Industrial Power Control Business Update

Dr. Peter Wawer
Division President Industrial Power Control

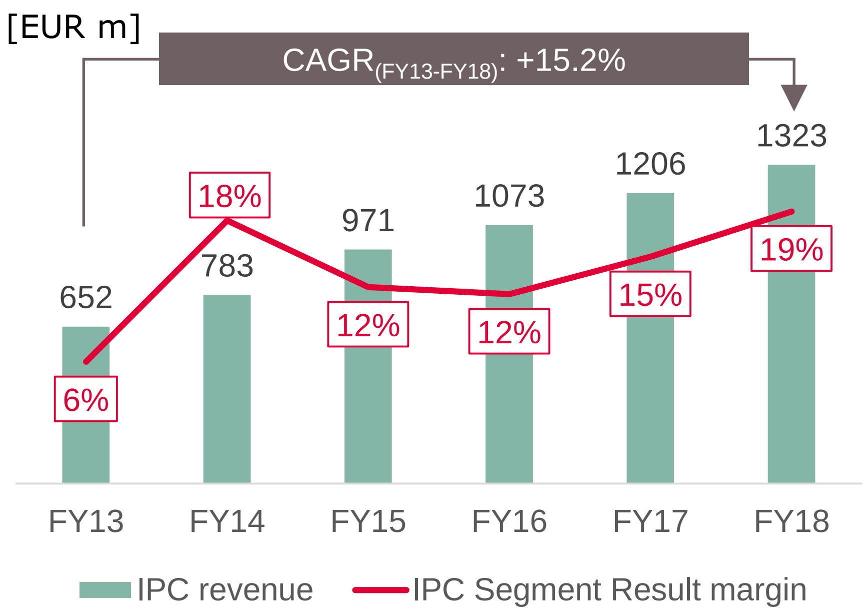
Dr. Peter Friedrichs
Senior Director Silicon Carbide Technology

PCIM, Nuremberg, 8 May 2019

Agenda

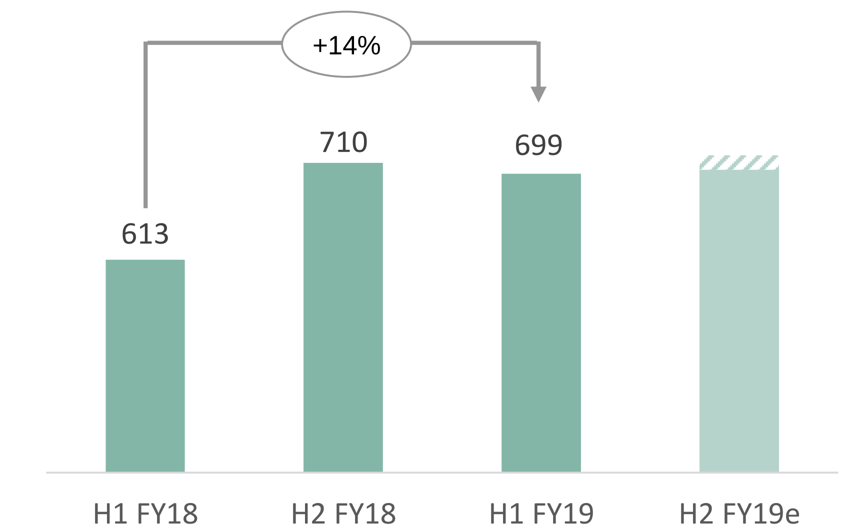
Q2 FY19 results and outlook

IPC revenue and Segment Result margin



- Above group-average revenue growth due to strong regional presence, growth in strategic target applications, and portfolio enhancement
- Segment Result margin improved due to product portfolio optimization and manufacturing landscape restructuring

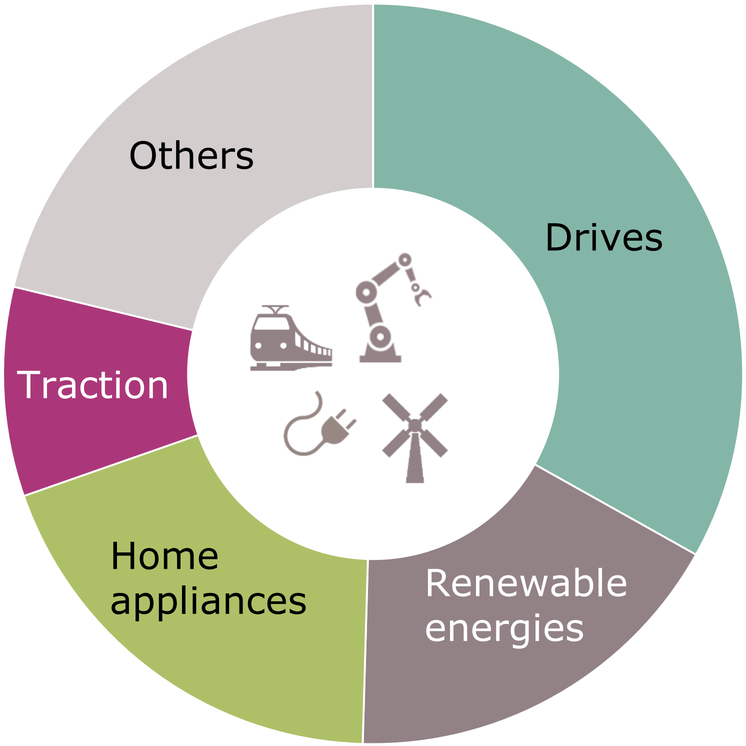
IPC half-year revenue development



- H1 FY19 showed strong y-y growth
- H2 FY19 expected to be about flat y-y
- Revenue in H2 FY19 driven by
  - traction and infrastructure, especially in China
  - home appliances
  - renewables, both wind and solar

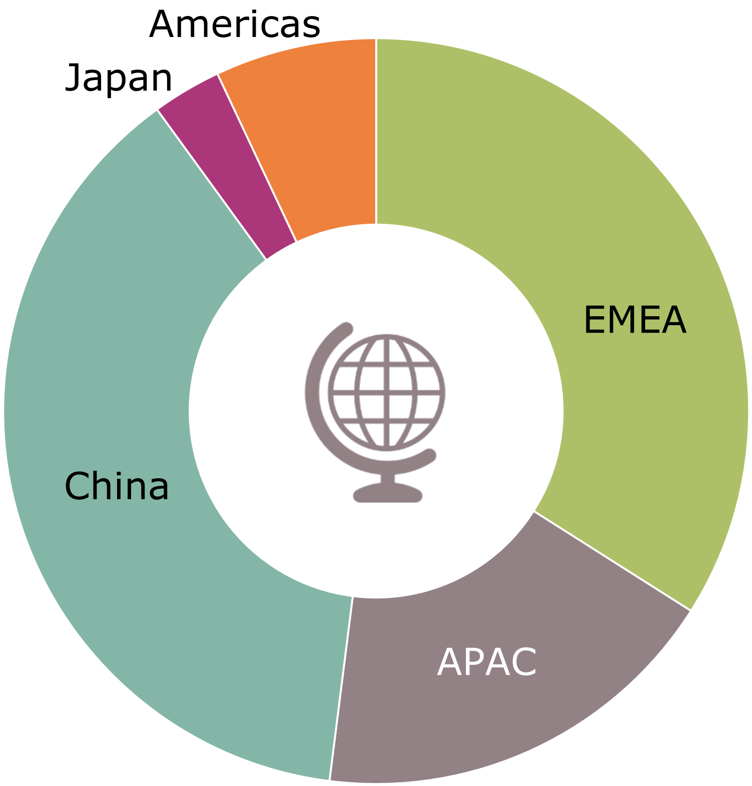
IPC at a glance: well-balanced portfolio of applications; China represents ~1/3 of sales

