Power Electronics
MAIN DRIVERS FOR POWER ELECTRONICS

- **Mechanic**
- **Electric**
- **Thermal**

**Autonomy**
- Going from product to service

**Electrification, “battery-fication”**

**Increase in efficiency**

**Clean energy**

**Smart solutions**

**Flexible, modulable system**

**Interlinked (global) solutions, connectivity**

**Automatization and green manufacturing**

**source:** Yole Développement
Even if there have been fluctuations in power electronics demand depending on the final segment, today all applications are demanding high volumes of power components.
A HUGE VARIETY OF POWER ELECTRONICS SYSTEMS

System requirements differ, depending on:

- Power level
- End-user application
- Integration level

Requirements

- Reliability, thermal management, $$$
- Integration and reliability, thermal management, $$
- Compactness and integration, $$-$$$

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WHY WIDE BAND GAP MATERIALS FOR POWER APPLICATIONS?

Intrinsic properties

- High current density, low loss
- High breakdown field
- Fast switching capability

GaN for Power

Benefits at system level

- High efficiency and low thermal loss
- System size and weight reduction
- High operation temperature
- No need for heat sink → Cost & form factor reduction

>2 MV/cm for GaN while 0.3 MV/cm for Silicon

98% efficiency for power supply systems

Smaller dies
Less passive elements compared to Si systems

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Power GaN applications
GaN is mainly used for low voltage. The 600-900V range will be the field of competition for SiC and GaN technologies.

Current status and Yole’s vision for 2025*

* Based on current developmental status.
GAN POWER MARKET SEGMENTATION

- Motor drive
- Consumer
- Telecom & Infrastructure
- Industrial
- Power Supply
- UPS
- PV
- EV/HEV
- Wireless Power
- LiDAR
- Other App
CONSUMER - NEED FOR SPEED - GaN-BASED FAST CHARGERS

Competitive data: GaN vs. Si fast chargers

Price/Power ($/W)

Cased Volume (cc)

Innergie, 86 g
Apple, 193 g
Huawei, 62 g
Aukey, 92 g
Lenovo, 127 g
Ravpower, 105 g
Xiaomi, 82 g
Lenovo, 93 g
Xiaomi, 100 g
Remax, 200 g

Accessory chargers

After-market chargers

Inbox chargers

Players with design wins

140W adaptor for MacBook Pro

Who’s next?

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CONSUMER - FAST CHARGERS: GaN DESIGN WINS

Early adopters of GaN, Anker and RavPower have used GaN since 2018.
CONSUMER - FAST CHARGERS: GaN DESIGN WINS

Non-exhaustive list

In-box chargers

| Brand | Model | Power
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple</td>
<td>16-inch Macbook Pro</td>
<td>140W</td>
</tr>
<tr>
<td>Asus</td>
<td>ProArt StudioBook One</td>
<td>300W</td>
</tr>
<tr>
<td>Dell</td>
<td>Alienware X15 R1</td>
<td>240W</td>
</tr>
</tbody>
</table>

Accessory chargers

| Brand | Model | Power
<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>InfinityLab</td>
<td>65W</td>
<td></td>
</tr>
<tr>
<td>Hyper</td>
<td>100W</td>
<td></td>
</tr>
<tr>
<td>Lenovo</td>
<td>130W</td>
<td></td>
</tr>
<tr>
<td>Samsung</td>
<td>65W</td>
<td></td>
</tr>
<tr>
<td>ZTE</td>
<td>100W</td>
<td></td>
</tr>
<tr>
<td>SlimQ</td>
<td>150W</td>
<td></td>
</tr>
<tr>
<td>Huakesheng</td>
<td>2300W</td>
<td></td>
</tr>
<tr>
<td>On</td>
<td>120W</td>
<td></td>
</tr>
<tr>
<td>OneAl</td>
<td>65W</td>
<td></td>
</tr>
<tr>
<td>Oppo</td>
<td>65W</td>
<td></td>
</tr>
<tr>
<td>Motorola</td>
<td>Edge X30</td>
<td>68W</td>
</tr>
<tr>
<td>Nubia</td>
<td>iQOO 9 Pro</td>
<td>120W</td>
</tr>
<tr>
<td>Nubia</td>
<td>Red Magic 7 Pro</td>
<td>165W</td>
</tr>
<tr>
<td>Realme</td>
<td>GT Neo 3</td>
<td>150W</td>
</tr>
<tr>
<td>Vivo</td>
<td>300W</td>
<td></td>
</tr>
</tbody>
</table>

Which flagship is next?

... and MORE!
## AUTOMOTIVE - xEV POWER ELECTRONICS CONTENT

What power rating and devices could each EV/HEV type use?

