Green Industrial Power – Driving decarbonization

GIP call at PCIM
May 11, 2023
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Speakers

Dr. Peter Wawer
Division President GIP

Dr. Peter Friedrichs
Vice President SiC
Our purpose

We empower a world of unlimited Green Energy

Emphasizes our contribution to energy transition

Fosters pride and engages external stakeholders

Sets a mark for the paradigm shift towards rapid growth and highly dynamic applications

The new name for the division demonstrates our transformation.
Decarbonization & Digitalization are the driving forces for

Cutting CO₂ emissions in all sectors

CO₂ emissions rose to 36.8 Gt in 2022 – highest level in history

Increasing electricity demand

IEA, Global energy-related CO₂ emissions by sector, IEA, Paris

* EJ (Exajoule) = 278 TWh
GIP markets accelerate growth – Enabling green energy and driving decarbonization

Key facts

- The acceleration of the energy transition drives GIP markets
- SiC penetration accelerates
- SiC is a key point of differentiation and drives GIP profitability

Renewable Energy, Power Infrastructure, EV charging, Public & Commercial Mobility

Home Appliances, Automation & Drives and others

Infineon analysis

CAGR FY22–27e
Decarbonization of heating

Heat pump

– Heat pumps play a crucial role in the decarbonization of heating. EU objective: 60m heat pumps by 2030 (15m current installed base). This translates to a **22% CAGR**.

– Infineon offers full solution
  Power: Modules, discretes, IPMs Si and SiC
  Control: MCU, sensors
  Usability: HMI
  Connectivity and Security

**Major design-win in Europe:**
Low-power modules using SiC and IGBT8 for different power classes.

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Energy efficient and reliable rail transport is key to reducing the greenhouse gas emissions

Traction application – Key requirements
– Energy efficiency
– High power density
– Long lifetime (> 30 years) with demanding mission profiles

3.3 kV CoolSiC™ MOSFET XHP™ 2
– 10% overall losses reduction
– 10% to 25% system volume reduction
– Robust modules with high cycling capabilities
– Less noise

Enjoy the silence
Business update
Excellent start into FY23
Another record quarter in March with a SR-Margin of 32%

GIP revenue and Segment Result Margin

<table>
<thead>
<tr>
<th>Year</th>
<th>GIP Revenue (€ m)</th>
<th>Segment Result Margin</th>
</tr>
</thead>
<tbody>
<tr>
<td>FY19</td>
<td>1,418</td>
<td>18%</td>
</tr>
<tr>
<td>FY20</td>
<td>1,406</td>
<td>18%</td>
</tr>
<tr>
<td>FY21</td>
<td>1,542</td>
<td>18%</td>
</tr>
<tr>
<td>H1 FY22</td>
<td>812</td>
<td>20%</td>
</tr>
<tr>
<td>H1 FY23</td>
<td>1,058</td>
<td>31%</td>
</tr>
</tbody>
</table>

FY22 revenue split by product group

- Discretes (incl. SiC)
- Modules (incl. SiC)
- Gate driver ICs

Key customers

ABB  alpitronic  ALSTOM  Bloomenergy  CRRC  GOLDWIND  INOVANCE  LG  Midea
OMRON  Rockwell Automation  Schneider Electric  SEMIKRON DANFOSS  SIEMENS  SMA  SUNGROW  Vestas  YASKAWA
Despite weak macro sentiment, GIP market outlook remains positive. Strong demand in decarbonization related applications

### Applications

<table>
<thead>
<tr>
<th>% of FY22 segment revenue</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>~35%</td>
<td>Automation and Drives</td>
</tr>
<tr>
<td>~26%</td>
<td>Renewable Energy Generation</td>
</tr>
<tr>
<td>~10%</td>
<td>Power Infrastructure</td>
</tr>
<tr>
<td>~17%</td>
<td>Home Appliance</td>
</tr>
<tr>
<td>~5%</td>
<td>Transportation</td>
</tr>
<tr>
<td>~7%</td>
<td>Others</td>
</tr>
</tbody>
</table>

### Market Outlook for CY23

- Analysts expect market pullback in 2H/2023 due to decline in demand, but no contraction due to ongoing energy transition and energy efficiency trends
- Customers see still strong demand overall, for China demand seems to slow down (increased stock levels)

- Growth rates remain strong for global PV installations (43% YoY); demand for green hydrogen boost outlook
- Wind project delays in China pushed demand from 2022 to 2023 (51% YoY growth of global wind installations), project push outs in Europe into 2024/2025 impair growth in 2023

