Statut des technologies grand gap, stratégie ST et structuration de la filière française en GaN

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WBG Strategic Marketing Manager
STMicroelectronics Italie
Understanding the impact of global energy consumption

~23,000 TWh: total worldwide electricity consumption (2019)

Electricity Consumption by Sector

- Industry: 42%
- Commercial and public services: 21%
- Residential: 27%
- Transport: 2%
- Others: 8%

1% efficiency improvement in industrial electricity consumption

Would yield total energy saving of 95.6 TWh

32 Million tons of CO2e
11 Million tons of coal equivalent
8 Million tons of oil equivalent
55 Million Barrels of Oil Equivalent

Corresponding to ~ 15 nuclear plants

Source: IEA (International Energy Agency)
Commitment to Carbon Neutrality

ST will be Carbon Neutral by 2027

Milestones

• Compliance with the 1.5°C scenario (Paris COP21) by 2025
• Carbon neutral by 2027
• Sourcing 100% renewable energy by 2027
• Collaborative programs and partnerships for carbon neutrality throughout our ecosystems
SiC and GaN target energy-efficient applications

Wide bandgap semiconductors offer superior benefits and characteristics vs. conventional silicon MOSFETs and IGBTs for the power transistor market

<table>
<thead>
<tr>
<th>Advantages of GaN and SiC</th>
<th>Differences between GaN and SiC</th>
</tr>
</thead>
<tbody>
<tr>
<td>• High-voltage capability</td>
<td>• GaN switches faster than SiC</td>
</tr>
<tr>
<td>• Faster switching speed</td>
<td>• SiC operates at higher voltages than (lateral) GaN</td>
</tr>
<tr>
<td>• Higher operating temperature</td>
<td>• SiC requires high gate drive voltage</td>
</tr>
<tr>
<td>• Lower conduction resistance (less heat / power dissipation, greater efficiency)</td>
<td></td>
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</table>
SiC and GaN enable simpler and more efficient topologies

- **CCM Totem Pole** can only be done with SiC and GaN
- Higher power density
- Higher efficiency with lower BOM
- 3-Level becomes bidirectional with SiC
- Higher frequencies allowed (48 kHz+ vs. Typ. < 20 kHz)
- Higher efficiency with same or lower BOM

**LLC and Active Clamp Flyback in Si and GaN**

**3-Level / HB (SiC) like Vienna topologies**

**Totem Pole PFC (SiC and GaN)**

Efficiency improvement and BOM reduction
Technologies and manufacturing strategy overview

**Existing plants**
- SiC 150mm fabs Catania and Singapore
- RF GaN 200mm fab in Catania
- HV Si MOSFET 150mm and 200mm fabs in Catania and Singapore
- IGBT 150mm and 200mm fabs in Catania and Singapore
- Assembly plants in Shenzhen, Muar, Calamba and Bouskoura
- High power module assembly line in Shenzhen

**New / Planned plants**
- Full integrated SiC facility in Italy
- Power GaN 200mm pilot line in Tours

**Outsourcing**
- Exploring foundries opportunity for HV Si MOSFET, IGBT and GaN
- Balancing back-end subcontracting

* 300mm: studying future technology expansion for Silicon High Voltage Power MOSFET
** Vertical integrated company through NORSTEL AB acquisition
Silicon Carbide – latest press releases

7 Jan. 2019
Cree and STMicroelectronics Announce Multi-Year Silicon Carbide Wafer Supply Agreement

2 Dec. 2019
ST closes acquisition of silicon carbide wafer specialist Norstel AB

27 Jul. 2021
STMicroelectronics Manufactures First 200mm Silicon Carbide Wafers

25 Nov. 2021
A*STAR’s Institute of Microelectronics and STMicroelectronics Team Up on Silicon Carbide R&D for the EV Market and Industrial Applications

19 Nov. 2019
Cree and ST Expand and Extend Existing Silicon Carbide Wafer Supply Agreement

15 Jan. 2020
ROHM Group Company SiCrystal and ST Announce Multi-Year Silicon Carbide Wafer Supply Agreement

17 Aug. 2021
Cree | Wolfspeed and STMicroelectronics Expand 150mm Existing Silicon Carbide Wafer Supply Agreement

9 Dec. 2021
STMicroelectronics Drives the Future of EVs and Industrial Applications with New Silicon-Carbide Devices
ST is the market leader in SiC MOSFETs

