Tutorial #1

SiC Power Devices: Physics, Current Status, and Future Trends

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James A. Cooper is Jai N. Gupta Professor Emeritus of Electrical and Computer Engineering at Purdue University and President of Sonrisa Research, Inc., a 501(c)3 corporation doing government contract research. He received his Ph.D. from Purdue in 1973 and was a member of technical staff at Bell Laboratories, Murray Hill, NJ from 1973 until 1983, when he joined the Purdue faculty. His research group at Purdue is responsible for a number of advances in SiC technology including the first DMOS power transistors, the oxide-protected UMOS power transistor, the self-aligned short-channel DMOSFET, and the first n-channel IGBTs on free-standing epilayers. Professor Cooper was elected Fellow of the IEEE in 1993. He served on the editorial boards of IEEE Transactions on Electron Devices and IEEE Proceedings, and was Technical Program Co-Chair for the International Conference on Silicon Carbide and Related Materials in September 2017. He has coauthored over 250 referred journal articles and presentations, and the textbook Fundamentals of Silicon Carbide Technology (Wiley, 2014).

Silicon carbide (SiC) has long been recognized as an ideal semiconductor for power electronics because of its wide bandgap, high critical field, high-quality native oxide (SiO2), and the availability of single-crystal SiC substrates. SiC diodes entered commercial production in 2002, and have accumulated hundreds of billions of hours in the field with a failure rate 10x lower than silicon parts they replace. SiC power MOSFETs entered production in 2011, and are now offered by multiple vendors in Europe, Asia, and the US. The worldwide SiC market is currently $300 million per year, and is projected to exceed $600 million by 2021. Spurring this growth is the availability of high-quality 150 mm 4H-SiC wafers that can be processed on fullydepreciated 6" silicon production lines. SiC power devices have made great progress over the past several years, but SiC technology is still in its adolescence, and progress is expected to accelerate in coming years as material quality improves, production volume increases, and device innovation takes hold. In this tutorial I will discuss three SiC power devices: the JBS diode, power MOSFET, and IGBT. I will describe the operating physics and current status of each, review material and performance limitations, and highlight current research leading to the next generation of SiC power devices.