Future Packaging Technologies in Power Electronic Modules
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Some Words on Fraunhofer Institutes
- *from the general to the specific* -

Part Two

Future Packaging Technologies in Power Electronic Modules

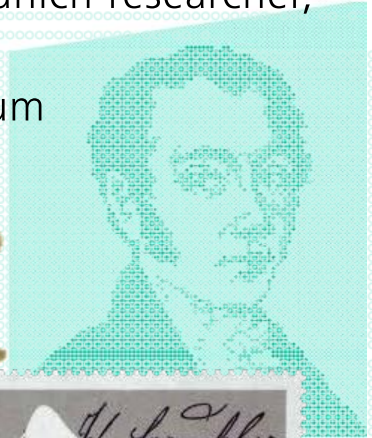
FRAUNHOFER GESELLSCHAFT

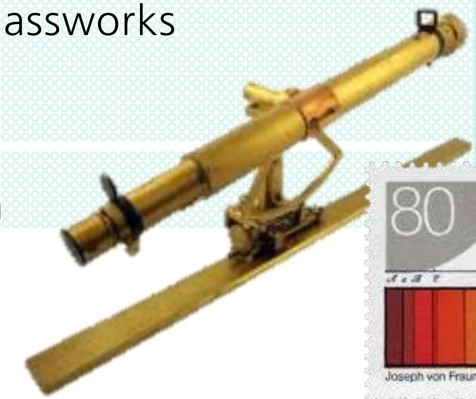
JOSEPH VON FRAUNHOFER
(1787 – 1826)

The **Fraunhofer-Gesellschaft** is a recognized non-profit organization that takes its name from ‘**Joseph von Fraunhofer**’ (1787–1826), the illustrious Munich researcher, inventor and entrepreneur.

- **Researcher** – discovery of the ‘Fraunhofer lines’ in the solar spectrum
- **Inventor** – new processing method for lenses
- **Entrepreneur** – director and partner in a glassworks

- **Fraunhofer foundation in 1949**
  → from military to recent industrial research and engineering (today’s staff 24,500)





Fraunhofer IISB

INSTITUTES AND RESEARCH ESTABLISHMENTS
IN GERMANY

Fraunhofer Research Institutes

- Legal status: Non-profit association (e.V.)
- Mission: Application-oriented R&D
- 72 institutes with approx. 2.1 billion euros budget
- Through contract research 1.9 billion euros
- About 70 pct. of the Fraunhofer-Gesellschaft's contract research revenue comes from publicly financed research projects