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>On-board charger</th>
<th>Main inverter</th>
<th>Boost converter</th>
<th>DC-DC converter</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICE</td>
<td></td>
<td>5-20 kW, Av: 15 kW</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MHEV</td>
<td></td>
<td>IGBT or SiC MOSFET, Av: 70 kW</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>HEV</td>
<td></td>
<td>IGBT or SiC MOSFET, Av: 70 kW</td>
<td>IGBT 30-100 kW, Av: 50 kW</td>
<td>-</td>
</tr>
<tr>
<td>PHEV</td>
<td>IGBT or SiC MOSFET or HV MOSFET or GaN HEMT, possible Av: 10 kW</td>
<td>IGBT or SiC MOSFET, Av: 70-150 kW</td>
<td>IGBT 30-100 kW, Av: 50 kW</td>
<td>-</td>
</tr>
<tr>
<td>BEV</td>
<td></td>
<td>IGBT or SiC MOSFET, Av: 60-600 kW</td>
<td>IGBT or SiC MOSFET, Av: 50 kW</td>
<td>-</td>
</tr>
<tr>
<td>FCEV</td>
<td></td>
<td>IGBT or SiC MOSFET, Av: 40-120 kW</td>
<td>IGBT or SiC MOSFET, Av: 50 kW</td>
<td>-</td>
</tr>
</tbody>
</table>

48V is currently optional depending on the vehicle, but 12V is still the rule, so we can find vehicles with both batteries.

CO₂ emissions

100 %

0 %
# APPLICATION DRIVERS FOR GaN

**Significance of drivers for each application:**

<table>
<thead>
<tr>
<th>Efficiency</th>
<th>Cost</th>
<th>Form factor/weight</th>
<th>Frequency</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumer power supply</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Datacom power supply</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industrial</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Automotive and mobility</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PV</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>UPS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wireless charging</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LiDAR</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

- **Low level**
- **Medium level**
- **High level**

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Power GaN players
A STRONG ACCELERATION SEEN LATELY

A notable increase in GaN activities over the last few years. Beyond $2.5b invested.
GAN VALUE CHAIN

Main players and foundries

- **Foundry**
- **IDM**
- **Fabless**

*Non-exhaustive list*

TSMC can outsource epitaxy to Unikorn, a subsidiary foundry of Epistar.
Power GaN market
GAN POWER DEVICE MARKET TO REACH MORE THAN 2B$ BY 2027!

Yole Développement – Feb 2022

GaN Power Device Market size by market segment

- Automotive
- Energy
- Defense/Aerospace
- Industrial
- Consumer
- Others
- YoY growth (%)

Year: 2020, 2021, 2022, 2023, 2024, 2025, 2026, 2027

Market size in $M:
- $500M
- $1,000M
- $1,500M
- $2,000M
- $2,500M

YoY growth (%):
- 151%
- 138%
- 84%
- 92%
- 64%
- 51%
- 38%
- 35%

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WITH AMERICAN PLAYERS TAKING THE LION’S SHARE UP TO NOW
GAN POWER WAFER SHIPMENT EXPECTED TO REACH 1M+ UNIT BY 2027

Yole Développement – Feb 2022
FEW WORDS ON POWER GAN TECHNOLOGY

Choices for differentiation

**Substrate**
- **Silicon**
  - Most-used substrate and moving from a 6” to 8” platform
  - 72% of market share*
- **Sapphire**
  - As of today, only one player is offering GaN-on-sapphire
  - 28% of market share
- **Bulk GaN**
  - At the R&D level, no volume yet, expected to increase FoM thanks to vertical GaN

*All % values in this slide represent their respective technology market share in 2020

**Technology**
- **D-mode**
  - Mostly used for high-power applications
  - 35% of market share
- **E-mode**
  - Better leverage of low losses
  - 65% of market share

**Voltage**
- **<200V**
  - 25%
- **650V**
  - 75%
- **900V**
  - At the R&D level
- **1200V**
  - Commercially available

**Integration**
- **Discrete**
  - Mostly used for high-power applications, offering flexibility in system design
  - 42%
- **SoC**
  - System-on-Chip preferred for low-power applications and compact designs
  - 29%
- **SiP**
  - System-in-Package mostly used with a silicon driver and available for high-power applications
  - 29%

**Packaging**
- **WLP**
- **Embedded die**
- **SMD**
- **TO/QFN**
  - Mostly outsourced to OSATs

**Topologies**
- **PFC-less**
- **LLC**
- **QR**
- **ACF**
  - Several topologies are offered by GaN providers as a differentiator

Newcomers might use a standard fab process and an innovative topology to differentiate

Different players have multiple choices to differentiate and offer competitive products. Newcomers might focus on different strategies to develop devices for applications targeting mass market. Start-ups most often spend some time on product quality, reliability or advanced packaging…

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LEADING TO A VERY EXCITING ROADMAP IN FRONT OF US FOR POWER GaN!
Status of the Compound Semiconductor Industry 2022
DO NOT HESITATE TO CONTACT US FOR ANY QUESTIONS

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