Study on Proton Radiation Effect and Self repair Characteristics of SiC-JBS Devices

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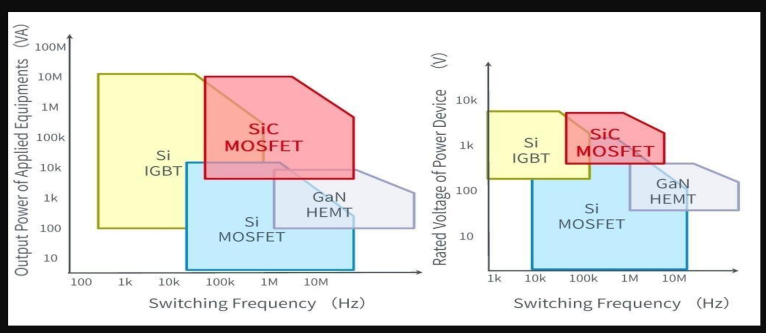
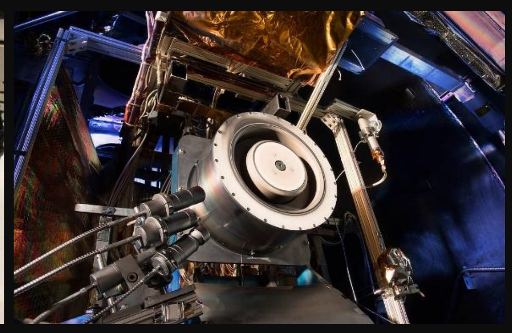
Introduction

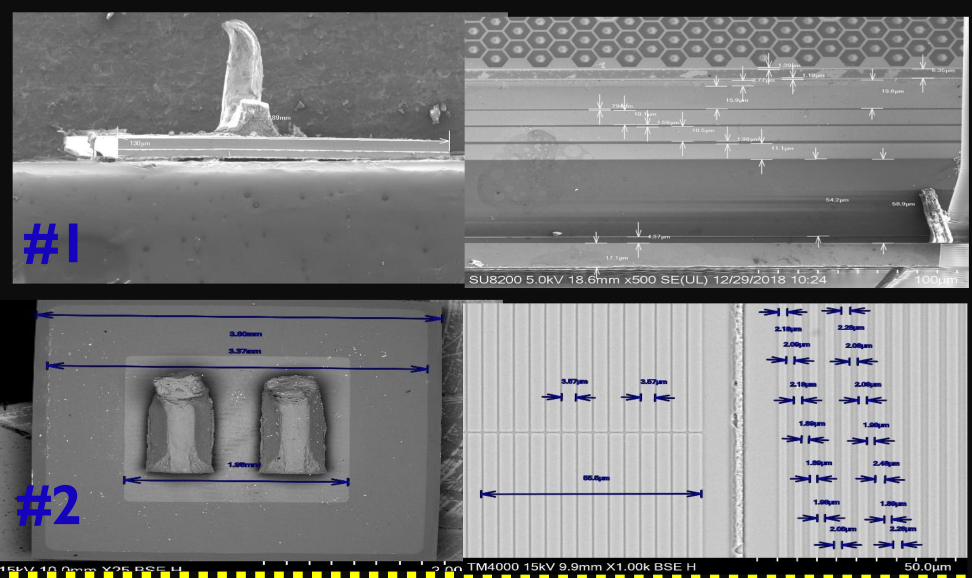
Silicon carbide barrier Schottky diode (SiC JBS) is a key component of the new generation spacecraft electric propulsion system, but the radiation effect of Intermediate energy protons seriously threatens its reliability and stability. In order to reveal the degradation mechanism of Displacement damage effect and reserve data for the design and assessment of radiation reinforcement, proton irradiation experiments were carried out with the help of ground simulated irradiation platform.

