TECHNOLOGY STAGE

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NUREMBERG, GERMANY

mesago

1200V High Temperature SiC Power-Module as Reference Development Platform

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M.Sc. Jan Dick

Fraunhofer IISB

Messe Frankfurt Group

SiC Power Module Development Platform

Motivation

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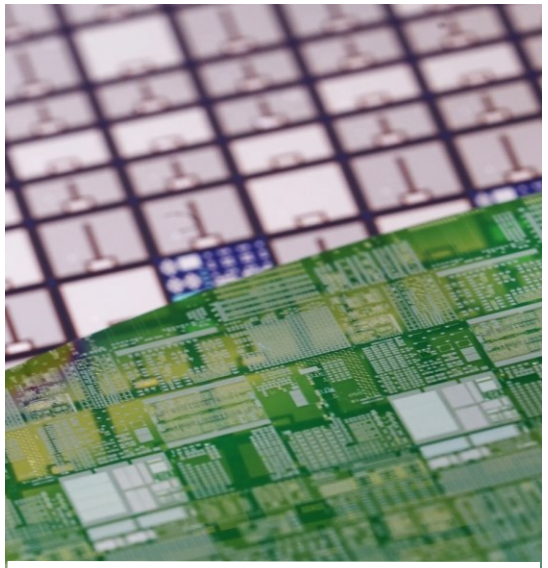
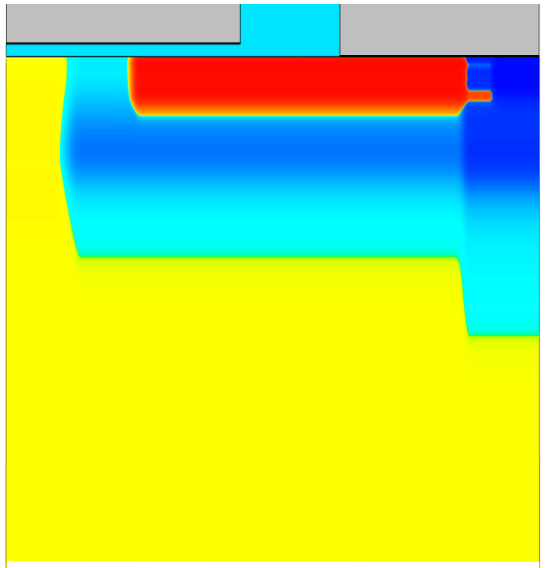
SiC-Device Design & Fabrication



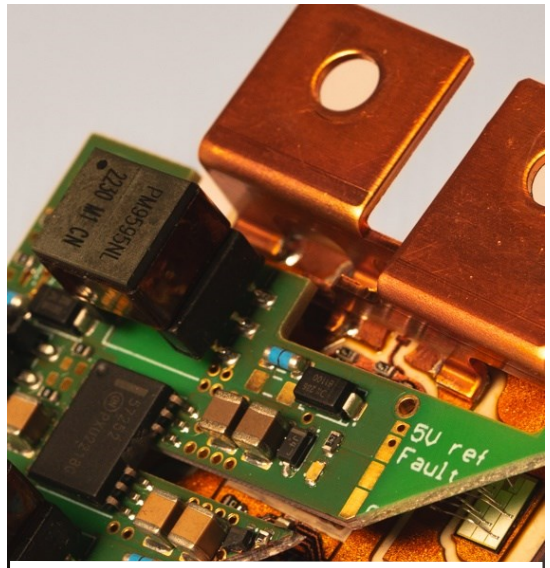
GAP: no independent reference module for characterization in system context

Simulation



GAP: no public module with high temperature capability available

Power Modules



GAP: no public module available as a development starting point

Reliability

GAP: no public reference available as benchmark for reliability

SiC Power Module Development Platform

Motivation

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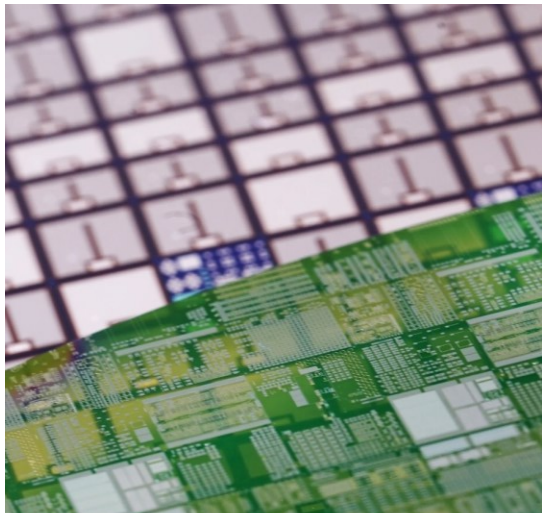
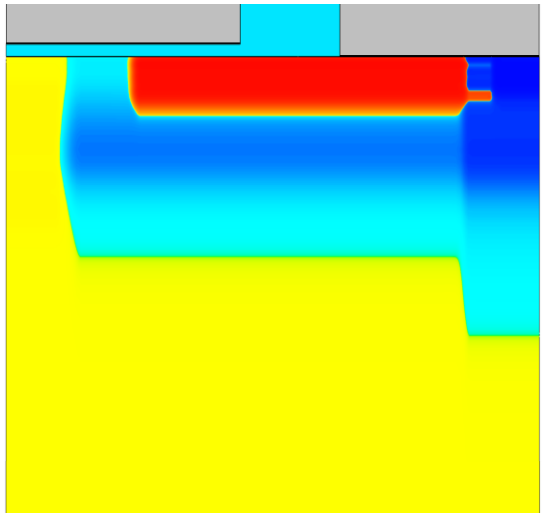
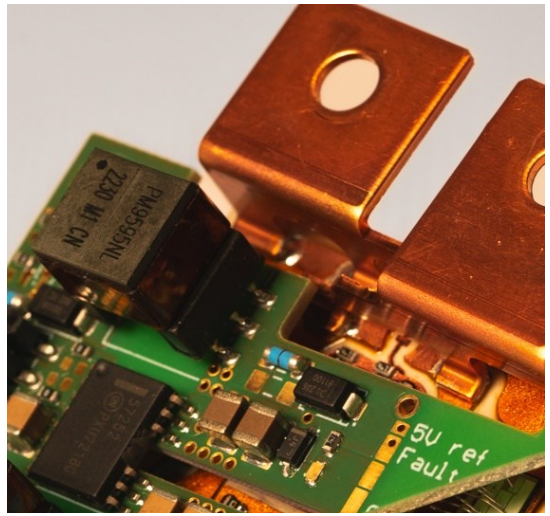
SiC-Device Design & Fabrication



Simulation



Power Modules



Reliability

Customer independent **SiC Power Module Development Platform:**
Enabler to speed up development processes & evaluate new technologies in application near setup