Real solutions in production for key global customers and markets

>50% Today market share

>$1B SiC revenues in 2024

>90 projects in development

Focus applications and key benefits

- Power supply
- UPS
- Industrial Motors
- EV Charger
- Traction
- OBC, DC-DC

50% lower losses
5x Frequency
20% Reduced Total Cost of ownership
70-80% reduced/smaller size with an average weight reduction of 50%

Technology roadmap

1st Gen
2nd Gen
3rd Gen
4th Gen

Available

Advanced packaging offer

- HiP247-4 leads
- HU3PAK
- STPAK
- ACEPACK SMIT
- Bare die
- ACEPACK 1 - 2
- ACEPACK DRIVE

Source: OMDIA - Power Semiconductors Market Share Database – 2021
### SiC power industry and supply chain challenges

<table>
<thead>
<tr>
<th>Wafer cost improvement</th>
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<tbody>
<tr>
<td>Quality improvement and reduction of defects</td>
</tr>
<tr>
<td>Bulk wafer and epitaxy compatibility</td>
</tr>
<tr>
<td>Speed-up migration to 8-inch diameter</td>
</tr>
<tr>
<td>Process-step optimization, automation, and repeatability</td>
</tr>
</tbody>
</table>

1st Gen DIODE using 8” Demonstrator
Different GaN HEMT alternatives

<table>
<thead>
<tr>
<th>d-mode GaN</th>
<th>e-mode GaN</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Source</strong></td>
<td><strong>Source</strong></td>
</tr>
<tr>
<td><strong>Schottky Gate</strong></td>
<td><strong>Gate</strong></td>
</tr>
<tr>
<td><strong>Drain</strong></td>
<td><strong>Drain</strong></td>
</tr>
<tr>
<td>AlGaN</td>
<td>AlGaN</td>
</tr>
<tr>
<td>GaN</td>
<td>GaN</td>
</tr>
<tr>
<td>2DEG</td>
<td>2DEG</td>
</tr>
</tbody>
</table>

**Cascode**
1. Use of standard MOSFET gate driver
2. Stable Vth>0 of the Si MOSFET

**p-GaN gate**
1. Low resistance under the gate
2. No dielectric issue

**Recessed gate**
1. Minimization of gate leakage
2. Vth higher than 1V

**Normally-off operation**
- Cascode
- p-GaN gate
- Recessed gate

**Advantages**
- Use of e-mode Si MOSFET in series to d-mode GaN HEMT to create a global e-mode HEMT
- Assembly process complexity
- Optimized Si MOSFET needed in each application
- Not suitable for low voltage (<200V) and high frequency (>500kHz)

**Drawbacks**
- Limited positive gate voltage swing
- Trapping effect due to the p-GaN dopant
- Not suitable for low voltage channel resistance
- Threshold voltage instability due to the traps in insulator
- Dielectric impact on device performance (Ron and reliability)

2DEG=bidimensional electron gas
IRT POWERGAN transistor

- New power device based on GaN HEMT with a recessed-MOS gate
- Principle of operation
  - The recess in GaN cut the 2DEG ensuring a Normally-off operation
  - The dielectric inserted between GaN and gate-metal ensure a low gate leakage and a higher endurance with respect to maximum allowed gate voltage

Source: Leti ceatech
IRT POWERGAN transistor

- Main results
  - Normally-off operation obtained thanks to the recessed-gate architecture, with very low level of gate current, and good electrostatic control of the channel
  - A 30nm oxide-based dielectric allows to sustain a 10 years lifetime in terms of dielectric breakdown at a maximum gate voltage of 8V & 150°C (12V@25°C)

- Process manufacturing fully compatible with ST pilot line

Source: Leti ceatech
PowerGaN* product family

A serious alternative to silicon in power conversion applications

<table>
<thead>
<tr>
<th>Product</th>
<th>Voltage</th>
<th>Mode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>G-FET</td>
<td>650V</td>
<td>D-MODE</td>
<td>Very fast, ultra-low Qrr, robust GaN cascode FET with silicon gate drive for power applications</td>
</tr>
<tr>
<td>G-HEMT</td>
<td>650V</td>
<td>E-MODE</td>
<td>Ultra-fast, zero Qrr e-mode HEMT, easily paralleable, for very high frequency and power applications</td>
</tr>
<tr>
<td>G-DRIVE**</td>
<td>650V</td>
<td>D-MODE</td>
<td>Ultra-fast GaN switch with embedded gate drive to simplify board design and minimize parasitic inductance</td>
</tr>
</tbody>
</table>

