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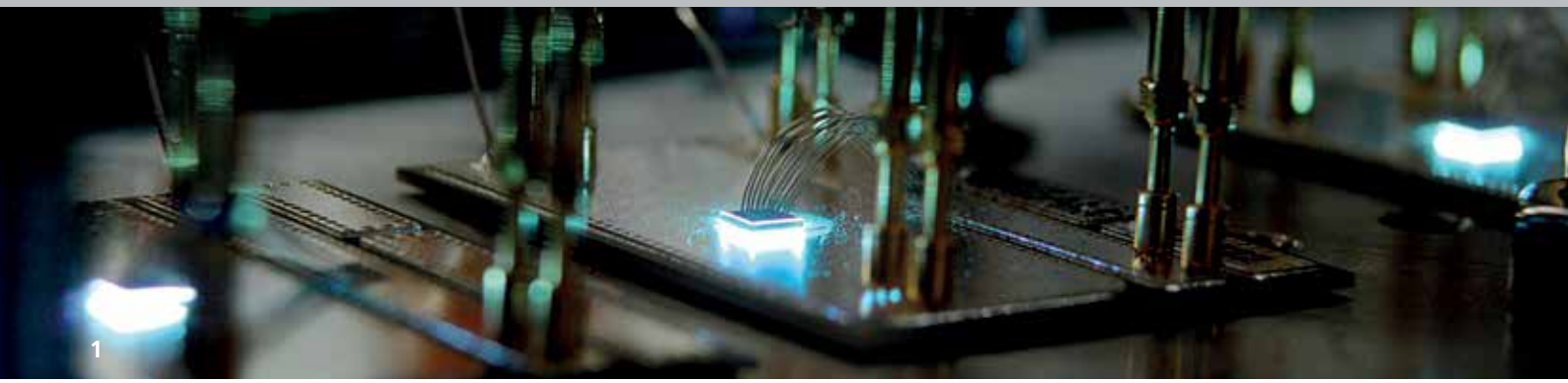
FRAUNHOFER INSTITUTE FOR INTEGRATED SYSTEMS AND DEVICE TECHNOLOGY



1 *Mounting samples on a cold plate*

ACTIVE POWER CYCLING TEST

LIFE TIME CHARACTERIZATION OF POWER MODULE TECHNOLOGIES

Fields of research and service

- Design and assembly of power modules for testing (silver sintering, soldering, wire bonding)
- Generation of lifetime data
- Statistical analysis and interpretation of measured life time data
- Life time modelling for die attach technologies and power modules
- Long time experience on power cycling tests and analyzing of failure mechanisms
- Consultancy on test planning, failure modes and result interpretation

Special features

- 5 independent test benches available
- Up to 20 devices within one test run
- On-line measurement and control system for each device under test (indirect measurement principle)
- Thermal impedance Z_{th} measurement during each cycle and of all samples
- Individual setting of gate-voltage for every device under test
- Automatic end-of-life-detection
- Heating current from 0.1 A up to 2000 A
- Heating voltage up to 35 V
- Heating and cooling power up to 20 kW
- Coolant temperatures from -60... +350 °C possible

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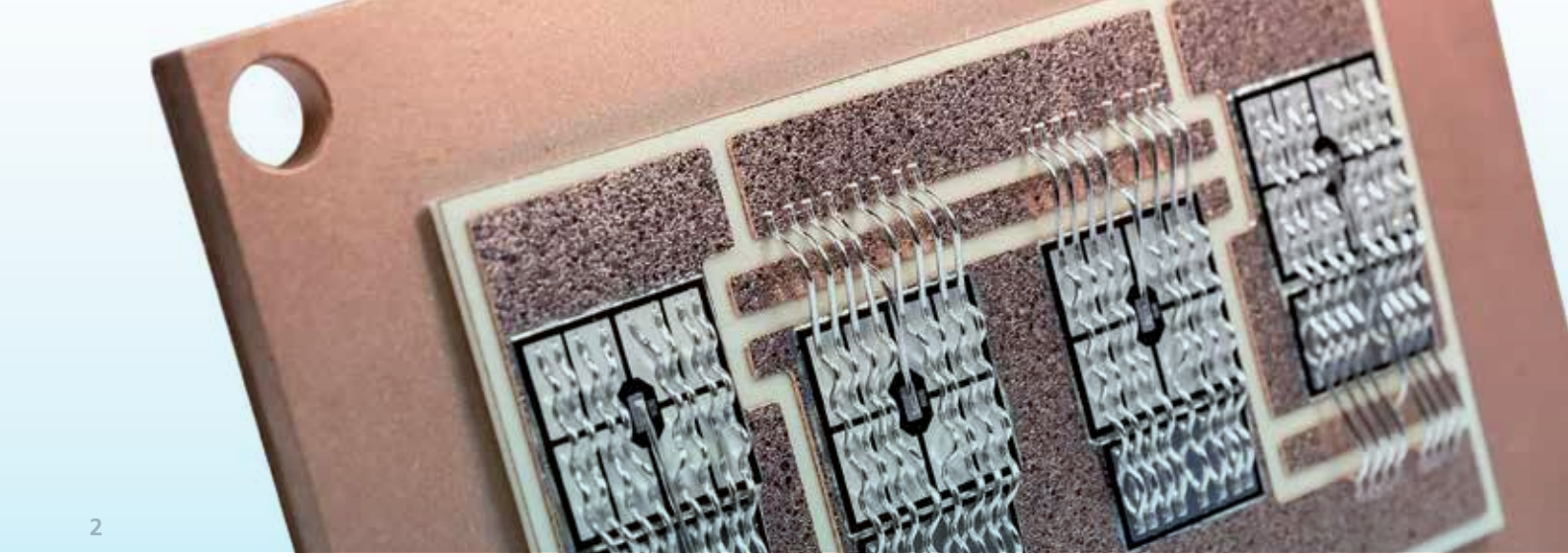

