Industrial Power Control Business Update
6 May 2021

Dr. Peter Wawer, Division President Industrial Power Control
Dr. Peter Friedrichs, Vice President Silicon Carbide
IPC at a glance

IPC revenue and Segment Result Margin

- **FY20 revenue split by product group**
  - Siemens
  - Midea
  - OMron
  - Rockwell Automation
  - Danfoss
  - Eaton
  - Schneider Electric
  - CRRC
  - Toshiba
  - Vestas
  - Sanyo Electric

**FY20 revenue split by product group**

- **SiC**
- **discrete IGBTs**
- **driver ICs**
- **IPMs**

**Key customers**

- ABB
- ALSTOM
- Bombardier
- Goldwind
- Inovance
- Siemens
- Sungrow
- Toshiba
- Vestas
- Yaskawa

**IPC revenue and Segment Result Margin**

- **CAGR** (FY16-FY20): 7.0%
- **[EUR m]**
  - FY16: 1.072
  - FY17: 1.206
  - FY18: 1.323
  - FY19: 1.418
  - FY20: 1.406
  - H1 FY21: 723

- **IPC revenue**:
  - FY16: 12%
  - FY17: 15%
  - FY18: 19%
  - FY19: 18%
  - FY20: 18%
  - H1 FY21: 17%
## Market outlook for IPC division’s target applications

<table>
<thead>
<tr>
<th>Applications</th>
<th>Market Outlook for CY21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automation and Drives</td>
<td>~30%</td>
</tr>
<tr>
<td></td>
<td>› Industrial Drives recovering in high single digits with demand growing mainly in GC region</td>
</tr>
<tr>
<td>Renewables</td>
<td>~24%</td>
</tr>
<tr>
<td></td>
<td>› Wind: installations forecasted to increase to all-time-high</td>
</tr>
<tr>
<td></td>
<td>› PV: market forecast continuously corrected upward</td>
</tr>
<tr>
<td>Home appliances</td>
<td>~16%</td>
</tr>
<tr>
<td></td>
<td>› Catch-up of delayed purchases and energy efficiency incentive programs will drive growth</td>
</tr>
<tr>
<td>Transportation</td>
<td>~13%</td>
</tr>
<tr>
<td></td>
<td>› Diminished COVID-related travel activities caused further push-out of construction of passenger trains and e-Busses</td>
</tr>
<tr>
<td>Power Infrastructure</td>
<td>~9%</td>
</tr>
<tr>
<td></td>
<td>› Growing demand in EV charging infrastructure, Industrial UPS and energy storage systems</td>
</tr>
<tr>
<td></td>
<td>› Delays in Transmission &amp; Distribution projects</td>
</tr>
<tr>
<td>Others</td>
<td>8%</td>
</tr>
<tr>
<td></td>
<td>› Growth driven by general market recovery</td>
</tr>
</tbody>
</table>

- Industrial Drives recovering in high single digits with demand growing mainly in GC region
- Wind: installations forecasted to increase to all-time-high
- PV: market forecast continuously corrected upward
- Catch-up of delayed purchases and energy efficiency incentive programs will drive growth
- Diminished COVID-related travel activities caused further push-out of construction of passenger trains and e-Busses
- Growing demand in EV charging infrastructure, Industrial UPS and energy storage systems
- Delays in Transmission & Distribution projects
- Growth driven by general market recovery
Clean energy
Infineon will profit from all CO₂ saving measures needed to reach the goals of the Paris Climate Agreement.

For the 1.5°C climate target, global CO₂ emissions need to drop to net zero by 2050.

Source: IRENA, „World Energy Transitions Outlook, 1.5°C, Preview“
Along the energy conversion chain, Infineon develops technologies that are directly linked to megatrends.

- Renewable energies: 8-15%* (GW, PV & Wind installations)
- Transmission & storage: 5-10%* GW, HVDC & FACTS installations
- High voltage supply: 10-15%* GW, battery storage installations
- Energy storage systems: 25-30%* (xEV) unit growth vehicles, 35-40%* (Charging Infrastructure) unit growth charging piles
- Energy conversion: 10-15%* revenue growth IoT HW, 10-15%* revenue growth RU shipments
- Industrial applications: 3-5%* revenue growth motors & drives
- Data centers & 5G: 8-10%* unit growth inverterized appliances
- Smart building: 3-5%* unit growth rolling stock
- Consumer appliances: 10-15%* revenue growth RU shipments
- Electro-mobility: 20-25%* (CAV) unit growth electrified vehicles
- Transport: 8-15%* (CAV) unit growth electrified vehicles