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POWER ELECTRONIC SYSTEMS

From Material to Power Electronic Applications

SIMULATION

MATERIALS

TECHNOLOGY AND MANUFACTURING

DEVICES AND RELIABILITY

VEHICLE ELECTRONICS

ENERGY ELECTRONICS

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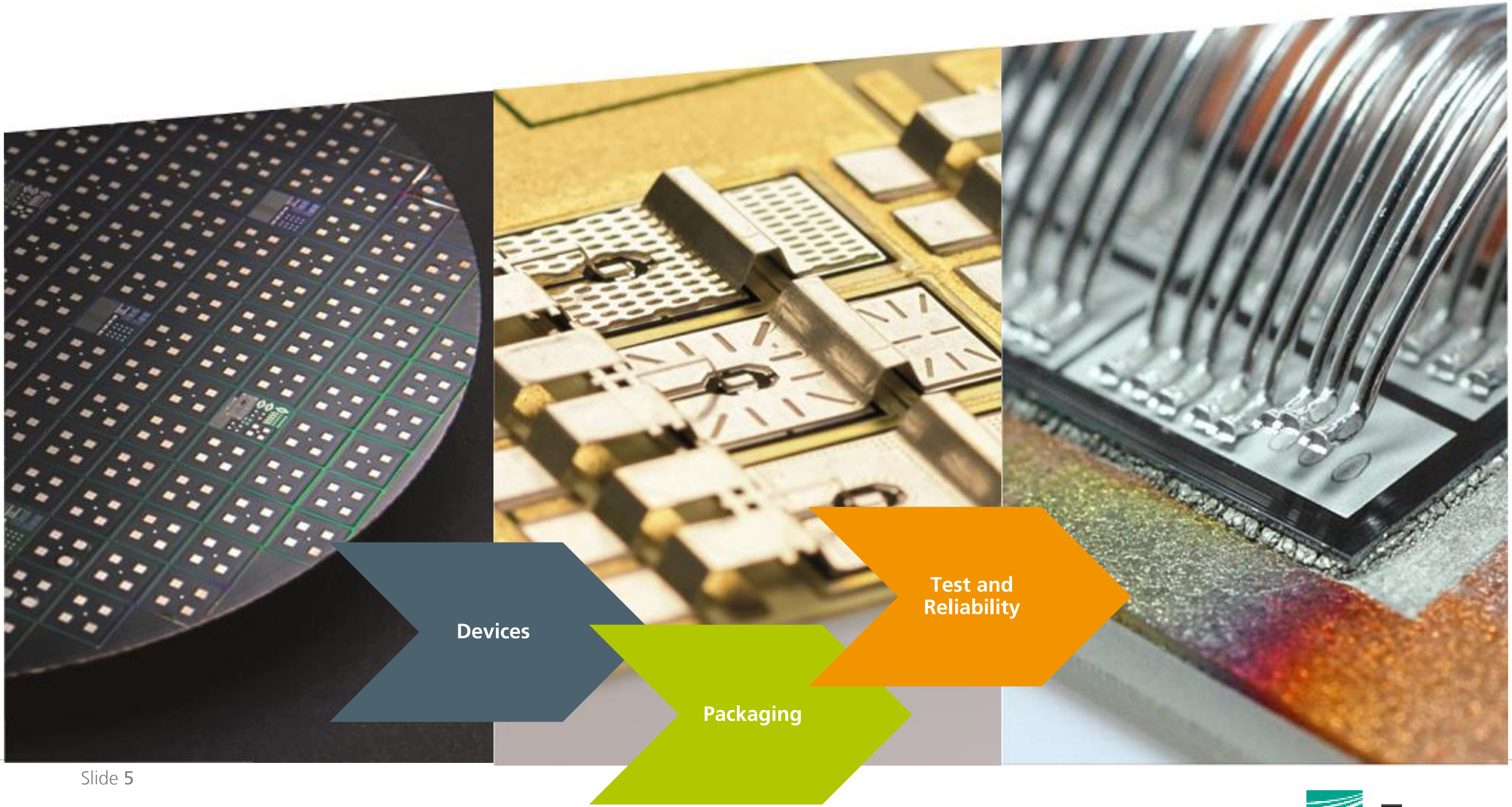
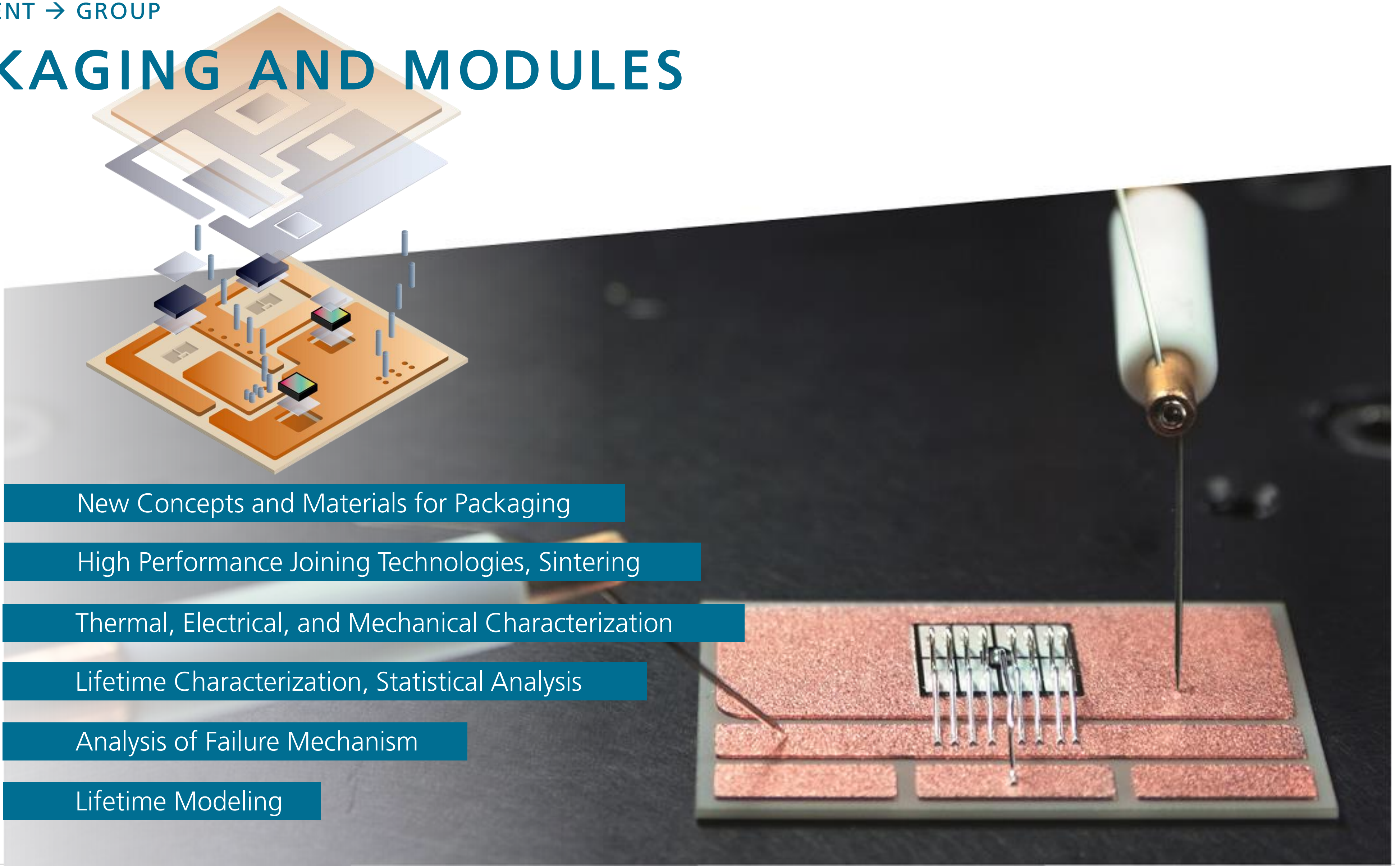
DEVICES AND RELIABILITY



