ANALYST CORNER

600V devices set to switch on GaN power electronics

While significant market penetration will have to wait until 2013, wall plug and electric vehicle applications could see GaN device sales multiply rapidly thereafter says Yole Développement's Philippe Roussel.

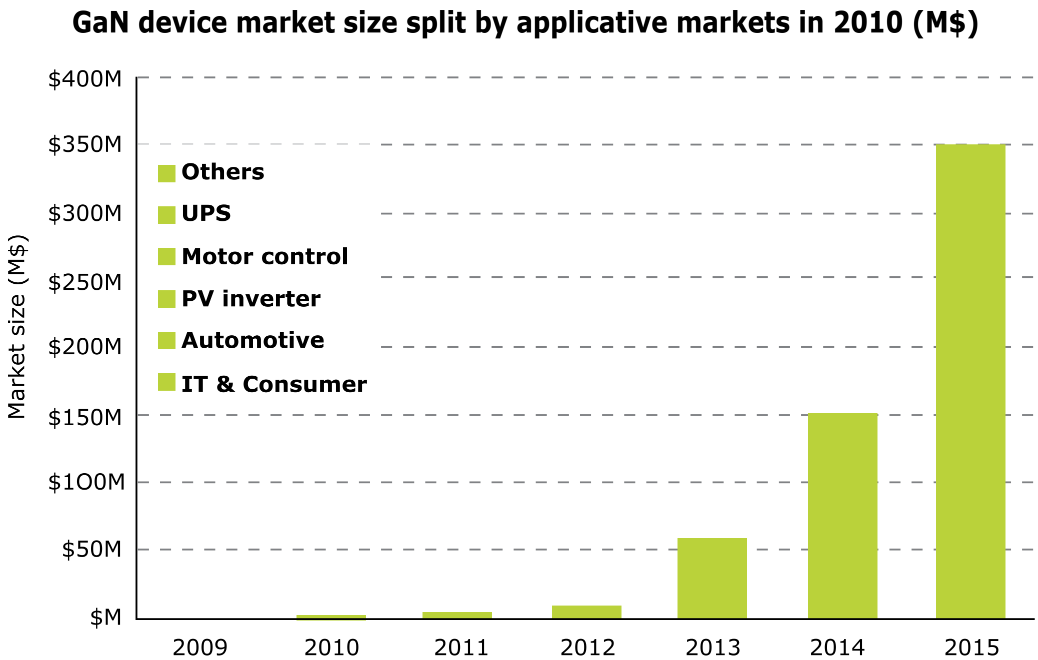
Dr Philippe Roussel, Senior Project Manager, Yole Développement

The actions being taken by GaN power device manufacturers today could lead to an approximately fourfold leap in market size between 2012 and 2013. That will see overall annual sales reach $50 million in 2013, according to Philippe Roussel, senior manager for compound semiconductors and power electronics at market analyst Yole Développement. From there the rapid growth should continue with annual device sales hitting $350 million by 2015, he predicted, thanks to passing one crucial performance threshold. "GaN technology is already mastered by most manufacturers," Roussel told Power Dev'. "It's just a question of being able to supply 600 V devices."

A diverse range of companies have been striving to bring the high temperature and voltage operation, switching frequency and efficiency GaN promises to the power electronics market. Even the first two companies to have released GaN devices, which operate at voltages up to 200 V, to the market in 2010 are good examples of this diversity. Both headquartered in El Segundo, International Rectifier (IR) is already one of the largest power device vendors, while EPC Corporation is a start-up controversially co-founded by ex-IR chief executive officer Alex Lidow. While this led to IR suing Lidow over an alleged "elaborate fraudulent scheme to rob" it of its GaN-on-silicon technology, EPC claims its normally-off devices do not use IR's approach. Roussel points out that the companies' product offerings are as different as their current market presence. "International Rectifier decided to have a point-of-load integrated circuit," he explained. "It's a GaN MESFET embedded into a full IC, not a discrete. EPC decided to launch a discrete transistor so that people can take it and implement it the way they want."

