FAST NEUTRON IRRADIATION EFFECTS ON SILICON BIPOLAR JUNCTION TRANSISTOR

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Fast neutron irradiation incurs the lattice damage owing to the displacement of silicon atoms. This lattice damage introduces a deep level in the silicon band gap, which acts as a recombination center. The electrical characteristics of the Si BJT are varied with an increase in the fast neutron irradiation fluence. The experimental results showed that the base current and collector-emitter saturation voltage were increased, and the collector current and base-to-collector current amplification ratio were decreased with increasing of the fast neutron fluence.

I. INTRODUCTION

BJT (Bipolar Junction Transistor) is a three-terminal device with an important feature in that the current through two terminals can be controlled by small changes we make in the current or voltage at the third terminal. This control feature allows us to amplify small AC signals or to switch the device from an on state and off state and back. These two operations, amplification and switching, are the basis of a host of electronic functions [1]. Fast neutron irradiation incurs lattice damage in bulk Si [2][3][4]. The recombination rate of minority carriers is increased by the lattice damage. This study will investigate the electrical characteristics of a pnp-Si BJT through the fast neutron irradiation experiments.

II. FAST NEUTRON EFFECTS ON SILICON BJT

II.A. Electrical Characteristics of BJT

In a pnp-BJT, the forward-biased emitter junction injects holes into the center n-region, and the reverse-biased collector junction collects the injected holes. The p-region, which serves as the source of injected holes is called the emitter, and the p-region into which the holes are swept by the reverse-biased junction is called the collector. The center p-region is called the base. To have a good current amplification characteristic, it is preferable that all holes injected by the emitter into the base be collected. If the saturation current at the collector region is neglected, the collector current (I_C), the base current (I_B), and the base-to collector current amplification ratio (β) is given by (1), (2), and (3) respectively.

$$I_C = BI_{Ep} \qquad (1)$$

$$I_B = I_{En} + (1-B)I_{Ep} \qquad (2)$$

$$\beta = \frac{I_C}{I_B} = \frac{BI_{Ep}}{I_{En}+(1-B)I_{Ep}} \qquad (3)$$

Where, I_{Ep} is the current by hole component injected from emitter junction, I_{En} is the current by electron component injected from the base to the emitter, *B* is the base transport factor. In accordance with the base current, the rates at which electrons are lost from the base by injection across the emitter junction and the rate of electron recombination with holes in the base region are considered. In each case, the lost electrons must be supplied through the base current. If the fraction of injected holes making it across the base without recombination is *B*, then it follows that (1-*B*) is the fraction recombining in the base region. If the base transit factor is small because *B* is less than unity, the base-to-collector current amplification ratio is small as well.

II.B. Experimental Results

General purpose pnp-Si BJTs were used for the fast neutron irradiation experiments. The MC-50 cyclotron in KIRAMS (Korea Institute of Radiological & Medical Sciences) was used for fast neutron irradiation. The fast neutrons were generated from Be target with 30MeV proton by the cyclotron. The experimental results showed that the base currents was increased and the collector current and base-to-collector current amplification ratio were decreased with increasing fast neutron fluence, as shown in Figure 1, 2, and 3. This result indicates that the displacement damage caused by fast neutron irradiation increases the recombination rate of injected holes with electrons in the base region. In addition, the electrons lost to recombination in the base region must be resupplied through the base contact. The recombination rate of injected holes from the emitter region is increased in the base region with an increase in fast neutron irradiation. And the holes reaching in the collector region are reduced because the injected holes from the emitter region are lost by a recombination in the base region. Thus, the base-to-collector current amplification ratio was decreased with increasing of fast neutron irradiation. The collector-emitter saturation voltage was increased with an increase in the fast neutron irradiation, as shown in Figure 4.

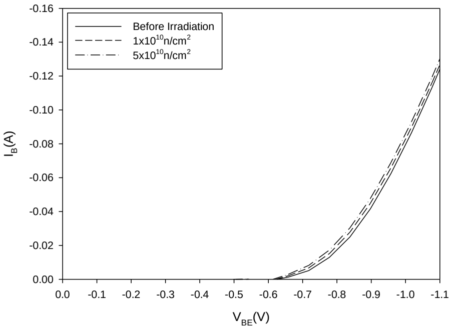

Fig. 1. Base currents.

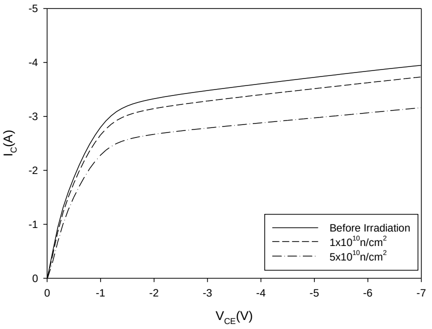

Fig. 2. Collector currents.

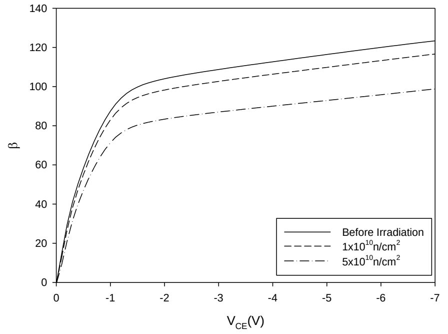

Fig. 3. Base-to-collector current amplification ratios.

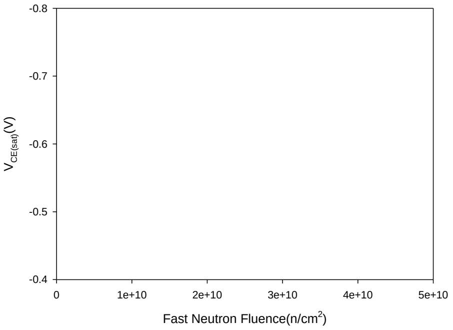

Fig. 4. Collector-emitter saturation voltage.

III. CONCLUSIONS

In this paper, the fast neutron irradiation effects were investigated for a pnp-Si BJT. The lattice damage caused by fast neutron irradiation increases the recombination rate of minority carriers and resistors. The experimental results show that the base current and collector-emitter saturation voltage were increased, and the collector current and base-to-collector current amplification ratio were decreased with increasing of the fast neutron fluence.

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