IPC FY18 revenue by application

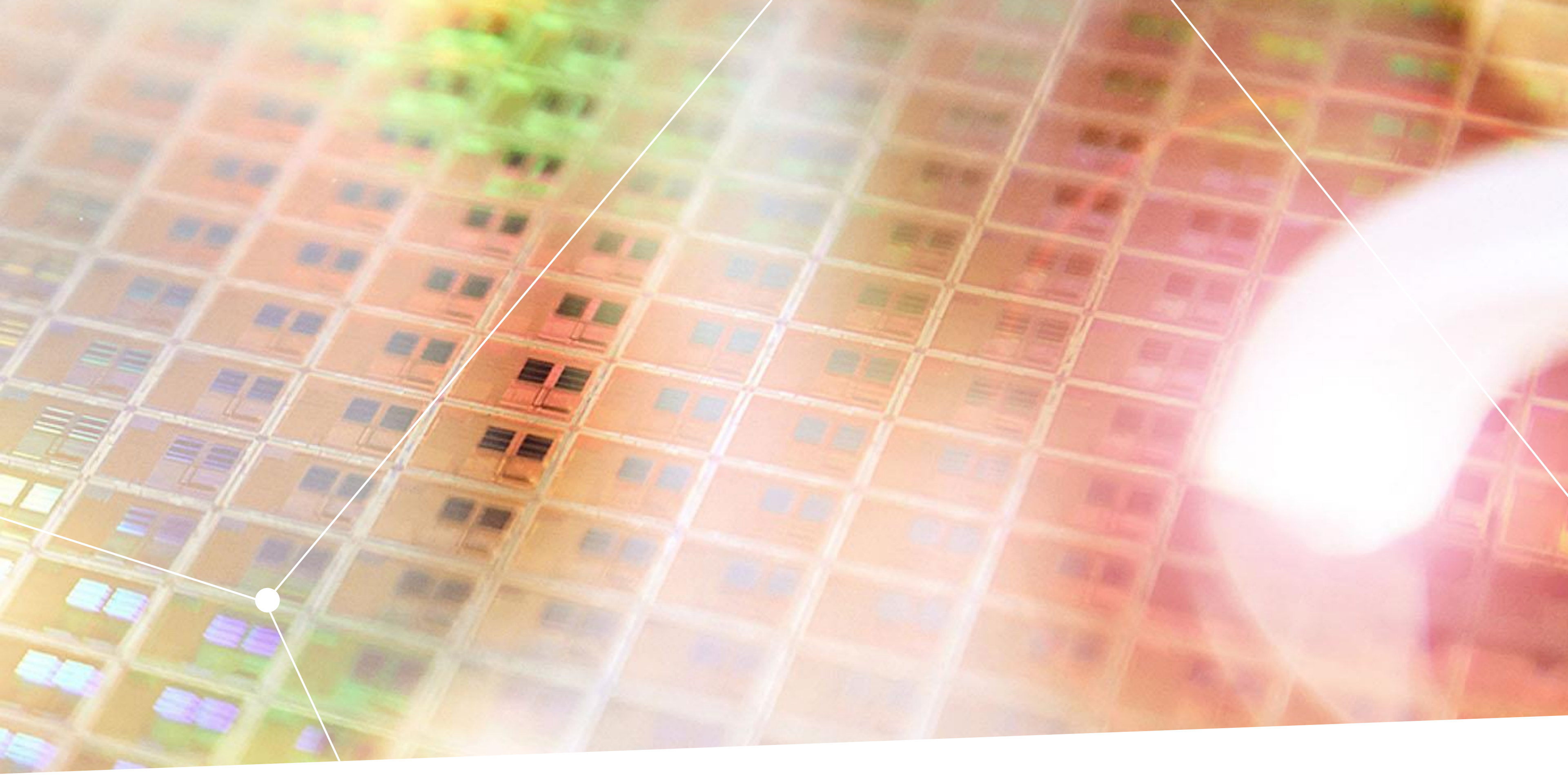


- Distribution share: ~40%

IPC FY18 revenue by region



- US$ exposure: ~30%



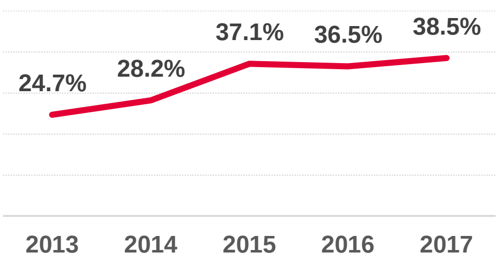
Infineon – the leading player in power semiconductors

While market shares in some IGBT markets are difficult to increase IPMs offer room to grow

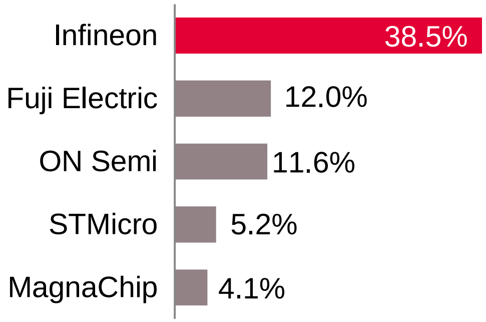
Discrete IGBTs

total market in 2017: $1.10bn

Market share development



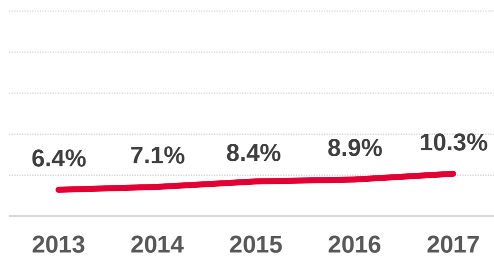
2017 market share



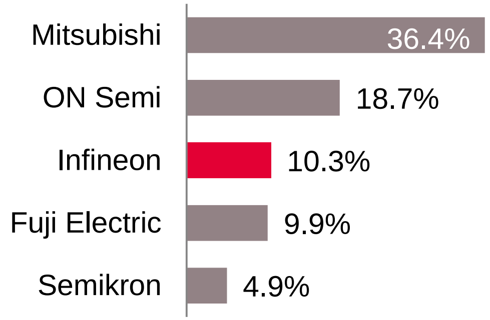
IPMs

total market in 2017: $1.57bn

Market share development



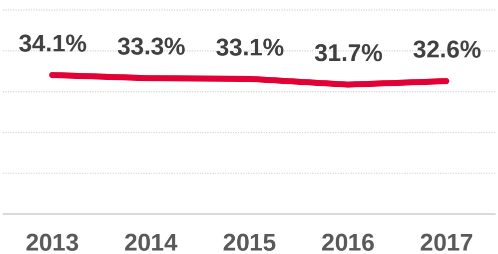
2017 market share



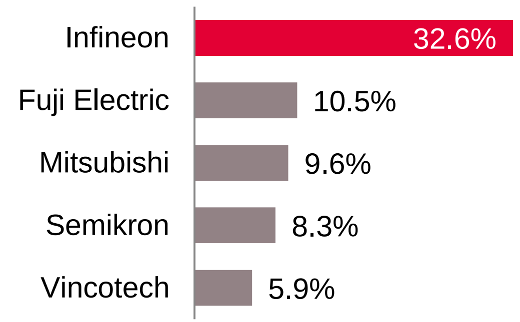
IGBT modules*

total market in 2017: $2.63bn

Market share development

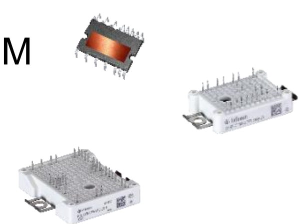
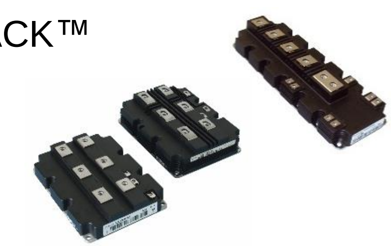


2017 market share



* Including standard (non-integrated) IGBT modules and power integrated modules (PIMs) / converter inverter brake (CIB) modules.
Source: Based on or includes content supplied by IHS Markit, Technology Group, "Power Semiconductor Market Share Database 2017", September 2018.

Due to the extensive power module portfolio Infineon can address the whole range of drives applications

	Servo drives	Low-power drives*	Mid- and high-power drives
	370 W – 75 kW	370 W – 500 kW	500 kW – 10 MW
Requirements	› high positioning accuracy › fast response with no overshoot › high reliability	› performance and reliability › safety features › good price/performance ratio	› safety › durability › high reliability and low downtime
Key applications	› robotics › material handling › machine tools 	› pumps and fans › process automation › cranes › marine drives 	› oil & gas industry › chemical industry (e.g. air compressors) › cement mills 
Infineon products	› CIPOS™ IPM › Easy 1B › Easy 2B 	› iMOTION™ › CIPOS™ IPM › EasyPack › EconoPACK™ 	› PrimePACK™ › IHM › IHV 

*Low-power drives include compact drives, standard drives, premium drives and brushed DC drives.

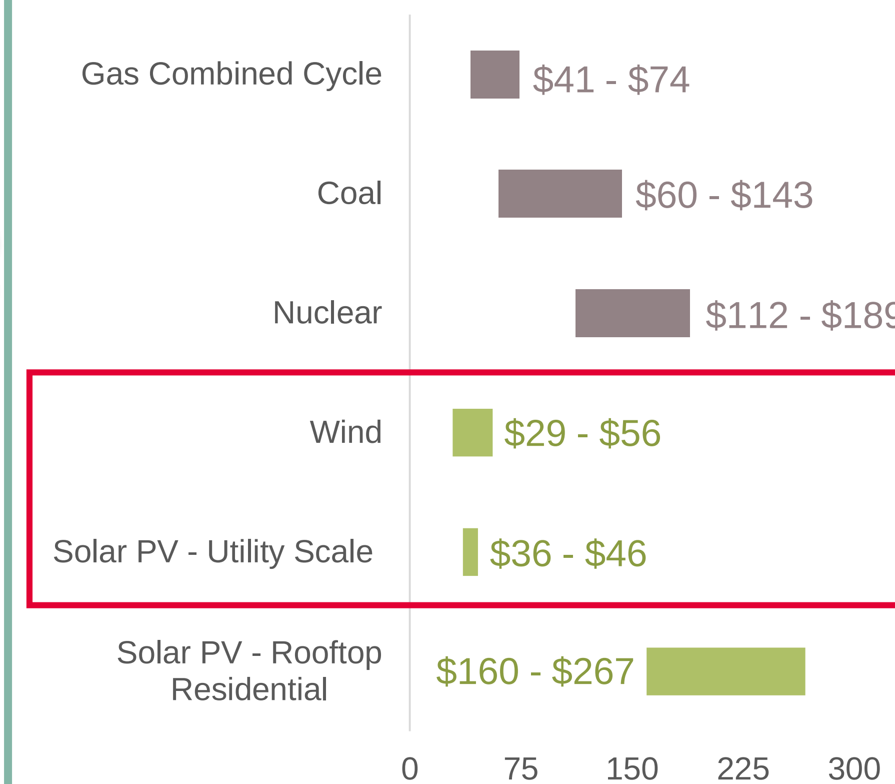
Already today, renewables achieve lower production costs than conventional power plants

Solar provide competitive electricity cost already today

Legend:[1]

