SiC Schottky Diodes Tout Breakdown Voltage

By John Day, Contributing Editor, *Power Electronics Technology*

After lying dormant in research laboratories for decades, silicon carbide (SiC) is beginning to realize its potential as a substrate material.

"[Transistor inventor William B.] Shockley called it the ideal semiconductor," notes Dr. John Palmour, vice president of the advanced devices group and a founder of Cree Inc. (Durham, N. C.), "but the industry learned how to grow silicon effectively and that became the basis for the market."

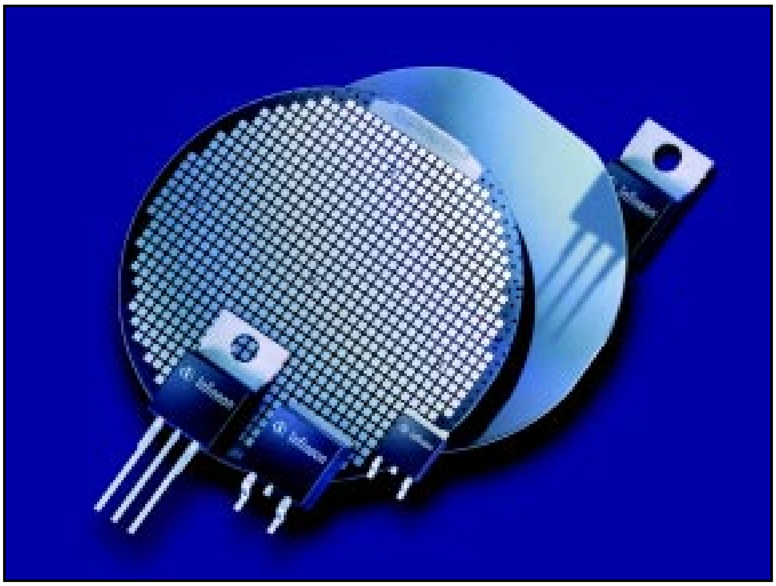
However, within the past few years, using single-crystal wafers grown at Cree, firms have begun fabricating SiC Schottky diodes to leverage the material's order of magnitude-higher breakdown field and faster switching speed compared with silicon. The diodes are finding sockets in high-value applications where heat is problematic (for example, in high-end servers).

Palmour explains that semiconductor scientists have known for decades about the potential of SiC as a substrate material, but found it difficult to grow SiC crystals in sufficient numbers to manufacture semiconductor wafers. "It's a high-temperature process, very difficult to control," he says.

Research was conducted in the 1960s and into the 1970s, abandoned for a number of years, then resumed in the late '70s. Cree spun out of one such research effort at North Carolina State University (Raleigh, N.C.). "Breakthroughs enabled us to grow high-quality single-crystal SiC wafers, though we needed more work to achieve a high-enough wafer density and crystal quality to compete in the power semiconductor market," states Palmour.

"Silicon carbide has about 10 times the breakdown field of silicon for the same breakdown voltage, with lower specific on-resistance and faster switching," adds Michael Povey, vice president of high-reliability products at Sensitron Semiconductor (Deer Park, N.Y.). Sensitron packages finished die purchased from Cree, and offers 300-V, 600-V and 1200-V Schottky rectifiers to replace doped silicon PN junction devices. Other suppliers of SiC devices include Infineon Technologies AG (Munich) and Microsemi Corp. (Irvine, Calif.)

Targeting applications for which switching speed is critical, Microsemi offers Schottky diodes that combine Cree's SiC technology and Microsemi's Powermite packaging. Schottky diodes traditionally have been used for their high efficiency in low-voltage (5-V to 40-V) power applications where their "near zero" switching speed makes them the most cost-effective solution. In high-voltage (greater than 100 V) applications, designers switch to ultrafast rectifiers that have a higher resistance and slower switching speed. Microsemi claims that its line of high-voltage SiC Schottkys combines efficiency and high voltage beyond the capabilities of silicon.



Infineon's SiC Schottky diodes are produced on 3-in. wafers.

"Silicon carbide also offers three times better thermal conductivity than silicon, three times the bandgap and higher temperature operation," notes Sensitron's Povey. SiC Schottky diodes and rectifiers help lower system costs by eliminating the need for snubber circuits and enabling smaller switches, smaller magnetics, a smaller EMI filter and a smaller heat sink. "The 'catch' is that SiC rectifiers have a positive coefficient of V_f versus temperature, thus they stabilize at a higher operating temperature compared with fast-recovery epitaxial diode (FRED) devices."

Cree's Palmour explains that the switching characteristics of SiC Schottky diodes are unaffected by temperature, di/dt (the rate of change in switching current) or forward current, all of which increase reverse recovery current in silicon diodes.

"That's a huge benefit for power devices. Schottky diodes fabricated in silicon are unwieldy and expensive above 100 V, so designers have used bipolar, silicon-based PIN diodes, which offer higher current density and lower resistance per square centimeter," Palmour notes.

"The disadvantage of a PIN diode compared with a Schottky device, however, is its slower switching speed. Because silicon carbide diodes can operate at 10 times the voltage of silicon, we can produce a device with the high-speed advantage of a silicon-based Schottky diode, but without the disadvantages of size and cost," Palmour says.

Designers want more power from their power supplies without the supplies being any bigger. Because of their faster switching speed compared with PIN diodes, Schottky devices are more efficient. They reduce switching loss by as much as 40%, enable power supplies to be made smaller and enable them to operate at lower temperatures.

Sensitron's Povey says that in one design, his firm was able to improve efficiency by 3% to 7% (depending on load and input voltage) by replacing an 8-A silicon diode and 10 snubber components with one 4-A SiC Schottky diode. "This is the only way to meet the growing demand for smaller, more efficient power supplies," Povey asserts. "And the higher the switching frequency, the more important silicon carbide Schottky diodes become."

The downside is that SiC devices are still more expensive than silicon-based PIN diodes; thus, SiC tends to go into applications where power density is particularly important. As volumes increase and costs come down, we expect to see more penetration in mainstream markets."

According to Palmour, the largest market for SiC Schottky diodes is high-end servers, where the Schottkys serve as boost diodes in the power factor correction (PFC) circuits of switch-mode power supplies. "There's limited space and a lot of heat," he says.

The next major application for SiC devices is likely to be variable-speed motor control, which accounts for more than 50% of the energy consumed in the world. "If we can increase efficiency by as little as 2%," says Palmour, "the savings can run into the billions." **PETech**

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