SiC Power Module Development Platform

Agenda

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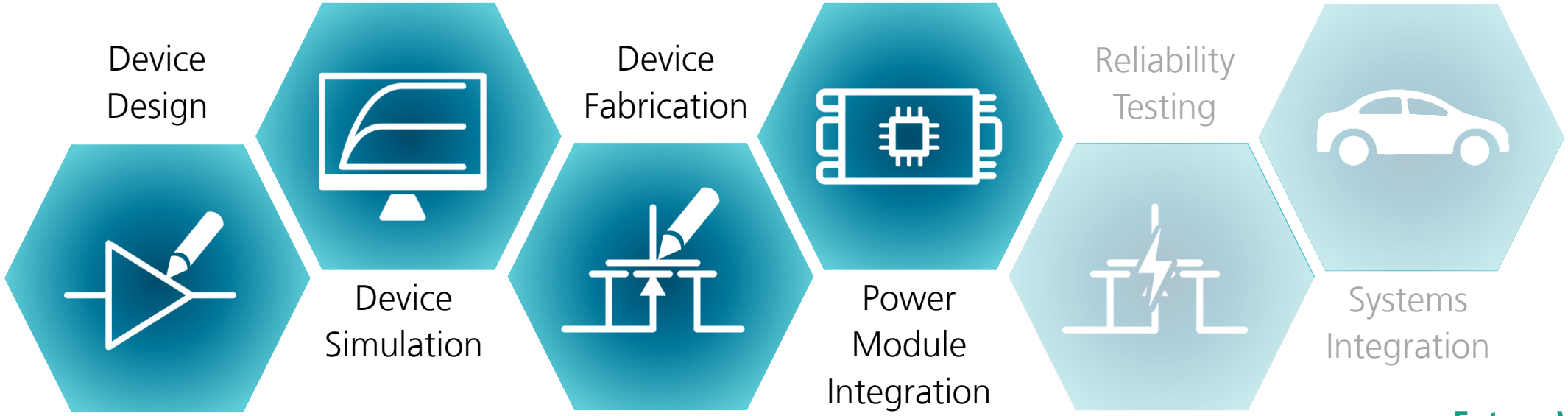
With our **SiC Power Module Development Platform** we support you along the whole value chain

Todays Focus



Future Work – What's next?

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Fraunhofer IISB

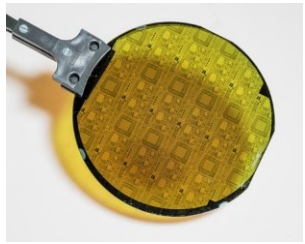
The Power Electronics Institute

AS LEADING CENTER OF EXCELLENCE FOR **WIDE-BANDGAP-BASED POWER ELECTRONICS** IN EUROPE, WE ENSURE SUSTAINABLE AND COST-EFFECTIVE **MOBILITY AND ENERGY SUPPLY, CLIMATE PROTECTION, AND THE CONSERVATION OF RESOURCES**

Scientific ROADS

Semiconductors	**Siliziumcarbide (SiC)**
	Ultra-Wide-Bandgap-Semiconductor (UWBG)
	Galliumnitride (GaN)
	Semiconductors for special applications
Power Electronic Systems	**Converter Systems** (for mobility, energy, iIndustrie)
	Cryo-Powerelectronics (for electric aviation)
	Energiestorages & -nets
Quantum technology	**Quantum – base technologies**
	Quanten - applications

Digitale tools



R & D ALONG THE COMPLETE VALUE CHAIN

MATERIAL – DEVICES – MODULES – SYSTEMS

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booth 6-260

- Locations: Erlangen, Freiberg, Hallstadt
  ~Staff members ~ 400
  ~Annual budget ~ 50 Mio. €
  ~140 Patent families
- Institutional University Partners:
  FAU Erlangen-Nürnberg (Chairs LEB, LEE, FAPS)
  TU Bergakademie Freiberg (Institut IAP)
  University of Bayreuth (Chair LEEE)
- Member of:

LZE Leistungszentrum Elektroniksysteme

Forschungsfabrik Mikroelektronik Deutschland

Fraunhofer IISB

The Power Electronics Institute

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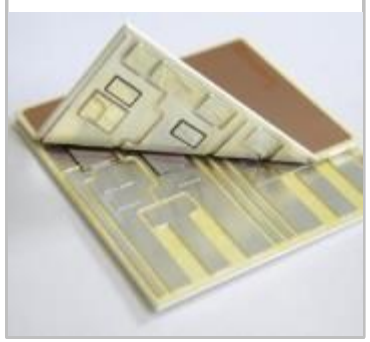
THE Power Electronics Institute

Business Area Semiconductors			Business Area Power Electronic Systems	
Materials	Technology	Power Modules	Vehicle Electronics	Intelligent Energy Systems



Branch lab: Fraunhofer THM

Partner: Energie Campus Nürnberg

Cooperation with Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU):

