“Radiation Effects in Silicon-Based Heterostructure Device Technologies”

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Abstract

Bandgap engineering is a power tool for electronic and photonic device optimization, but until recently it has been the exclusive domain of III-V technologies such as GaAs or InP. The advent of robust epitaxial growth techniques in the silicon material system, however, is generating worldwide interest, because it enables bandgap-engineering on far-more-manufacturable silicon wafers. The most mature of the Si-based heterostructure electronic device platforms is the Silicon-Germanium Heterojunction Bipolar Transistor (SiGe HBT). At the present state-of-the-art, SiGe HBTs with frequency response above 300 GHz have been demonstrated, on CMOS foundry compatible 200 mm wafers, and is being practiced commercially around the world. The combination of ultra-high-speed SiGe HBTs with scaled silicon CMOS, to form SiGe HBT BiCMOS technology, represents a unique opportunity for highly-integrated, low-cost, silicon-based system-on-a-chip or system-in-a-package solutions for emerging high-frequency wireless and wireline applications ranging from RF as high as mm-wave frequencies (e.g., to 100 GHz).

Interestingly, SiGe HBTs have been shown to have a built-in tolerance to total-ionizing dose radiation, and are also well-suited for operation down to very low-temperatures (to 4.2 K), and up to very high temperatures (to 300 C), making them very appealing for a wide-variety of emerging extreme environment electronics applications, which might be needed, for instance, in space exploration.

This presentation will focus primarily on radiation effects in SiGe HBT devices and circuits. After an introduction to bandgap engineering, SiGe strained layer epitaxy and its use in SiGe HBT design and fabrication, a detailed assessment of the impact of radiation on SiGe materials, devices, and circuits is presented, including: radiation tolerance; basic damage mechanisms; the effects of different radiation types; technology scaling issues; single event upset mitigation approaches; cryogenic operation; and the future directions of SiGe technology. Finally, recent developments in other Si-based bandgap-engineered electronic devices, including strained-Si CMOS will be discussed, as well as the possibilities of Si-based photonic devices.

John D. Cressler received his Ph.D. in applied physics from Columbia University in 1990. He was on the research staff at IBM Research, Yorktown Heights, NY (1984-1992), the faculty of Auburn University, Auburn, AL (1992-2002), and currently is Ken Byers Professor of Electrical and Computer Engineering at Georgia Tech, Atlanta, GA (2002-present). His research interests center on silicon-based heterostructure devices and circuits, and he has published over 350 papers in this area. He is the co-author of Silicon-Germanium Heterojunction Bipolar Transistors (2003) and the editor of Silicon Heterostructure Handbook: Materials, Fabrication, Devices, Circuits, and Applications of SiGe and Si Strained-Layer Epitaxy (2006). To date, Dr. Cressler has graduated 20 PhD students and 17 MS students during his academic career. He has served as associate editor for the IEEE Journal of Solid-State Circuits (1998-2001), the IEEE Transactions on Nuclear Science (2002-2005), and the IEEE Transactions on Electron Devices (2005-present), and in various roles on numerous conference program committees, including as Technical Program Chair of the 1998 ISSCC and the 2007 NSREC. He has received a number of awards for both his teaching and research, and is a Fellow of the IEEE.