Shizuoka University)

Co-authors: Mr HAYASHI, Kohei (Shizuoka University); Mr SAKURAI, Tatsuhiro (Shizuoka University); Prof. INOUE, Yoku (Shizuoka University); Prof. AOKI, Toru (Shizuoka University)

Presenter: NAKANO, Takayuki (Shizuoka University)

Session Classification: #05 - Nuclear Power Reactors and Nuclear Fuel Cycle

Track Classification: 05 Nuclear Power Reactors and Nuclear Fuel Cycle