- At grid parity
- Close to grid parity (< 5%)
- Not yet near grid parity

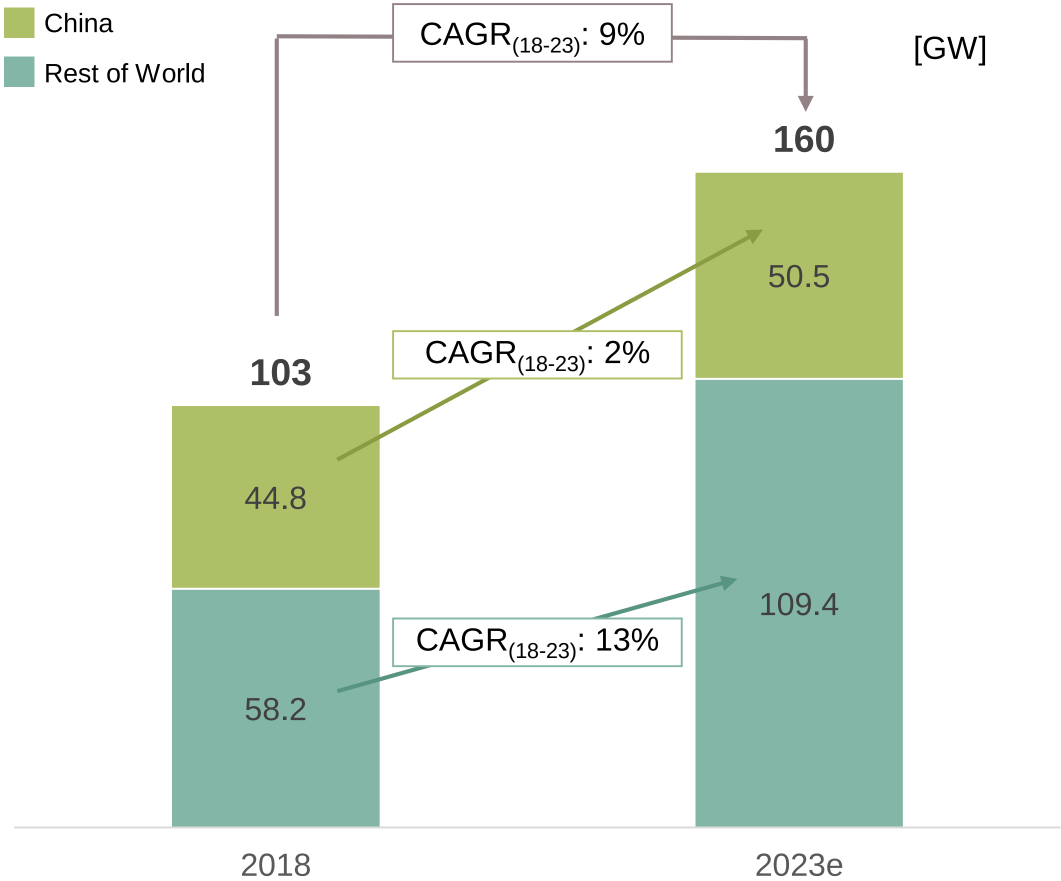
Overview: levelized cost of energy[2]



1) Financial Times, "Chinese solar industry starts to hit grid parity", April 2019, referring to Citigroup research
2) Lazard, "Levelized Cost of Energy Analysis – Version 12.0", November 2018; unsubsidized analysis

Infineon is a key player in the PV market providing solutions to the leading inverter manufacturers

Global installed PV capacity[1]



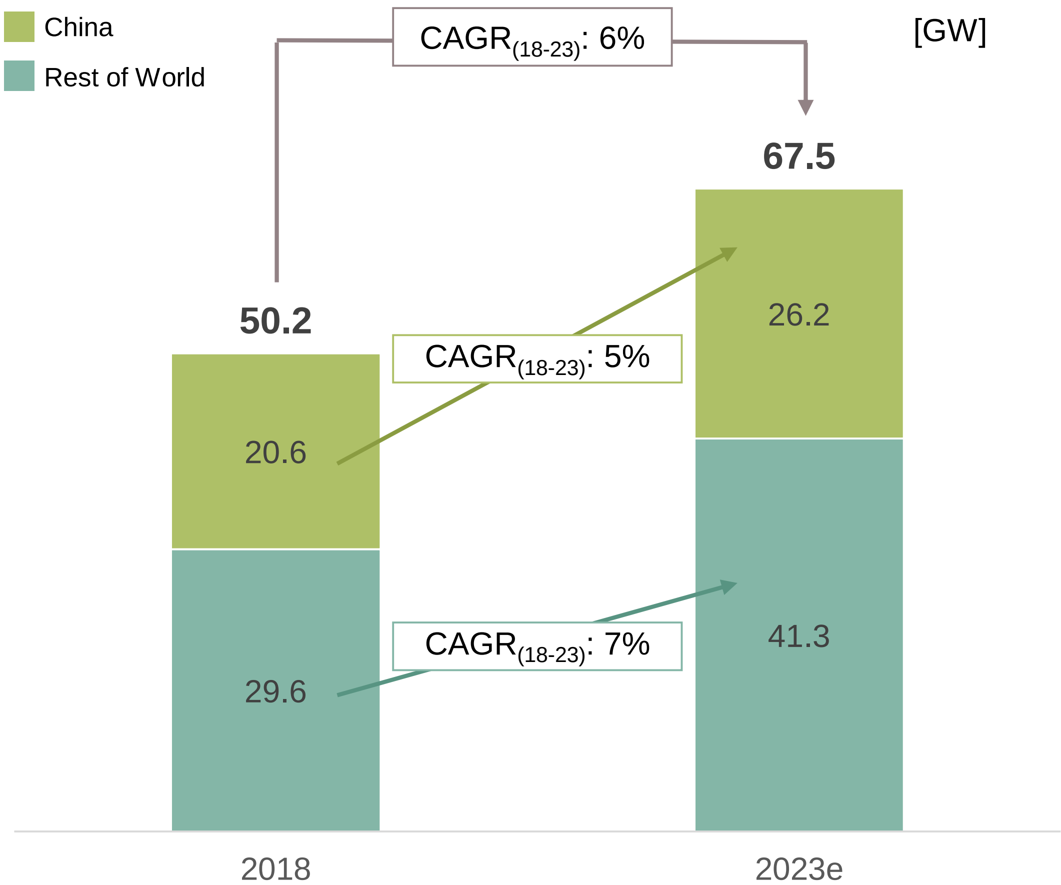
Infineon is present at top-10* inverter manufacturers (2017)[2]

1 | Huawei ✓
2 | Sungrow ✓
3 | SMA ✓
4 | TBEA Sunoasis ✓
5 | Wuxi Sineng ✓
6 | ABB ✓
7 | Kstar ✓
8 | Goodwe ✓
9 | Growatt ✓
10 | Power Electronics ✓

* Infineon is serving the top-10 but not necessarily as a sole supplier.
1) based on or includes content supplied by IHS Markit, Technology Group, "PV Installations Tracker – Q1 2019"; March 2019; including off-grid
2) by shipped capacity in MW: based on or includes content supplied by IHS Markit, Technology Group, "PV Inverter Market Tracker – Q4 2018"; December 2018

Infineon is the leading power semiconductor supplier for the wind turbine industry

Global installed wind capacity[1]



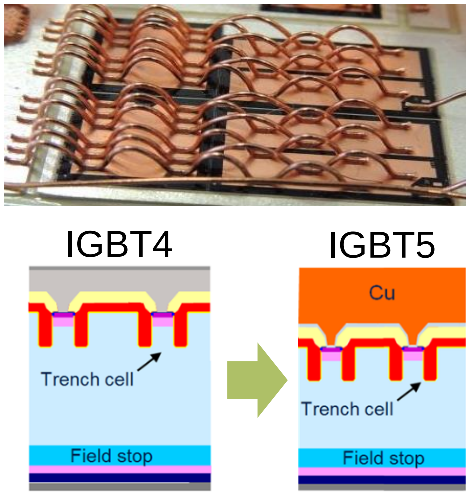
Infineon is present at top-10* wind turbine manufacturers (2018)[2]

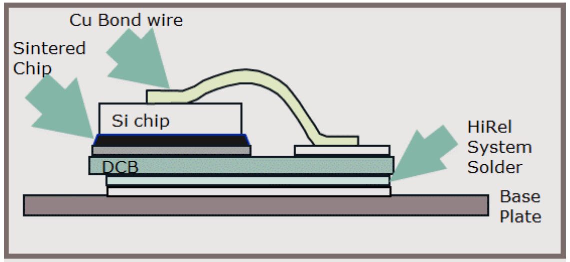
1	Vestas	✓
2	Goldwind	✓
3	Siemens Gamesa	✓
4	GE	✓
5	Envision	✓
6	Enercon	✓
7	Nordex	✓
8	Mingyang	✓
9	Sewind	✓
10	United Power	✓

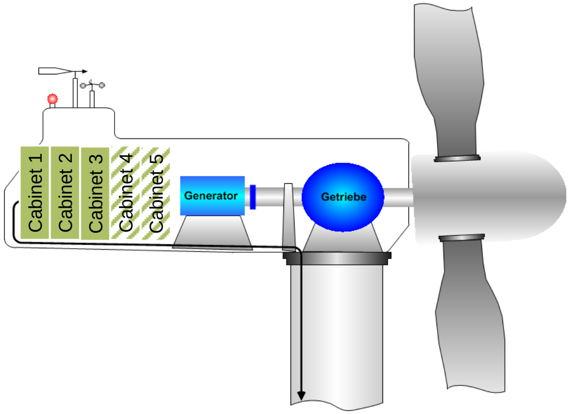
* Infineon is serving the top-10 but not necessarily as a sole supplier.
1) Wood Mackenzie Power & Renewables, "Market Outlook Update", March 2019
2) by shipped capacity in MW: Wood Mackenzie, Power & Renewables, "Historic wind turbine OEM market share", March 2019