- Growth in EV charging infrastructure is expected to remain strong supported by government push programs
- Further growth of ESS (34% YoY) and T&D required to capture renewable energy generated

- Overall market is weak, semiconductor demand more stable in areas linked to progressing inverterization
- Residential AirCon demand slowed down, China government measures expected to induce stabilization in 2H/2023; heat pump demand remains strong

- Strong growth opportunities for CAV and OBC (electrification)
- Traction: growth for locomotives & metro to stay flat, demand for high-speed trains still weak, but slightly ramps

- Long-term positive outlook driven by general trend of electrification in emerging applications (e.g. e-aviation, e-marine)
Wide bandgap strategy
The benefits of using WBG are evident in a variety of end applications – thus contributing to a greener future.

**Industrial drive**
- Precise control saving energy
- Infinitum’s Air Core uses 66% less copper than traditional motors
- Powered with CoolSiC™ MOSFETs

**Electric car**
- Increasing power density – OBC
- SiC

**Mobile charger**
- Saving weight and energy
- GaN

<table>
<thead>
<tr>
<th>Technology</th>
<th>Energy Savings</th>
<th>Size &amp; Weight</th>
<th>CO₂ Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiC</td>
<td>10%</td>
<td>50%</td>
<td>30%</td>
</tr>
<tr>
<td>SiC</td>
<td>2 kW/L 2020</td>
<td>4 kW/L 2024</td>
<td>&gt;6 kW/L &gt; 2025</td>
</tr>
<tr>
<td>GaN</td>
<td>&gt;30%</td>
<td>2x</td>
<td>20%</td>
</tr>
<tr>
<td>GaN</td>
<td>&gt; &gt;30% energy savings</td>
<td>2x less size &amp; weight</td>
<td>20% lower system cost</td>
</tr>
</tbody>
</table>
SiC momentum further accelerating: Significant new design-wins in auto, continuous leadership in industrial applications

Most recent automotive SiC design-wins

- Stellantis
- Fiat
- Chrysler
- RAM
- US OEM
- Genesis

More than 3,600 active customers being served

In addition, ~20 OEMs and ~10 Tier-1s already won

Most recent industrial SiC design-wins

- ChargePoint
- Bloom Energy
- Delta
- SolarEdge
Chargepoint will become one of our leading customers in the fast growing EV Charger market

EV charging is an attractive business opportunity

Power device market value for EV DC chargers

- 20% CAGR 22 – 28

- Significant CRA signed for EASY 3B SiC-modules
- Chargepoint runs an EV charging network with an integrated portfolio of hardware, cloud services and support

Yole, DC Charging for Automotive 2023
Overview of key investment highlights

Strengthening GaN portfolio, reinforcing global leadership in Power Systems

Addressing fast-growth applications with highly complementary strengths in IP, application understanding, customer access and project pipeline

Leadership in Power Systems through mastery of all relevant power technologies – Si, SiC, GaN

Significant roadmap acceleration through unmatched R&D resources and application expertise
Undisputed power systems leadership mastering all three key materials

Reliable multi sourcing of raw materials
World-scale fabs

Controller
Driver IC
Power switch

Software + Algorithms

Leadership in Power Systems across all materials and technologies

Silicon
Diode – MOSFET – IGBT – Driver – Controller

Silicon carbide
Diode – MOSFET

Gallium nitride
HEMT – Driver
Infineon leveraging Si leadership, strengthening position in wide bandgap

Market size (2022 vs. 2028)

- Different applications require different solutions
- Infineon offers the broadest portfolio in silicon, silicon carbide and gallium nitride
- Leadership in Power Systems across all materials and technologies

The boxes’ area represents 2022 (solid) and 2028 (shaded) market revenues; Yole Intelligence: Compound Semiconductor Market Monitor-Module 1 Q1 2023.
Expanding our SiC substrate supplier base

Well diversified regional supply

- Resilient substrate sourcing from Europe, USA, Japan and China

- New supply contract with SICC and TanKeBlue from China adding to Resonac, Coherent and Wolfspeed

- 5 material supply contracts in place

- Further suppliers qualified or in qualification

- Contracts cover boules and wafers

- Roadmap for 200mm transition

Price quotation per SiC bare wafer (150 mm)

Significant delta between high- and low-price suppliers, low-price suppliers with excellent performance

Infineon secured sufficient wafer supply for planned growth

Pricing gets competitive
Trench vs. Planar
most effective area utilization enabled by Trench