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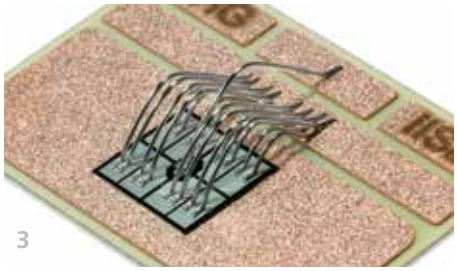
Description of test principle

- Active temperature cycling is an accelerated life time test for power electronic devices
- Reliability characterization of new packaging concepts, materials, devices and technologies
- The device is heated up via DC-current by semiconductor power losses
- After heating the samples are cooled down by the heat sink coolant



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Devices for testing

- IGBTs, MOSFETs, JFETs, thyristors
- Resistors
- Schottky-diodes, pn-diodes
- Si, SiC and GaN devices

4

Packaging for testing

- Power modules with or without baseplate
- PCB-Boards with discretes (To-devices, D^2Paks, etc.)
- In-house test layouts and samples

5

Coolant strategies

- Liquid and air cooling
- Coolant temperatures from -60... +350 °C possible
- Coolant pressure up to 8 bar possible
- Various coolants possible
- Interaction of power cycling with temperature or pressure swings in coolant possible

Test procedures

- Constant heating current (application near)
- Constant temperature swing (academic by adjusting the gate voltage)
- Constant heating power

2 *Power modules*
3 *In-house test layout*
4 *Discrete on PCB*
5 *Heat sink for 10 power modules*

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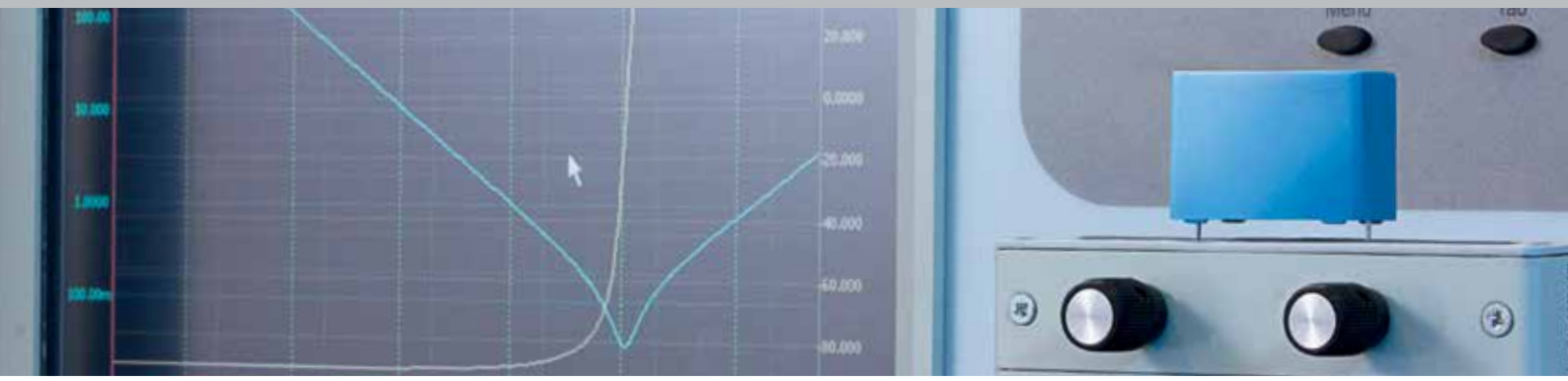

