The Rise of Power SiC and GaN Market and The Impact of COVID-19

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Abstract

Despite the COVID-19 outbreak, the power Silicon Carbide (SiC) and GaN market continue their ascension. The high growth of the EV/HEV market impacted significantly the wide SiC industry, numerous carmakers continue qualifying SiC devices in main inverters, on-board chargers (OBC) and DC/DC converters. While GaN has found its killer application in consumer fast charging. This paper provides an overview of SiC and GaN device technology, including Yole Développement's understanding of the market's current dynamics and future evolution of wide band gap materials compared to mainstream Silicon power electronics market.

INTRODUCTION

While the COVID-19 has had a swift and severe effect on several manufacturing industries including automotive and consumer, SiC and GaN fabrication shrugs off pandemic and continue to grow. For example, Tesla have had a shutdown in the beginning of 2020, however its sales of electric cars accelerated by the end of the year and hit a new record despite difficult first half.

The main inverter market is still driving the SiC based electric and hybrid electric vehicles (EV/HEV), with more than $300B of EV/HEV investments announced by different OEMs [1], clearly confirming the automotive industry's commitment to governmental CO2 reduction targets.

New players from different technology areas (material and equipment suppliers, power electronic device manufacturer, system integrators, car makers…) are entering EV/HEV business. New divisions or joint ventures fully dedicated to EV/HEVs are being established by many companies. The strong technology requirements and at the same time tough product qualification challenges call for development of new power electronic technologies. The high volume demand for EV/HEV attracts many players to be first to develop and implement such new solutions.

EV/HEV charging, energy storage and other markets related to the EV/HEV follow the trends in the EV/HEV industry: increasing EV battery pack voltage (400V/800V) leading to demand for 1,200 V rated power electronic devices. The companies involved in related applications have to continuously adapt their products while often benefiting of the technology development done for EV/HEVs.

In the consumer market, the ever-evolving power-hungry smartphones are increasing their battery capabilities to accommodate their multi-functionalities. Thus, pressuring the smartphone industry to find solutions to reduce the charging time, which became a crucial parameter for OEMs and an important differentiator for the choice of the flagship. Chargers are preferably low on cost, efficient, and small. This approach is favorable for the use of GaN HEMT where