LEB – Lehrstuhl für Elektronische Bauelemente, Prof. Dr.-Ing. Jörg Schulze

LZE – Leistungszentrum Elektroniksysteme

Lehrstuhl für Leistungselektronik, Prof. Dr.-Ing. Martin März

Power Modules & Packaging Technologies

More than 15 years of Power Modules @ IISB

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Power

Performance

Integration

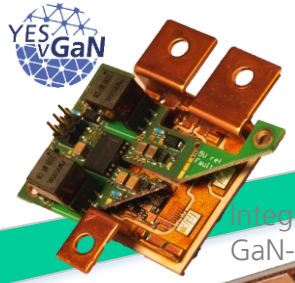
Power Modules

Packaging

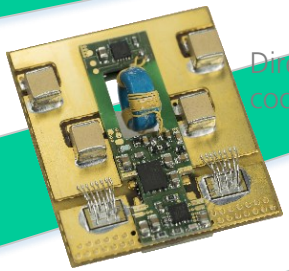
Transfer mold

Multichip

RC-Snubber

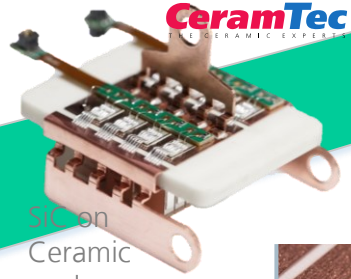


Integrated GaN-driver



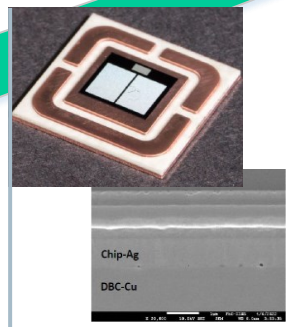
Direct cooling

SiC- Chip on busbar



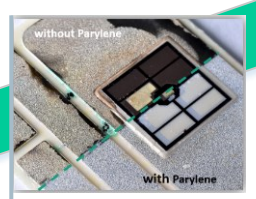
SiC on Ceramic cooler

vGaN-Membrane attach

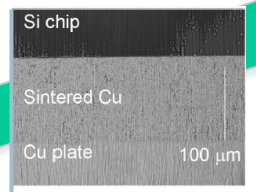


Direct bond

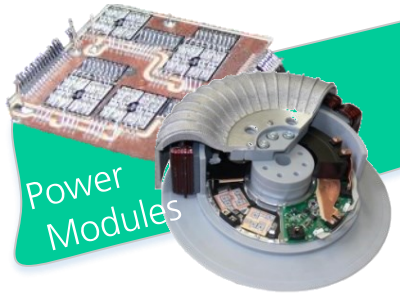
Laser structurization



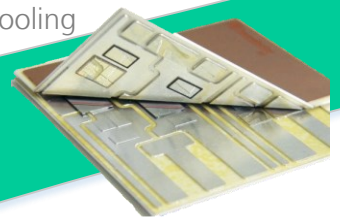
Coating & potting solutions



Copper sintering



Power Modules



Double sided cooling

Double side sintering

3D-Ceramic Printing

SiC Power Module Development Platform

Agenda

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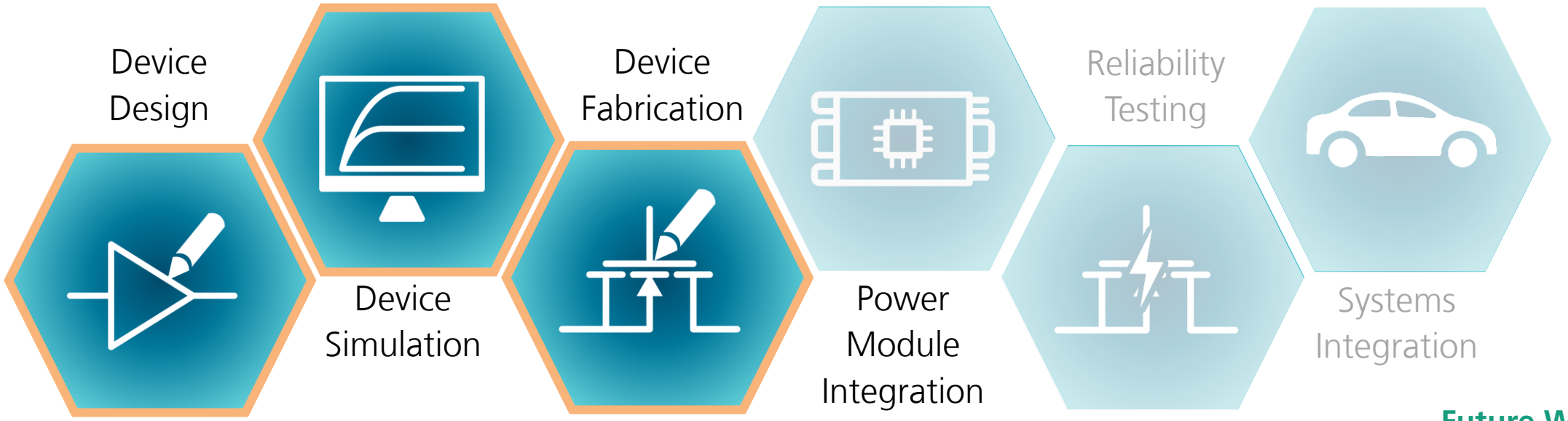
Todays Focus



Future Work – What's next?

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SiC Power Module Development Platform

Experience with High-Temperature Capable Devices on the SiC-CMOS Plattform

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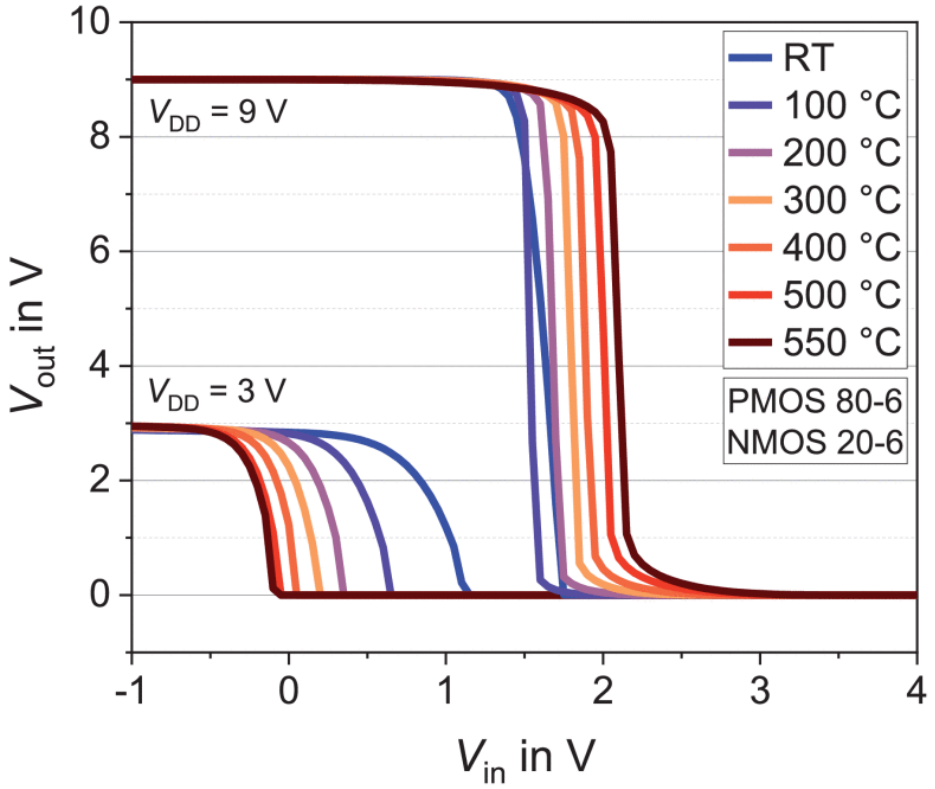
High-Temperature SiC CMOS platform

- Multiproject wafer runs for research and SMEs
- Circuit operation shown up to 550 °C
- Integration of temperature- and UV-sensors
- Lateral power transistor integration including RESURF

EUROPRACTICE IC SERVICE



A. May *et al.*, "A 4H-SiC CMOS Technology enabling Smart Sensor Integration and Circuit Operation above 500 °C," *2024 Smart Systems Integration Conference and Exhibition (SSI)*, Hamburg, Germany, 2024

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SiC Power Module Development Platform

High-Temperature Gate Driver

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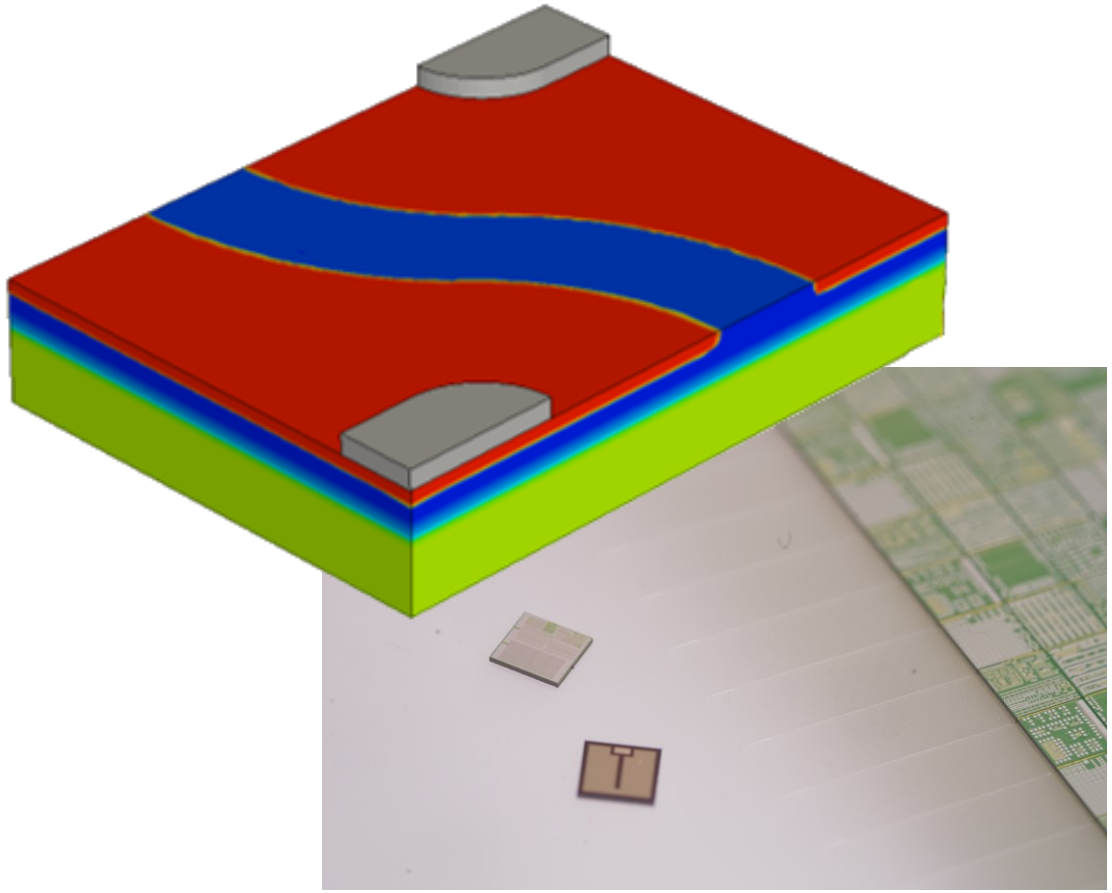
Custom High-Temperature Gate Driver Design

