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Radiation Damage of SiGe HBT Technologies at Different Bias Configurations

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SiGe BiCMOS technologies are being proposed for the Front-end readout of the detectors in the middle region of the ATLAS-Upgrade. The radiation hardness of the SiGe bipolar transistors is being assessed for this application through irradiations with different particles. Biasing conditions during irradiation of bipolar transistors or circuits have an influence on the damage and there is a risk of erroneous results. We have performed several irradiation experiments of SiGe devices from IHP in different bias conditions. We have observed a systematic trend in gamma irradiations, showing a smaller damage in transistors irradiated biased compared to shorted or floating terminals. On the other hand, no differences have been observed in neutron irradiations.

Summary

The LHC at CERN is expected to start taking data during this year. In the meantime, a new project has started to try and extract more physics benefits after its expected life span of 10 years. The plan is to upgrade the accelerator in order to increase its luminosity in around one order of magnitude, it is called the Super-LHC. It has been shown that this will force the modification of the different experiments installed in the accelerator. In particular, the total inner detector of the ATLAS detector will have to be upgraded. Some of the microelectronics technologies proposed for the for the front-end readout of the detectors in the middle region of the upgraded inner detector are the SiGe BiCMOS technologies. These technologies should provide better performances in terms of power consumption, signal to noise, and processing speed, but they have to be evaluated in terms of radiation hardness.

In order to perform this evaluation, the devices should be submitted to different irradiation experiments, and then measure their performance after irradiation. These experiments are usually performed in complex irradiation facilities with difficult access to the irradiation area. This complicates the irradiation setup, in particular, biasing the devices during irradiation in order to mimic the real conditions is very difficult, and often impossible. This work studies the different result of radiation damage in the SiGe HBT transistors when submitted to irradiations with different particles in various bias configurations.

We have performed irradiations of SiGe HBT transistors with Co60 gamma particles, nuclear reactor neutrons, and 24 GeV beam protons in three different bias configurations: biased in forward active region (in similar conditions as they will be working in the real experiment); with all their terminals short-circuited; and with all their terminals floating. Differences in radiation damage have been observed for SiGe transistors submitted to gamma irradiations in biased configuration with respect to shorted and floating configurations. Biased transistors suffer less current gain degradations than shorted transistors, and these suffer less degradations than floating transistors. This tendency has not been observed in transistors submitted to neutron irradiations, where the radiation damage is the same for all bias configurations. Results proton irradiations will be also shown.

The variation of radiation damage in time after irradiation (annealing) has also been studied in order to discard differences in radiation degradation coming only from different degree of annealing of the damage due to their different biases during irradiation. Transistors have been measured right after irradiation, and then left some time for annealing in the same bias conditions, then re-measured. Less annealing has been observed for gamma irradiations in the biased transistors indicating that some of the damage differences observed actually come from different annealing levels, nevertheless some differences in damage remain after the full annealing process.

These results indicate that some differences can be observed in the damage of bipolar transistors submitted to ionizing radiation in different bias configurations. Comparison to previous result indicate that the quantitative value of these differences is very technologically dependent with respect to total dose, therefore these effects should be studied in detail before performing irradiation experiments of bipolar devices in bias conditions different of the real life ones, at the risk misleading results.

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