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Experimental Study on Energetic Particles Irradiation for BJT

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1. Introduction

When energetic particles are irradiated to semiconductor devices, the ionization and non-ionizing energy loss are caused [1][2]. Particles can lose their energy by ionization, which is a consequence of collisions between energetic particle and atomic electrons, leading to excitation or ionization. The non-ionizing energy loss that is the consequence of interactions with nuclei causes displacement damage. When semiconductors are irradiated by gamma rays, the effects of ionization are more common than the effects of non-ionizing energy loss [3]. On the other hand, when semiconductors are irradiated by fast neutrons, the effects of non-ionizing energy loss are more common than the effects of ionization [4]. This paper presents changes in current characteristics of BJT (Bipolar Junction Transistor) for gamma irradiation and fast neutron irradiation experiments.

2. Irradiation Effects of Energetic Particles for BJT

When gamma rays are irradiated to BJTs, the effects of ionization occurs predominantly [1][2]. Due to this ionization, a large accumulation zone is formed near the base-SiO_2 interface and a small depletion zone is formed in the emitter-SiO_2 interface region by the positive oxide trapped charges [3]. Thus, the base current increases due to recombination in the depletion zone of the emitter-base junction. And there are more electrons injected into the emitter from the surface, which leads to an increase of the base current.

When fast neutrons are irradiated to BJTs, the non-ionizing energy loss occurs predominantly [4]. The non-ionizing energy loss causes displacement damage in the bulk of BJT. In displacement damage, vacancies and interstitials are created in defects. These defects introduce deep level centers that serve as recombination sites and carrier traps within the lattice affecting the transport of carriers. The minority carrier lifetime decreases due to increases of recombination at defects in the base region of BJT. Therefore, the base current increases, and the collector and current amplification factor decrease due to displacement damage.

3. Experimental Results JT

In this section, the experimental results of characteristics changes of a pnp BJT for gamma irradiation and fast neutron irradiation. General purpose pnp Si BJTs were used for the gamma irradiation experiments. The pnp Si BJTs were irradiated by the gamma ray of 1500 Gy (600 Gy/h) and $5\text{x}10^{10}$ neutrons/sec with the package state.

Fig. 1 shows the base current (I_B) versus the base-emitter voltage (V_{BE}) of the BJT, measured before and after irradiation for gamma and fast neutron. It is shown that the base current increases in both cases with gamma irradiation and fast neutron irradiation.

Fig. 2 shows the collect current (I_C) versus the base-emitter voltage of the BJT, measured before and after irradiation for gamma and fast neutron. It is shown that the base current decreases in both cases with gamma irradiation and fast neutron irradiation.

Fig. 3 shows the base-to-collector current amplification ratio (β) versus the base-emitter voltage of the BJT, measured before and after irradiation for gamma and fast neutron. It is shown that the base-to-collector current amplification ratio decreases in both cases with gamma irradiation and fast neutron irradiation.

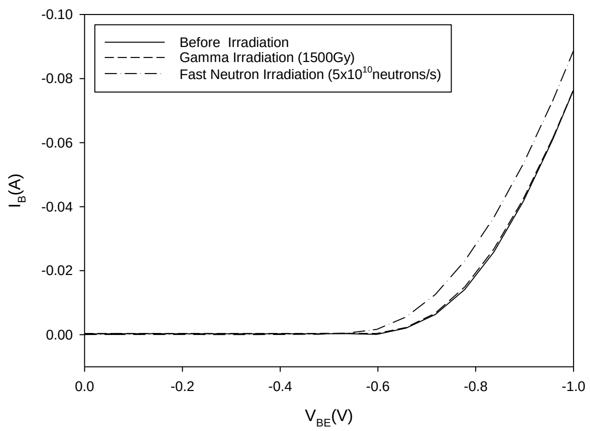

Fig. 1. Base current versus base-emitter voltage.

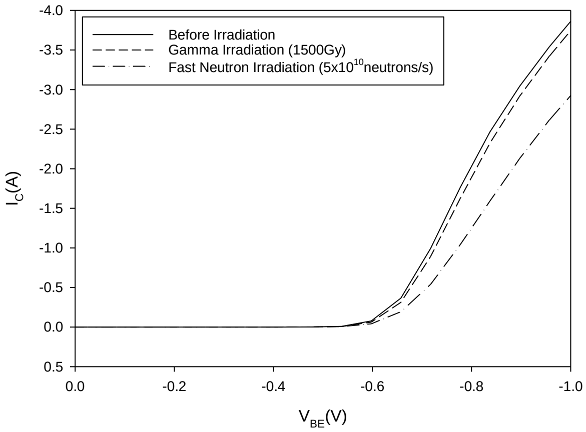

Fig. 2. Collect current versus base-emitter voltage.

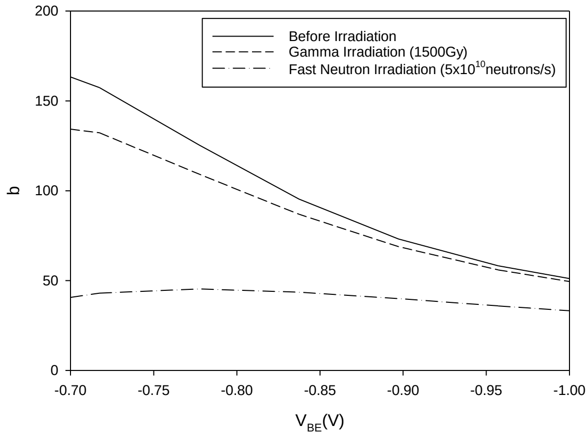

Fig. 3. Base-to-collector current amplification ratio versus base-emitter voltage.

4. Conclusions

When the energy particles such gamma and fast neutron are irradiated to semiconductor, the electrical properties of the semiconductor are changed. In this paper, the changes in the characteristics of a pnp Si BJT measured through irradiation experiments with energy particles such as gamma and fast neutron are presented. The experimental results showed that the base current was increased, and the collector current and base-to-collector current amplification ratio were decreased for both gamma and fast neutron irradiations.

ACKNOWLEDGEMENT

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REFERENCES

[1] A. H. Siedle, L. Adams, Handbook of radiation effects, 2nd Edition, Oxford University Press, 2007.
[2] B. J. Baliga, Fundamentals of Power Semiconductor Devices, Springer, New York, 2008.
[3] C. Pien, H. Amir, and S. Salleh, A. Muhammad, Effects of total ionizing dose on bipolar junction transistor, American Journal of Applied Sciences, Vol 7, No. 6, p. 807-810, 2010.
[4] S. H. Ahn, G. M. Sun, Effects of fast neutron irradiation on switching of silicon bipolar junction transistor, Journal of Radiation Protection and Research, Vol. 48, No. 3, p. 124-130, 2023.