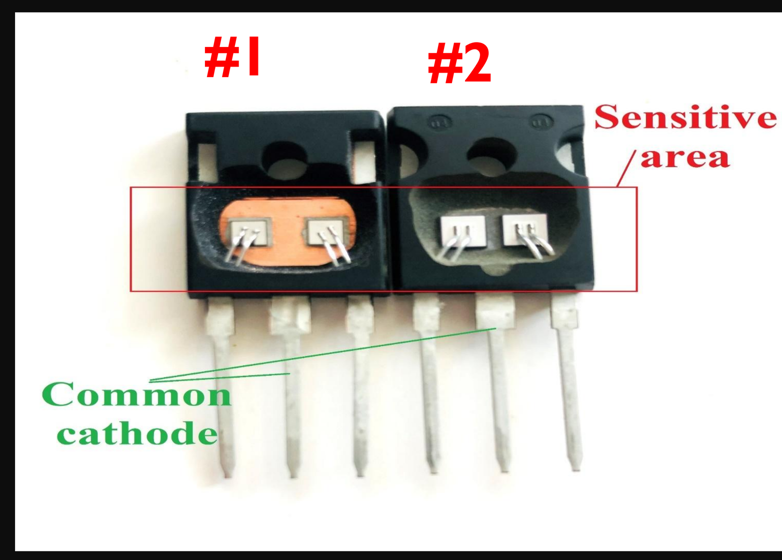




Examples

◆Two experimental samples. #1 is hexagonal cell, and # 2 is strip cell. The cap was opened and the BV exceeds 1200V before irradiation,





Experiments and Discussion

◆The I-V electrical properties of SiC JBS devices show the continuous change after 40 MeV proton irradiation and 336 hours annealing in total at room temperature. After irradiation, the device is difficult to conduct normally in the forward direction, and the forward current decreases; After 168 h annealing, the conduction characteristics and current have slightly recovered. After 336 h annealing, the positive characteristic was further restored. The reverse current changed slightly after irradiation, decreased at low test voltage after 168h annealing, and the current of # 2 decreased significantly after 336h annealing.

Table. 1 Experimental condition

Conditions	Units	value
Enery	MeV	40
Flux	$cm^{-2}\cdot s^{-1}$	1E8
Fluence	cm^{-2}	2.27E12
Bias	V	——
Annealing temperature	K	300
Annealing times	h	168
		336

