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GaN Power Devices Transition To Production Phase

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Since gallium nitride (GaN) based power devices have a vast potential to grow in usage, this market opportunity continues to attract more new suppliers. As a result, the list of manufacturers of GaN technology based power devices is steadily expanding. Since my last column on this subject, I have uncovered some more players who have entered the GaN power arena to join the pioneers International Rectifier (IR) and Efficient Power Conversion (EPC). As a result, with the addition of newcomers like GaN Systems, NXP Semiconductors, ON Semiconductor, Panasonic, and Toshiba there are now some dozen or so GaN device manufacturers who are either in the production phase or are planning to take their respective GaN-based power devices to production. That list is presented in the table.

Table. Suppliers of GaN power devices and the device types they offer.

Suppliers	Epi substrate	Wafer size	Transistor type	Max. Voltage (V)	Diode	Max. Voltage (V)
Avogy	gallium nitride	2 in. (50 mm)	enhancement-mode vertical JFET	1200	Schottky PN	600 (Schottky) 1700 (PN)
Efficient Power Conversion	silicon	6 in.	enhancement-mode FET	200 100 40	--	--
Fuji Electric	--	--	--	--	Schottky	600
Fujitsu Semiconductor	silicon	6 in.	--	--	--	--
GaN Systems	silicon carbide	3 (75 mm) and 4 in. (100 mm)	depletion-mode HEMT*	600	--	--
International Rectifier	silicon	6 in. (150 mm)	depletion-mode HEMT*	600	--	--
NXP Semiconductor	silicon	--	--	--	Schottky	650
RF Micro Devices	silicon carbide	4 in.	source switched FET	650	--	--
ON Semiconductor	--	--	--	--	--	--
Panasonic	silicon	6 in.	normally-off gate injection transistor (GIT)	600	--	--
Power Wafers Development	sapphire	--	--	--	Schottky	600
RF Micro Devices	silicon carbide	4 in.	source switched FET	650	--	--
Sameo	--	--	--	--	--	--
STMicroelectronics	silicon	6 in.	enhancement-mode HEMT	200	--	--
Transphorm	silicon	6 in.	HEMT	600	Schottky	600

*Offered in cascode form.

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Consequently, the market for GaN-based power devices is forecasted to grow substantially in next five to ten years. Research firm Yole Développement predicts that worldwide revenue from sales of GaN power semiconductors will reach about $5 million this year. By comparison, it was around $2.5 million last year. As per Yole's study, the real ramp-up will start in 2014. The research firm is forecasting 90% CAGR over the 2015-2020 time frame.

600-V GaN Transistors

This year is also significant for the new technology as several vendors are transitioning to production. Among them is International Rectifier (IR). IR has begun shipping GaN power transistors based on its in-house 150-mm GaN-on-silicon (GaN-on-Si) epitaxial process. Although, IR did not disclose any specs for the GaN-on-Si based depletion-mode HEMT taken to production, it had demonstrated the complete development of its first-generation 600-V GaN-on-Si based power HEMT at APEC 2013. In fact, for commercial use, the company has combined the GaN-based depletion-mode HEMT with enhancement-mode silicon MOSFET and anti-parallel diode to create a normally-off cascode switch. IR said that all required metrics for large scale commercial adoption have been achieved (see the reference.)

Reports indicate that IR's commercial GaN-on-Si power devices are currently being adopted in a home theater system manufactured by a leading consumer electronics company. However, IR did not identify the consumer OEM.

Meanwhile, EPC continues to expand its product portfolio. The supplier is planning to take another 100-V, 14-mΩ enhancement-mode GaN (eGaN) FET to production next month. Currently, the part is in the sampling phase, according to CEO Alex Lidow. EPC's eGaN FETs are fabricated on 6-inch silicon substrates by Taiwan's foundry service provider Episil. Also, the company prefers offering eGaN FETs in land grid array (LGA) format with solder bars applied in wafer form because it features minimum package size and cost. Plus, it offers zero parasitic resistance and inductance (Fig. 1.)

Fig.1. EPC's eGaN FETs are offered in die form to cut package cost and parasitics.

Although, the current product range for EPC is 40 V to 200 V, Lidow indicated that EPC is also readying 600-V eGaN FETs, which are expected to be released by the year's end. In addition, the company is also developing monolithic ICs that integrate driver circuit and eGaN power transistors on a single chip. Lidow expects monolithic GaN ICs to be ready by early 2015.

Likewise, Transphorm has announced that its 600-V GaN-on-Si devices, which include power HEMTs and diodes, are JEDEC-qualified. These devices are being targeted at power supply adapters, PV inverters for solar panels, motor drives, and power conversion for electric vehicles and electric hybrid vehicles. "The introduction of the total GaN family dispels the myth that qualification of high-voltage GaN on silicon is not possible, and enables the introduction of new power products in the marketplace that are dramatically more efficient compared to silicon-based products," said Primit Parikh, president of Transphorm.