Both companies are well positioned to accommodate any future demand surge thanks to their products' compatibility with existing semiconductor manufacturing equipment. "Although the epitaxy is definitely something very specific to GaN technology, the rest of the process is very CMOS compatible," Roussel said. "The key players can easily start with GaN-on-silicon instead of pure silicon and then ramp up." While IR can use its existing facilities, EPC is collaborating closely with giant Taiwanese silicon CMOS foundry Episil. But despite the low costs that

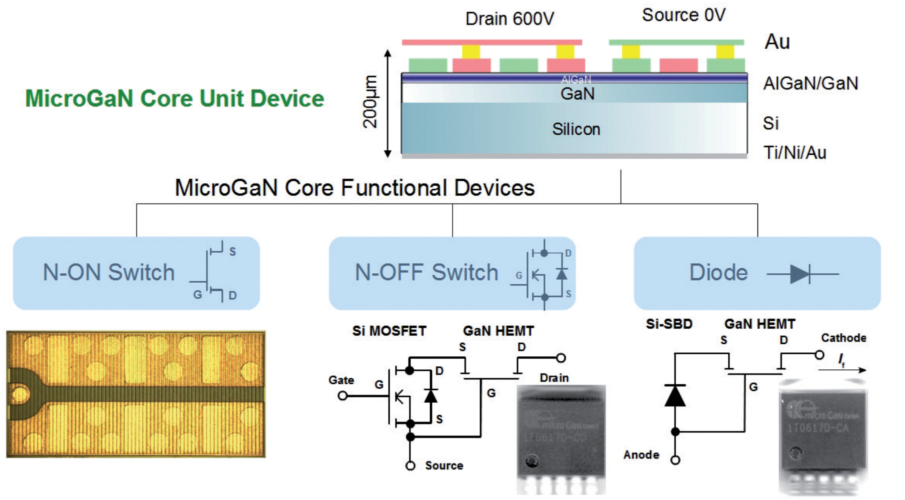
"The holy grail will be automotive applications in electric vehicles (EV) and hybrids (HEV)," says Dr Roussel.



Primed for explosion: Revenues from GaN power electronic devices are poised to multiply several fold after the time still needed for product launches and qualifications has elapsed (Power GaN report, Yole Développement).

this allows compared to devices made using GaN's fellow wide-bandgap semiconductor SiC, demand is limited at low voltages. "The 200 V range is limited to point-of-load or very specific applications where silicon is already well implemented, and cost doesn't favour GaN in that case," Roussel noted.

But following IR and EPC closely with 600 V field-effect transistors and diodes is Ulm, Germany's MicroGaN, one of several companies announcing products in the range Roussel says is the key to broad usage. "600 V will really open the door to everything that you can plug into the wall, a lot of UPS systems, even some low-to-medium voltage and power PV inverters and similar applications, where 600 V is the minimum requirement," he said. MicroGaN is due to release its 5 A normally-on FETs to the market in October, while IR has also announced a 600 V, 15 A FET set to be available in late 2011.