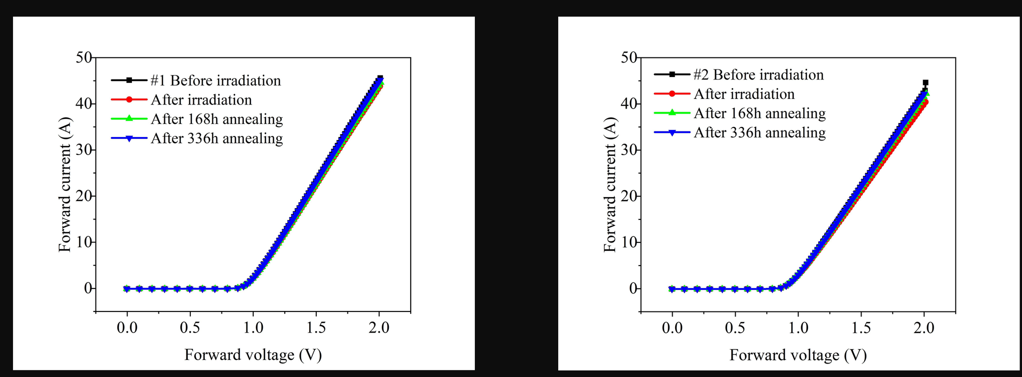


Fig. 1 Forward IV before and after processing

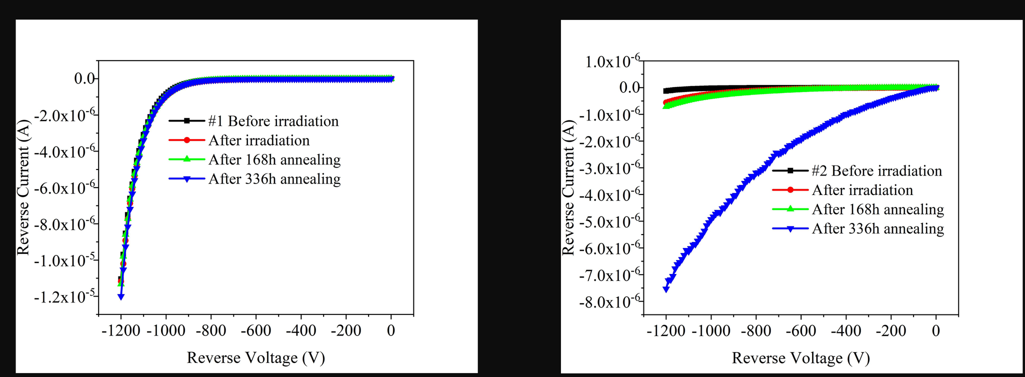


Fig. 2 Reverse IV before and after processing

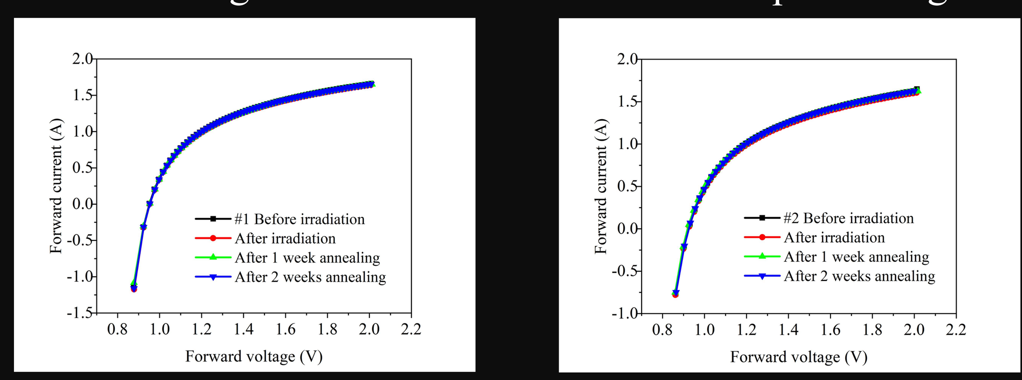


Fig. 3 Logarithmic curve of forward IV

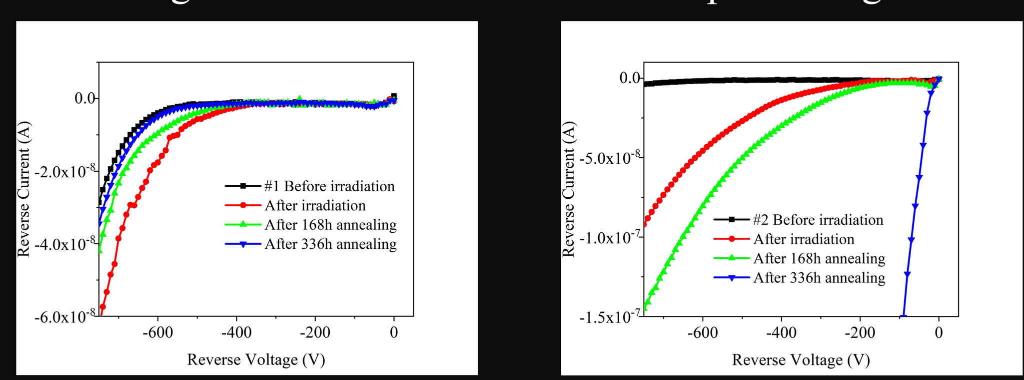


Fig. 4 Low bias part of reverse IV

◆The CV shows the rise of built-in potential and reduction of carrier concentration. And #2 has a higher degradation rate, , which proves that the stability of the device is weak.