- Based on our 2 µm SiC-CMOS technology
- Full CMOS implementation
- 3 µm channel length
- Pt based 2-layer metallization
- Custom MOSFET layout for high drive currents



Features:

- Voltage range: +20 V / -5 V
- Drive current: 3 A
- Galvanic isolation circuitry on-chip
- Active Miller clamp

SiC Power Module Development Platform

Simulation Calibration for Devices at High Temperature

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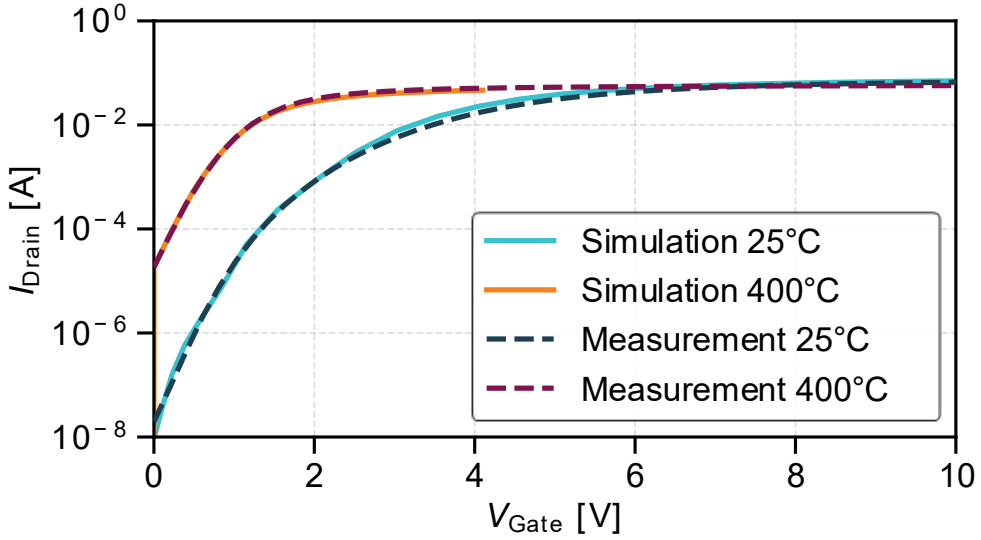
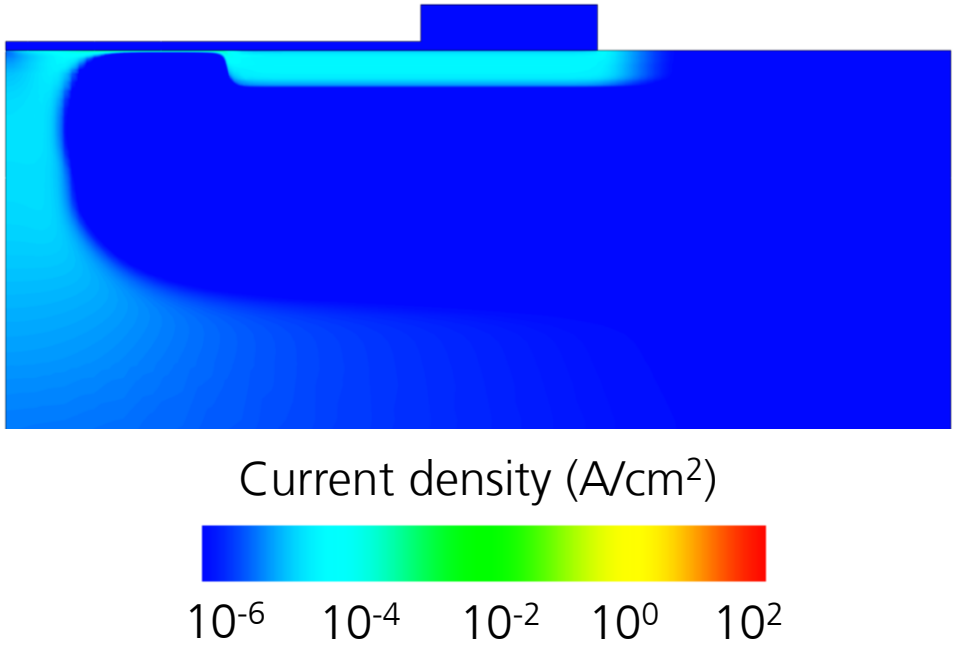
Calibration of high-temperature simulation models using reference IISB VDMOS

- Simulation Method → Sentaurus TCAD
- Fitting & Optimization → In-house optimization tool
- Single- and multi-temperature calibration





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SiC Power Module Development Platform

High-Temperature Lateral SiC MOSFET Operation up to 600 °C

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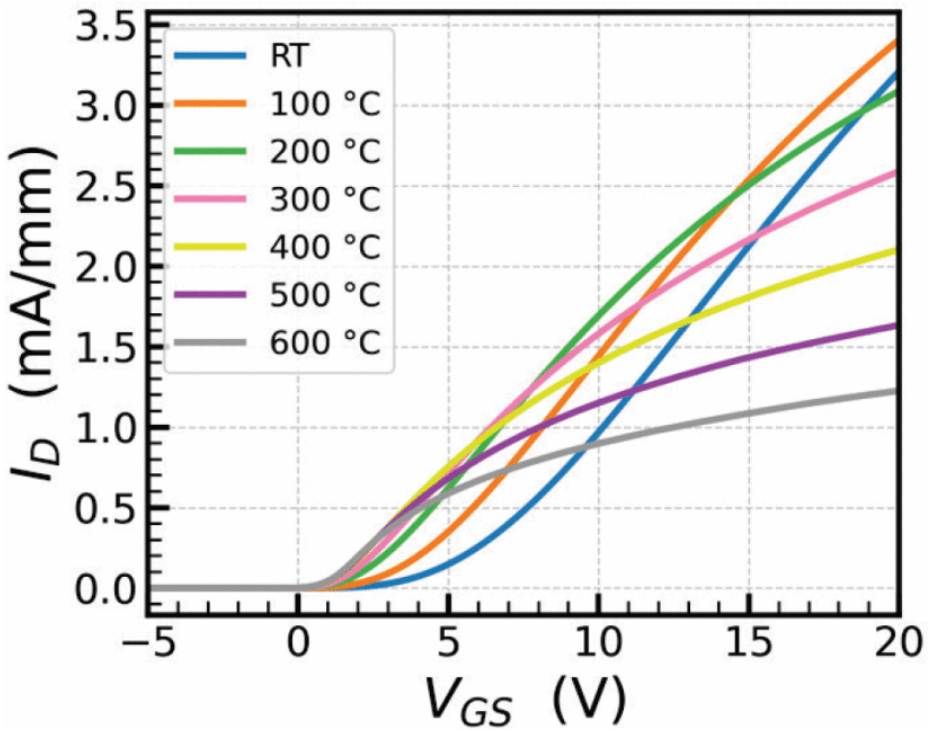
LDMOS on our SiC-CMOS platform as vehicle for high-temperature device characteristics