PACKAGING AND MODULES



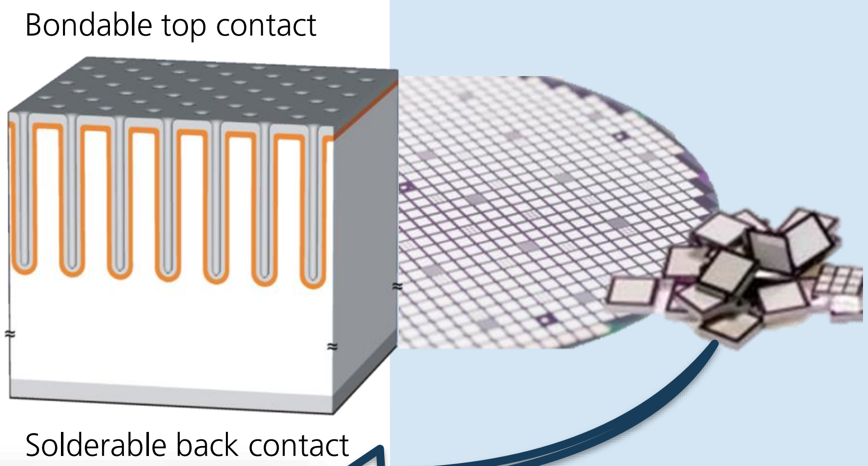
- New Concepts and Materials for Packaging
- High Performance Joining Technologies, Sintering
- Thermal, Electrical, and Mechanical Characterization
- Lifetime Characterization, Statistical Analysis
- Analysis of Failure Mechanism
- Lifetime Modeling