Being at the heart of wind turbines: PrimePACK™ with IGBT5 and .XT technology

IGBT5 chip technology	.XT joining technology	PrimePACK™ module

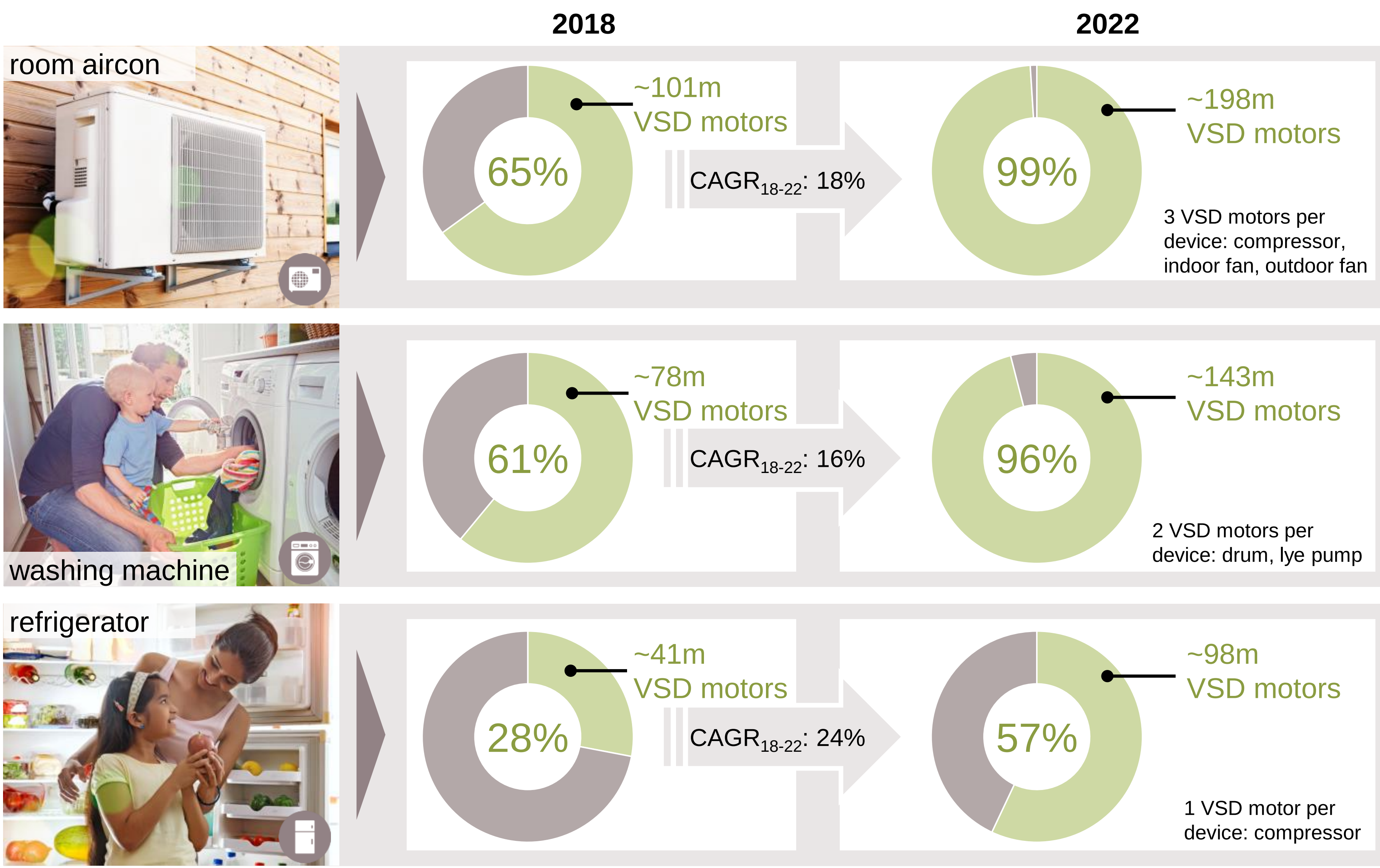






- high reliability and robustness, esp. for off-shore wind turbines
- long lifetime
- power cycling capabilities increased by factor of 10
- high power density: using IGBT5 and .XT power modules, with the same number of cabinets about 30% more electrical power increase feasible
- excellent system efficiency

Inverterization is driving the global demand for power semiconductors for the next years



Note: Based on or includes content supplied by IHS Markit, Technology Group, “Home Appliance Database: All Devices & Associated Electronics”, May 2018

What comes next? Examples for mid- to long-term structural growth opportunities

Emerging fields

EV Charging

Fuel Cell in Traction

Courtesy: Alstom

Robotics

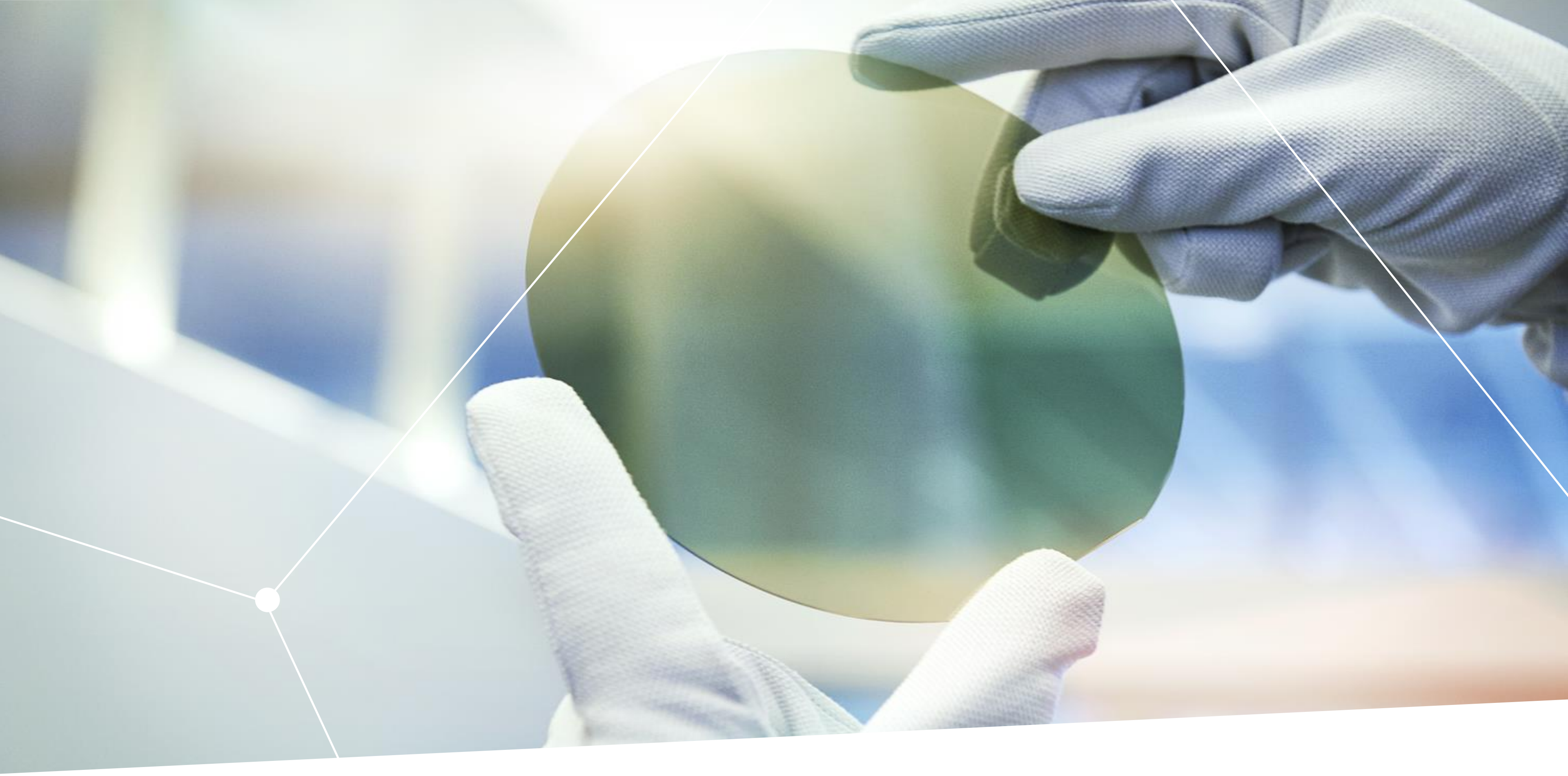
eDelivery vehicles

Energy Storage

Courtesy: McKinsey

eAviation

Courtesy: Lilium GmbH

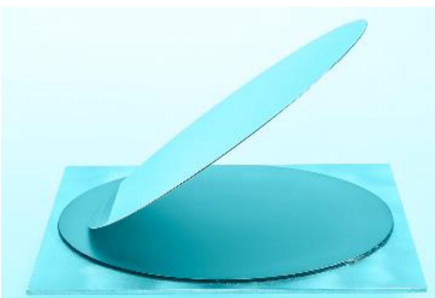


How Infineon grabs the lion’s share in SiC for industrial applications

Four key success factors: Infineon well positioned to defend its leadership in power semis also in SiC

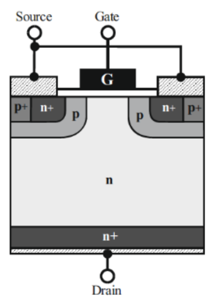
1.) Substrate

SILTECTRA

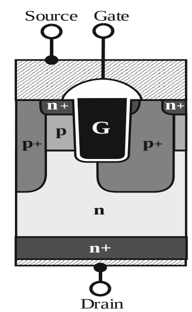


2.) Device

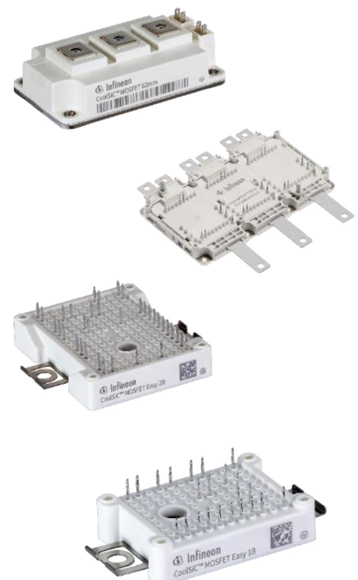
planar



trench



3.) Module



4.) System

Courtesy: Kaco and pv magazine

2008	2011	2016	2018
100 kW	50 kW	50 kW	125 kW
1129 kg	151 kg	70 kg	77 kg
			SiC

- multi-year SiC wafer supply agreement
- acquisition of Siltectra

- trench-based architecture
- 150 mm conversion completed

- expertise from industrial heritage
- high-volume manufacturing

- deep application and system know-how
- Product-to-System

SiC MOSFET has passed or will soon reach the tipping point of various applications

