GaN and SiC power device: market overview

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Power Electronics market
DRIVING POWER ELECTRONICS

Power Electronics Market 2010

Climate change
• Governmental subventions
• Artificial Intelligence
• Adjacent application needs

Power Electronics Market 2018

Needs
• Efficient
• Cost
• Reliability
• Integration
• Manufacturing
• Supply chain
Looking forward: 2017-2023 by type of device

*Module: IGBT, MOSFET and Bipolar devices that are sold as modules, not including rectifiers in that category

<table>
<thead>
<tr>
<th>Device Type</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>2023</th>
<th>CAGR 17-23</th>
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</thead>
<tbody>
<tr>
<td>Modules &amp; IPM</td>
<td>$15,427M</td>
<td>$16,047M</td>
<td>$16,784M</td>
<td>$17,325M</td>
<td>$17,890M</td>
<td>$18,554M</td>
<td>$19,458M</td>
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<tr>
<td>IGBT</td>
<td></td>
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<td></td>
<td></td>
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<td>5.5%</td>
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<tr>
<td>X-FET</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>2.9%</td>
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<tr>
<td>Bipolar</td>
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<td></td>
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<td></td>
<td></td>
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<td>2.0%</td>
</tr>
<tr>
<td>Thyristors</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0%</td>
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<tr>
<td>Rectifiers</td>
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<td></td>
<td></td>
<td></td>
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<td>1.8%</td>
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</table>

CAGR 2017-2023: 3.9%
Low voltage applications keep being the biggest market.

2017 market for power devices in power electronics, split by voltage range

- Low Voltage: 68%
- Medium Voltage: 20%
- High Voltage: 8%
- Very High Voltage: 4%

Total market: $15.4B
POWER VS FREQUENCY ON ELECTRONICS

Silicon Power device technology positioning (2018)

Switching power (W)

10^0 10^1 10^2 10^3

10^3 10^4 10^5 10^6

Operating frequency (Hz)

Thyristor

IGBT/IPM

MOSFET

Si Bipolar

Grid

Wind

Rail

PV

EV/HEV

UPS

Home appliances

Power supplies for servers

Switching power supplies

AC adapters

Audio equipment

Switching power supplies

Servers

UPS

Wind

Grid

Home appliances

Power supplies for servers

Switching power supplies

AC adapters

Audio equipment
Why WBG?

GaN is interesting for high-frequency switching and SiC for high temperature applications.

**GaN**
- 3x higher bandgap of Si ➔ 14x higher breakdown field
- Co(tr) of GaN device is ~10x lower than SJ FET
- Qrr > 100x lower for GaN devices
- Low Rdson
- Very fast switching ➔ High frequency operation
- Reduction of conduction and switching loss
- Compactness and weight reduction

**SiC**
- 3x thermal conductivity of Si
- 3x higher bandgap of Si ➔ 10x higher breakdown field
- Up to 1000x lower Rdson
- 2x switching speed
- Reduction of conduction and switching loss
- Size reduction: 1/10x drift region for same Vbd
- High temperature operation

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1. The Tc for GaN is given here for typical GaN-on-Si. It has been demonstrated that the Tc of bulk GaN could reach four W/cm²°C.
2. The electrical field profile can also be controlled by the doping concentration.
KEY PLAYERS AND POWER ELECTRONICS LANDSCAPE

Main power electronics players involved in power WBG

Power Electronics discrete and module revenues, 2017

- Infineon Technologies
- ON Semiconductor
- Vishay Intertechnology
- Fuji Electric
- STMicroelectronics
- Mitsubishi
- Renesas Electronics Corporation
- Toshiba
- ROHM Semiconductor
- Littelfuse
- Diodes
- Nexperia
- Bosch
- Semikron
- Alpha and Omega Semiconductor
- Microsemi
- Shindengen
- Sanken Electric Company

Extracted from the report “Status of Power Electronics Industry 2018” from Yole Développement
SiC power market
SiC POWER DEVICE TARGET APPLICATIONS OVERVIEW

- UPS
- EV/HEV
- Power Supply
- Wind
- PV
- Rail
- Other App
- Motor drive
- Charging Station
The total SiC-based power device market is expected to grow steadily, reaching more than $1.5B in 2023.

Including discrete diodes, discrete transistors, diode bare die in hybrid modules and full SiC modules.
OUTLOOK OVER 2022

Gradually towards a module dominating market

The transistors portion is increasing and the module market will become more and more important.
SIC POWER INDUSTRY - MAIN REMAINING CHALLENGES

From materials to system integration

**Material**
- High cost
- High defect density
- Limited wafer size
- Shortage

**Device**
- Low manufacturing yield
- High cost
- Multi-sourcing (no longer an issue for diode, but still for transistors as of 2017)
- Long-term reliability
- What is the right packaging?

**System**
- How to integrate the active component (driving, EMI, topology choices, etc.)?
- What are the available choices for passive components and dielectric materials?
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GaN power market
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GAN POWER DEVICE TARGET APPLICATIONS OVERVIEW

- UPS
- EV/HEV
- Server and Data Center
- Envelope tracking
- PV
- Power Supply
- LiDAR
- Wireless Power
- Other App
GaN FOR POWER ELECTRONICS APPLICATION

Market (M$)

- Data centres ++
- Fast charger +++
- Wireless charging +++
- LiDAR
- Wireless Power
- EV/HEV

Time

2018 2023

Bull case scenario
Base scenario

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GaN POWER INDUSTRY - MAIN REMAINING CHALLENGES

From materials to system integration

- High cost
- High defect density
- Relatively low yield
GaN POWER INDUSTRY - MAIN REMAINING CHALLENGES

From materials to system integration

Epi
- High cost
- High defect density
- Relatively low yield

Device
- High cost
- Multi-sourcing
- E-mode vs D-mode
- Long-term reliability

System

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GaN POWER INDUSTRY - MAIN REMAINING CHALLENGES
From materials to system integration

- **Epi**
  - High cost
  - High defect density
  - Relatively low yield

- **Device**
  - High cost
  - Multi-sourcing
  - E-mode vs D-mode
  - Long-term reliability

- **System**
  - How to integrate the active component (driving, EMI, topology choices, etc.)?
  - What are the available choices for passive components and dielectric materials?
CONCLUSION: HOW TO ACCELERATE WBG ADOPTION

Scientist Dream
- Optimistic
- Performances are better
- Obviously the next generation

Accelerator
- Low On Resistance
- High Switching Capability
- High Temperature Capability

Limiter
- Cost
- Reliability
- Integration (Module & Drivers)
- Sourcing

Designer Challenge
- Realistic
- How do use the device
- How to design?
- How long to develop
- Why changing?
CONCLUSION

• In general, the power electronics market will be driven by module and IGBT growth over the next 5 years. Many standard power applications are being upgraded to enable higher efficiencies or reduced size systems, leaving an open door to SiC and GaN penetration.

• New applications are also coming up. WBG could penetrate to those markets.

• The SiC power device market outlook is without doubt promising as market adoption is ongoing. One of the main driving application is EV/HEV. Shortage, cost and multi-sourcing need also to be taken into account for forecasts.

• GaN is still a path away from SiC, less mature so at the moment being less adopted. Need high value addition to the end system to include it in the end product. Reliability seems to be still a barrier for high power systems.

• SiC and GaN will grow in shares in the power electronics devices in the future. Each one in a different speed and entering in different applications. However, they will always a co-exist with Silicon devices.
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FOR MORE INFORMATION SEE YOLE’S REPORTS…

New report: December 2018

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