Classical planar MOSFET
Due to critical dimensions in lateral direction, planar MOSFETs come along with a lot of non-used area for current flow ➔ shrink limited

Infineon’s superior trench design
Trench allows rigid quality controls (electric stress testing) selecting devices with undetected defects

Major cost disadvantage in addition to SiC specific drawbacks of planar concepts, history in silicon proved trench as long-term winner

Infineon’s device with performance benchmark and outstanding stability ➔ not a single failure in the field in a wide range of applications

Trench needs less wafer surface.
The gap will widen, better shrink potential in trench.
Reliability is building the fundament for every power-device development of Infineon

Extrinsics can be regarded as localized oxide thinning

- Extrinsics lead to early failures ($\beta < 1$)
- Screening improves the use life time period ($\beta = 1$) and reduces the quantity of early field failures
- SiC has a higher extrinsic failure probability compared to Si
Reliability is building the fundament for every power-device development of Infineon

Marathon test to setup the model

A straightforward electrical method to determine screening capability of gate-oxide extrinsics in arbitrary, commercially available SiC MOSFETs

Gate-oxide reliability and failure-rate reduction of industrial SiC MOSFETs
Defect Density Screening made by Infineon: Keeping the Promise of low FiT-Rates\(^1\)

Potential Field Failures based on 100,000 sold cars

- Valid for base material but higher defect density in planar vs. trench (due to add. horizontal plane)
- Same defect density level assumed
- Worst case boundary conditions used
- \(V_{GS} = 18\ \text{V} \); \(T_J = 150^\circ\text{C} \); 8,000 h use life (50% duty cycle)
- Package: HybridPACK™ Drive assembled with 24 SiCMOS

The FiT rate after voltage screening (FiT\(_{post,scr}\)) is then defined as the original FiT rate at the end of processing (FiT\(_{EoP}\)) divided by the failure reduction factor \(H_{scr}\):

\[
\text{FiT}_{post,scr} = \frac{\text{FiT}_{EoP}}{H_{scr}}
\]

1) FiT = Failure in Time (1bn hours)

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Defect Density Screening made by Infineon: Keeping the Promise of low FIT-Rates

Gate-oxide thickness optimization

Planar

<table>
<thead>
<tr>
<th>FIT</th>
<th>PPM</th>
</tr>
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<tbody>
<tr>
<td>0.6</td>
<td>4.8</td>
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Trench

<table>
<thead>
<tr>
<th>FIT</th>
<th>PPM</th>
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<tbody>
<tr>
<td>0.06</td>
<td>0.48</td>
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14.4 115.2

CoolSiC™ G2
Superior trench technology drives sustainable competitiveness in cost and performance

Infineon’s trench roadmap

Reduction of the resistance and shrink of the device go hand in hand
.XT interconnection for discretes solves thermal challenges in small form factor ➔ smaller chips require innovative assembly technologies

Standard interconnection widely used in discrete package

Standard soldering

CoolSiC™ chip

Package leadframe (Cu)

(a)

SiC chip

solder

package leadframe

(b)

Standard soldering

Diffusion soldering

CoolSiC™ chip

Package leadframe (Cu)

Elimination of solder joint drawbacks by diffusion soldering

Enhanced thermal performance in small form factor

Max \( R_{th} \)

0.66 K/W

25% reduction

0.50 K/W

Standard soldering

.XT

Max \( Z_{th} \) @ 1 ms

0.23 K/W

45% reduction

0.15 K/W

Standard soldering

.XT
High performance ceramics for modules – driven by assessment of the actual system pain

Impact of new ceramics on system performance:
- Minimization of the cavity between module and heat sink enabled by superior ceramics allows much thinner thermal grease layers ➔ in total significant better thermal performance
- Chip power handling capability increased by 30% for typical applications

Impact of Infineon ceramics on total thermal resistance

Significantly better cavity situation and superior thermal conductivity
Cold split successfully established in production environment, roll-out to Kulim in progress

Laser based SiC splitting as important productivity lever

Cold split

Wire sawing
30% market share target in SiC by end of decade underpinned by significant capacity expansion

Well positioned for strong SiC market growth

- Revenue growth of >60% in FY23
- Ramp in Villach on schedule
- Construction in Kulim according to plan.
  - Production will start in H2 2024
  - Setup of cold split production in existing facilities in Kulim
  - Start of volume production in H2 2024
- Training of Kulim staff in Villach/Dresden has started

Infineon is executing

We rock the ramp
Questions & answers