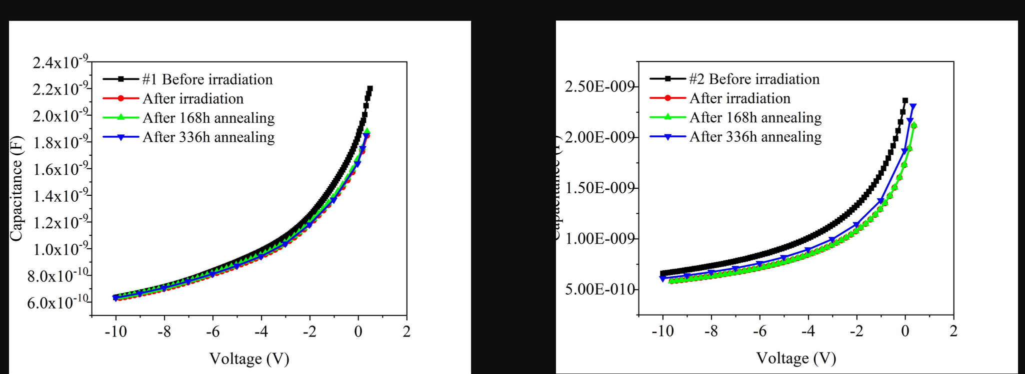


Fig. 5 CV before and after irradiation

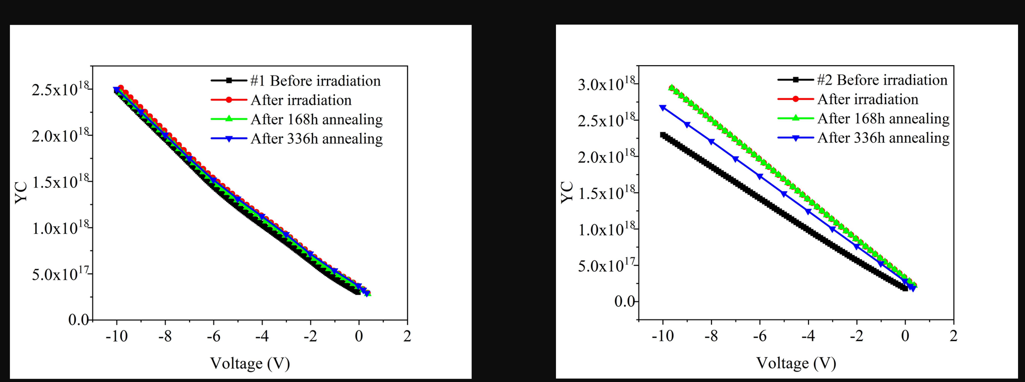


Fig. 6 $1/C^2$-V before and after irradiation

$$I_F = I_S\left(\exp\frac{qV}{nK_BT} - 1\right)$$

$$I_S = AA^*T^2\exp\left(-\frac{q\Phi_B}{K_BT}\right)$$

$$n = \frac{q}{K_BT}\times\frac{\partial V}{\partial \ln I}$$

$$\Phi_B = V_{bi} + \Phi_n =$$

$$V_{bi} + [\ln(\frac{N_C}{N_D}) + 1]\times\frac{K_BT}{q}$$

$$\frac{1}{C^2} = \frac{2}{\varepsilon_s qA^2N_{eff}}(V_{bi} + V)$$

◆The series resistance and ideal factor increase after irradiation based on calculation. From irradiation to 336h after annealing, the barrier height and carrier concentration of the device are gradually restored, but it is difficult to restore the original state. However, hot electron emission current is the main current before and after irradiation.

Table.2 Parameters of the SiC JBS devices

No.		I_S	R_S / mΩ	N_r	SBH / eV	N_{eff} / cm^{-3}
#1	Before irradiation	5.37E-13	851.22	1.03	1.15	1.62E17
	After irradiation	3.18E-13	890.15	1.53	1.31	0.98E16
	After annealing	4.25E-13	861.08	1.23	1.20	1.07E16
#2	Before irradiation	1.96E-11	365.04	1.03	1.13	2.33E16
	After irradiation	——	——	——	——	——
	After annealing	1.85E-11	421.02	1.11	1.22	2.01E16

Conclusions

- The IV and CV characteristics of the device will change after proton irradiation and continue to return to the pre-irradiation state with annealing at room temperature.
- Proton irradiation will introduce ionization defects and displacement defects into the SiC-JBS devices, in which the disappearance of displacement damage defects will eventually lead to the degradation of electrical properties of reverse IV and CV.
- the SiC-JBS device with hexagonal cells is more resistant to proton irradiation displacement damage and has stronger room temperature annealing self-recovery ability than the SiC-JBS device with stripe cells.
- the SiC-JBS device with hexagonal cells can be used preferentially in the radiation environment where there is a large amount of proton.

References

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