* CAGR 2020 – 2025
Infineon serves all applications in the field of renewable energy

**Onshore**

- Application: Full Converter & Partial/DFIG* converter based wind turbine
- Output: 1 MW – 6 MW
- Power semi content: €2,000 - €3,250 per MW

**Offshore**

- Application: Full Converter based wind turbine
- Output: 3 MW – 14 MW
- Power semi content: €3,250 - €3,500 per MW

**HVDC**

- Application: HVDC - VSC
- Output: 100 MW – 4 GW
- Power semi content: €5,200 - €18,000 per MW

**String inverter**

- Application: residential, commercial and utility-scale PV plants
- Output: 1 kW – 200 kW
- Power semi content: €2,500 – €5,000 per MW

**Central inverter**

- Application: utility-scale PV plants
- Output: 600 kW – 1,250 kW
- Power semi content: €2,000 – €3,000 per MW

* DFIG – Doubly fed induction generator ** HVDC - High-voltage direct current transmission
Renewables growth supported by constantly falling LCOE

Selected Historical Mean Unsubsidized Levelized Cost of Energy Values (LCOE)

› Wind and Solar have become the cheapest energy source

› Battery storage is rapidly gaining competitiveness

We are the #1 semiconductor enabler of renewable energies

Average annual solar PV and wind capacity additions

<table>
<thead>
<tr>
<th>Year</th>
<th>Solar PV</th>
<th>Wind</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011-15</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2016-19</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>2020-25</td>
<td>150</td>
<td>0</td>
</tr>
<tr>
<td>2026-30</td>
<td>300</td>
<td>0</td>
</tr>
</tbody>
</table>


Enabling Technologies

› Reduces system size
› Reduced power losses up to 50% compared to a traditional IGBT

All leading renewable energy players are our customers*

**PV inverter**¹
1) Huawei
2) Sungrow
3) SMA
4) Power Electr.
5) Solar Edge
6) ABB
7) TMEIC
8) Sineng Electric
9) Growatt
10) Ginlong

**Wind**²
1) Vestas
2) SGRE
3) GE
4) Goldwind
5) Enercon
6) Nordex Group
7) Envision
8) Mingyang
9) United Power
10) Suzlon

* Infineon is serving the top-10 of each category but not necessarily as a sole supplier.


Increased lifetime of power products
› Highest reliability and performance
Energy storage is essential to further deploy decentral and renewable energy generation

**Battery storage capacity and share of variable renewables**

![Chart showing battery storage capacity and share of variable renewables for European Union, India, China, and United States.](chart)

**Key drivers**

- **Decentralization** of power generation
- **Peak shaving** of energy generation and energy consumption
- **Limited capacity** and flexibility of today's grids
- **Reduction of standby cost** of fossil power plants

~€3,200 of power semiconductor content per MW of installed energy storage capacity

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2) Infineon estimate
Growing penetration of electric vehicles will drive roll-out of charging infrastructure

<table>
<thead>
<tr>
<th>DC charging system</th>
<th>charging time$^1$</th>
<th>power semi content$^2$</th>
<th>Subunit</th>
</tr>
</thead>
<tbody>
<tr>
<td>350 kW (6 racks of 60 kW each)</td>
<td>7 min</td>
<td>$1,500 - $3,000 Si / SiC-based</td>
<td>A power electronic arrangement build from both active and passive components to convert AC input to dedicated DC output. Often referred to as &quot;module&quot;.</td>
</tr>
<tr>
<td>150 kW (5 racks of 30 kW each)</td>
<td>16 min</td>
<td>$300 - $900 Si / SiC-based</td>
<td></td>
</tr>
<tr>
<td>50 kW (3 racks of 20 kW each)</td>
<td>48 min</td>
<td>$100 - $300 Si / SiC-based</td>
<td></td>
</tr>
<tr>
<td>20 kW (2 racks of 10 kW each)</td>
<td>120 min</td>
<td>$40 - $90 Si / SiC-based</td>
<td></td>
</tr>
</tbody>
</table>

1) Charging time for 200 km  2) Infineon estimates per charging pole  3) Based on or includes content supplied by IHS Markit Automotive: “EV Charging Infrastructure Forecast”. April 2020