1 *Impendance measurement of a capacitor*

CAPACITORS

CHARACTERIZATION FOR POWER ELECTRONIC APPLICATIONS

What we aim for

- Characterization of new capacitors (ceramic, film, etc.)
- Evaluation of their potential for power electronic applications
- Evaluation and modelling of life time and reliability
- Reduction of volume and cost
- Improvement of the thermal management and increasing the power density

Characterization

- Impedance analysis of dielectric materials and capacitors dependent on frequency, temperature and voltage (DC bias)
- Hysteresis of capacitors and dielectric materials
- Leakage current (temperature-dependent)
- Thermal behavior, thermal impendance and resistance

Reliability test

- Temperature and humidity tests
- Passive thermal cycles
- Power cycling of capacitors

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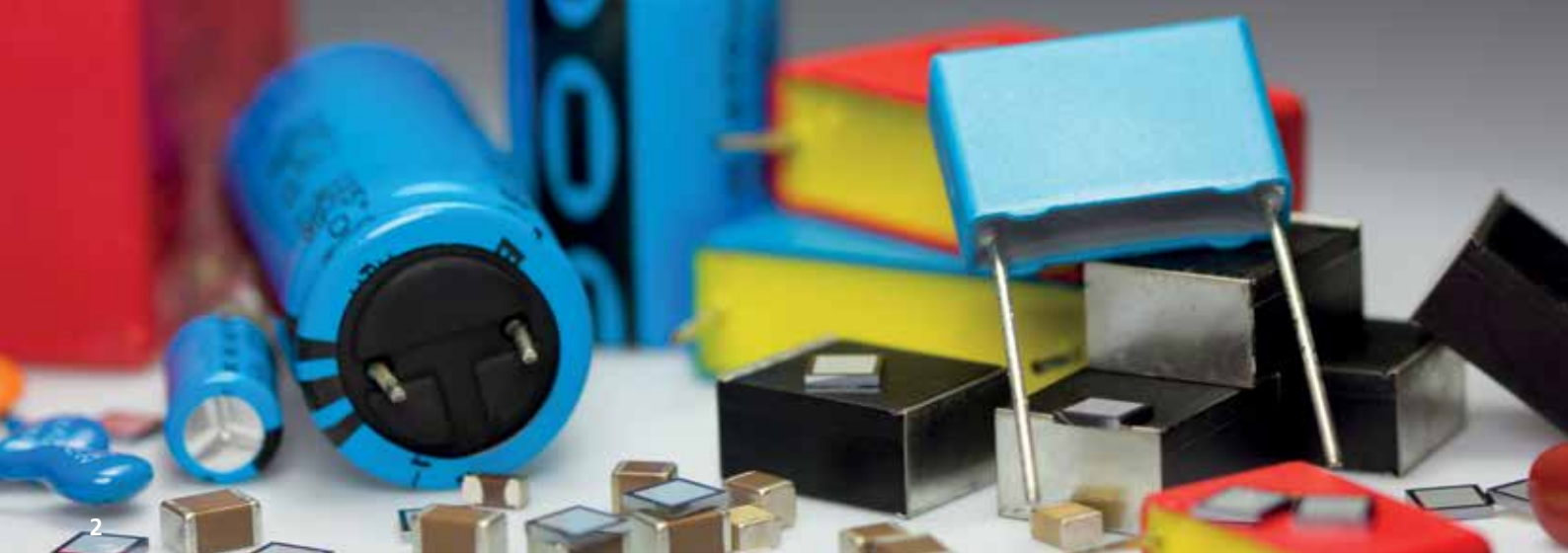

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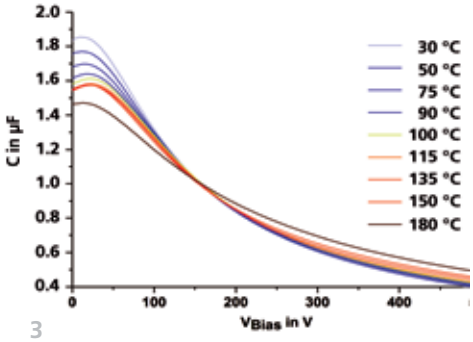
Failure analyses

- Cross section analysis and optical inspection
- Scanning electron microscopy and material analyses via EDX
- Lock-In-thermography
- Focused ion beam preparation



