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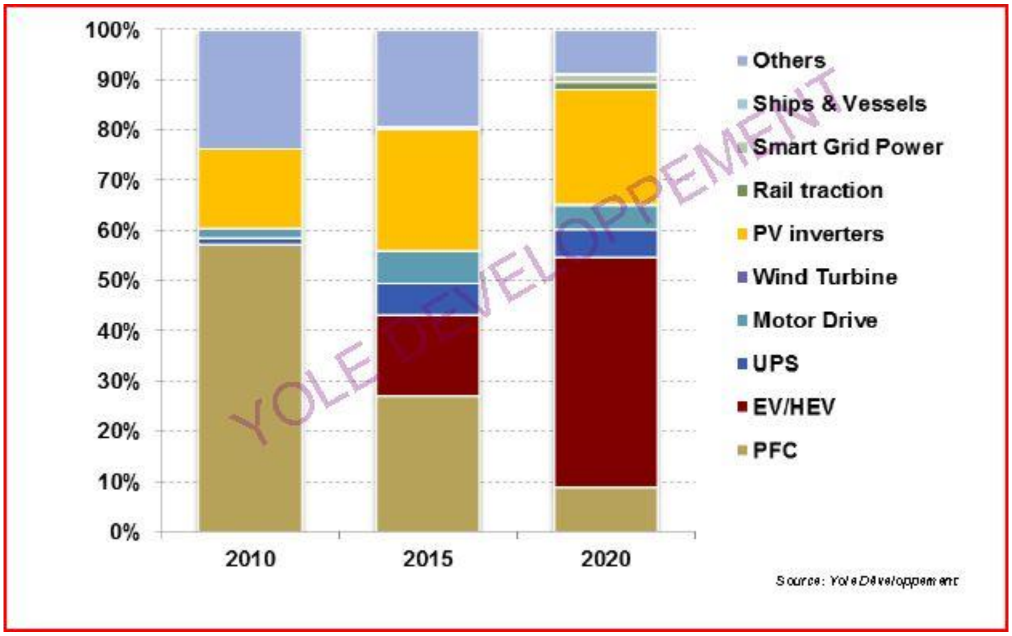
Is Silicon Carbide Technology Ready To Take Off?

by Ashok Bindra, Technology Writer, Technika

Despite gains made in silicon carbide (SiC) technology, it continues to represent a very small percentage of the overall power semiconductor market. By some accounts, it could be less than 1%. But, going forward, the situation looks a lot brighter. With both SiC MOSFETs and diodes now available, and wafer makers continuing to deliver high-quality substrate materials while increasing the diameter, SiC is poised for rapid growth in the next five to ten years as usage proliferates in applications ranging from PFCs and UPSs to solar inverters to EVs/HEVs, motor drives, and others (Fig.1.)



Source: Yole Développement

Fig. 1. Although SiC devices today are primarily used for PFC applications, as the product portfolios expand and costs drop, these devices will spread into solar power inverters, motor drives, hybrid and electric vehicles, traction and many other applications in the next five to 10 years.

Last year, according to estimates made by wafer and device manufacturer Cree, the global market for SiC devices (including the military market) reached approximately $100 million in sales for the first time. Market research firm Yole Developpement estimates that the global market for the commercial and industrial sectors only could reach $75 million by the end of 2012. By comparison, the overall global power semiconductor market in 2012 is estimated to be $20 billion.

Growth projections for the next 10 years is impressive. Some analysts are projecting a compound annual growth rate (CAGR) of over 45% until 2022. At this rate, it is estimated that the SiC device market will reach over $5 billion by 2022.

While performance and reliability continue to improve, cost has been an impediment for these devices. But, with the availability of larger (6-inch) diameter substrates, device manufacturers promise to bring the cost down to make SiC devices competitive with silicon. In fact, Yole had predicted that 2012 would be the starting point for commercial availability of 150-mm substrates, which will provide the needed incentive for the market (see the table).

Table. As SiC substrate diameter increases to 6 inches, device cost will drop significantly. (Data courtesy of Yole Developpement.)