- Chip-level and Wafer-scale electrical testing up to 600 °C
- LDMOS operates with expected V_{th} reduction at elevated temperatures

Device operation is not limited by its physics but by its long-term reliability



R. Kammel, J. F. Dick, et al., "600 °C Operation of a LDMOS Integrated on a 4H-SiC CMOS Platform," *2025 MIPRO 48th ICT and Electronics Convention*, Opatija, Croatia, 2025, pp. 1674-1679

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Development Approaches Towards Cost-Efficent High-Temperature Capable Devices

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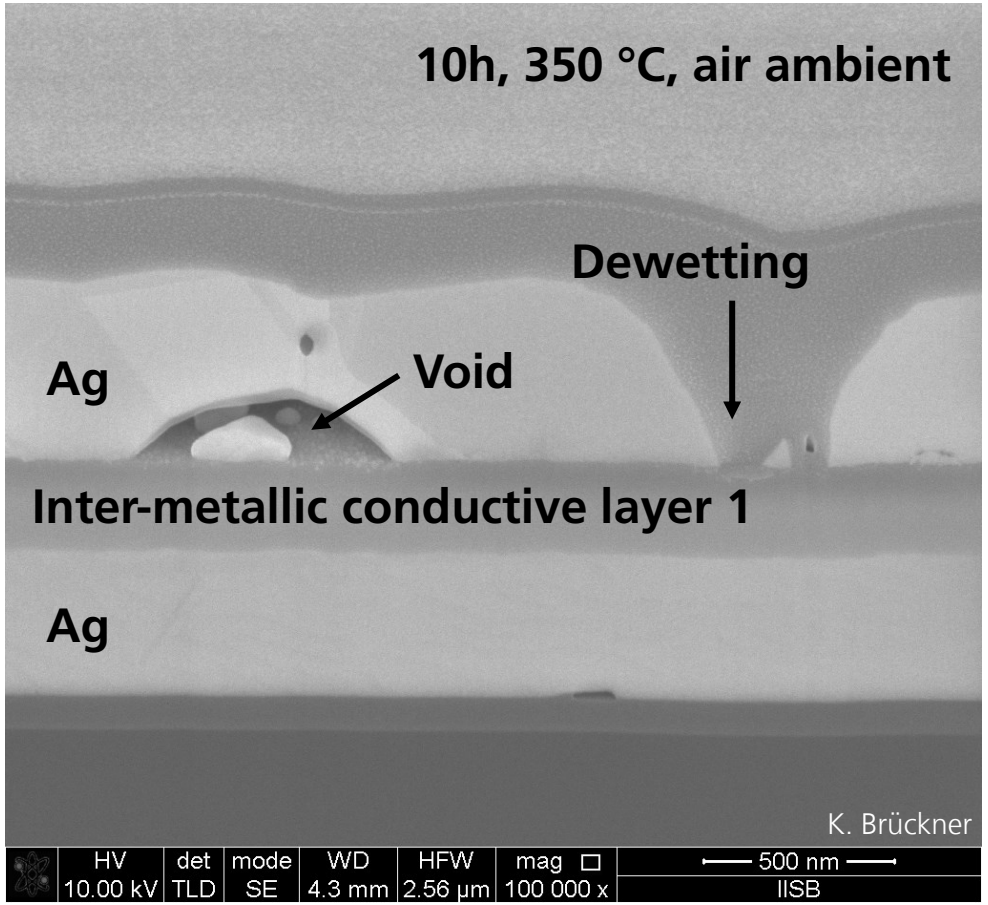
Challenges in power devices for high-temperature applications

- Metal Alloying / intermixing
- Adhesion
- Void formation
- Dewetting
- Reaction with ambient
- Diffusion

→ Technology development on our in-house SiC-VDMOS technology



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SiC Power Module Development Platform

Development Approaches Towards Cost-Efficent High-Temperature Capable Devices

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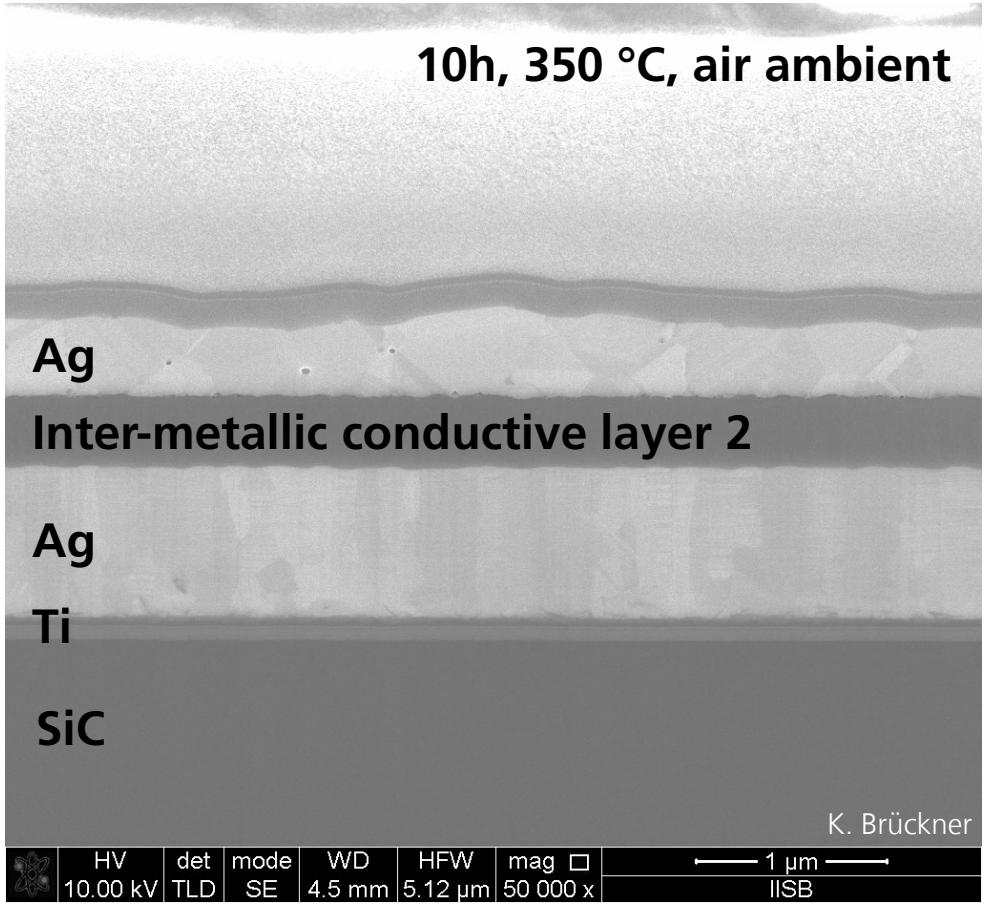