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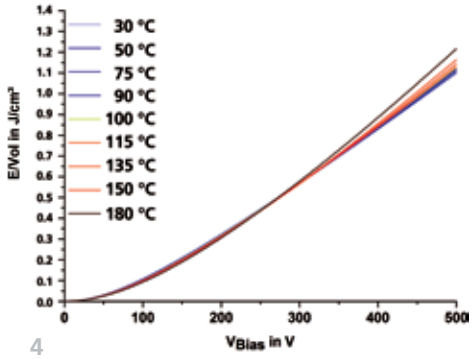
Example measurement on ceramic capacitors

- Temperature dependence of MLCC is important at low DC bias voltage only
- Influence of DC bias voltage on the capacitance is dominant at high voltages
- Fig. 4 shows energy density calculated from the data from Fig. 3
- High temperature has a small positive effect on the energy density
- Example for voltage and current waveforms to stress capacitors in IISB's reliability test setup (Fig. 6)
- Testing under different electrical conditions (voltage, current, frequency and environmental conditions)
- Measurement of thermal impedance at different cooling temperatures



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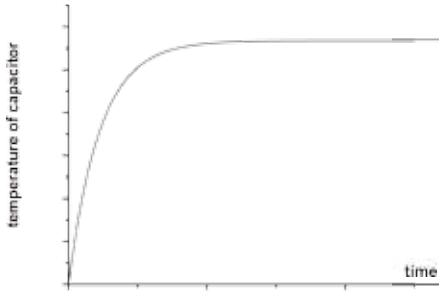

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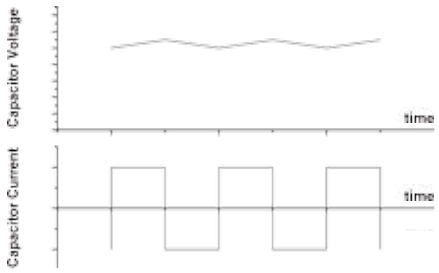

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2 *Diversity of capacitors characterized and analyzed at IISB*

3 *Capacitance of a X6S MLCC under different DC bias voltages and temperatures*

4 *Energy density of MLCC for different DC bias voltages and temperatures*

5 *Temperature of specimen during stress test*

6 *Voltage and current waveforms applied to stress a capacitor*

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1 *Graphite between power semiconductor and insulating substrate for heat spreading and life time improvement*

CTE MANAGEMENT

GRAPHITE MATERIAL FOR POWER MODULES

Conceptional idea

- Life time improvement by matching of thermal expansion coefficient by graphite
- Life time improvement by overall CTE management
- Heatspreader between semiconductor die and insulating substrate or base plate configuration
- Direct bonding of graphite to ceramic insulator by different joining technologies

Conceptional investigation

- Evaluation of cooling, heat spreading by special graphite material
- 3D simulation of thermal behaviour
- 3D simulation of electrical performance especially for the graphite material
- Analytical calculation of three layer spreading resistance

Packaging

- Metallization of graphite surface with different technologies
- Different metals like nickel (solderable) and silver (sinterable)
- Bonding of the graphite direct to DCB (aluminum nitride or alumina)
- Silver sintering of semiconductor dies to the graphite metallization
- Soft soldering of semiconductor dies to the graphite metallization

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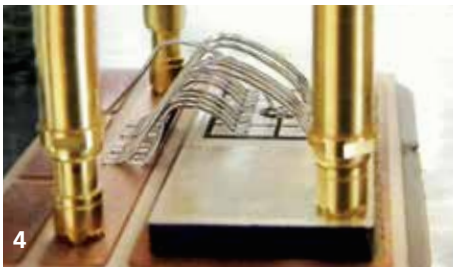
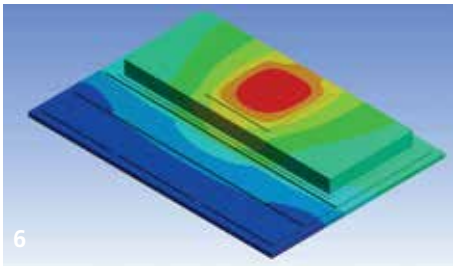
Testing

- Shear testing to characterize the graphite metallization
- Thick wire bonding to characterize the surface
- Measurement of the thermal behaviour, static (R_{th}) and dynamic (Z_{th})
- Measurement of the electrical performance
- Life time characterization of packaged semiconductor devices (active power cycling till end of life)
- Life time characterization of the material stack in terms of environmental conditions (humidity, temperature, etc.)