Charging infrastructure market; roll-out by rack performance$^3$

- **CAGR$^{(20-25)}$: 32%**
- **2020**
  - Commercial: 1,700 units k
  - Public: 14,800 units k
  - Domestic: 3,800 units k
- **2025e**
  - Total: 18,600 units k
  - Commercial: 2,200 units k
  - Public: 14,800 units k
  - Domestic: 3,600 units k

**Key:**
- **Commercial**
- **Public**
- **Domestic**
Green hydrogen is bound to become an important pillar in decarbonization

Demand scenarios for green hydrogen

- **Cost reduction** - for the electrolyser and renewable energy
- **Massive government support / regulation** – several governments ranging from Chile to China announced hydrogen strategies

Source: Barclays Research Estimates: „European Energy Services, Green H2“, 2021

Production cost of green hydrogen

Source: Hydrogen council: “Hydrogen Insight”
Electrolyser require power semiconductors

2020-30e electrolyser installations (development scenario)

Old technology with much room for improvement

› Cost reduction for the electrolyser – economies of scale in module manufacturing and process technology

› Several private initiatives are pushing H₂ e.g. the “Green Hydrogen Catapult”* targets the deployment of 25 GW through 2026 of renewables-based hydrogen production, with a view to halve the current cost to below $2/kg.

~€2,000 – €3,500 of power semiconductor content per MW of installed electrolyser capacity

Source: Barclays Research Estimates: „European Energy Services, Green H2: 150x bigger in 10 years“, 2021

*Founding partners include: ACWA Power, CWP Renewables, Envision, Iberdrola, Ørsted, Snam, and Yara
Hydrogen as a substitute for fossil energy will become a feasible option

Required hydrogen production cost for breakeven with conventional solutions, with 100 USD/t CO₂e

<table>
<thead>
<tr>
<th>[USD/kg in 2030]</th>
<th>‘In the money’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buses</td>
<td>5.4</td>
</tr>
<tr>
<td>Trains</td>
<td>5.1</td>
</tr>
<tr>
<td>Trucks</td>
<td>2.8</td>
</tr>
<tr>
<td>SUV</td>
<td>4.4</td>
</tr>
<tr>
<td>Mid-sized vehicle</td>
<td>2.3</td>
</tr>
<tr>
<td>Ammonia</td>
<td>2.2</td>
</tr>
<tr>
<td>Refinery</td>
<td>2.2</td>
</tr>
<tr>
<td>Steel</td>
<td>4.6</td>
</tr>
<tr>
<td>Power generation</td>
<td>1.4</td>
</tr>
<tr>
<td>High grade heat</td>
<td>1.5</td>
</tr>
<tr>
<td>Heating</td>
<td>1.2</td>
</tr>
<tr>
<td>Ships</td>
<td>1.0</td>
</tr>
<tr>
<td>Airplanes</td>
<td>1.0</td>
</tr>
<tr>
<td>Diesel</td>
<td>Natural Gas</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>Coal</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>Ship Fuel</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>Kerosene</td>
</tr>
<tr>
<td>Reference technology</td>
<td>Source: Hydrogen council: “Hydrogen Insight”</td>
</tr>
</tbody>
</table>

At ~2 USD/kg Hydrogen becomes competitive in several large applications

In the money

Required hydrogen production cost for breakeven with conventional solutions, with 100 USD/t CO₂e
There are further emerging applications developing which promise a positive environmental contribution and future business.

E-Aviation

E-Marine

Hydrogen

Courtesy: Lilium GmbH

Courtesy: Siemens AG

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Wide band gap materials
SiC MOSFET has reached the tipping point for a variety of applications

Photovoltaic
› reduction of system cost
› reduction of system size

EV charging
› faster charging cycles

IPS/UPS
› higher efficiency,
› reduced total cost of ownership

eMobility
› higher reach per charge
› more compact main inverter

Traction
› lower system cost
› higher seat capacity

Drives
› reduced system size
› reduced total cost of ownership

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Raised forecast - Doubling the revenue in FY21
More than half of the incremental growth contributed by automotive

Industrial and automotive applications driving the growth

- CAGR_{(FY17-FY21e)}: ~55%
- ~100%
- ~200 different CoolSiC™ products
- ~3,000 total active customers including distribution
Strong CoolSiC™ portfolio expansion: by packages and by voltages

