MODELING AND CHARACTERIZATION OF SILICON CARBIDE POWER DEVICES

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ABSTRACT Several Silicon Carbide (SiC) power diode and MOSFET structures are characterized and compact device models are developed for circuit simulation.

BACKGROUND SiC power devices are expected to show superior performance compared to devices made with other semiconductors. This is primarily because 4H-SiC has an order of magnitude higher breakdown electric field (2×10^6 V/cm to 4×10^6 V/cm) and higher temperature capability than conventional Si materials. The higher breakdown electric field allows the design of SiC power devices with thinner (0.1 times that of silicon devices) and more highly doped (more than 10 times higher) voltage-blocking layers. For majority carrier power devices such as power Schottky diodes, the combination of 0.1 times the blocking layer thickness with 10 times the doping concentration can yield a SiC device with a factor of 100 advantage in resistance compared to that of Si majority carrier devices. For minority carrier conductivity modulated devices such as the PiN diode, a blocking layer of 0.1 times the thickness of a Si device can result in a factor of 100 faster switching speed. This is possible because the diffusion length, L, required to modulate the conductivity of the blocking layer can also be reduced to $1/10^{th}$ the value required for Si, thus permitting the reduction of the lifetime, t, by a factor of 100 according to $L = \sqrt{Dt}$, where D is the diffusion coefficient. Because SiC has a larger band gap (3.26 eV for 4H-SiC versus 1.1 eV for Si), SiC devices have the potential to operate reliably at much higher temperatures than their Si counterparts (300 °C for SiC versus 150 °C for Si).

In this work, compact device models for SiC devices are developed for circuit simulation so that circuit designers can better utilize SiC devices as they emerge.

WORK DONE Devices characterized and models validated so far include 1.5 kV 0.5A and 10A Merged-PiN-Schottky (MPS) diodes, 600V 1A and 4A Schottky diodes, 5kV and 10kV PiN diodes rated from 0.25A to 10A, and a 2kV 5A Double-implanted MOSFET (DiMOSFET).

RESULTS Fig. 1 shows the reverse recovery temperature dependence of a 1.5kV, 0.5A MPS diode.

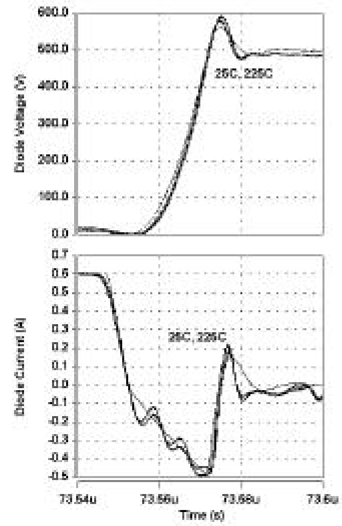

Fig. 1. Measured (solid) and simulated (dashed) SiC MPS reverse recovery waveforms versus temperature for a di/dt of 95 A/µs.

Fig. 2 shows the on-state simulation results of a 2kV, 5A SiC DiMOSFET at 100ºC.

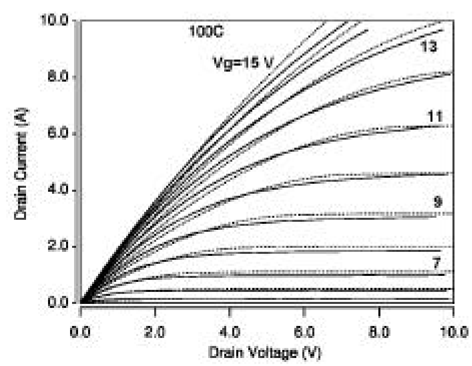

Fig. 2. SiC DiMOSFET simulated (dashed) and measured (solid) output characteristics versus gave voltage for 100C.

FUTURE WORK Next, numerical simulations will be performed on various SiC power device structures to validate experimental observations. The results will be incorporated into compact device models.