Future Packaging Technologies in Power Electronic Modules

- New Connection Technologies for Recent Modules
  - Si Modules with IISB Addon for SiC
  - Double Sided Sintering
  - Spot Welding for Terminals
- Sintering → Selective Sintering on Organic Substrates
- Die-to-Die Bonding for Power Electronics
- Ceramic Embedding
  - Diamond Devices and WBG in Hot Hermetic Housings
- Outlook in Further Projects
  - Simulation in Power Electronics and Topology Optimization
  - Lifetime, Corrosion and Environmental Issues

New Connection Technologies for Recent Modules

Si Modules with IISB Addon for SiC[1-5]

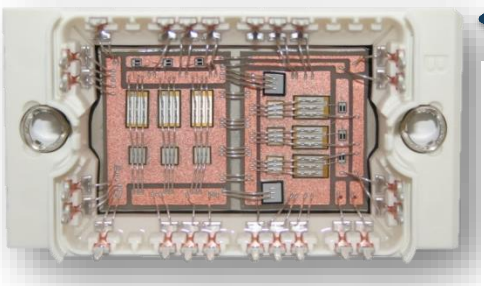


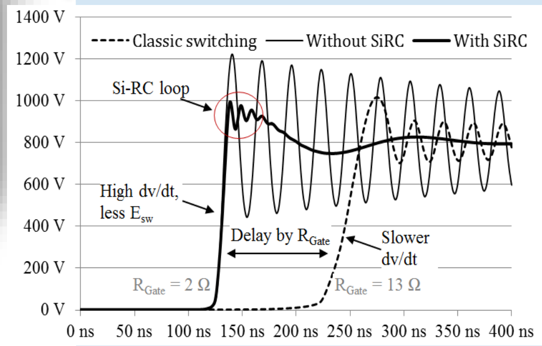
Device Concept and Implementation

- RC-snubber combination on a silicon chip
- Voltage rating: e.g. 200 V to 900 V
- Capacitance: typ. 5 nF to 30 nF

Comparison of Switching Methods

- Classic slow (200 V overshoot)
- High speed (400 V overshoot, -50 % switching losses)
- High speed with Snubber (200 V overshoot, -50% switching losses!)





New Connection Technologies for Recent Modules

Double Sided Sintering[6-10]

Sintering of Both Sides of the Devices

1. Top side leadframe
   - Pressure-assisted device sintering
   - Pressure-assisted or -less leadframe sintering

2. Top side DBC/DBA/AMB

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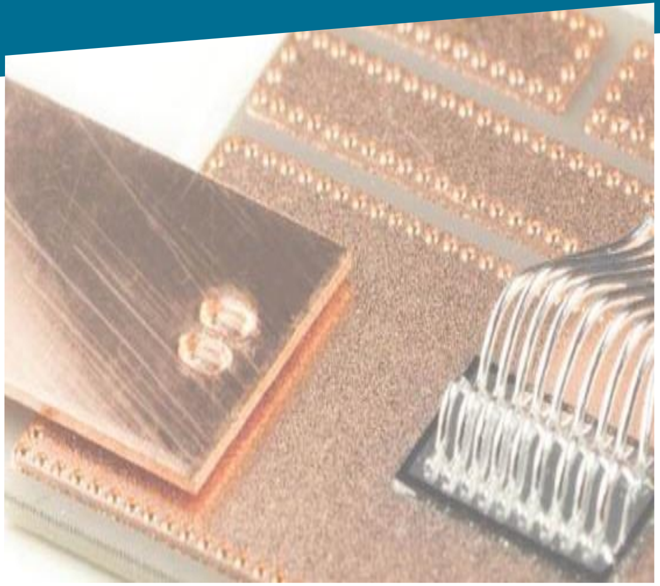
New Connection Technologies for Recent Modules

Spot Welding for Terminals[11]



Spot Welding of Copper Terminals to DBC Circuit Carriers

- Cu/Cu bonding with no interconnection layer
- Low thermal and mechanical stress during process
- DBC ceramic AlN and $Al_2 0_3$
- High lifetime and no lifetime impact on surroundings