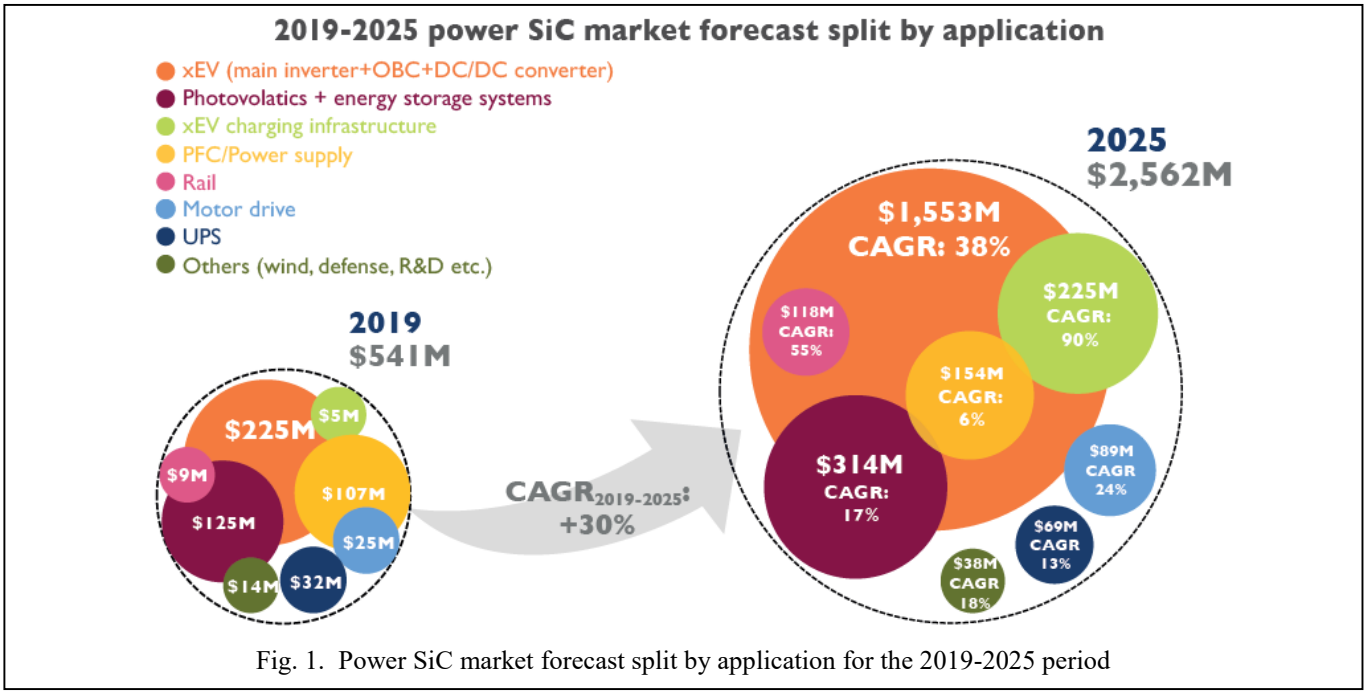

Fig. 1. Power SiC market forecast split by application for the 2019-2025 period

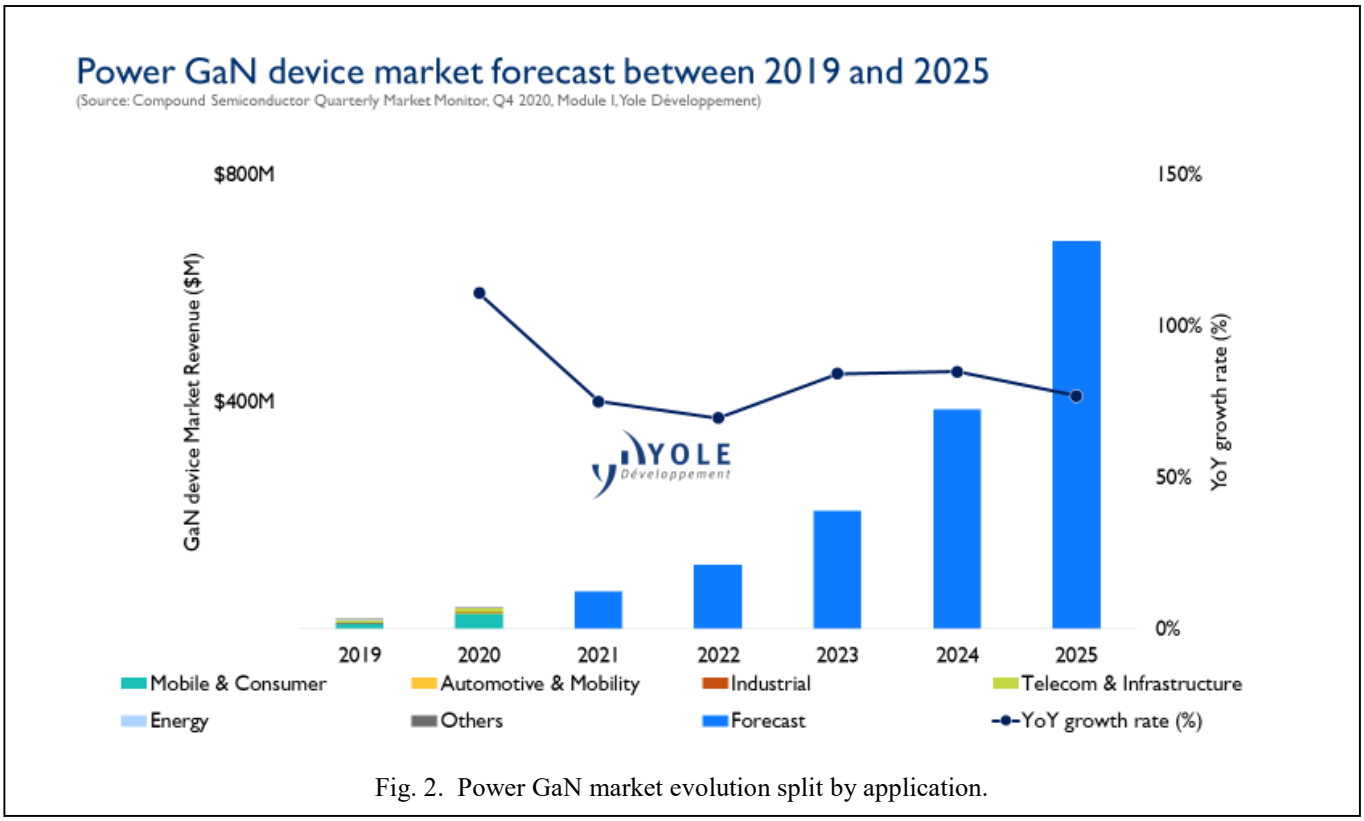

Fig. 2. Power GaN market evolution split by application.

traditional silicon semiconductor is limited to switching frequencies of a few hundred kilohertz, whereas GaN goes beyond the megahertz range. Combining its high frequency capacity and its high-power density, GaN-based product entered the fast charger application with augmented power devices in a compact design.