Graphite material properties

- Coefficient of thermal expansion (CTE) below 5.10^{-6} 1/K perfectly matched to low CTE base plate materials such as AlSiC or AlN insulating substrates and semiconductor dies like Si, SiC, GaN
- Thermal conductivity (λ) approx. 100 W/mK



2 *Metallized graphite*
3 *Graphite as base plate material*
4 *IGBT on heatspreader during power cycling test*
5 *Cross section of heatspreader bonded to DCB substrate*
6 *Thermal simulation of heatspreader design*

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1 *Analysis and discussion of sinter layers by optical microscopy*

FAILURE-ANALYSIS OF ELECTRONIC DEVICES AND SYSTEMS

DESTRUCTIVE AND NON-DESTRUCTIVE ANALYSIS FOR POWER ELECTRONICS

Fields of research and service

- Investigation of field returns
- Characterization of samples accompanying in-house and external life time tests such as active power cycling.
- Analysis of new packaging concepts and joining technologies, for instance sinter technology versus soldering
- Competitive analysis of power electronic systems, modules and devices like power electronics of hybrid vehicles
- Physics of failure analysis, material characterization for parameterization of existing life time models or enhanced ones
- Interpretation of test results and failure mechanisms such as edge termination break down of semiconductor devices
- Consultancy on the different investigated failure modes, for instance chip damage due to improper bond wire process parameters

Analyzing methodes

- Non destructive techniques, for instance scanning acoustic microscopy
- Destructive techniques such as cross sections, focused ion beam or shear tests

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Destructive analysis

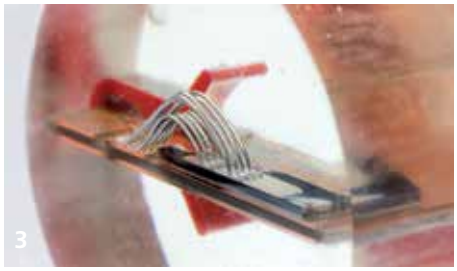
- Cross-sectioning
- Optical microscopy (magnification up to 5000x)
- Scanning electron microscopy (SEM)
- Element analysis (EDX, distribution and quantity)
- Focused ion beam (FIB)
- Decapsulation of mold compounds and silicone gels
- Chemical removal of chip topside metallization and contacts, for instance bond wires and ribbons out of different materials
- Nanoindentation, tensile tests under extended temperatures
- Shear, pull and peel tests

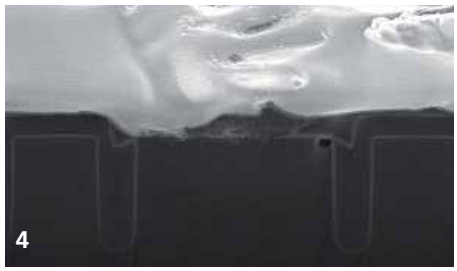
Non-Destructive analysis

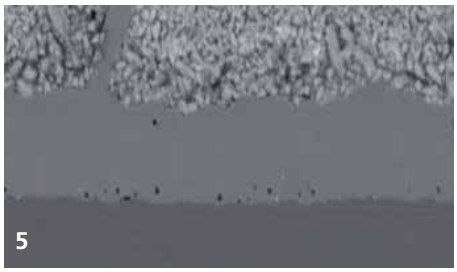
- Scanning acoustic microscopy (investigation of voids, cracks, delamination)
- Partial discharge measurement for isolation quality investigations
- Ultra-violet imaging of discharge effects
- Infrared imaging, thermography for thermal resistance measurements
- Lock-In-Thermography for localizing of defects
- Eigen frequency measurement to determine cracks inside the material
- Static and dynamic electrical characterization

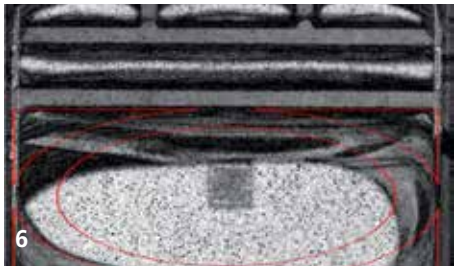
„Physics of Failure“ method

- The „physics of failure“ method assists to get a better understanding of the reasons behind the symptom
- Fraunhofer IISB helps to ask the right questions for the interpretation of failure analysis
- Failure-Mode: What kind of failure effect? Short/ open circuit, heating, etc
- Failure-Cause: What kind of process? Crack formation and growth, migration, corrosion, etc
- Failure-Mechanism: What triggers the failure? Bond wires, solder layer, cooling, etc.
- Failure-Model: How can the failure be described? Mathematical or statistical model, FEM simulation, etc.