	4H n-type SiC raw substrate	FE + BE process[note 2]	Overall device cost	Cost of a 600-V/6-A diode, 3.2 mm^2
Cost/surface 2010 status (Based on 4-inch wafers)	~\$0.12/mm^2[note 1]	~\$0.14/mm^2	~\$0.26/mm^2	~\$0.85
Cost/surface 2015 status (Based on 6-inch wafers)	~\$0.06/mm^2	~\$0.12/mm^2	~\$0.18/mm^2	~\$0.60

Notes: 1. Highly volume dependent. 2. Epitaxy + front end + packaging + test (includes 80% process yield.)

In line with Yole's projection, Cree last month announced the availability of high-quality, low-micropipe 150-mm 4H n-type SiC epitaxial wafers. In a statement, Cree's materials product manager Vijay Balakrishna stated, "Cree's ability to deliver high volumes of 100-mm epitaxial wafers is unrivaled in the SiC industry and our latest 150-mm technology continues to raise the standards for SiC wafers."

Another supplier in the race to deliver larger-diameter SiC wafers is Dow Corning. Concurrently, China's start-up Dongguan Tianyu Semiconductor Technology Co. Ltd. has also begun to supply SiC epitaxial wafers outside China after the completion of three contracts in August 2012. The Chinese manufacturer can supply 4-inch, 3-inch and 2-inch diameter wafers with a production capacity of 10,000 wafers per month.

Meanwhile, after releasing its first-generation SiC MOSFETs to full production in 2011, Cree is now pushing second-generation transistors with higher current-handling capabilities and higher breakdown voltages. This past summer, the Durham, NC-based SiC device maker readied a new family of 50-A SiC devices, including the industry's first 1700-V Z-FET SiC MOSFET. According to Cree's director of marketing Paul Kierstead, the new 50-A SiC devices, which also include a 1200-V Z-FET SiC MOSFET and three Z-Rec SiC Schottky diodes, will enable a new generation of power systems with unprecedented energy efficiency and lower cost of ownership than with conventional technologies.

Previously, the reliability of high-voltage SiC at high temperature was a concern. However, the manufacturer claims that significant advancement has been made in the gate-oxide reliability of SiC MOS devices to enable the commercial release of the product. Results from tests-to-failure and tests-to-pass predict that the Cree 1200-V Z-FET SiC MOSFET product CMF20120D will demonstrate excellent lifetime and stable operation in the field (Fig.2.)

In fact, quality tests using the more-appropriate stress conditions indicate excellent device stability that is well within the JEDEC/AEC acceptable limits of parametric shifts, claims Cree. Test results depicted in Fig. 2 show an ~10 billion year lifetime, which is two orders of magnitude better than Si lateral MOSFETs.

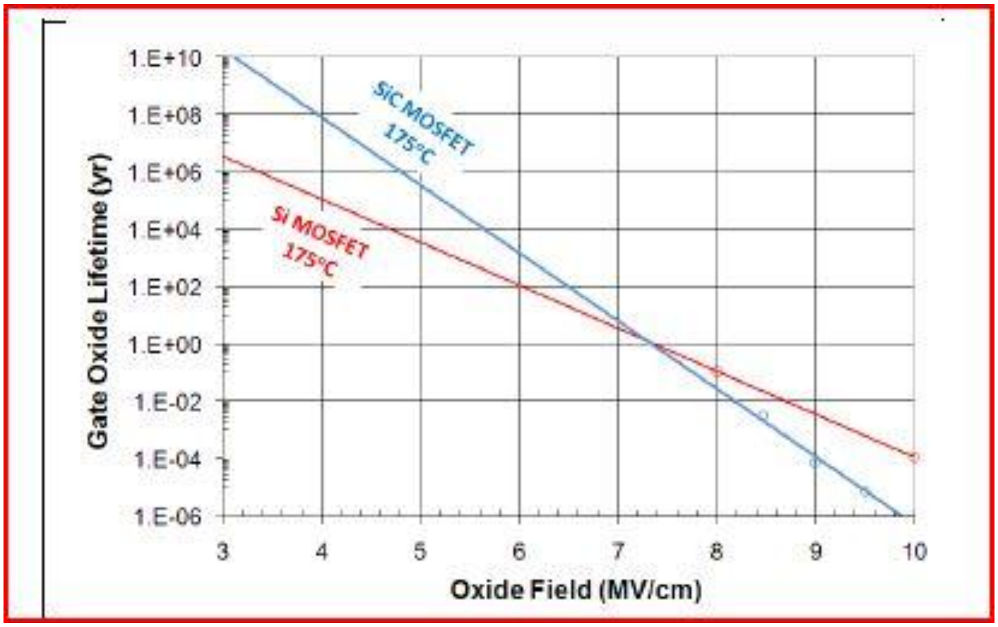


Fig. 2. Results from tests-to-failure predict that Cree's CMF20120D 1200-V Z-FET SiC MOSFET will demonstrate excellent lifetime and stable operation in the field. Measurements reveal that it offers an ~10 billion year lifetime, which is two orders of magnitude better than silicon lateral MOSFETs.

