Ion Beam Induced (IBIC) Studies of SiGe Heterojunction Bipolar Transistors (HBTs)

by **G. Vizkelethy, R. A. Reed[*], P. W. Marshall[+], and J. A. Pellish[*]**

Motivation—SiGe HBTs are potential candidates for parts used in space vehicles. The performance of these devices is comparable to III-V devices. At the same time these devices are compatible with today's standard Si technology. As a bonus they are inherently radiation hard concerning total dose effects. Unfortunately, SiGe HBTs were found to be susceptible to Single Event Effects (SEEs). Broad beam tests found the SEE cross section to be significantly larger than the active device area. IBIC is an ideal tool to determine the source of this high cross section.

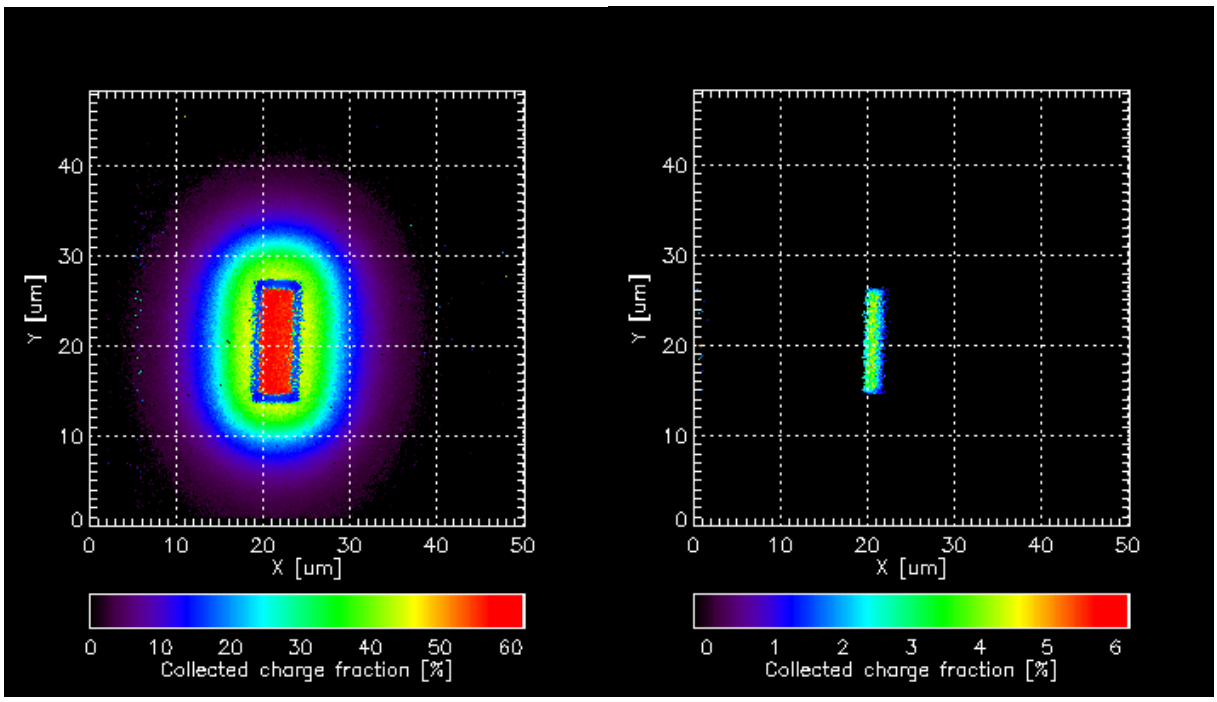
Accomplishment—At the Sandia nuclear microbeam facility we conducted a series of IBIC tests on SiGe HBTs from different vendors using a 36 MeV oxygen beam focused to 1 μm^2. The collector, the base, and the emitter were kept at 0 V while the substrate was set to 5 V to simulate the worst case scenario. The induced charge on all four electrodes was measured simultaneously with the *x* and *y* coordinates of the ion hit. Figures 1a and 1b show the 2D charge induction maps of the collector and the base electrodes. The charge induction map of the substrate electrode was very similar to that for the collector, while there was no detectable signal on the emitter. The collector map shows a very well defined high charge collection area, which coincides with the size and location of the deep trench isolation area. The base map shows a lower, but still well defined area, which is the shape and size of the p-type SiGe base. In addition, the collector map shows a much larger, lower charge induction area surrounding the active area in a shape of an ellipse. To interpret these images we need to apply the Gunn-theorem to the device structure shown in Fig. 2. According to the Gunn-theorem, in order to induce current in an electrode, the charge carriers have to move in a region where the electric field changes when the voltage changes on that electrode. Now it is obvious why we did not detect a signal from the emitter. A voltage change on the emitter does not change the electric field in the device apart from a tiny region under the emitter electrode. On the other hand, the change in the voltage on the base causes the field to change in the junction between the p-type SiGe base and n-type collector; changes in the collector or substrate voltage change the electric field in the full width of the device, especially at the n+p- junction at the bottom of the device. This explains the well-defined areas where the carriers drift through the fielded regions, while the charge induction from hits outside the deep trench is due to the carriers diffusing into the junction and then drifting through it.

