Single-event damages on SiC junction barrier Schottky diodes

M. Iwata,[*1] M. Takahashi,[*1] and H. Shindou[*1]

Silicon carbide (SiC) power devices are being applied to various fields because of their excellent properties such as high breakdown voltage and high frequency. Although Si power devices have been used for space applications, there is an urgent demand for SiC power devices for realizing future advanced missions. The mechanisms of single-event effects (SEEs) on SiC devices caused by heavy ions are yet to be well understood, and there is no product that is sufficiently resistant against space radiation. In this study, irradiation test results for SiC diodes that use a junction barrier Schottky (JBS) structure, as shown in Fig. 1 are reported. This structure is widely used in commercial products because of its lower off-state leakage current.[1)]

In this study, the charge collection characteristics of the 1200 V commercial SiC JBS diodes were measured by the EPICS system[2)] during irradiation. This system enabled measurements of higher signal levels of ∼50 nC, which is sufficient for detecting the sign of the single-event burnout (SEB). Irradiation tests were performed by bombarding ^{136}Xe ions (544 MeV) perpendicularly at the test device surface at room temperature in air using RIKEN RILAC2 in combination with the RIKEN Ring Cyclotron (RRC). The range of ions was calculated as 30.0 μm in SiC by the SRIM code;[3)] this range is sufficient to reach the active layer of the samples.

Figure 2 shows the collected charge spectra at different reverse voltages, V_R. The cross marks represent the maximum collected charge for each spectrum. The total counts of the spectra at $V_R = 240$ V increased significantly, especially at lower charges, and therefore, it did not show the accurate number of the ion-induced charge. This result indicates that a permanent leakage path was created at this voltage. The maximum collected charge did not reach the order of nanocoulombs, which is observed as the sign of the SEB in Si power metal-oxide-semiconductor field-effect transistors (MOSFETs). This is attributed to the higher electron-hole pair creation energy of SiC compared to that of Si and the lack of a charge amplification mechanism like the parasitic bipolar transistor in MOSFETs in the JBS diodes. If a leakage path was created by local heating, a considerably large current would flow instantaneously in a tiny area. Transient current measurement is required to clarify the failure mechanism because charge collection measurements cannot check the time distribution of the collection process.

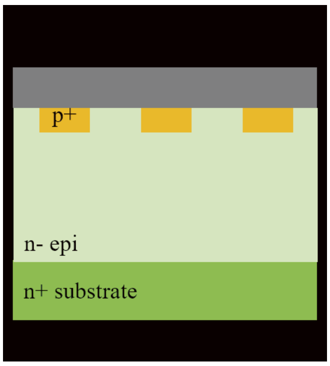

Fig. 1. Cross-sectional structure of JBS diodes.

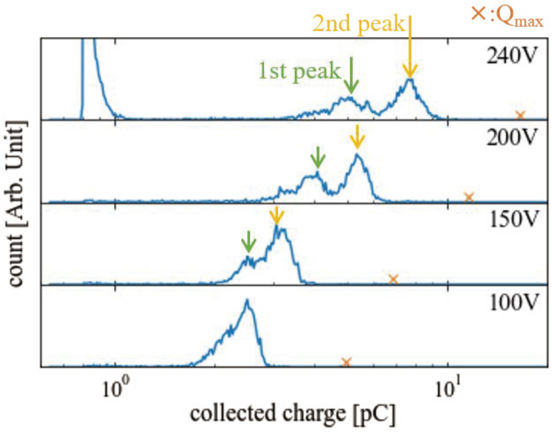

Fig. 2. Collected charge spectra taken by the EPICS system.

The peaks of the spectra shifted to the higher charge level, and the charge distribution was gradually divided into two with an increase in V_R. It is assumed that these two peaks appear based on whether the heavy ions pass through the Schottky interface or the p+ region because only one peak is observed in our previous experiment of the planar type SiC-SBD devices.[4)] The ratio of these peak levels indicate that the charge level of the first peak corresponds to the case wherein the incident ion passes through the p+ region, while the second peak level corresponds to the one wherein the incident ion passes through the Schottky region. Further, it is assumed that the charge generated by ions passing through the Schottky region is amplified further by impact ionization because the fluctuation in the positions of the second peaks are larger than those of the first peaks. Therefore, it might be possible to increase the voltage at which the leakage path is formed by adjusting the size, pitch, and doping concentration of the p+ region such that the electric field applied to the Schottky region is relaxed.

*1 Research and Development Directorate, Japan Aerospace Exploration Agency

References

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