(*) The enhanced product portfolio includes devices from Exagan, a subsidiary of ST
(**) For industrial market only
PowerGaN
market segmentation by product family

- **Personal Electronics**
  - Chargers
  - Adapters
  - USB PD
  - Consumer Electronics Power Supply

- **Smart Industry**
  - PSU for Telecom
  - PSU for Datacenter and Servers
  - Solar
  - PSU for Industrial Drives

- **Car Electrification**
  - On-board Chargers
  - 400V-12V DC/DC converter
  - 48V-12V DC/DC converter
  - LiDAR
  - Traction Inverter

- **G-FET / G-DRIVE, G-HEMT**
  - Low to mid frequency
  - Low to mid Power
  - SiP solutions
  - Legacy package

- **G-FET / G-DRIVE, G-HEMT**
  - Mid to very high frequency
  - Mid to high Power
  - 100V GaN availability
  - Legacy and new package

- **G-FET / G-HEMT**
  - Very high frequency
  - High Power
  - 100V GaN availability
  - Assembly requirements (CSP and KGD)
  - PCB embedding trends
Accelerating our GaN execution strategy

Partnerships and acquisitions today

TSMC partnership
Leveraging ST’s market expertise and TSMC foundry know-how to bring Power GaN & GaN ICs to market

EXAGAN majority stake acquisition
A step forward in product development and epitaxy expertise for our long-term GaN roadmap, ecosystem and business

Optimized manufacturing strategy tomorrow

External
Complement roadmap by partnering with foundries to improve time-to-market and enable multi-site high volume

Internal
Targeting internal 200mm manufacturing in Tours leveraging proprietary technology (100V…650V)

2020 2021 2022 2023 2024 2025
GaN 200 mm line in Tours

New Building, clean room & full production line…
GaN 200 mm line in Tours … mastering Epitaxy step
ST GaN ecosystem

People
Dedicated R&D experts in new WBG materials and power solutions to replicate a new successful story on GaN as already done with SiC, Power and Smart Power Technologies

Application knowledge
ST can leverage on an unmatched knowledge of power systems to take the full benefits of GaN products in any applications

GaN Technology
ST is the sole supplier capable of offering a comprehensive PowerGaN product line-up covering main application domains

Package Technology
ST can offer a robust family of packages with enhanced thermal performances through the exposed top metal and reduced parasitic thanks to bond wire free technologies

Manufacturing
ST can leverage on in-house Si fabs with easy scaling up for high volume production and established supply chain.
**In house epy-wafers manufacturing as key enabling factor for strategic supply chain independency**
PowerGaN vs. Silicon MOSFET

<table>
<thead>
<tr>
<th>Device</th>
<th>$B!V_{DSS}$ @ 1mA [V]</th>
<th>$V_{Gth}$ @ 250 µA [V]</th>
<th>$R_{DS(on)}$ @ 5A [mΩ]</th>
<th>Chip size Normalized %</th>
</tr>
</thead>
<tbody>
<tr>
<td>GaN</td>
<td>700</td>
<td>1.14</td>
<td>113</td>
<td>22.9</td>
</tr>
<tr>
<td>SJ A</td>
<td>645</td>
<td>4.38</td>
<td>114</td>
<td>90.5</td>
</tr>
<tr>
<td>SJ B</td>
<td>635</td>
<td>4.18</td>
<td>112</td>
<td>100</td>
</tr>
</tbody>
</table>

*Converter efficiency @ 100 kHz*

*Converter efficiency @ 300 kHz*

*Converter efficiency @ 500 kHz*

*ΔEfficiency GaN vs. SJ @ 500 kHz*
Points clés à retenir

• Les semiconducteurs à grand gap répondent aux exigences de l’économie décarbonée et à celles de la transition énergétique permettant d’améliorer l’efficacité de conversion systématiquement.

• ST poursuit une stratégie globale sur les produits à grand gap.

• Présence solide dans le marché des voitures électriques grâce aux composants (MOSFETs) en SiC.

• Coopération en cours avec l’IRT Saint Exupéry: SiCRET. GaNRET prochainement. ECSEL: TRANSFORM et GaN4AP.

• Feuille de route complète en GaN.

• La filière du GaN s’appuie sur un écosystème de compétences industrielles et de recherche avancée.
Our technology starts with You

Find out more at www.st.com/stpower