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SiC Power Module Development Platform

Agenda

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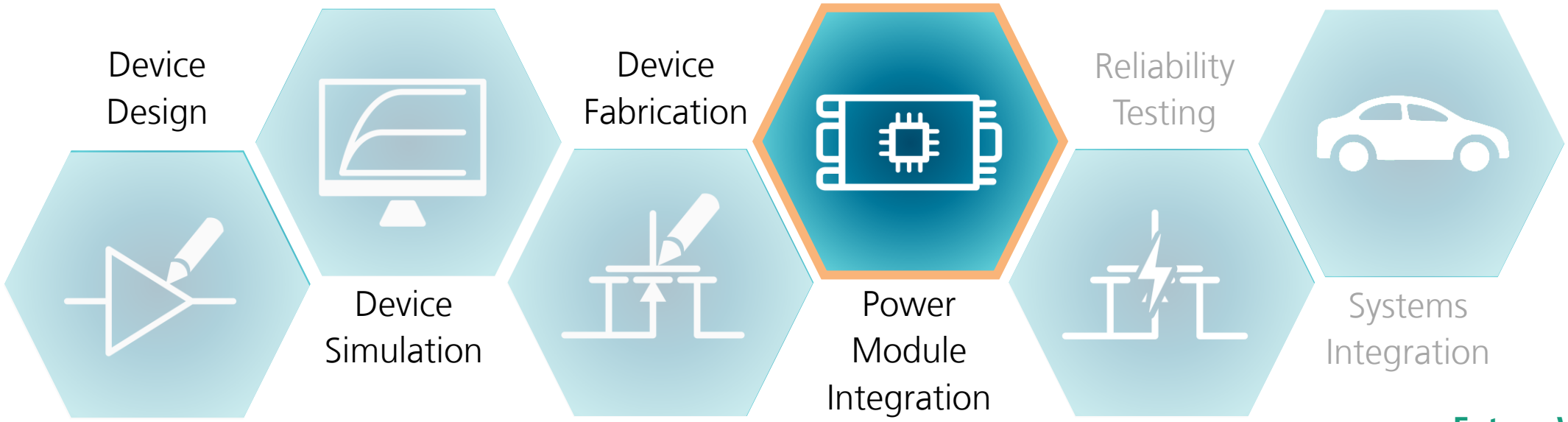
Todays Focus



Future Work – What's next?

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SiC Power Module Development Platform

Power Module Design - Requirements

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Platform for **IISB High temperature 1200V SiC devices**

Transfer-Mold-Layout with leadframe to the side

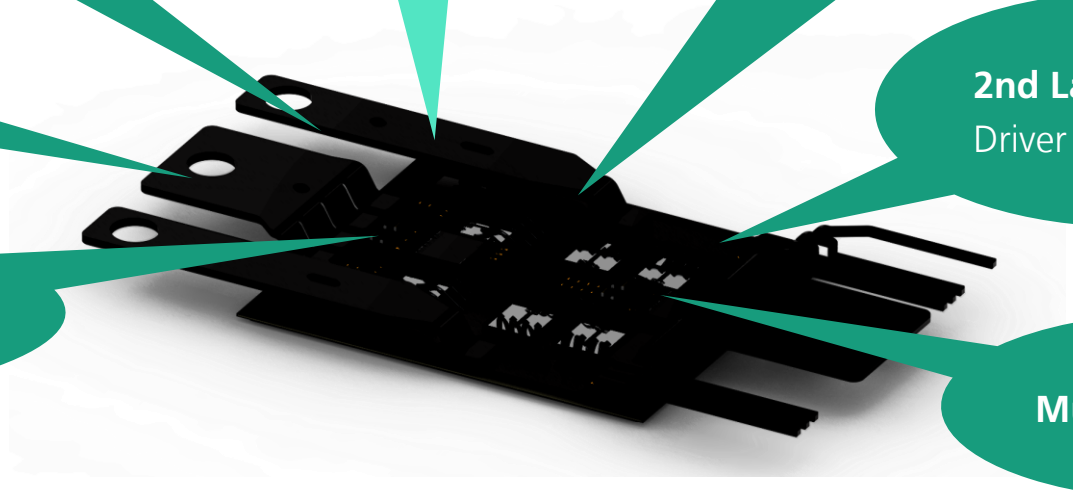
Option: **Integration** of additional Components (e.g. Temperature, RC-Snubber, DESAT, …)

Easy access for **development partners**

2nd Layer for Gate Driver Integration

Variable internal module design for IISB-Devices & external devices

Multichip-Design



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Power Module Design - Design

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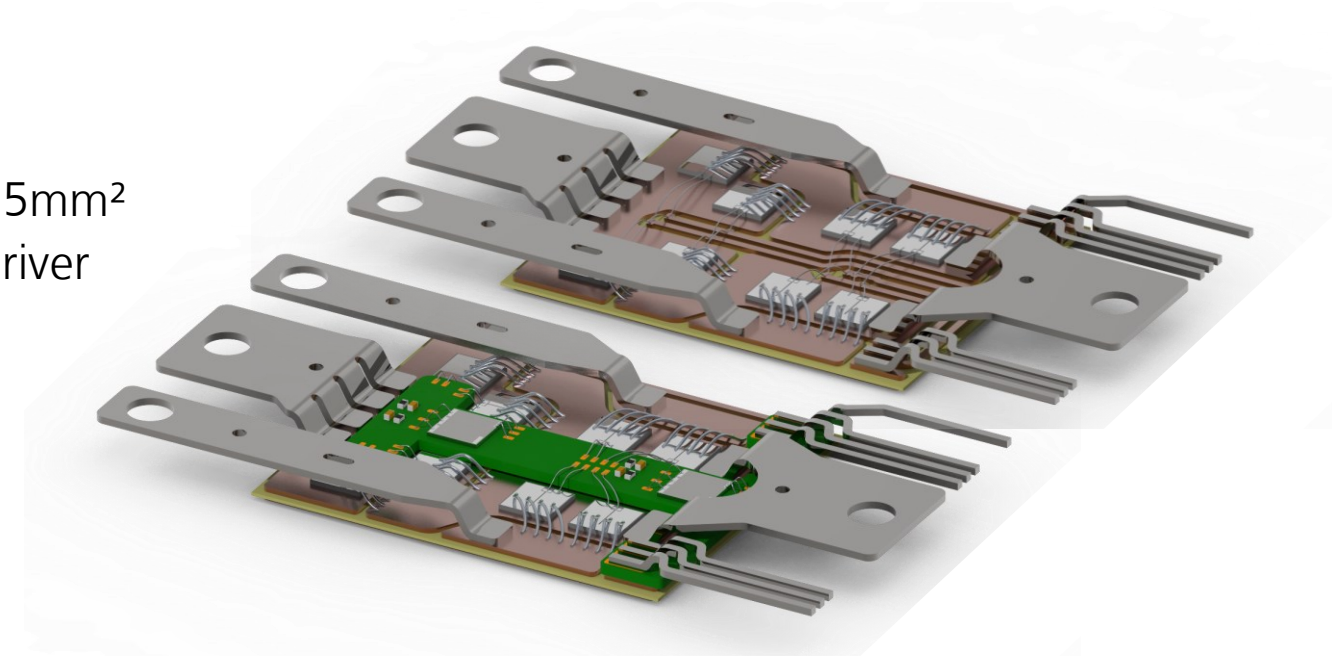
For start **two design variants**:

- Classic half bridge approach
- With integrated High-Temperature SiC gate-driver IC

Facts

- 4x IISB 1200V SiC-VDMOS with 25mm²
- IISB high temperature SiC-Gate-Driver on additional circuit carrier
- Dimensions: 35 mm x 41 mm



SiC Power Module Development Platform

Your Benefits from the Development Platform - Customization

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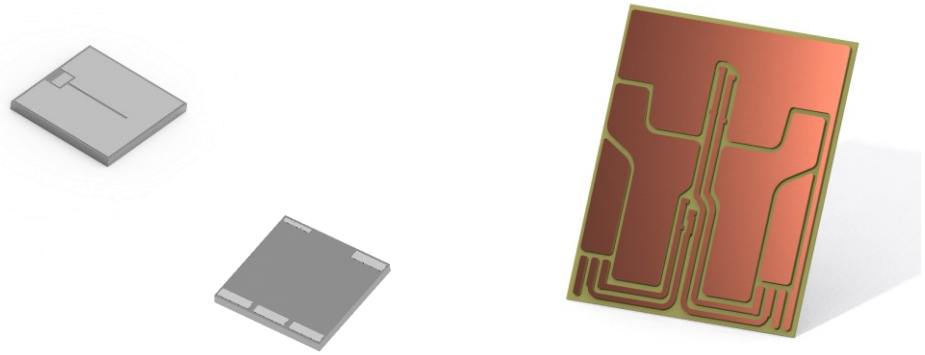
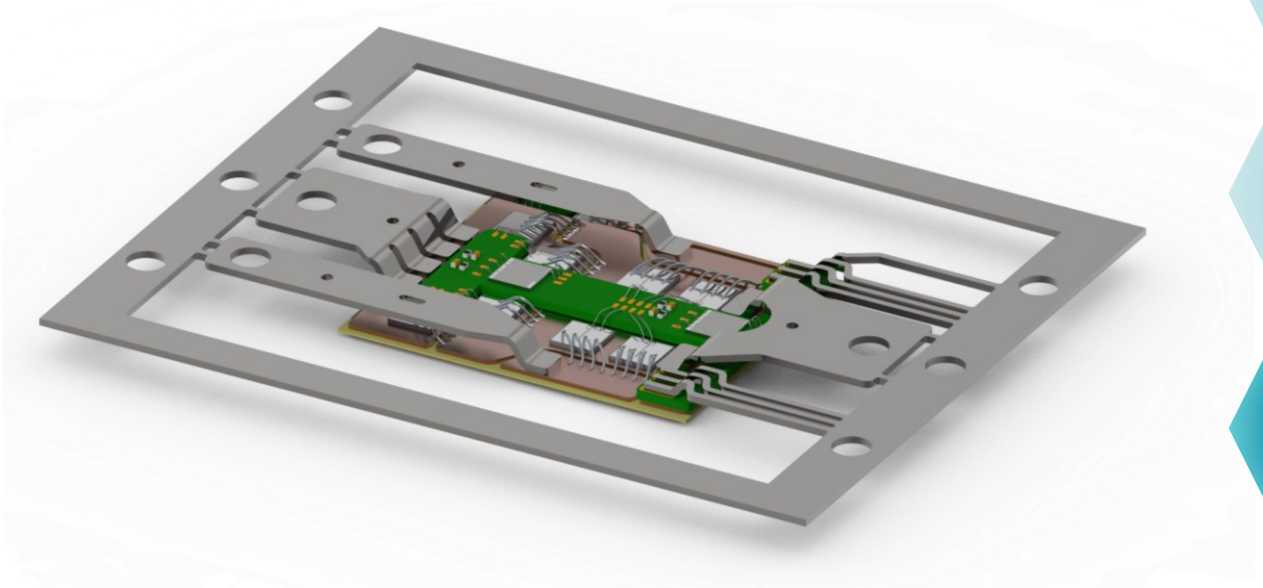
Flexible internal layout

- Semiconductor types (SiC, GaN, …)
- Number & size of chips
- Substrate type and layout
- Optional second layer for gate drivers/ signals / functions
- Assembly and interconnection technology



Fixed outlines

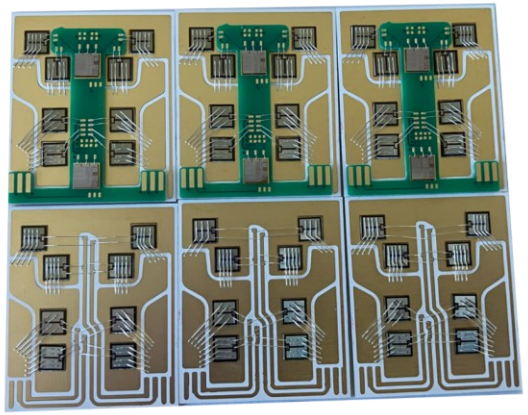
- Substrate dimensions
- External leadframe positions



→ Fast prototyping with reduced effort & cost!

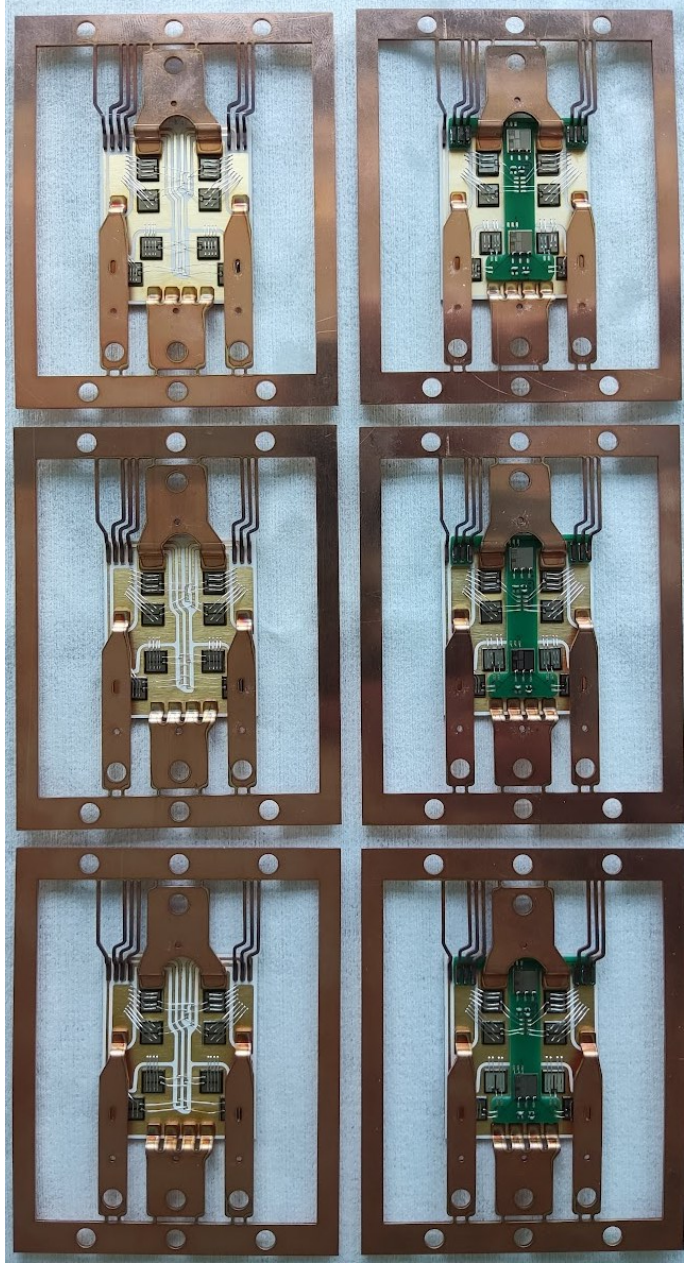
SiC Power Module Development Platform

Manufacturing & Prototyping



Manufacturing steps

- Sintering of SiC-Devices
- Wirebonding / Top-Side-Clip-Sintering
- Welding of Leadframe
- Encapsulation of Module



