Single-event effects in SiC planar and trench power MOSFETs

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Wide-bandgap semiconductors such as silicon carbide (SiC) have been attracting attention as materials for high-efficiency semiconductor devices. The adoption of SiC power modules has recently progressed in the field of railways and automobiles. In the aerospace industry, the use of SiC devices requires the effects of radiation to be clarified and these issues to be overcome. In this paper, we report the results of radiation tests for SiC power metal-oxide-semiconductor field-effect transistors (MOSFETs).

Two types of commercial n-channel SiC power MOSFETs were used in this experiment, as shown in Fig. 1. The maximum rating for the drain-source breakdown voltage of these devices is 1200 V. Test samples were irradiated with ^{136}Xe ions of 638 MeV perpendicularly at the device surface at room temperature in air using RIKEN RILAC2 in combination with the RIKEN Ring Cyclotron (RRC). During irradiation, the gate voltage, V_{GS}, was set to 0 V. The drain bias voltage, V_{DS}, was initialized at 100 V and increased in 20 V steps. The total fluence at each V_{DS} was 3.0×10^5 ions/cm^2.

Figure 2 shows the current transition of I_{DS} during irradiation up to V_{DS} = 160 V. The leakage current of the planar-type sample started to increase gradually at V_{DS} = 140 V, as shown in Fig. 2(a). This behavior is quite different from that usually observed during heavy-ion irradiation on Si power MOSFETs, where the leakage current abruptly increases by single-event burn-out. The tendency of gradual increase on the planar sample is analogous to the failure modes of SiC Schottky barrier diodes.[1)] On the other hand, the leakage current of the trench-type sample increased rapidly at the beginning of irradiation, as shown in Fig. 2(b). In Si trench MOSFETs, a degradation mechanism related to a micro-dose effect due to heavy-ion irradiation was reported,[2)] and we assume that the same effect is caused in the SiC

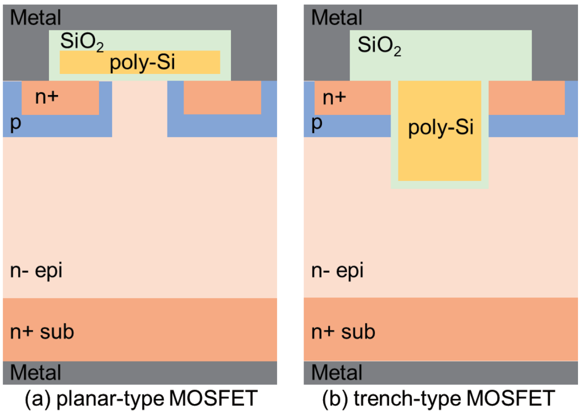

Fig. 1. Cross-sectional structure of the test devices.

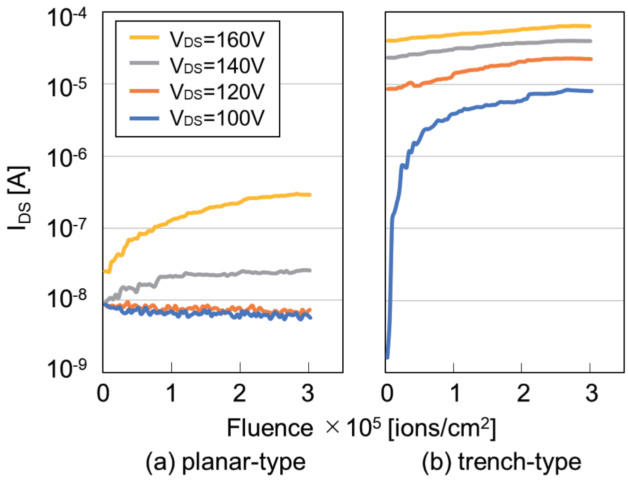

Fig. 2. Result of current monitoring during irradiation.

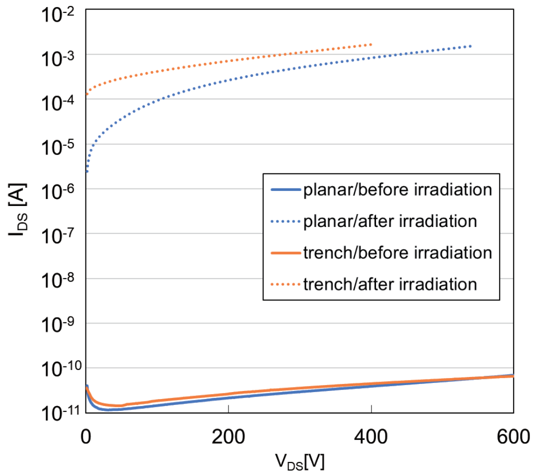

Fig. 3. Result of current monitoring before and after irradiation.

trench-type sample. The trench structure enables the irradiated ions to pass through the gate oxide along the entire length of the channel and generate electron-hole pairs. Trapped holes might exist in the gate oxide because the hole diffusion velocity is less than that of electrons, and they might introduce a large leakage current path immediately after the start of irradiation.

Figure 3 shows the I-V curves of the drain leakage current before and after irradiation. The degradation by irradiation seemed worse in the trench-type sample than in the planar sample.

Because the planar-type SiC MOSFETs did not show the microdose effect and its leakage current after irradiation was less than that of the trench-type sample, the planar gate structure can be considered suitable for use in space.

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References

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