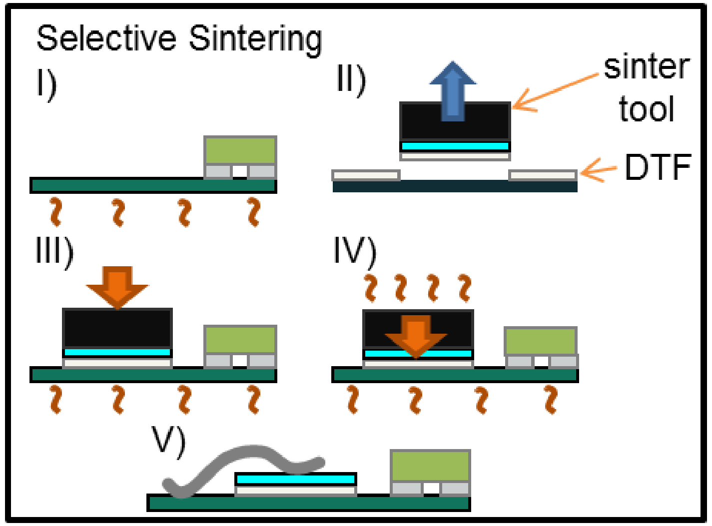
Selective Sintering on Organic Substrates[12-13]

Generel Sintering Topics

- Pressure-assisted sintering with different materials, such as silver-with-copper paste or copper paste
- Pressure-less sintering
- Jet dispensing of sinter/solder paste
- Selective sintering

Sintering of Bare Dies or SMD Devices on pre-populated Circuit Boards

- Selective sintering process
  - Picking device then sinter film (DTF), placing
  - Final sintering by die placer



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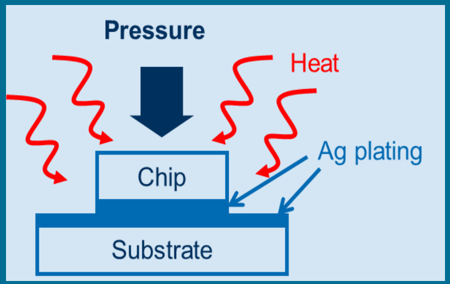
GROUP – PACKAGING AND MODULES

Die to Die Bonding for Power Electronics[14-15]



Goal

- Bonding without explicit bonding material (without solder/sinter paste)

Solution

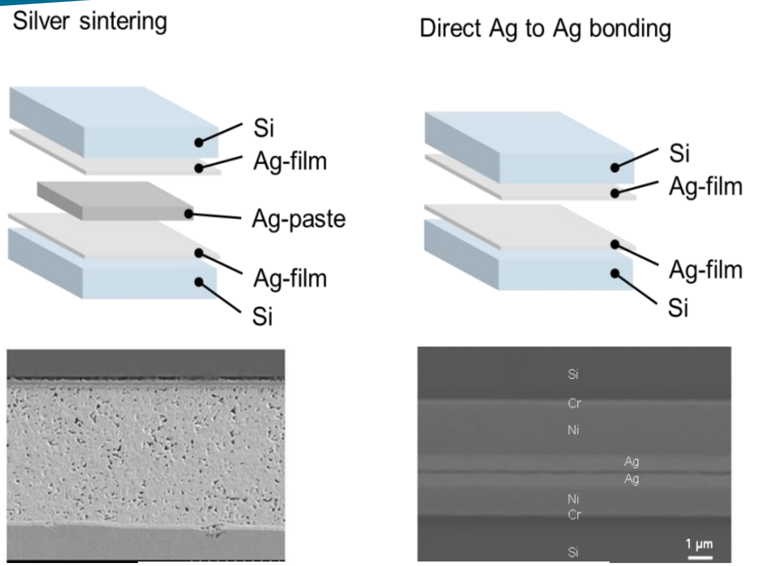
- Chip on chip bonding from MEMS adopted to power electronics
  → enabling technology: general sintering