Photovoltaic
- reduction of system cost
- reduction of system size

EV charging
- faster charging cycles

IPS
- higher efficiency,
- reduced total cost of ownership

tipping point reached

eMobility
- higher reach per charge
- more compact main inverter

Traction
- lower system cost
- higher seat capacity

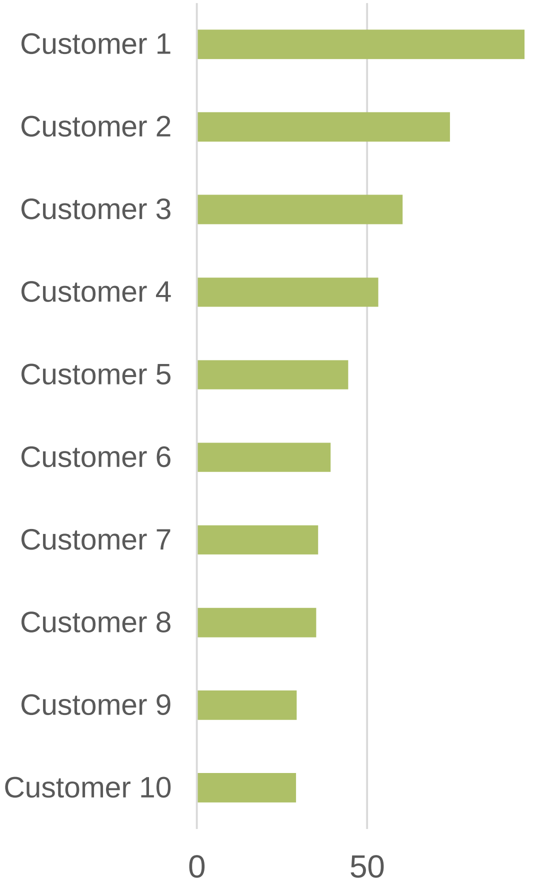
Drives
- reduced system size
- reduced total cost of ownership

future tipping points

Infineon's SiC revenue opportunity for industrial applications amounts to more than €1.2bn

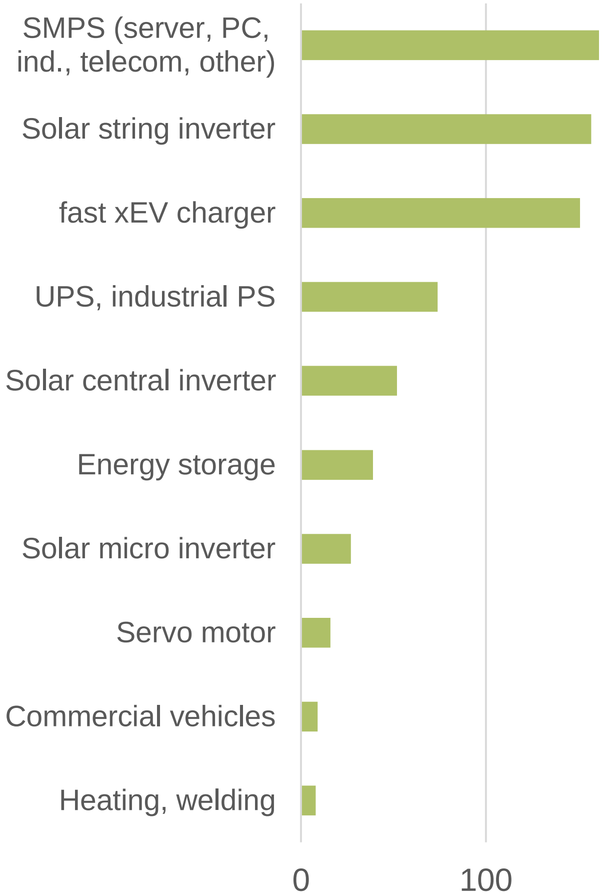
SiC revenue potential by customer

[EUR m]

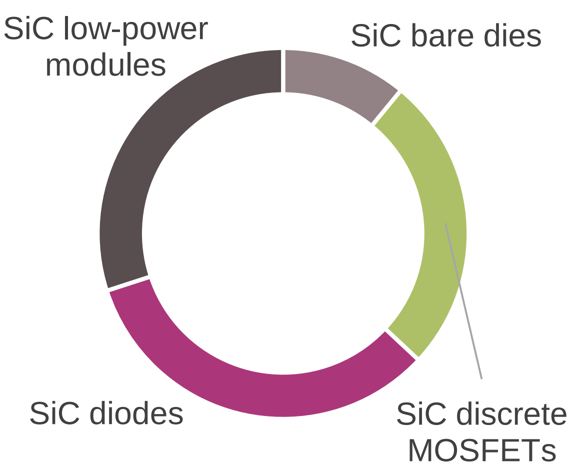


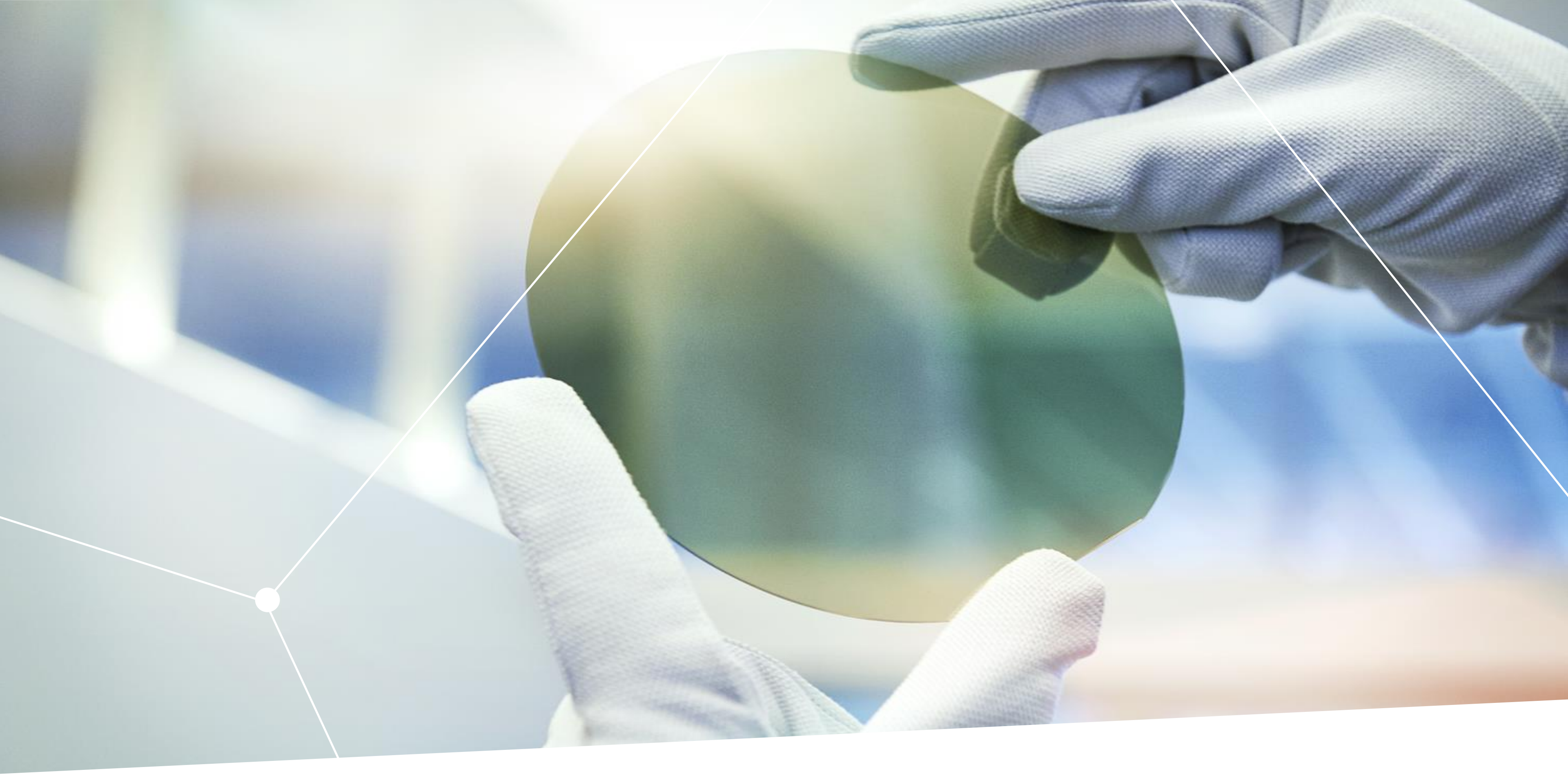
SiC revenue potential by application

[EUR m]



SiC revenue potential by product type





Planar versus trench: Advantages and challenges of next-generation SiC cell concepts

2019-05-08

Multiple electrical characteristics of a SiC MOSFET have to be balanced

Performance

static behavior based on
- resistance x area (R_{on} x A)
- and more

dynamic behavior based on
- total loss energy (E_{tot})
- device capacitances (C's)
- gate and recovery charges (Q,s)
- and more

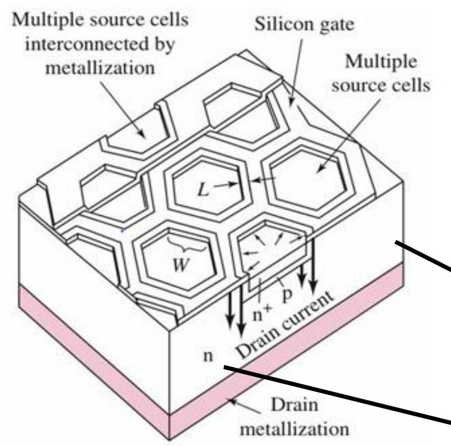
Robustness and manufacturing stability

- high threshold voltage
- high gate oxide reliability
- short circuit capability (~3µs)
- V_{GS_on} 15 V .. 18 V
- stable manufacturing process
- and more