### Brodest and best-in-class SiC portfolio

<table>
<thead>
<tr>
<th>Package options</th>
<th>Industrial</th>
<th>Automotive grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>voltages</td>
<td>CoolSiC™ Diode</td>
<td>CoolSiC™ Diode</td>
</tr>
<tr>
<td></td>
<td>CoolSiC™ Hybrid</td>
<td>CoolSiC™ Hybrid</td>
</tr>
<tr>
<td></td>
<td>CoolSiC™ MOSFET</td>
<td>CoolSiC™ MOSFET</td>
</tr>
<tr>
<td>Discrete</td>
<td>Discrete</td>
<td>Discrete</td>
</tr>
<tr>
<td>Module</td>
<td>Module</td>
<td>Module</td>
</tr>
<tr>
<td>IPM</td>
<td>Discrete</td>
<td>Discrete</td>
</tr>
</tbody>
</table>

- **600 V**
- **650 V**
- **1200 V**
- **1700 V**

Continuous expansion of portfolio
Second generation (2\textsuperscript{nd} Gen.) CoolSiC™ Trench MOSFET will increase the addressable market

1\textsuperscript{st} Gen. with lowest losses is the leading technology today

2\textsuperscript{nd} Gen. will expand the lead

› 2\textsuperscript{nd} Gen. CoolSiC™ Trench MOSFET is in advanced development phase

› Enhanced power handling capability by 25% – 30%

› Enhanced safe operating area without compromising quality

› Enabling SiC in further high volume applications

Traditional wire sawing wastes ~3/4 of the raw material

**Current status of SiC device manufacturing**

The supplier cuts the boule into 350 µm thick wafers thereby losing almost half of the material as kerf. The resulting wafers are processed and ground to ~100 µm before finishing them. Thereby losing another half of the material.

→ ~¾ of raw material lost

**Phase 1: boule splitting in volume prod. starting FY22**

We source boules and use our splitting technology to cut it into wafers. The process is kerf-free and therefore losses are minimal. The resulting 350 µm thick wafers are processed according to the current process flow.

→ Raw material losses reduced by half

<table>
<thead>
<tr>
<th>Supply chain</th>
<th>Infineon manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wire sawing</td>
<td>Epitaxy</td>
</tr>
<tr>
<td></td>
<td>Frontside processing</td>
</tr>
<tr>
<td></td>
<td>Grinding</td>
</tr>
<tr>
<td>Boule</td>
<td>Wafer 350 µm</td>
</tr>
<tr>
<td>Backside processing</td>
<td>Wafer dicing</td>
</tr>
</tbody>
</table>

The kerf and grinding consume ~75% of the raw material

<table>
<thead>
<tr>
<th>Supply chain</th>
<th>Infineon manufacturing</th>
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</thead>
<tbody>
<tr>
<td>Boule</td>
<td>Boule splitting</td>
</tr>
<tr>
<td></td>
<td>Epitaxy</td>
</tr>
<tr>
<td></td>
<td>Frontside processing</td>
</tr>
<tr>
<td></td>
<td>Wafer 350 µm</td>
</tr>
<tr>
<td></td>
<td>Grinding</td>
</tr>
<tr>
<td></td>
<td>Backside processing</td>
</tr>
<tr>
<td></td>
<td>Wafer dicing</td>
</tr>
</tbody>
</table>

~2x number of wafers per boule compared to wire sawing
Boule splitting plus wafer twinning or advanced boule splitting quadruples output out of a given boule

**Phase 2: wafer twinning**

The starting material are either wafer from the phase 1 boule splitting process or sourced wafer. The 350 µm thick wafer is processed and instead of grinding it down to 100 µm the lower part is split off and processed again.

→ Combining boule and wafer twinning → minimal raw material losses

**Phase 3: advanced boule splitting**

The advanced boule splitting results in thin wafers that can be processed directly.

→ Most efficient process with minimal raw material losses

<table>
<thead>
<tr>
<th>Wafer 350 µm</th>
<th>Epitaxy</th>
<th>Frontside processing</th>
<th>Wafer twinning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frontside processing</td>
<td>Upper half</td>
<td>Wafer dicing</td>
<td>Lower half</td>
</tr>
<tr>
<td>Backside processing</td>
<td></td>
<td>Epitaxy</td>
<td>Front/Backside processing</td>
</tr>
<tr>
<td>Wafer dicing</td>
<td></td>
<td></td>
<td>Wafer dicing</td>
</tr>
</tbody>
</table>