Regarding the compound semiconductor industry, vehicle electrification and phone fast charging bring new market opportunities for wide band gap materials such as SiC and GaN.

MARKET OPPORTUNITIES FOR SIC

The 2018 - 2019 SiC power device market is notable for Tesla's adoption of SiC in its main inverter. Recently, several carmakers have multiplied announcements for SiC solution design wins. In 2020, BYD has also adopted SiC-based main inverter solutions for its premium models. Other carmakers, such as Audi, Volkswagen, and Hyundai, are expected to adopt SiC in their next-generation models. Moreover, 800V battery vehicles represent a significant market opportunity for SiC owing to its interesting performance/cost ratio compared to silicon IGBTs. Players like STMicroelectronics, Infineon, Rohm, Onsemi and GE have already 1200V AEC qualified SiC MOSFETs and are ready to serve this market.

The xEV market is the primary market driver for Si power devices, and it is the source of excitement for SiC - which is not surprising at all.

Forecasts range from the conservative, at several hundred million dollars, to optimistic, such as the $3 billion estimate from STMicroelectronics. But they all agree that the SiC market is poised for healthy growth driven by the automotive segment.

Based on our discussions with different players, Yole sees a prospering SiC power device market. In fact, we expect the SiC power semiconductor market's value to approach $2.5B by 2025, with a compound annual growth rate (CAGR) of 30% for 2019 – 2025 (See Fig. 1) [2].

The automotive market is undoubtedly the foremost driver, and as such will hold around 60% of total device market share in 2025.

In 2018, the increase of wafer demand as well as the transition from 4" to 6" resulted in wafer shortages. Consequently, securing wafer supply has become the priority for device manufacturers. Several companies invested heavily, and others signed long-term supply agreements. In parallel, the US-China trade tensions, accelerated the domestic supply chain development in China, with more than $2 billion invested in SiC covering wafer, epiwafer and device.

Along with EV applications, SiC is of great interest to the charging infrastructure market, which is growing significantly. Indeed, high power chargers can benefit from SiC's higher efficiency and higher frequency by offering more business. By acquiring Ascatron and Innovion and licensing GE's SiC module technology, II-VI has internalized