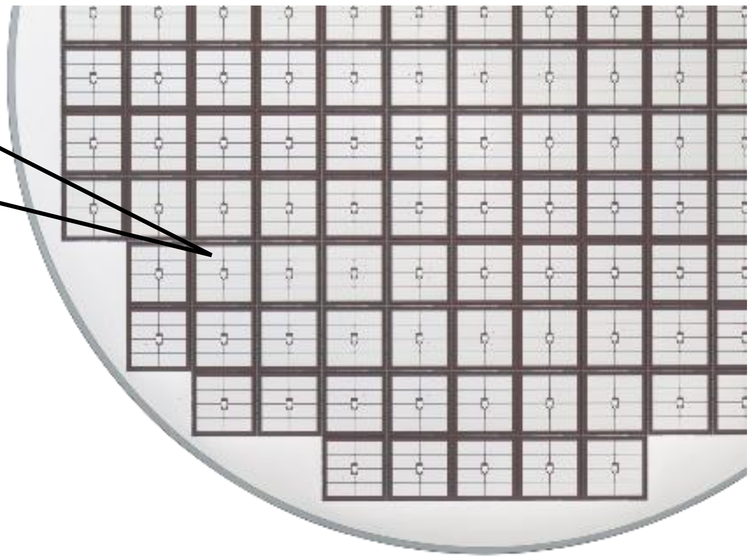
Power transistors are a parallel connection of multiple cells

Power Transistor - MOSFET

Structure



- Cell width is a key indicator for high material utilization
- Concept with best volume utilization favored

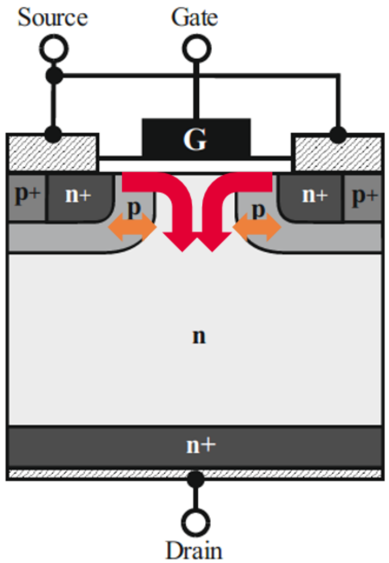


A single power MOSFET may contain several thousands parallel cells.

These individual cells are paralleled to form large-area devices.

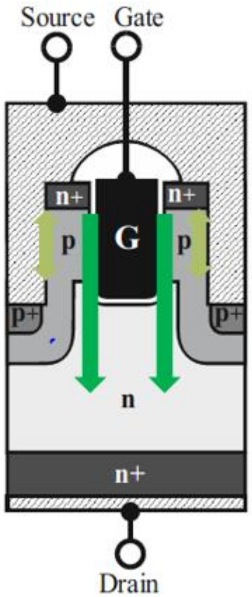
General MOSFET considerations – planar versus trench cell concept

Planar



- Current flow needs to change direction
  - ➔ certain space required to avoid crowding
- Critical dimension channel length in lateral direction

Trench

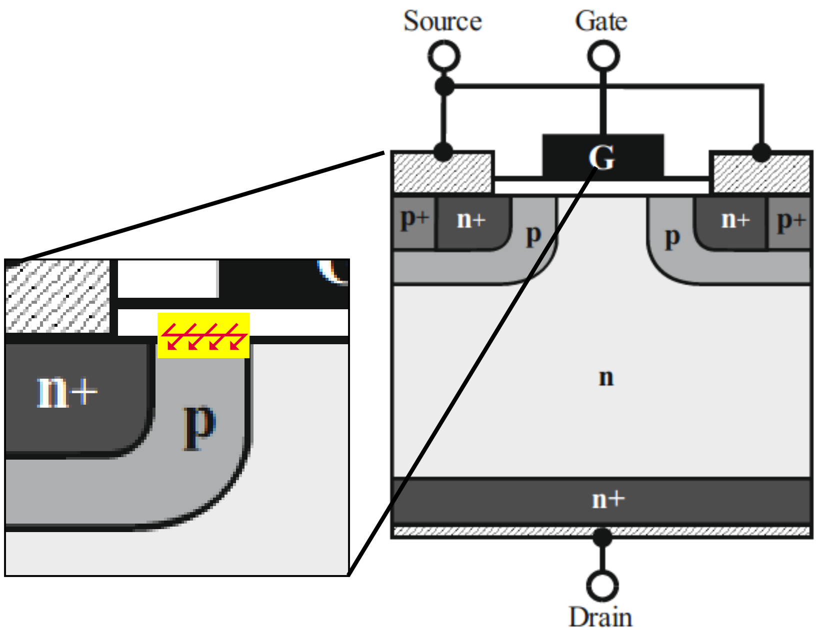


- Current flow directly vertical
- Critical dimension channel length in vertical direction

During the semiconductor manufacturing process
vertical dimensions can be better controlled than lateral ones

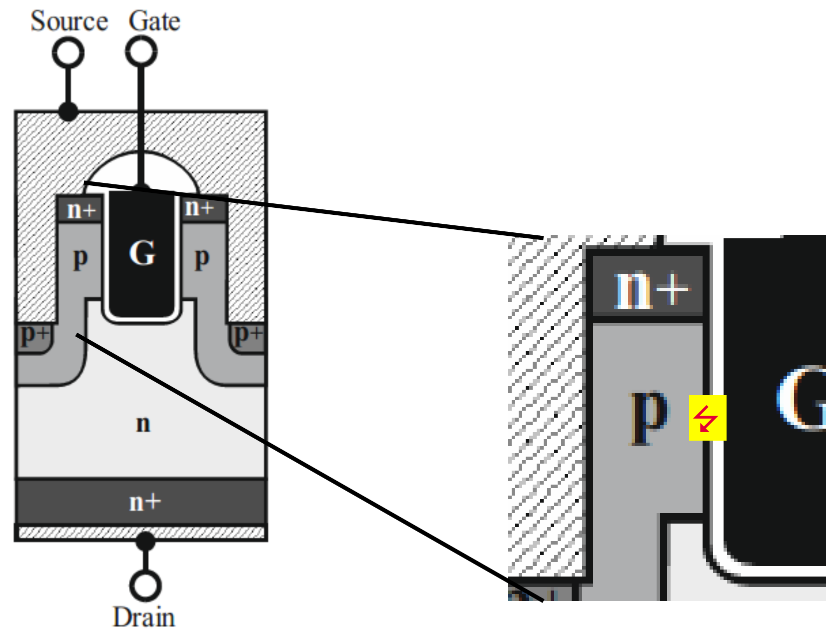
Implications on the cell concept based SiC-specific interface properties

SiC Planar



- High density of defects lead to high channel resistance
- Low on-resistance achievable via high electric fields across the gate oxide
- all planar SiC MOSFETs today with more than 3 MV/cm for turn on, low V_{GS_th} and high V_{GS_on}

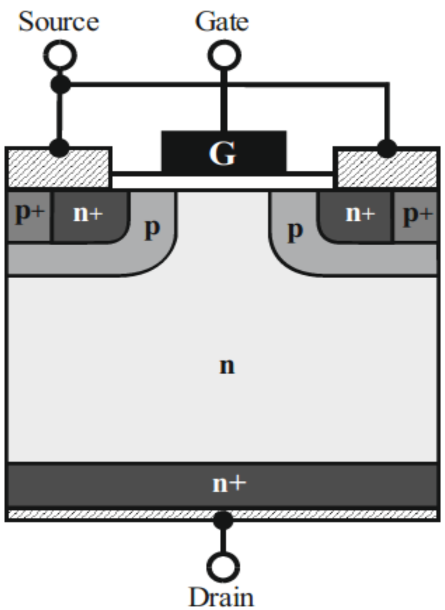
SiC Trench



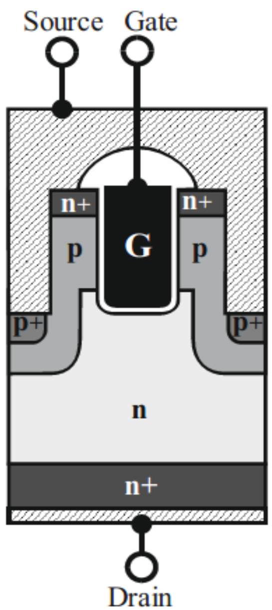
- Low density of defects leads to low channel resistance
- Low on-resistance achieved at oxide field below 3 MV/cm
- Possible to achieve high V_{GS_th} and IGBT like V_{GS_on}