2 *Demolded IGBT and diode of an D²Pak device*
3 *Cross section of IGBT power module*
4 *Focused ion beam analysis of an IGBT*
5 *Scanning electron microscopy*
6 *Scanning acoustic microscopy of an DBC substrate with conchoidal fracture*

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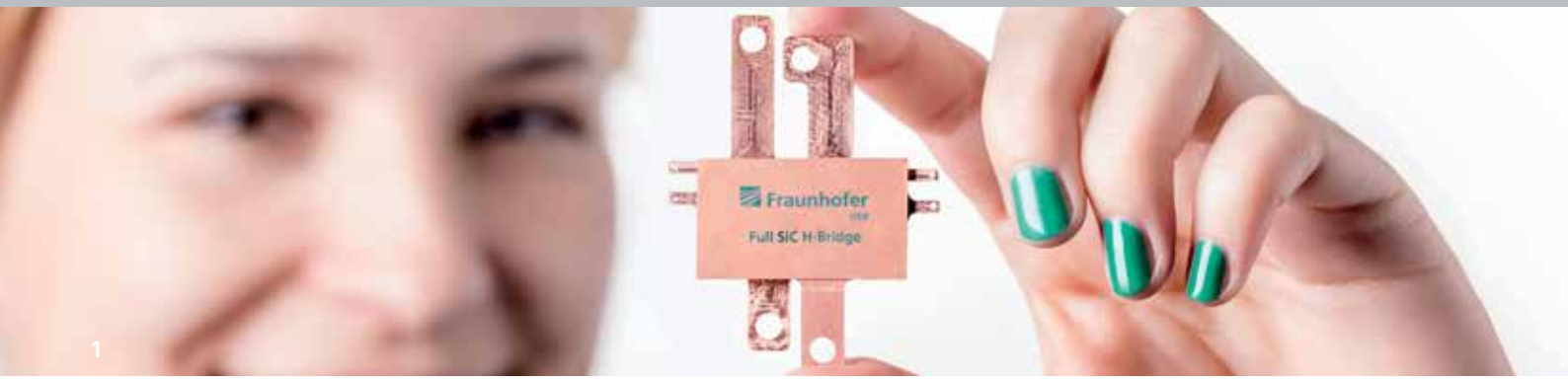

1 *Employee with full SiC Power Module*

FULL SIC DOUBLE SIDED BUSBAR POWER MODULE

LOW INDUCTIVE AND HIGH TEMPERATURE POWER MODULE CONCEPT

Idea of concept

- Low inductance and high temperature power module for e-drives
- Fast switching with SiC
- DC+ & DC- on outer metalliztion for lowest parasitic C to ground
- High reliability and temperature capability by silver sintering
- Low cost due to copper busbars with hybrid polymer isulation layers instead of DBC substrates
- Double sided cooling, high thermal capability

Module properties

- Nominal 80 A/1200 V
- SiC-FETs with low $R_{DS,on}$
- Integrated Si-pulse capacitors
- Low inductance of < 1 nH
- R_{th} of 0.4 K/W

Assembly concept

- Modular design of Full SiC H-Half-Bridge
- High temperature capability (up to 300 °C)
- 70 % less mounting space compared to state-of-the-art modules with same power

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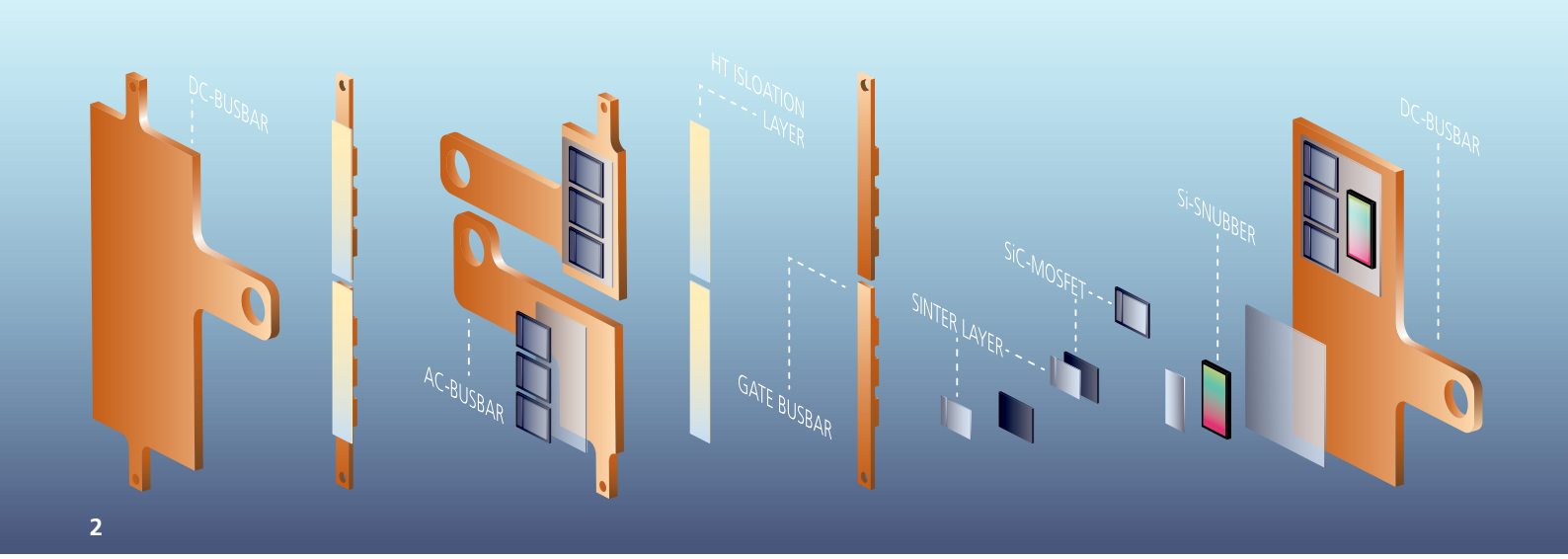

