Investigation of single event effects observed in SiC-SBDs

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Wide bandgap semiconductor devices such as GaN and SiC are attractive for next-generation satellites to reduce the energy losses in high-power and high-frequency systems. Although Si remains the dominant material used in space systems, there is now a strong demand for new and more efficient devices. However, there are few reports about power-handling applications. For such use in satellite power applications, the mechanisms of single event effects (SEEs) must be resolved at first with some appropriate steps.

In this study, we report the results of evaluating SEEs on SiC-Schottky barrier diodes (SiC-SBDs) for power-handling applications. The ion species we used in the experiment was ^{86}Kr, 1242 MeV. The ion range was 113 μm; LET was 27 MeV/(mg/cm^2) at the device surface. Figure 1 shows the device structure. The SiC-SBD in this study was a type of commercial off-the-shelf (COTS) 1200 V device.

It is known that the failure modes of SiC-SBDs are separated into three regions as shown in Fig. 2.[1)] Region 1 is the non-destructive region where the collected charge is reproducibly measured with no damage. Region 2 is where there is a permanent increase in leakage current and thus, we define "Region 2" as the permanent damage region. Region 3 is defined as the catastrophic failure region where an SEE occurs. However, the cause of the transition from Region 1 to Region 2, and then to Region 3 has yet to be clarified. We therefore focus on the area of transition and discuss Region 1 and 2, particularly in terms of experiments and simulation.

Figure 3 (left) shows the transition of the leakage current (Ir) at reverse bias condition after irradiation. In Fig. 3 (left), Ir was shown not to increase up to 220 V but increased above 240 V. We assume that the threshold between 220 V and 240 V is the area of transition from Region 1 to Region 2. Figure 3 (right) shows the Ir values at 220 V and 240 V during irradiation. Ir was shown not to increase with Kr fluence at 220 V but does increase at 240 V.

Figure 4 shows the TCAD (technology computer-aided design) simulation results of one particle traversing in SiC-SBD by ECORCE.2) The parameters of SiC-SBDs that we used were obtained by measuring the electrical characteristics. A calculated point in Fig. 4 was an incident point of particles, directly below the electrode. In Fig. 4, at first, a particle traverses in a device with electron-hole pairs being generated and thus, the electric field was enhanced further. Second, the total current (Itot) was increased. Finally, the increase in current causes the temperature of the calculated point to rise. Compared to $V_r = 220$ V, the temperature value at $V_r = 240$ V was remarkably high and above the melting point (3000 K) of the SiC crystal. Thus, the temperature exceeding the melting point is assumed to be one owing to device deterioration.

In these experiments, we evaluated the area of transition between the three regions. To assess the experimental data, we conducted TCAD simulation of single event effects. This simulation was available to observe the electron behavior inside SiC-SBDs when one particle makes an incident on a device. On comparing the before and after data, we found a significant difference regarding temperature at the incident point of particles. Although certain issues regarding the simulation parameters remain to be resolved, the ability to simulate the causes of SEE deterioration for power devices is necessary. To resolve these effects, additional experiments are required.

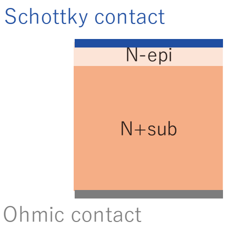

Fig. 1. Device structure.

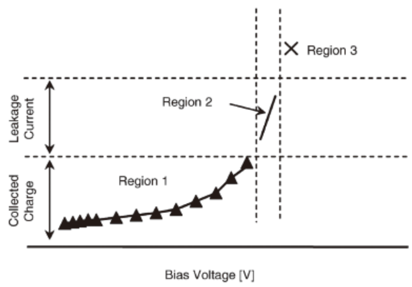

Fig. 2. Characteristic regions observed by heavy ion irradiations on SiC-SBDs.

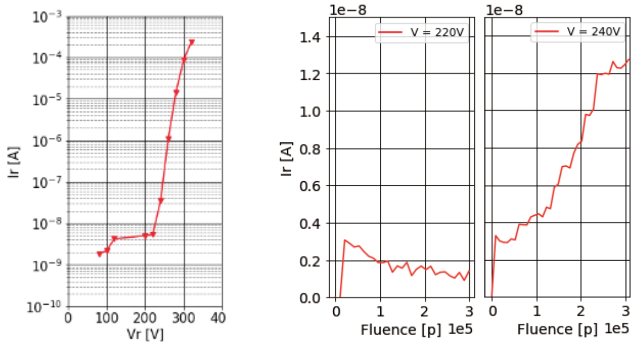

Fig. 3. Ir values at each voltage after irradiation (left) and increase of Ir during irradiation at 220 V and 240 V (right).

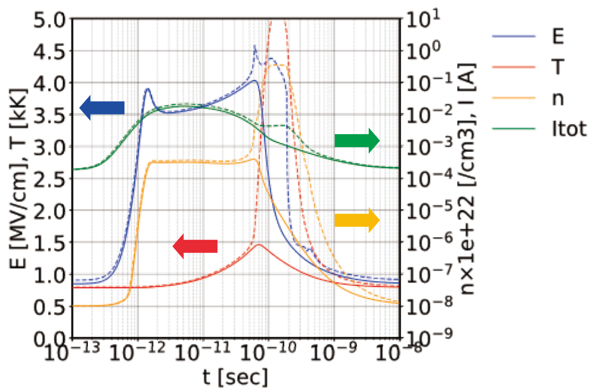

Fig. 4. TCAD simulation results of one particle traversing in SiC-SBD. ($V_r = 220$ V; solid line/$V_r = 240$ V; dashed line).

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References
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