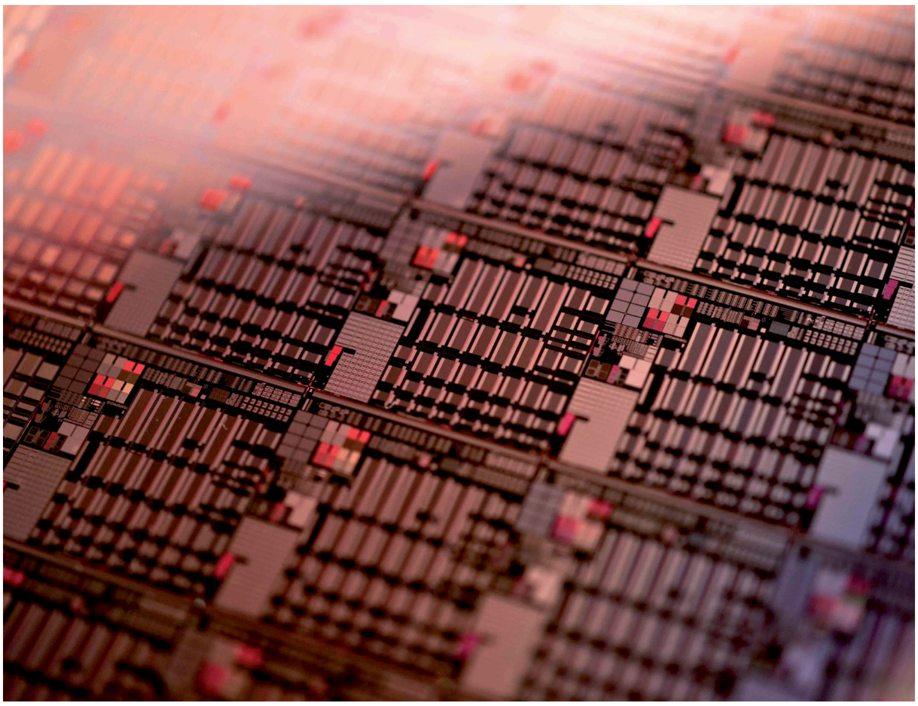
Three-in-one: Set to become one of the first suppliers of 600 V GaN switches, Germany's MicroGaN can convert its normally-on HEMT to a diode and normally-off switch by packaging with other components (Courtesy of MicroGaN).

Partnering up

How MicroGaN, as a startup, might be able to accommodate increasing demand is unclear but could see them calling on their GaN-on-silicon epiwafer supplier compatriot, Magdeburg-based Azzurro Semiconductor. "If Azzurro is able to supply the epiwafers, then MicroGaN is able to ramp up production quite easily," Roussel speculated. Meanwhile, Asia's leading GaN power device developers are large Japanese companies like Panasonic and Renesas, who boast silicon processing facilities in abundance. However, their aim may not be to sell the transistors at all, though their true intention is unclear as Japanese companies are typically very secretive about their plans. "We think that Panasonic will probably use its FET for its own systems first," the analyst said. Secrecy also makes it hard to determine the likely impact of Powdec, a Japanese startup with GaN vertical diode technology. However, Roussel "wouldn't be surprised to see a 600 V device from Powdec in the very short term".

User specifications will encourage 600 V device suppliers to follow the example EPC set at 200 V, Roussel explained. "Customers will typically be power module makers and they want to buy chips, not packaged discretes," he said. "We think the key product will be a die, a die-on-wafer, a "naked" product." But how quickly these products are actually supplied will play an important role in determining whether the analyst's prediction is realised. "It will be really significant this year to see how those announcements will be turned into commercially available products," Roussel said. Once devices are available, there must then be a time lag before they can be deployed more broadly, he pointed out. "There is a qualification time you cannot compress much more. After that 2013 should be the time when take-off will occur."

Photovoltaic inverter producers who are currently adopting SiC will likely be one group behind the rapid market growth. "Last year especially, those guys started implementing SiC," Roussel said. "They are now familiar with wide-bandgap technologies, so they can probably jump from silicon to GaN as well." SiC's use in motor control applications by companies like Mitsubishi will also pave the way for GaN, if it offers the same performance at a lower cost. Yole also sees uninterruptable power supplies (UPS) as a key GaN application. However the continued market expansion through to 2015 will rely on adoption in one pivotal sector. "The holy grail will be automotive applications in electric vehicles (EV) and hybrids (HEV)," Roussel said. "Some are thinking that maybe GaN could be a first good solution for the EV/HEV, not for the inverter, but for the boost converter, or even for the battery charger. Moving from silicon to GaN you can probably improve efficiency by another one or two percent."



GaN-on-silicon: Thanks to cheap silicon substrates GaN transistors, like these ones made by Belgian research centre IMEC, can be more economical than their SiC rivals (Courtesy of IMEC).

Competition rules

Beyond its efficiency, GaN's high temperature operation capability could benefit automotive applications greatly, because it means water cooling systems currently used in HEVs can be removed. But with SiC offering the same advantage, and silicon devices constantly improving, GaN's adoption in this segment is far from guaranteed. "The problem is that no choice has already been made by vehicle makers," Roussel said. "They are all asking, 'Should we stay with IGBT, should we push the silicon limits to the maximum, or should we start looking at GaN/SiC wide bandgap technologies?'"