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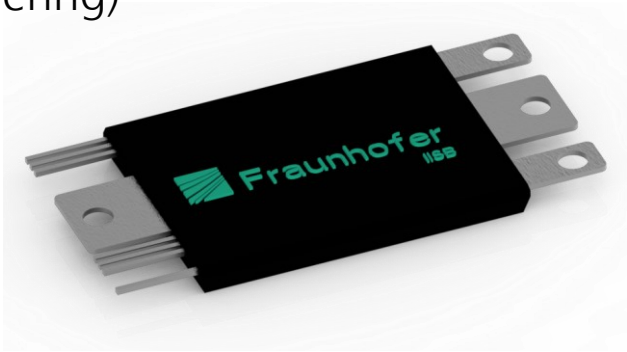
All relevant manufacturing capabilities are available onsite!

- Module & Die Attach (Sintering & Soldering)
- Wire & Ribbon bonding
- US-Welding of Terminals
- Transfer-Mold for Module



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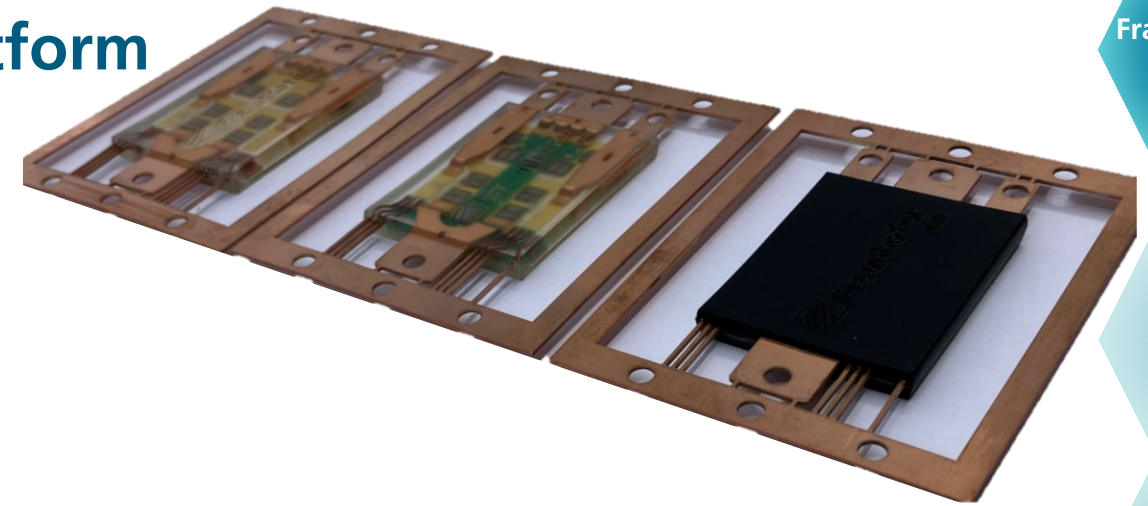
Power Module Design



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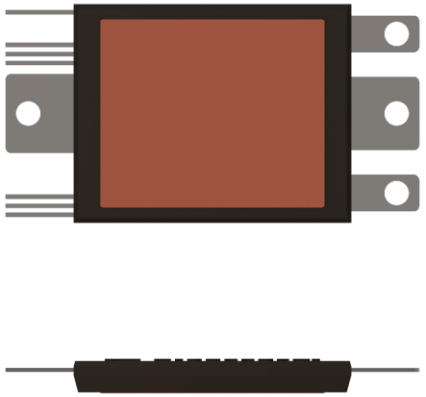
Current status

- First power module samples are available
- Layout / Design phase closing soon



What's next

- Design freeze of transfer mold encapsulation
- Realization of final prototypes
- Electrical characterization
- Reliability testing

→ The power module development platform is an ongoing process with permanent improvements

SiC Power Module Development Platform

Your R&D Entry Point along the Complete SiC Value Chain

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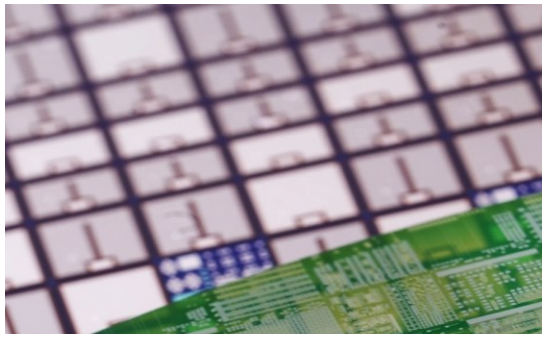
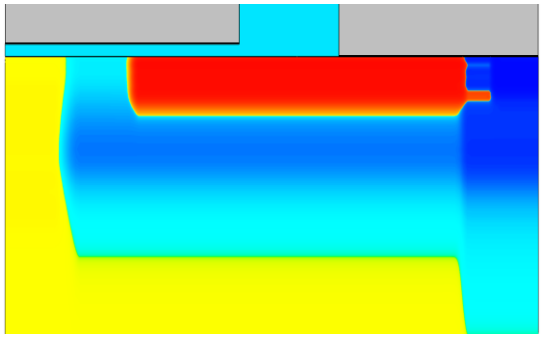
SiC-Device Design & Fabrication



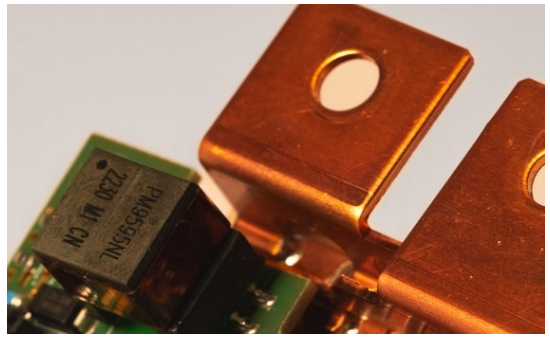
- in-house 2 µm high-temperature **SiC-CMOS platform** up to 550 °C
- **SiC-VDMOS** & Trench-MOS process
- **High-temperature** specific chip layout & metal stacks

Simulation



- Commercial software & in-house optimizer
- Device optimization
- Measurement calibrations
- Temperature-consistent modeling

Power Modules



- **Power Module Design**
- Simulations
- Processes
- **Power Module Prototyping**
- Characterization & Benchmarking

Reliability

- All tests according to AQG324
- Digital twin of manufacturing process

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We are pleased to answer your questions:

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jan.frederik.dick@iisb.fraunhofer.de

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