WIDE BAND GAP (WBG) TECHNOLOGIES
A STATUS REPORT: SiC & GaN

The strong dynamics of the power electronics industry is leading to ramp up in use of WBG[1] based materials, in particular SiC[2] and GaN[3] as Si[4] approaches its limits. Devices based on these materials are leading a next generation of energy efficiency and performance due to their intrinsic properties. In particular, GaN on Si power devices are more suitable for high frequency applications while SiC is better for high power density and high temperature inverters.

A market that is booming

Although still relatively small compared to the Si power device market, the SiC market has already reached a relatively significant size compared to GaN due to its more mature technology. In 2017, the SiC power device market was estimated at more than US$300 million[5], roughly ten times that of GaN power devices. In fact, nowadays we can affirm that end-users are beginning to adopt SiC as the final solution whereas several years ago the market was still very small.

Today, 82% of the SiC market is driven by diodes used in PFC[6] for power supplies, and in hybrid modules for applications such as PV[7].

Yole Développement (Yole) expects that the transistor market will still grow with a CAGR2017-2023[8] of 56% with the introduction of these devices into applications such as EV/HEV[9], including charging infrastructure, partly due to the implementation of full SiC modules. Indeed, this is a hot topic in the overall industry, where we see all the car manufacturers and their Tier One suppliers developing SiC solutions. We can already find SiC devices in EV/HEVs in the main inverter of Tesla Model 3[10], and in the OBC[11] from BYD. From industry feedback, it seems clear that the automotive segment will increasingly adopt SiC over the next 5-10 years.

By contrast, the GaN market is still some way behind, with a 2017 market estimated at at lower than US$20 million[12]. This is due to the lack of maturity of the devices. The main applications for GaN in the near future are fast charging adapters, as well as other high-end applications where the high performance of GaN is required such as LiDAR or wireless power. Last year we began to see some movement in the industry showing the potential market for these applications.

Technology developments for WBG devices

The end user is interested in buying a solution that is cost effective and reliable, without considering the underlying technology: Silicon, GaN or SiC devices. For the cost conscious, device manufacturers claim that the total cost of the system will be about the same or lower than Si solutions. Where reliability is concerned, no standards have currently been specified for GaN and SiC. As from the end of 2017, however, a JEDEC committee (JC-70) was created to set these standards. It is expected that once the JEDEC standards are specified, market competition will increase as end-users will be more confident that the technology is reliable.

In addition to the cost and reliability aspects, both GaN and SiC technologies still require some additional development. In packaging, for example, some changes in terms of substrate or encapsulation materials need to be made to SiC modules compared to the standard IGBT module in order to sustain the high-power density.

In terms of device processing, it is not straightforward to change from Si to SiC or GaN for power electronics. There are different requirements for clean rooms for both these materials. For GaN (GaN-on-Si), different equipment is needed for the epitaxial growth (MOCVD[13] manufacturing process), as well as every step where the surface of GaN is exposed, e.g., for contact etching.

About the authors

Dr. Hong Lin has worked at Yole Développement, as a Senior Technology and Market Analyst, Compound Semiconductors & Emerging Materials within the Power & Wireless division since 2013. She specialises in compound semiconductors and provides technical, strategic and economic analysis, and is the author or co-author of various SiC and GaN market reports.

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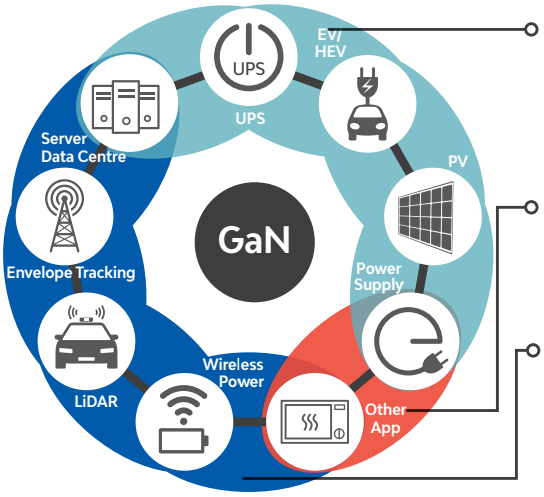
GaN power device – Target application overview