Offered in die form, these new MOSFETs are being designed into high-power modules for use in solar power inverters, uninterruptible power supply (UPS) equipment and motor drives up to 500 kW. Concurrently, Cree is also working on higher- and lower-current options for these high-voltage SiC transistors with plans to increase breakdown voltage capability to 3.3 kV, said Kierstead. Additionally, continued Kierstead, the lower amperage devices will be offered in packaged format such as the TO-247, as well as surface mount with DPAK as an option. Other packages are also under evaluation.

Meanwhile, Cree is also developing proprietary leadless packages for higher-amperage devices with the ability to co-pack diodes. Cree's roadmap shows that eventually the company will enhance the high-voltage capability of MOSFETs to 10 kV. The marketing director also indicated that 600-V SiC devices are in the works too. However, there is no timeline yet for the 600-V devices. Simultaneously, the chip maker is also improving the voltage capability of its SiC diodes.

As Cree continues to advance packaging technology to squeeze more power from these devices, the company is also improving performance while lowering cost, noted Kierstead. "At 1200 V and above, you are competing with IGBTs," asserted Kierstead.

Likewise, next month at Electronica in Munich, Germany, Fairchild Semiconductor will be demonstrating SiC-based 1200-V BJTs. Precisely, the company will be introducing 50-A and 15-A 1200-V BJTs in a TO-247 plastic package rated for 175°C operation. In addition, the company will also introduce 20-A and 6-A 1200-V BJTs in a TO-258, which is a hermetic package rated for 250°C operation.

According to Fairchild's CTO Dan Kinzer, "These devices are capable of more than double the current density of competing 1200-V SiC devices. They are capable of 40% to 50% reduction in losses compared to the best competing silicon IGBT devices that are in commercial use today. Our 50-A parts, with 19-mΩ (max) rated resistance, have the lowest on-state conduction losses by far in the market for any 1200-V device."

Although, Fairchild has been doing limited sampling from its pilot line, it plans to begin sampling the product from the final manufacturing process immediately following the Electronica show. "Mass production will begin after the production release, according to the needs of our customers," stated Kinzer.

Fairchild intends to expand the BJT line with higher-voltage parts at higher and lower current ratings. Together with SiC diodes in similar voltage and current ratings, the company also plans to make modules for specific applications.

Speaking of diodes, recently, STMicroeletronics unveiled a 1200-V ultra-fast Schottky diode with 6-A current handling capability. Concurrently, the chip maker is also expanding its 650-V SiC Schottky line with up to 20-A current capability.

In other news, late last month Infineon introduced the 5th-generation 650-V thinQ! SiC Schottky barrier diodes with improved thermal characteristics and figure of merit ($Q_c \times V_f$). Target applications for these generation 5 diodes are high-end server and telecom switched-mode power supplies (SMPSs), PC silverboxes and lighting.

"Within five years, we should see this market expand as SiC devices find their way into power electronics for UPS, motor drives, hybrid and all-electric vehicles, traction and more," stated Yole's principal analyst Philippe Roussel. Yole's principal analyst is predicting a big jump in consumption of SiC devices in next five to ten years.

About The Author

Ashok Bindra is a veteran writer and editor with more than 25 years of editorial experience covering RF/wireless technologies, semiconductors and power electronics. He has written, both for print and the web, for leading electronics trade publications in the U.S, including Electronics, EETimes, Electronic Design and RF Design. Presently, he has his own technical writing company called Technika through which he does writing projects for different trade publications and vendors. Prior to becoming an editor, Bindra worked in industry as an electronics engineer. He holds an M.S. degree from the Department of Electrical and Computer Engineering, Clarkson College of Technology (now Clarkson University) in Potsdam, NY, and an M.Sc (Physics) from the University of Bombay, India. He can be reached by email at bindra1[at]verizon.net.