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Evaluation of Two SiGe HBT Technologies for the ATLAS sLHC Upgrade

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As previously reported, silicon-germanium (SiGe) heterojunction bipolar transistor (HBT) technologies promise several advantages over CMOS for the ATLAS upgrade [8]. Since our last paper, we have evaluated the relative merits of the latest generations of SiGe HBT BiCMOS technologies, the 8WL and 8HP platforms. These 130nm SiGe technologies show promise to operate at lower power than CMOS technologies and would provide a viable alternative for the Silicon Strip Detector and Liquid Argon Calorimeter upgrades, provided that the radiation tolerance studies at multiple gamma, neutron, and proton irradiation levels included in this investigation show them to be sufficiently radiation tolerant.

Summary

SiGe technologies are known for their high transconductance at low current. BiCMOS Silicon-germanium (SiGe) Heterojunction Bipolar Transistor (HBT) technologies are of interest for high luminosity applications in high energy physics because they have the benefit of requiring less power than standard CMOS technologies while still having low noise and fast shaping times even after exposure to high radiation levels [3]. Prototype readout circuits using SiGe HBT technologies are currently planned for submission later this year. The prototype circuits are designed for use in the upgrade of the Silicon Strip Detector and Liquid Argon Calorimeter of the ATLAS detector as part of the Large Hadron Collider upgrade (sLHC) [1][2]. In these applications, power consumption is a critical parameter, which must be minimized. These preliminary circuit designs have been used to guide the assessment of relevant device parameters. The design of a low noise amp (LNA) with SiGe 8WL and 8HP technologies will be briefly discussed.

The intent of this investigation is to assess the relative radiation hardness of the 8WL and the 8HP SiGe platforms. This is a follow up to a previous paper from this 2005 conference where only preliminary results were presented [8]. Previous SiGe generations have already been reported to be quite radiation tolerant up to a high dose, showing post-radiation current gains well above workable limits [4-6]. Compared to 8HP, 8WL is a lower cost option, with 100 GHz peak fT versus 200 GHz for 8HP, and has reduced depth deep trench isolation, a thinner, implanted subcollector, and a higher resistivity substrate. Both are available with a 130nm CMOS technology to provide high-speed BiCMOS ASIC solutions.

This radiation study envelopes the predicted target radiation levels that will be reached at 60 and 20 cm radii in the upgraded ATLAS detector. For the inner most silicon strip detector we predict a 25 Mrad total ionizing dose (TID) and a total 1-MeV neutron fluence of 1.0x1015 neutrons/cm2, while the radiation levels for the liquid argon calorimeter are expected to be lower by more than an order of magnitude.

We investigated both ionization damage and displacement damage in with the use of gamma, neutron, and proton irradiations [8]. By comparing the effects of the various radiation sources, the two principal mechanisms behind the radiation damage can be differentiated [7]. In looking at these different mechanisms of the radiation damage, this investigation presents a breakdown of the effects of bias on SiGe technologies during proton and gamma irradiation. Variations in the effectiveness of bias in SiGe technologies during irradiation are briefly presented. Additionally, the effects of hard neutrons vs. thermal neutrons in SiGe technologies by use of cadmium shielding are also presented. This has potential effects on the need for thermal neutron shielding when using SiGe technologies in the ATLAS upgrade.

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