Source: Power SiC: Materials, Devices and Applications report, Yole Développement, 2018



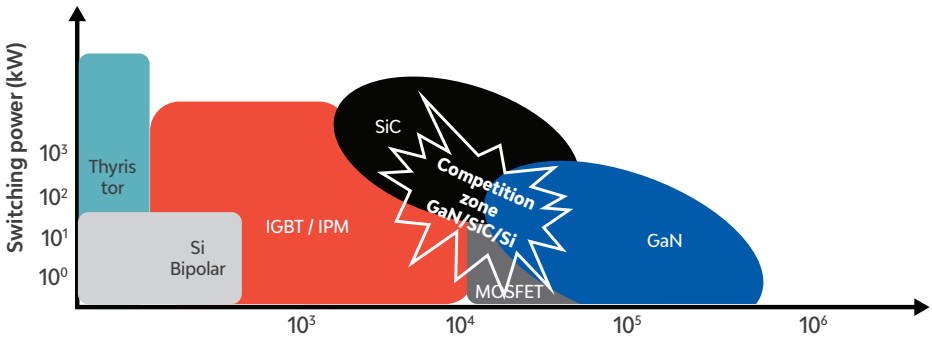
Industrial
GaN will compete directly with SiC. there is the need for high reliability and the cycle time to develop those technologies is about 3-5 years.

Consumer
In the coming years volume production of GaN for AC adapters for consumer applications will begin

High End
Applications where GaN has a high performance benefit. It is a market that has started smoothly already.

Power vs frequency on electronics: power device technology positioning in 2018

Source: Power SiC: Materials, Devices and Applications report, Yole Développement, 2018



1. *WBG : Wide Band Gap*
2. *SiC : Silicon Carbide*
3. *GaN : Gallium Nitride*
4. *Si : Silicon*
5. *Source: Power SiC report, Yole Développement, 2018*
6. *PFC : Power Factor Correction*
7. *PV : Photovoltaic*
8. *CAGR : Compound Annual Growth Rate*
9. *EV/HEV : Electrical Vehicles and Hybrid Electrical Vehicles*
10. *Source : Tesla Model 3 Inverter with SiC Power Module from STMicroelectronics report, System Plus Consulting, 2018*
11. *OBC : On Board Charger*
12. *Source: Power GaN report, Yole Développement, 2017*
13. *MOCVD : Metalorganic Chemical Vapor Deposition*

Supply chain for GaN and SiC devices

As well as developments in the both the device and market, an industrial supply chain for both SiC and GaN power devices has also had to be established, from wafer to epitaxy, bare die manufacturing, discrete/ module packaging and system end users.

The SiC power devices chain comprises companies with different business models:

- Vertically integrated companies from substrate to module, such as Wolfspeed and Rohm;
- Vertically integrated companies from bare die to end system such as Mitsubishi and Fuji Electric; Numerous players also occupy a fragment of the supply chain, such as substrate suppliers, epi suppliers, device manufacturing and packaging.
- A similar ecosystem for GaN power devices can be defined with different co-existing business models. We see established Si power players such as Infineon, On Semiconductor or Panasonic on one hand and start-ups using foundry models on the other.

Indeed, a foundry model is clearly developing which is facilitating both SiC and GaN fab-less and fab-lite companies in launching SiC and GaN products, thereby making the technology more accessible to the industry. For SiC power devices, the foundry model is currently driven by X-Fab supported by Power America.

But other foundries are also entering the market. On the GaN side, semiconductor giant TSMC is leading the business, partnering with different GaN start-ups such as Navitas and GaN systems.

SiC and GaN power device markets are still young compared to the well establish Si power device market. The fast-evolving markets are seeing plenty of activity and changes from participants. We see players moving up and down the supply chain. Ever increasing industry development is coming, according to Yole. In terms of market ranking, the competition becomes more and more fierce day by day. The future will tell who has the last laugh.