Significance—These IBIC experiments on the SiGe HBTs prove the theory that charge induction from hits outside the deep trench isolation area is significant and can cause unexpectedly high SEE cross sections. This has led to the development of different mitigation techniques. One of them – creating a charge-blocking buried layer below the end of the trenches – promises significant reduction of the induced charge due to diffusion according to TCAD simulations. In addition, these experiments have helped calibrate and validate the TCAD codes used to simulate SiGe HBTs.

***Vanderbilt University; [+]NASA Goddard Space Flight Center**

Sponsor for various phases of this work include: Defense Threat Reduction Agency

Contact: Gyorgy Vizkelethy, Radiation-Solid Interactions, Dept. 1111
Phone: (505) 284-3120, Fax: (505) 844-7775, E-mail: gvizkel@sandial.gov



(a) (b)

Figure 1. 2D charge induction maps of the collector (a) and base (b) electrodes of SiGe HBTs.

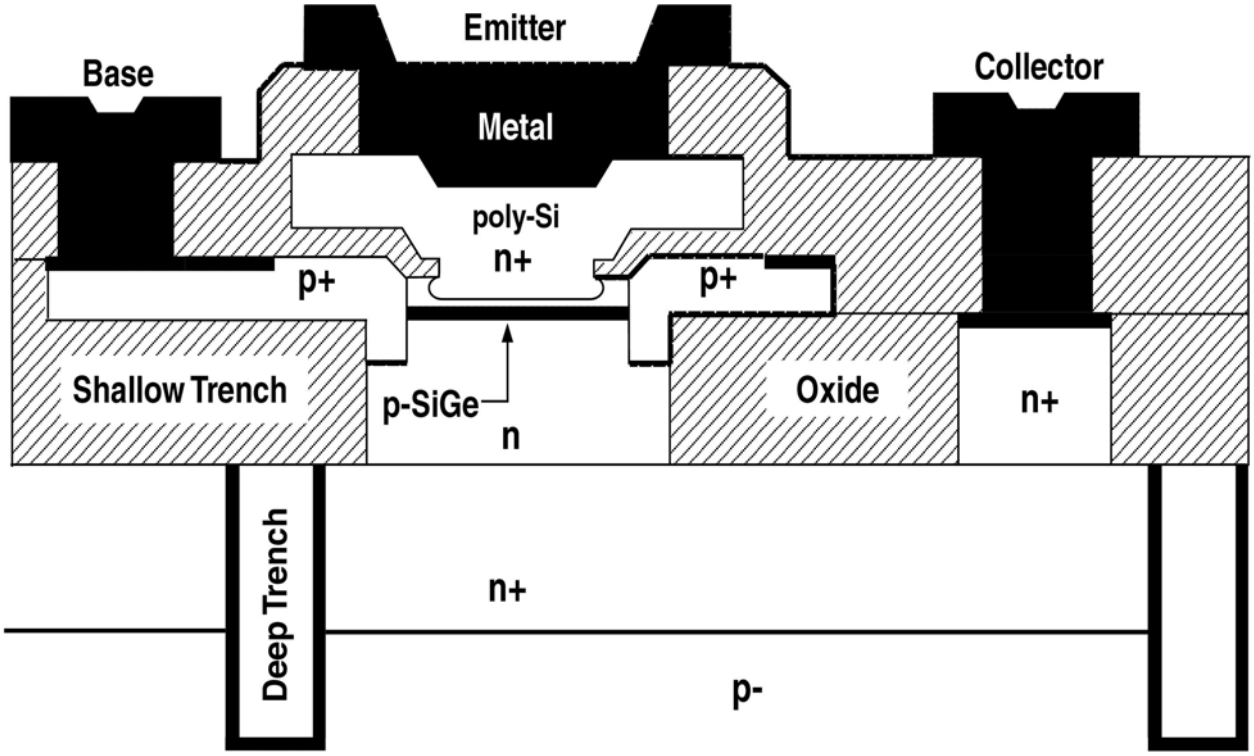


Figure 2. Cross section of a SiGe HBT (not to scale), J.D. Cressler and G. Niu, Silicon-Germanium Heterojunction Bipolar Transistors, Artech House, Boston, 2003.