Summary Trench vs. Planar in SiC – focus on long term success

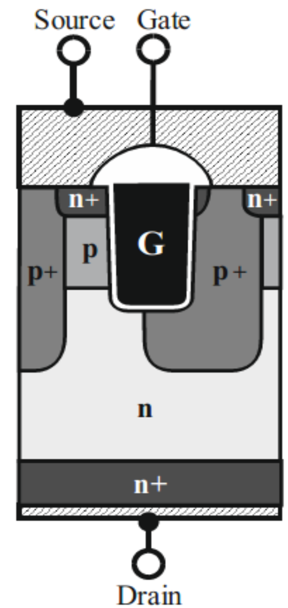
SiC Planar



SiC Trench



Infineon Trench



Granted by Infineon Trench technology experience over > 25 years

+
- Easy/cheap process
- Good shielding of oxide possible

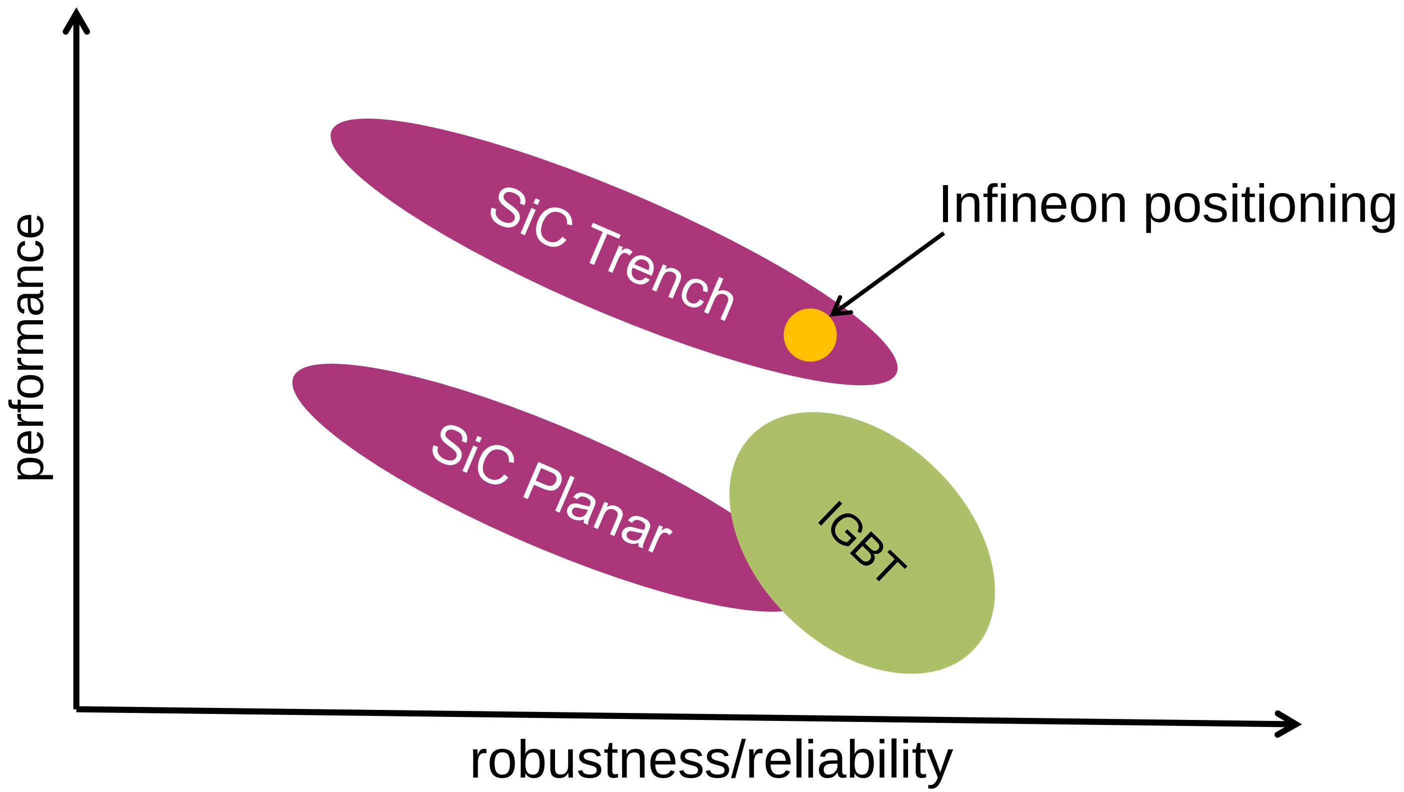
–
- Very low channel mobility
- Limited shrink options

+
- low channel resistance
- Shrink potential higher than in DMOS

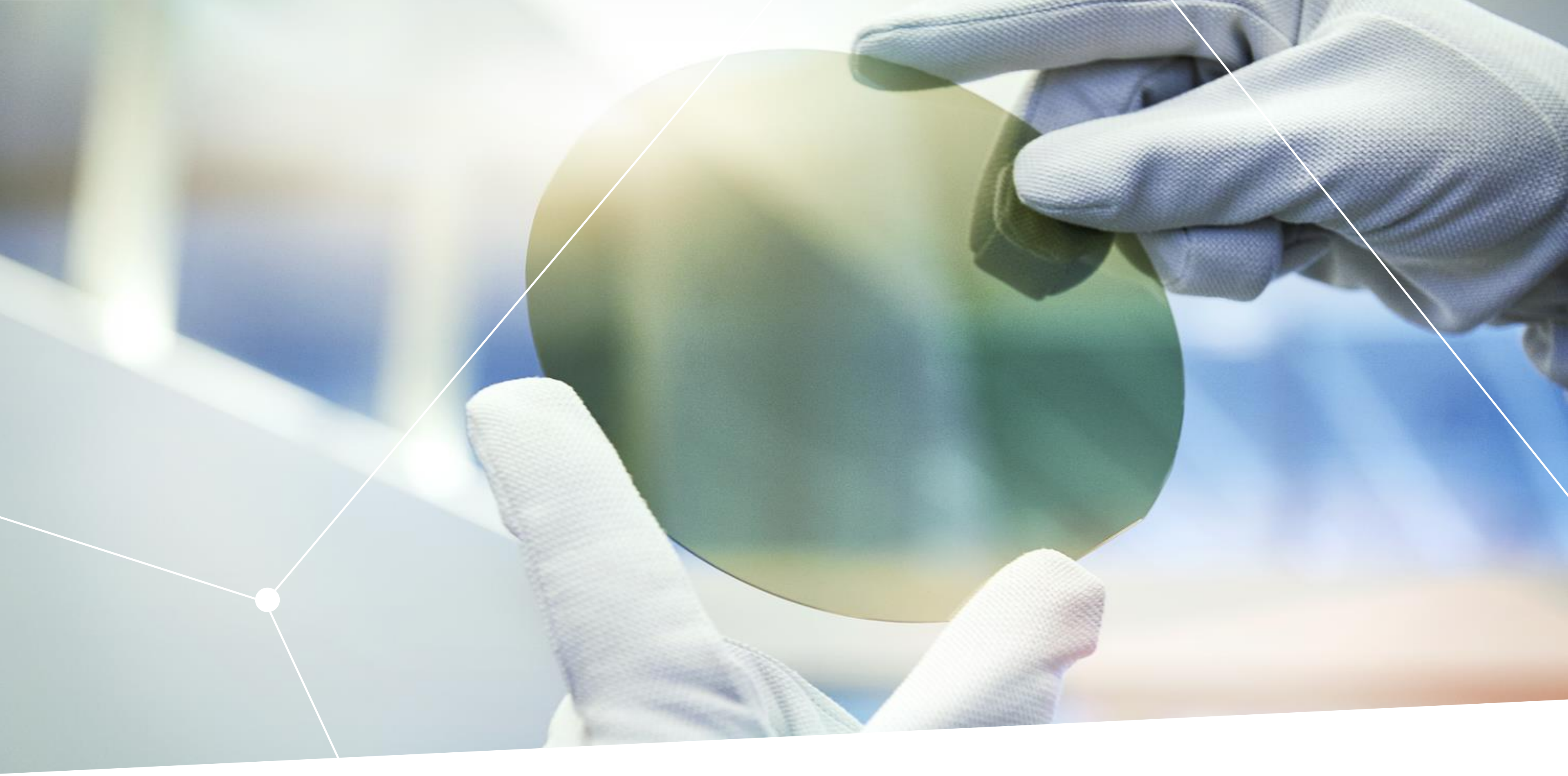
–
- Sophisticated process know how needed
- Protection of oxide corners needed

Granted by Infineon SiC folded double Trench structure

Infineon's trench-based CoolSiC™ technology has been optimized for highest reliability

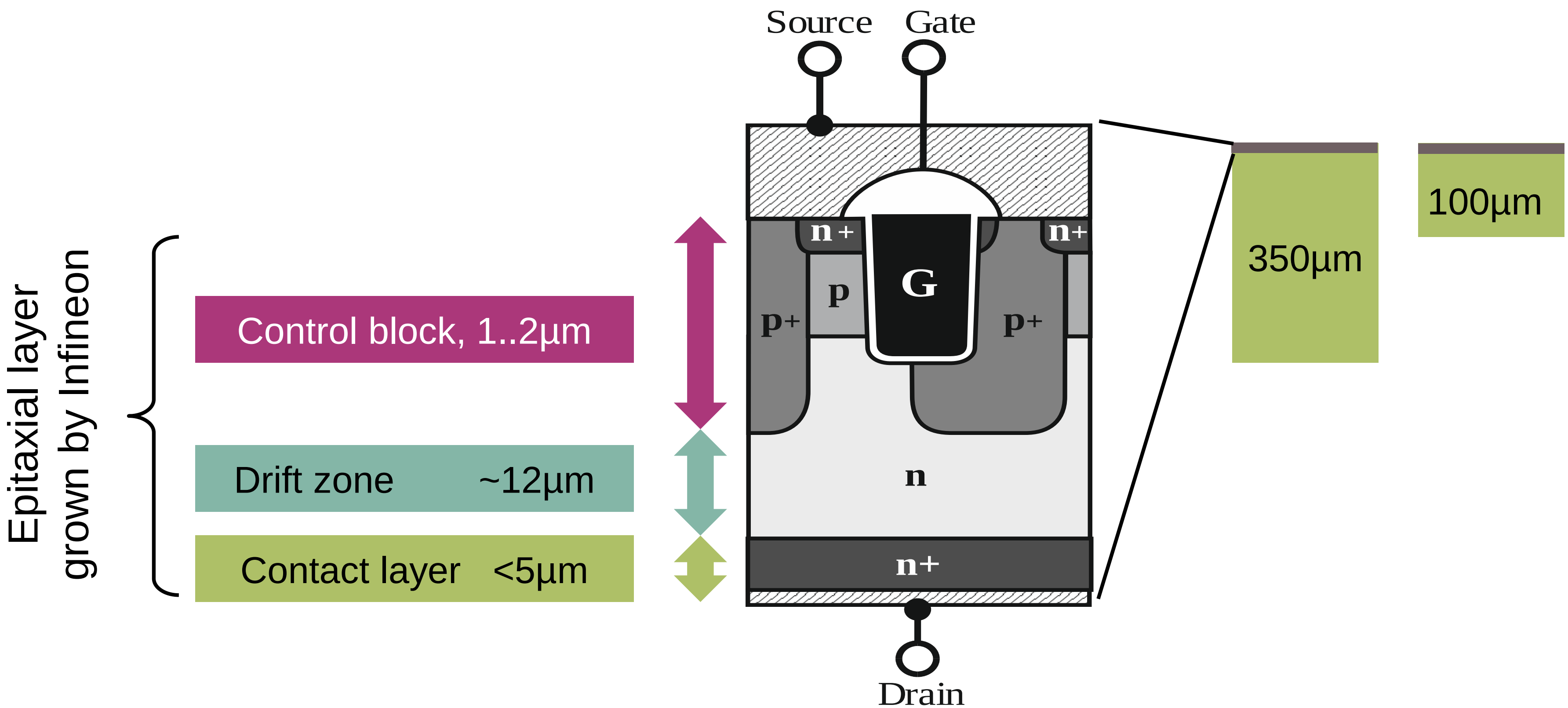


Combine best $R_{DS(on)}$ with robustness levels equivalent to IGBTs



To be or not to be vertically integrated: Does a device manufacturer need to own the SiC substrate crystal growth process?