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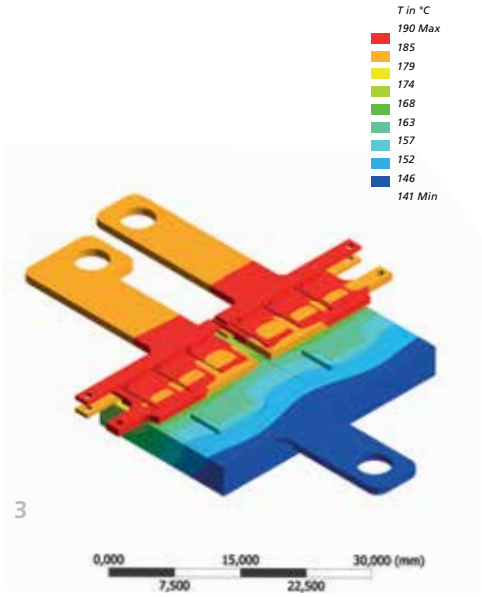
Busbar concept

- H-Bridge with 2x3 SiC-FETs in parallel
- Two Si-pulse capacitors with 10 nF capacitance
- No mold compound neccessary
- Electrical isolation of gate-busbars by hybrid polymer
- Electrical isolation of AC- and DC-busbars by hybrid polymer
- Annealed copper to lower thermo-mechanical stresses and to increase electrical and thermal conductivity
- No thermal shielding to electrical motor necessary
- Utilization of electrical motor tooth as a heat sink for high temperature applications



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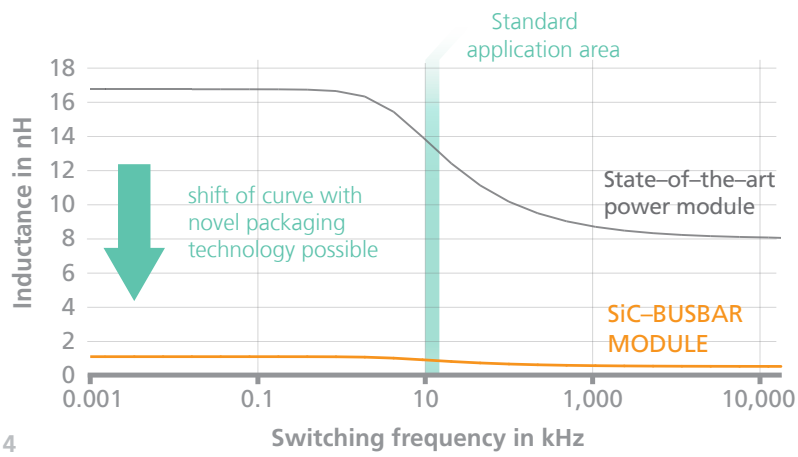
Electrical simulation

- Parasitic extraction by Finite Element Method (FEM) and Fast Multipole Method (FMM)
- State-of-the-art planar assembled power module: 13 nH inductance @ 20 kHz
- Full SiC Busbar concept: 0.7 nH inductance @ 20 kHz
- Low inductance of busbar concept due to integrated Si-pulse-capacitors

Thermal simulation

- Transient thermal simulation until steady state
- Single sided cooling with 65 °C
- Temperature of e-motor: 180 °C
- Temperature of SiC devices: 190 °C
- Temperature of Si capacitors: 149 °C
- Thermal resistance R_{th} from module to e-motor is 0.03 K/W
- Thermal resistance R_{th} from module to coolant is 0.4 K/W