Transphorm said that for approved customers, the company is offering 600-V TPH3006PS HEMT power transistor and TPS3410PK/TPS3411PK diodes in production quantities. Quantity pricing is available on the supplier's website.

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Japan's industrial devices company Panasonic has also started shipping its 600-V GaN-based power transistor for power supply applications. Panasonic's normally-off gate injection transistor (GIT) will be fabricated on a 6-inch silicon substrate.

Similarly, NXP Semiconductors is working towards commercializing its 650-V diodes and switches based on a proprietary GaN-on-Si process technology. NXP has stated that it plans to release a portfolio of GaN discrete devices made at the Hazel Grove PowerMOS wafer fab in the second half of 2014. The products will be targeted at applications where energy conversion efficiency is key, such as power-factor corrected (PFC) power supplies, solar energy, motor control and automotive electronics. For that, it has received about $3 million funding from the U.K. government while NXP is investing roughly $11.5 million for a total of $14.5 million.

Another European semiconductor company in this fray is STMicroelectronics. Participating in the EU-sponsored LAST POWER project, ST has successfully developed an AlGaN/GaN HEMT epitaxial structure grown on 150-mm silicon substrate, reaching a target of 3-µm thickness and 200-V breakdown. ST said that it has developed a normally-off AlGaN/GaN HEMT that is fully compatible with the device-fabrication flow-chart set by the manufacturer's production line.

GaN-on-SiC Based HEMTs

Unlike others, the Ottawa, Canada-based GaN Systems is presently using silicon carbide (SiC) substrates to build 600-V GaN-based depletion-mode HEMTs, which the company started sampling late last year. According to CEO Girvan Patterson, GaN Systems' will take its GaN-on-SiC based power HEMTs to production later this year. For commercial use, the company has combined the depletion-mode HEMT with an enhancement-mode silicon MOSFET and anti-parallel diode to create a normally-off cascode switch that is housed in a low-inductance package (Fig.2).

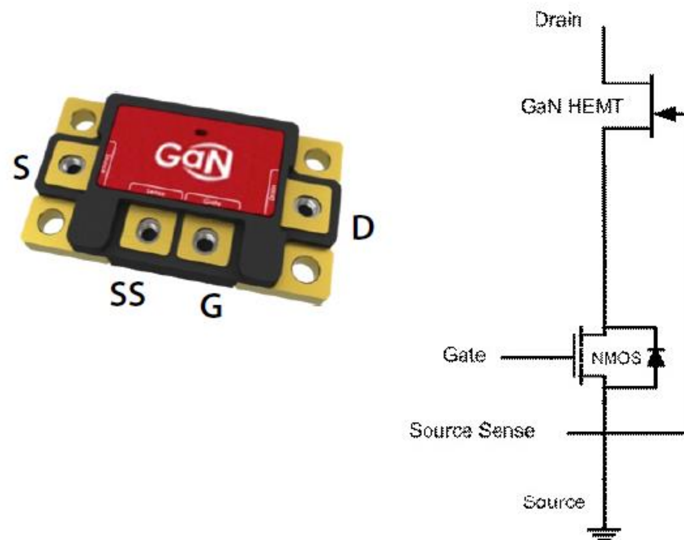

Fig.2: GaN Systems' normally-off cascode switch comes in a thermally enhanced package with minimum parasitic inductance.

While GaN Systems is currently using SiC substrate to produce GaN-based power transistors for 600 V and higher voltages, the supplier also has plans to introduce lower-voltage (<300 V) GaN transistors using a silicon substrate. Patterson said the plan is to introduce GaN-on-Si power HEMTs in the first quarter of 2014. Initially they wil introduce 100-V, 200-V and 300-V GaN-on-Si HEMTs.

Concurrently, the company is also developing GaN-based diodes and an integrated CMOS driver and GaN transistor in a single, thermally enhanced PQFN package. By combining 2D heat-removal techniques for cooling GaN devices with through silicon vias (TSV) to minimize the source electrode inductance, the manufacturer has developed a high-performance PQFN that is optimized to accommodate a GaN power transistor and a CMOS driver in a single, low-cost compact package. As per the plan, both the diodes and the integrated package are expected to be announced by early next year.

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In essence, GaN power devices have transitioned to a new production phase this year. And the future looks bright as suppliers begin to ramp up production to make the new devices a compelling option in power electronics.

Reference

"Summit Showcases GaN Developments For Improving EVs, Lighting, And Solar Power," by Ashok Bindra, How2Power Today, April 2013.

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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.

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