As carmakers like Toyota and Nissan ponder this question, their answer will largely depend on which technology provides the most economical performance. Yole has looked at the manufacturing cost difference between 200 V transistors made from silicon, GaN and a "virtual" device made from SiC, as no 200 V SiC devices exist. The result shows a balance of costs and performance that puts GaN devices in a difficult position. "Today there is a factor of three between the cost of silicon and GaN, whereas it's 'only' 50 percent more between GaN and SiC," Roussel said. "GaN has to really bring some huge added value compared to silicon, and a huge price difference compared to silicon carbide. This in-between position is not easy."

How GaN-on-silicon devices are made provides hope that their costs will come down enough to be competitive, however. "The good point for GaN is that you start with very cheap substrates," Roussel said. "However, epitaxy today is one-third or even half the cost of those devices because it is quite complex. Yet, this field of the market is really benefiting from the LED MOCVD reactor install base. If they can transfer a very tiny proportion of production to power electronics then the cost will be reduced further still." This means that while silicon transistor costs will fall at around 2-3 per cent per year, SiC transistor costs will fall at 10-15 per cent annually, and GaN at 15-20 per cent per year. "Silicon carbide will decrease a lot, for sure, but less rapidly than GaN," Roussel said. "Intrinsically the silicon carbide material and the crystal growth is expensive, because it's a long process conducted at 2,200ºC and there is a lot of electricity needed."

According to Yole the saving provided by eliminating cooling systems in HEVs would make a switch from silicon to GaN economical as soon as next year considering semiconductor material costs alone. However, voltage rating requirements currently prevent that change. "We need at least a 900 V device, so 2015 is probably much more realistic," Roussel explained. "We think that by 2015 we will have 1.2 kV devices with reasonable pricing and performance." That will allow GaN device manufacturers to claim at least $175 million revenues from EV/HEV applications annually by 2015, as long as they are more economical than competing materials, according to Roussel. "The users don't care about the technology, they care about the performance and the cost," he underlined.

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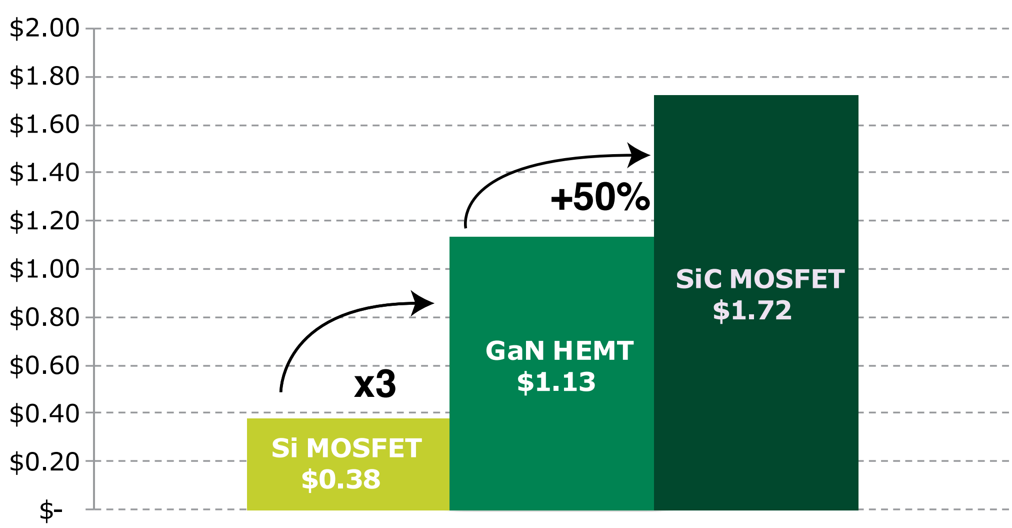
Manufacturing price comparison 200V/12A transistor in 2010



Squeezed in the middle: With their cost sandwiched between silicon and SiC, GaN transistors must provide a significant performance advantage over silicon and be distinctly cheaper than SiC (Power GaN report, Yole Développement).

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