GaN & SiC Power Electronics
Market Drivers
### GaN & SiC Power Electronics Market Opportunities

<table>
<thead>
<tr>
<th>Device</th>
<th>Application</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>(50V)</td>
<td>Satellite com, radar, Telecom base-stations, RF Power Amplifier for 5G, Industrial heating</td>
<td>GaN on Si</td>
</tr>
<tr>
<td>(&lt;200V)</td>
<td>Wireless charging (AirFuel™ standard), Powering LiDAR systems, DC-DC power conversion</td>
<td>GaN on SiC</td>
</tr>
<tr>
<td>(650V)</td>
<td>Fast chargers for mobile devices, Compact power supplies, On-Board Charger EVs</td>
<td>SiC on SiC</td>
</tr>
<tr>
<td></td>
<td>Diode, MOSFET (650, 1.2-3kV)</td>
<td>Silicon on Silicon</td>
</tr>
</tbody>
</table>

- Satellite com, radar
- Telecom base-stations
- RF Power Amplifier for 5G
- Industrial heating
- Wireless charging (AirFuel™ standard)
- Powering LiDAR systems
- DC-DC power conversion
- Fast chargers for mobile devices
- Compact power supplies
- On-Board Charger EVs
- Solar Inverter
- On-Board Charger
- Main Power Inverter EVs
- Charging piles

Sources: EPC, Wolfspeed
Advantages of SiC Power Electronics Systems

Early adopters:
SiC solar inverter & on-board chargers for PHEV and EV

SiC power electronics systems compared to Si:

- 5x lighter
- 3x smaller
- 25% lower semiconductor losses

Next big opportunity: SiC power inverter in electric vehicles (EVs)
SiC Automotive Market Opportunity is based on the Main Inverter as this consumes > 80% of the wafer area.

<table>
<thead>
<tr>
<th>Component</th>
<th>Power (kW)</th>
<th>Fraction 6” wafer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main inverter</td>
<td>20 – 150</td>
<td>0,1 – 0,5</td>
</tr>
<tr>
<td>DC-DC Converter</td>
<td>1 – 3</td>
<td>&lt;0,01</td>
</tr>
<tr>
<td>On Board Charger (OBC)</td>
<td>5 – 30</td>
<td>0,01</td>
</tr>
<tr>
<td>(Quick) Charging Pole</td>
<td>30 – 300</td>
<td>0,1 – 1</td>
</tr>
</tbody>
</table>

Higher efficiency enables
- Battery size reduction
- Cost savings
- Range extension

Brings 240 V AC energy from wall plug to battery
Brings 1–3 kV DC energy directly from grid to battery

Rough order-of-magnitude estimates
GaN and SiC Device Market Forecast – SiC expected to be largest WBG Power Semiconductor Segment by 2025

- SiC is expected to be the largest Wide Bandgap Power Market, followed by GaN RF and GaN power
- Largest upside is in the SiC Market with Opportunities in the Electric Drive train of EVs
AIXTRON's (MO)VPE—Key Enabling Technology for GaN & SiC
One Platform, two Material Systems, huge Market Opportunities

AIX G5+ C The Tool of Record for GaN on Si HVM

AIX G5 WW
Batch Reactor Productivity with Single Wafer Performance

GaN

SiC
The Enabling Solution

  - Multi-kW systems require large chip areas
  - Market needs HVM solution with high sensitivity to yield, cost and productivity

- **Requirements to (MO)VPE System**
  - Best Deposition Uniformity Control – at wafer level
  - Lowest Cost per wafer
    - High throughput
    - Low cost of consumables B

![AIX G5 WW](AIX G5 WW)
Highest Yields on 150mm – The Planetary Reactor® Principle

Radial symmetric horizontal Planetary Reactor®

- Individual wafer rotation = best material uniformity
- Individual wafer temperature adjustment = wafer level control/correction
- Laminar flow reactor = wide process window
- High growth rate processes using TCS = high throughput

SiC Epitaxy Requirements

<table>
<thead>
<tr>
<th>Device class</th>
<th>Drift layer thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>650V</td>
<td>6 μm</td>
</tr>
<tr>
<td>1200V</td>
<td>11 μm</td>
</tr>
<tr>
<td>1700V</td>
<td>16 μm</td>
</tr>
<tr>
<td>3.3kV</td>
<td>30 μm</td>
</tr>
<tr>
<td>6.5kV</td>
<td>60 μm</td>
</tr>
<tr>
<td>10kV</td>
<td>100 μm</td>
</tr>
<tr>
<td>15kV</td>
<td>150 μm</td>
</tr>
</tbody>
</table>

Different layer thickness for different products
SiC - New Product with Automation increases Tool Throughput

- Based on G5 WW 8x150 mm Planetary Reactor®
- Full Cassette-to-Cassette Wafer Automation (release to beta customers by Q4/18)
- Bay/Chase layout friendly
- Throughput gain enabled by hot loading/unloading of wafers
GaN – AIXTRON is the Tool-of-Record for 150 & 200 mm

- **Fab integration** with 150 & 200 mm wafer cassette-to-cassette handler module
- **Best uniformities** thanks to Planetary concept
- **In-situ Reactor Cleaning** for AlGaN on Si process robustness and yield
- **On-wafer temperature process control** for highest reproducibility and yield

G5+ C dual Planetary reactor module cluster with Cassette-to-Cassette wafer handling

Development of next-gen product ongoing, timing not disclosed yet