Reliability studies on NPN RF power transistors under swift heavy ion irradiation

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Silicon BJTs and MOS devices are extensively used in space and other radiation environments like large hadron colliders (LHCs). When semiconductor devices and circuits are operating in radiation environment, devices shows significant degradation in electrical characteristics and affect the performance of the electronic circuits. Literature survey reveals that the proton, electron and Co-60 gamma irradiation facilities are used to study the total dose effects on semiconductor devices, but the time required to reach high doses like 100 Mrad for LHC applications is very long (about a week). Therefore one can reduce the irradiation time to more practical value by using the high energy ion irradiation facilities to test the devices and time required to reach 100 Mard of total dose is only about tens of minutes (depends on LET). The effects of Co-60 gamma, proton and electron irradiation on semiconductor devices are well understood and it is important and interesting to study high energy ion irradiation effects on various semiconductor devices. In the present work NPN RF power transistors were irradiated with 50 MeV Li^{3+} ions, 100 MeV F^{8+} ions, 140 MeV Si^{10+} ions at 15UD 16MV Pelletron accelerator centre at IUAC, New Delhi, India in the dose range from 100 krad to 100 Mrad. The devices were exposed to Co-60 gamma radiation at Pondicherry University, Pondicherry, India in the same dose ranges to compare gamma irradiated results with the different ions. The transistor characteristics such as Gummel characteristics, excess base current ($\Delta I_B = I_{Bpost} - I_{Bpre}$), dc current gain ($h_{FE}$), transconductance ($g_m$) and collector-saturation current (I_{CSat}) are systematically studied before and after ion and gamma irradiation. The base current (I_B) was found to increase significantly after irradiation and this in turn decreases the h_{FE} of the transistors. When transistors are exposed to ionizing radiation, trapped charge accumulates in emitter-base (E-B) spacer oxide and increases the recombination current in E-B diode, therefore I_B increases. The g_m of the transistors was found to decrease significantly after irradiation. The output characteristics of the irradiated devices were also studied and observed that the collector current in the saturation region (I_{CSat}) decreased with increase in radiation dose. It was observed that the degradation in the DC electrical characteristics is almost same for different types of ion irradiated NPN RF power transistors with similar total doses although there is a large difference in the LET of the ions. Also it was observed more degradation in ΔI_B, h_{FE} and I_{CSat} for gamma irradiated devices up to 6 Mrad of total dose and after more degradation was found for ion irradiated transistors.

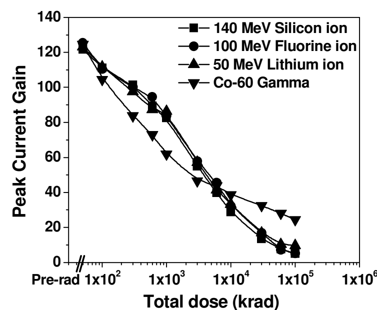

Figure. The peak current gain versus total dose for 50 MeV Li^{3+} ion, 100 MeV F^{8+} ion, 140 MeV Si^{10+} ion and Co-60 Gamma irradiated devices.

[1] N. Pushpa et al, Nucl. Instrum. Methods Phys. Res., Sect. A Vol 620 (2010) 450-455.