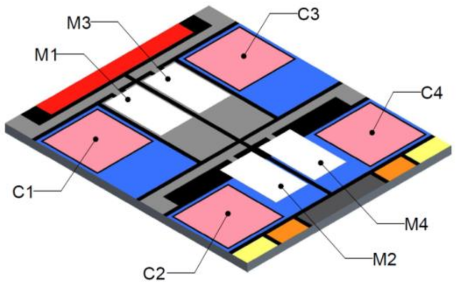
Highlights

- High integration density, high temperature capability >300 °C

Relevance

- Heterogeneous packaging
- Research directions – bonding without bonding material
  - Chip-on-chip, chip-on-interposer, chip-on-DBC/DBA/AMB
  - Chip/device stacking → more than two dies with adaption of chip metallization and insulation





48 V to pol-converter with GaN package

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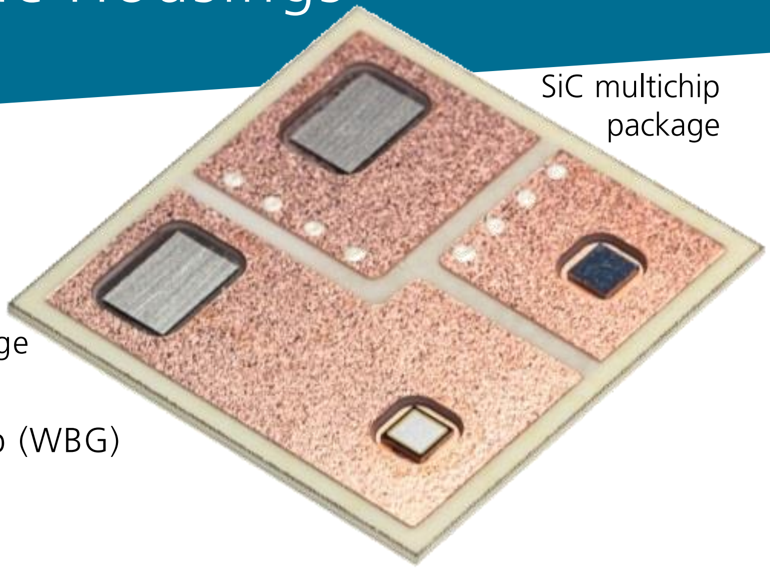
Ceramic Embedding

Diamond Devices and WBG in Hot Hermetic Housings[16-18]



SiC multichip package

Goal

- Compact and hermetic high temperature packaging for high voltage

Issue

- State of the art organic materials do not cover wide band gap (WBG) semiconductor devices' demands

Solution

- Embedding in ceramic circuit board like DBC/DBA/AMB
- Subtractive laser ablation for extremely fine pitch and cavities

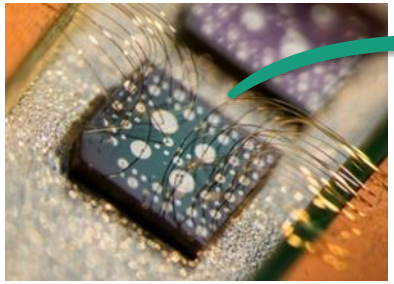
Highlights

- High integration density
- High temperature capability >300 °C
- High voltage resistant (>12 kV demonstrated)
- Hermetic for harsh environments