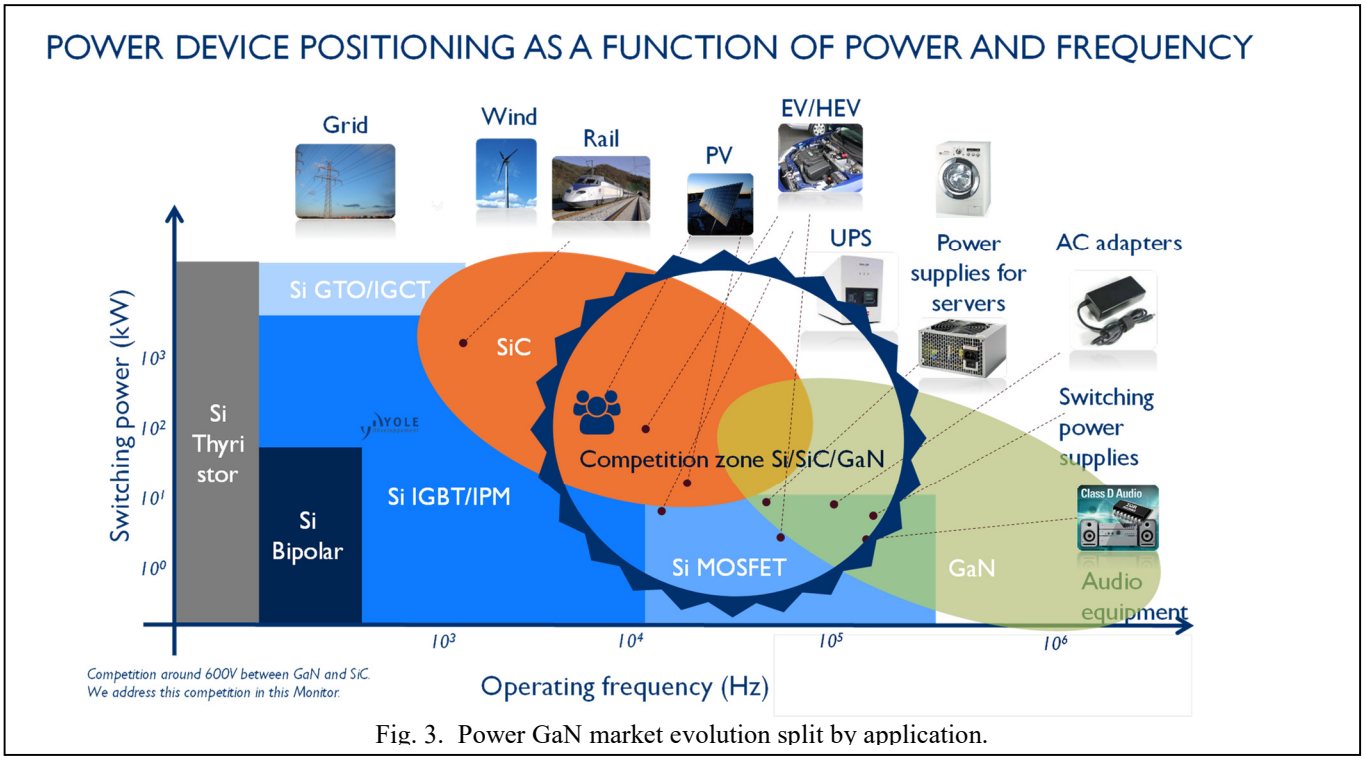

Fig. 3. Power GaN market evolution split by application.

the epi and device manufacturing steps in order to secure new business in the growing module market.

The SiC market is very dynamic, with lots of investments as well as partnerships to accelerate the time to market. Regarding the module business, in the 2019-2020 period, Cree partnered with StarPower, ABB, ZF and Delphi for SiC-based power train systems for electric cars and e-buses. ROHM teamed up with Vitesco and Leadrive Technologies to work on SiC powertrain solutions. Automotive Tier 1 player Bosch is also internally developing SiC modules.

Market Opportunities for GaN

For the GaN power market, the adoption of GaN HEMTs for Oppo's in-box fast charger at the end of 2019 boosted the penetration of this wide bandgap material. Indeed, several OEMs such as Oppo, Vivo, Realme and Meizu rushed to adopt GaN-based inbox fast charger for their flagship released in early 2020. Also, other players such as Samsung and Xiaomi have opted for GaN accessory chargers.

Another high-volume market opportunity can be found in automotive applications, where several OEMs are interested in GaN HEMT devices and currently testing and qualifying the technology. GaN is of great interest in 48/12V DC-DC converters in mild-hybrid electric vehicles and bi-directional on-board charging applications in electric-vehicles. Various Tier 1s, e.g. Valeo and Continental are already using and qualifying GaN product. Players like EPC, Transphorm, GaN Systems, and Texas Instruments have already obtained AEC qualification. Yole expects that GaN power will enter automotive OEM's supply chain and enjoy increasing volumes starting from 2023-2024.

The GaN journey has just started with the end-consumer mass market where it will gain volume production. In a few years, it will expand in the automotive and industrial market. The GaN device market is poised to reach more than $700 million in 2025 (See Fig. 2) [3-4].

SiC and GaN

SiC and GaN will compete around 600V. For applications with high power demand and high voltages such as rail, wind, and power grid, SiC will be preferred. For applications with small power demand and high frequency benefits like consumer fast chargers, and small power supplies for servers, GaN will be the winner (See Fig. 3) [4].

In automotive applications, the competition is again power dependent. We see an increasing demand for SiC in the inverter with high power. Depending on the evolution of GaN device, the cost erosion, and topology technologies, we might see GaN penetrating the low power inverters (small cars, urban vehicles…) in the long-term. In Off-board chargers SiC will be dominating this market, whereas in onboard chargers, we expect GaN to bring some benefits by increasing the Watts per Kg. For DC/DC applications, in high voltage there will be a co-existence of both technologies, and a slight advantage to GaN for bi-directionality function.

Conclusions

The industry shook after the pandemic hit most factories from raw materials to device level. However, wide band gap materials SiC and GaN stood and emerged with a positive outcome, they clearly show a strong growth potential in

EV/HEV and consumer market, respectively. Both compound semiconductors have significant added values and challenges for market adoption.

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ACRONYMS

EV/HEV: electric vehicles/ hybrid electric vehicles
BEV: battery electric vehicles
PHEV: plug-in hybrid electric vehicles
CAGR: Compound Annual Growth Rate
IGBT: insulated-gate bipolar transistor
OEM: original equipment manufacturer