~2x – 4x number of wafers per boule

<table>
<thead>
<tr>
<th>Boule</th>
<th>Boule splitting</th>
<th>Epitaxy</th>
<th>Front/Backside processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thin wafer</td>
<td></td>
<td></td>
<td>Wafer dicing</td>
</tr>
</tbody>
</table>

~4x number of wafers per boule
Infineon is ready to support and shape the growing SiC device market

**Today**

- Infineon is winning market share
- Leading Infineon technology with 1\textsuperscript{st} Gen. CoolSiC™ Trench MOSFET
- Already broad, fast growing portfolio
- System expertise and customer access

**Strategic projects to support growth**

- 2\textsuperscript{nd} Gen. CoolSiC™ Trench MOSFET
- Cold Split: boule and wafer
- Manufacturing lines already capable of processing 200 mm diameter
- SiC raw wafer and boule supply diversified with multiple providers, e.g. Cree, GTAT and Showa Denko

**SiC device market size**

- Acceleration of revenue growth from 2023 onwards

![Graph showing SiC device market size](image)

Source: Yole Développement: “Compound Semiconductor Quarterly Market Monitor, Module 1, Q1 2021”
GaN technology getting out of a niche
Infineon well positioned offering broad portfolio

Focus applications

- Telecom
- Charger
- Motor control
- Audio
- Server
- Wireless charging

GaN device market size

Exponential growth projected

Source: Yole Développement: "Compound Semiconductor Quarterly Market Monitor, Module 1, Q1 2021"
Part of your life. Part of tomorrow.
Clear leader in discrete IGBTs and IGBT modules; fostering position in IPMs

<table>
<thead>
<tr>
<th>Discrete IGBTs</th>
<th>2019 total market: $1.44bn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infineon</td>
<td>32.5%</td>
</tr>
<tr>
<td>Fuji Electric</td>
<td>11.7%</td>
</tr>
<tr>
<td>ON Semi</td>
<td>7.9%</td>
</tr>
<tr>
<td>Toshiba</td>
<td>6.1%</td>
</tr>
<tr>
<td>Mitsubishi</td>
<td>5.7%</td>
</tr>
<tr>
<td>STMicro</td>
<td>5.4%</td>
</tr>
<tr>
<td>Littelfuse</td>
<td>4.7%</td>
</tr>
<tr>
<td>Renesas</td>
<td>4.5%</td>
</tr>
<tr>
<td>MagnaChip</td>
<td>3.7%</td>
</tr>
<tr>
<td>Hangzhou Silan</td>
<td>2.2%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IPMs</th>
<th>2019 total market: $1.59bn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infineon</td>
<td>32.7%</td>
</tr>
<tr>
<td>Mitsubishi</td>
<td>17.9%</td>
</tr>
<tr>
<td>ON Semi</td>
<td>11.5%</td>
</tr>
<tr>
<td>Fuji Electric</td>
<td>7.8%</td>
</tr>
<tr>
<td>Semikron</td>
<td>7.0%</td>
</tr>
<tr>
<td>ROHM Semi</td>
<td>4.2%</td>
</tr>
<tr>
<td>Sanken Electric</td>
<td>2.9%</td>
</tr>
<tr>
<td>STMicro</td>
<td>2.4%</td>
</tr>
<tr>
<td>Jilin Sino-Micro</td>
<td>0.8%</td>
</tr>
<tr>
<td>Hangzhou Silan</td>
<td>1.1%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IGBT modules(^1)</th>
<th>2019 total market: $3.31bn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infineon</td>
<td>35.6%</td>
</tr>
<tr>
<td>Mitsubishi</td>
<td>11.9%</td>
</tr>
<tr>
<td>Fuji Electric</td>
<td>10.5%</td>
</tr>
<tr>
<td>Semikron</td>
<td>7.3%</td>
</tr>
<tr>
<td>Vincotech</td>
<td>3.5%</td>
</tr>
<tr>
<td>Hitachi</td>
<td>3.1%</td>
</tr>
<tr>
<td>Danfoss</td>
<td>2.5%</td>
</tr>
<tr>
<td>Starpower</td>
<td>2.5%</td>
</tr>
<tr>
<td>Toshiba</td>
<td>2.4%</td>
</tr>
<tr>
<td>ABB Semi</td>
<td>1.8%</td>
</tr>
</tbody>
</table>

\(^1\) Including standard (non-integrated) IGBT modules and power integrated modules (PIMs) / converter inverter brake (CIB) modules

Based on or includes research from Omdia: “Power Semiconductor Market Share Database 2020”. September 2020
Disclaimer

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