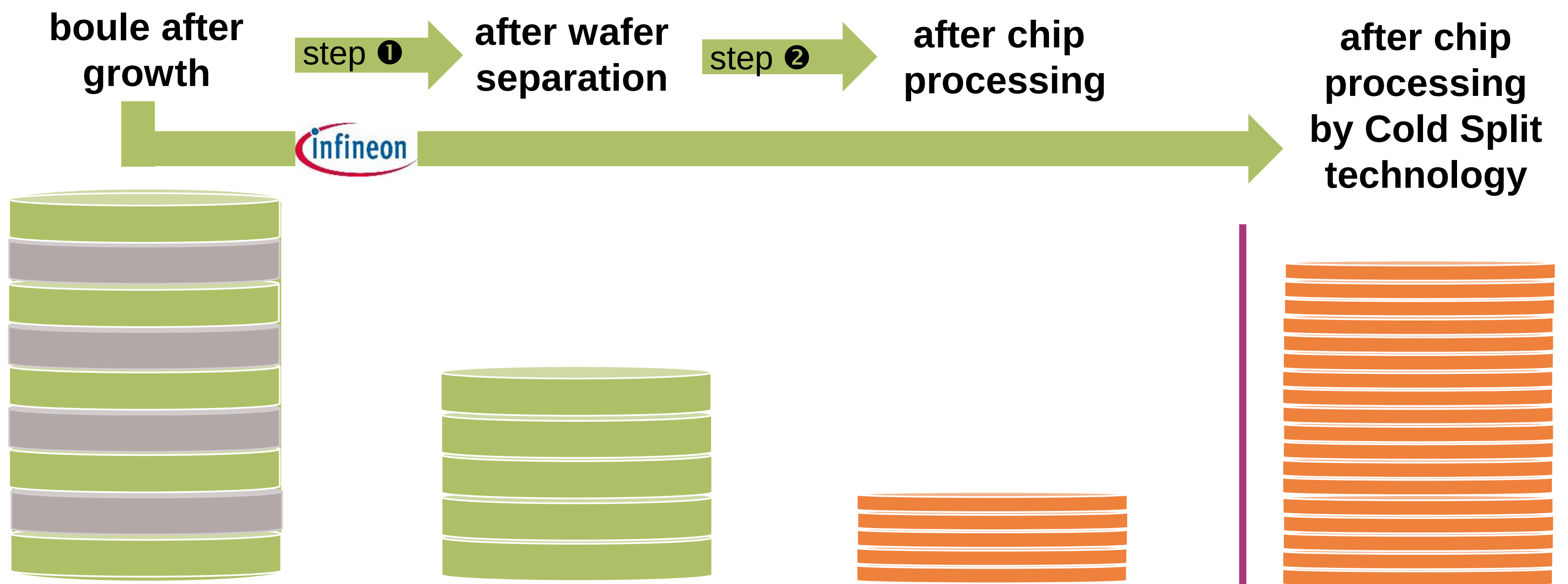
A deeper look into real dimensions of a SiC MOSFET



- In the actual device the substrate has no active role.
- The substrate delivers
  - the crystallographic information for the epitaxial growth, and
  - mechanical stability.

The SiC material irony

- The growth process is expensive, risky and time-consuming
- Today, 80% of the grown material is turned into dust during processing

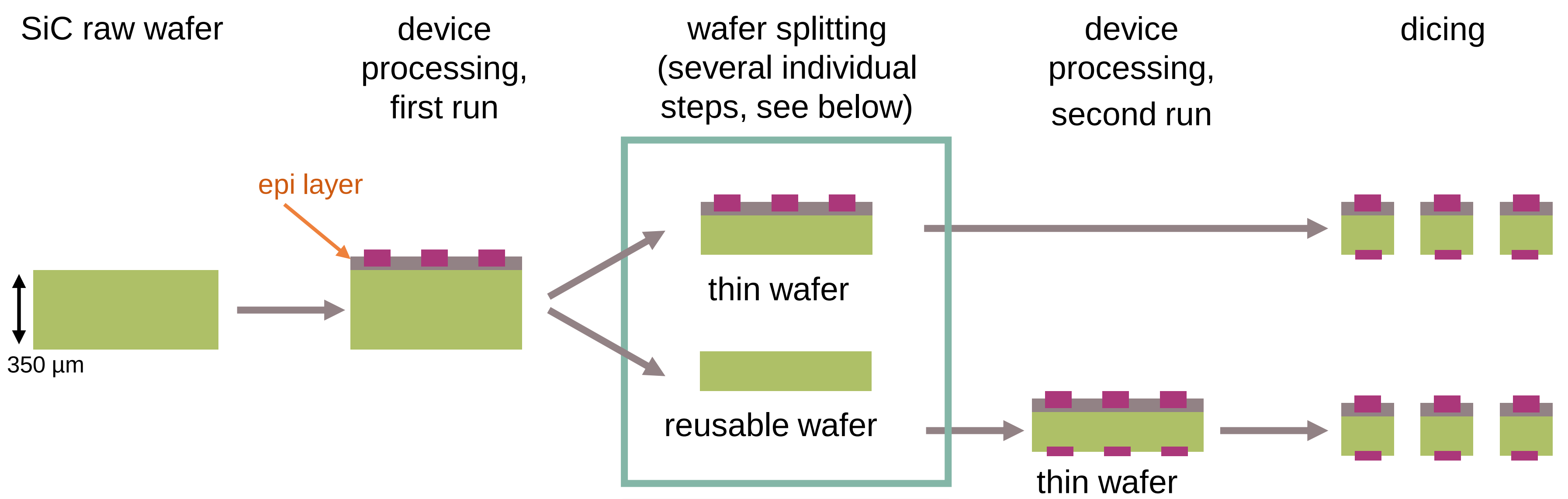


For extracting a 350 µm thick epi-ready wafer more than 700 µm crystal length is needed in case of wire saw technology today

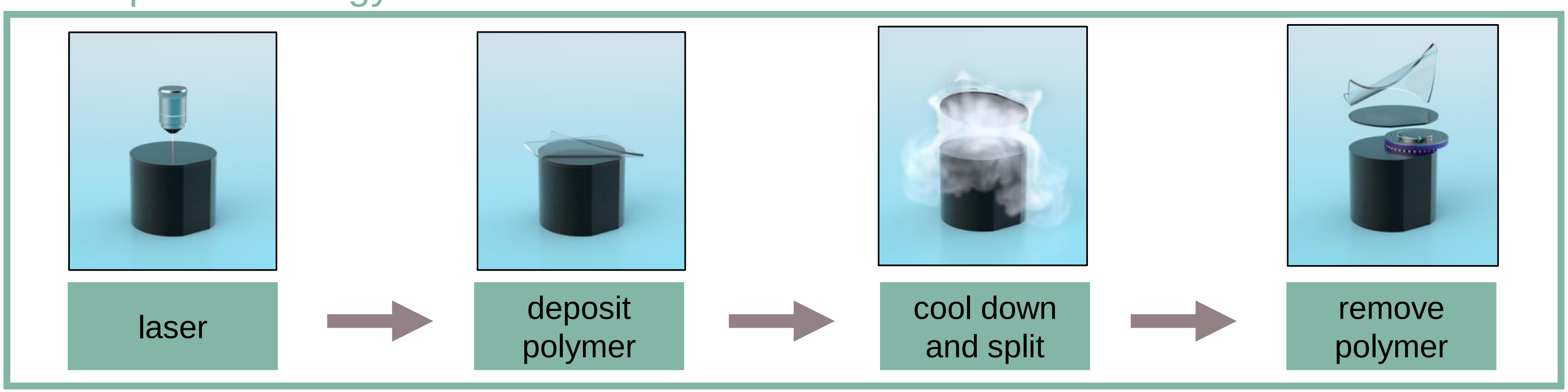
During thin-wafer *processing (final die thickness ~100 µm)* further 250 µm are grinded away

Significant increase of boule utilization

Infineon strategy: instead of growing own crystals improve material efficiency and keep capex low



Cold Split technology



Part of your life. Part of tomorrow.

Dr. Peter Wawer
Division President Industrial Power Control

- since 2016: Division President Industrial Power Control
- 2012: Member of the Management Board of the Power Management & Multimarket Division
- 2011: Senior VP Technology and Production at Q-Cells SE in Bitterfeld, Germany
- 2008 – 2011: Senior VP Technology at Q-Cells SE
- 1997 – 2008: various position at Infineon

- Dr. Peter Wawer was born in Berlin, Germany, in 1967. He holds a Diploma in Electrical Engineering from the Technical University in Berlin where he also received his PhD.
- He joined Infineon (Siemens AG until 1999) in 1997.

Dr. Peter Friedrichs
Senior Director SiC Technology

- since 2011: Senior Director SiC Technology at Infineon
- 2004 – 2011: Managing director of SiCED (Joint venture of Infineon and Siemens)
- 1996 – 2004: various positions at Siemens and SiCED

- Dr. Peter Friedrichs was born in Aschersleben, Germany, in 1968. He holds a Diploma in Microelectronics from the Technical University in Bratislava, Slovakia, and received his PhD from the Friedrich Alexander University in Erlangen, Germany. In addition, he holds a Diploma in Industrial Engineering from the University in Hagen, Germany.
- He joined Infineon (Siemens AG until 1999) in 1996.

Glossary

epi	epitaxy
HiRel	high-reliability products
IPS	industrial power supply
IGBT	insulated-gate bipolar transistor
LCOE	levelized cost of energy
MOSFET	metal-oxide silicon field-effect transistor
OBOR	China‘s initiative „One Belt One Road“
PV	photovoltaic
PS	power supply
SiC	silicon carbide
SMPS	switch-mode power supply
UPS	uninterruptable power supply
VSD	variable speed drive
xEV	all degrees of vehicle electrification (EV, HEV, PHEV)

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These statements are based on assumptions and projections resting upon currently available information and present estimates. They are subject to a multitude of uncertainties and risks. Actual business development may therefore differ materially from what has been expected.

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