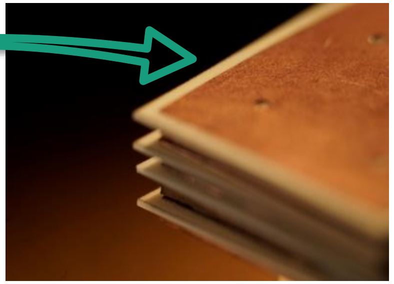
Relevance

- Air cooled power electronics solutions

diamond diodes



four stacked embedded diodes



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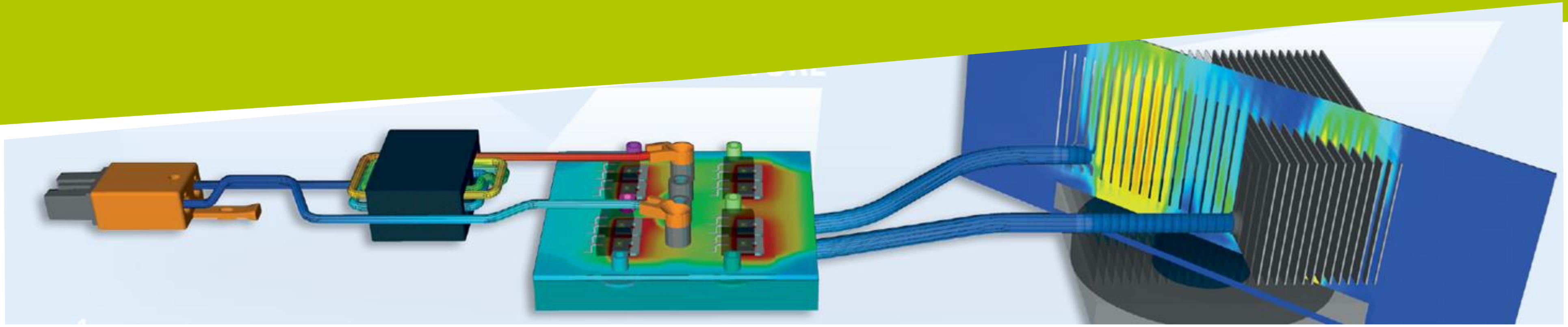
Outlook in Further Projects

Simulation in Power Electronics and Topology Optimization[19-23]



Simulation – Optimization – Rapid Prototyping

- Electrical, thermal, and mechanical simulation on device, module, and system level, electronic cooling design, thermal management, as well as extraction of electric parasitics and circuit simulation
- Coupled and multiphysics simulations
  → topology optimization, automated topology generation
- Subtractive and additive prototype generation of various power electronic components
  → 3D printing at IISB (ceramic, metal, organic), laser ablation for fast DCB structures

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Outlook in Further Projects

Lifetime, Corrosion and Environmental Issues[24-34]

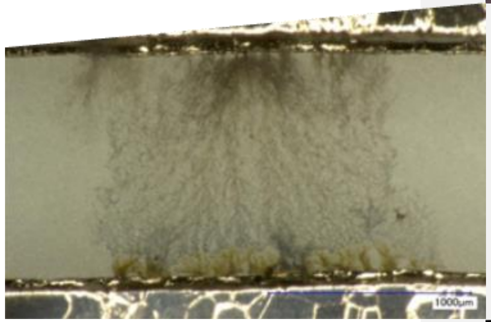
Lifetime Testing and Analysis

- Thermo-mechanical testing
  - Power cycling test, temperature cycling or shock test
- Chemical/environmental testing
  - Humidity, salt spray or corrosion gas testing
- Analysis
  - SEM, SAM, FIB (focussed ion beam), grinding, laser ablation, surface characterization techniques, lock-in thermography etc.

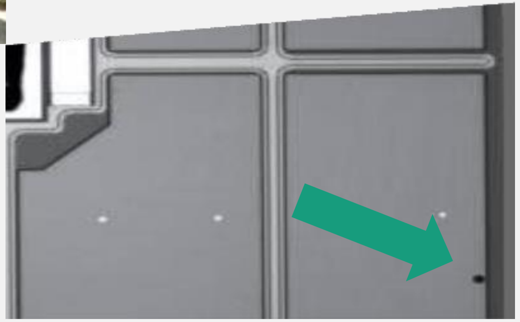
Lifetime Concepts and Coating

- Application of high temperature capable and narrow gap filling coating systems (e.g., Parylene)
- Conception of novel test methods for application oriented tests of insulation systems in WBG power modules
- Concepts for passives lifetime characterization and testing of capacitors

Active power cycling testing



Dendrite growth in isolation gap of a power module



Localized defect on IGBT by lock-in thermography

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Addon → Corrosion Clip

Electrochemical Corrosion (ECM)

https://www.iisb.fraunhofer.de/en/research_areas/packaging_reliability.html

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THANK YOU FOR YOUR ATTENTION!

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