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2 *Full SiC H-Bride busbar concept*

3 *Thermal simulation at steady state*

4 *Comparison of inductance of state-of-the-art commutation cells to new full SiC power module*

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1 *Lock-In-Thermography in action*

LOCK-IN-THERMOGRAPHY

NON-DESTRUCTIVE LOCALIZATION OF ELECTRIC ACTIVE DEFECTS

Description of Lock-In-Thermography analysis

- Detecting of failed power electronic devices such as IGBTs, MOSFETs, diodes and resistors
- Analysis of short circuits, ESD defects, oxide damages, edge termination defects, avalanche break down, whiskers and electrical conductive contamination
- High sensitivity for hot spot detection with a heat dissipation in the µW range
- 2D/3D defect localization for further destructive analysis to identify the failure mechanism

Special features

- Measurement voltage from mV up to 10 kV
- Decapsulation of mold compounds and silicone gels
- Chemical removal of chip topside metallization and contacts, for instance bond wires and ribbons out of different materials
- Follow up investigations such as cross-sections, scanning electron microscopy, micro sections with focused ion beam
- Interpretation of test results and failure mechanisms
- Consultancy on the different investigated failure modes, for instance chip damage due to improper bond wire process parameters

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Analysis principle

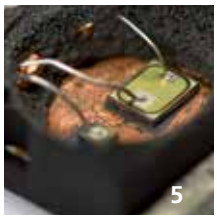
- The device under test is pulsed with the rectangular voltage by arbitrary Lock-In-Frequency (typical: 1 Hz to 25 Hz)
- Electrical defect dissipate thermal power
- Thermal power heats up the surface
- Measurement of infrared signal with infrared camera
- Acquisition of amplitude image as well as resulting time dependent step response (phase image)

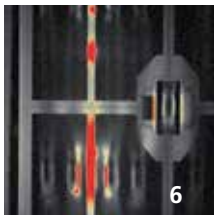
Advantages

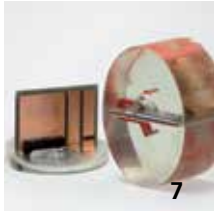
- Differential measurement principle
- Best suited for different emission coefficients of the device surface materials
- No influence of the ambient (temperature, reflections)
- Three different zoom lenses to investigate structures from complete power module to single IGBT cells

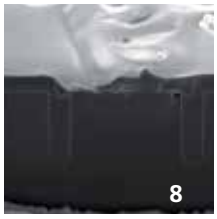
Application example

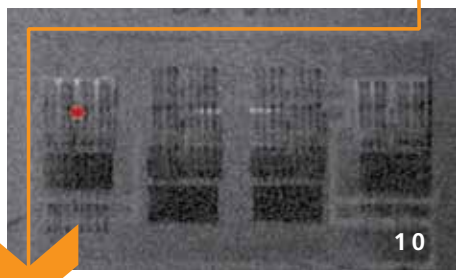
- After fabrication, a power module failed the final electrical quality test, for instance gate-emitter leakage current
- Lock-In-Thermography helps to detect which semiconductor is responsible for the leakage current and determines the exact position of the defect on the device
- Next step consists of removing bond wires and aluminum-metalization of the semiconductor followed by a second Lock-In-Thermography analysis to get the micro scale location of the defect
- An additional investigation can be a focused ion beam investigation with scanning electron microscopy to detect the cause of failure, for instance damaged gate structure

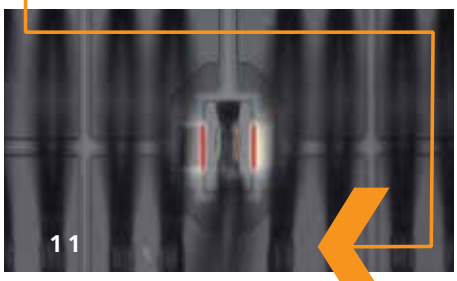












2 *Optical Microscopy of IGBT*
3 *Lock-In-Thermography Amplitude of IGBT*
4 *Lock-In -Thermography Phase of IGBT*
5 *Demolded device*
6 *Topography*
7 *Cross-section*
8 *Focused ion beam*
9 *Power modul*
10 *Lock-In overview*
11 *Lock-In detail*

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1 *Sample preparation for simultaneous thermal analysis at the NETZSCH STA 449 F3 Jupiter*

MATERIAL CHARACTERIZATION

FOR POWER ELECTRONICS PACKAGING MATERIALS

Why material charaterization?

- Get thermal and mechanical properties for Finite Element Simulations (FEM)
- Reveal best material combination for specific application
- Find adequate parameters for processing of solder- and sintering-layers, casting compounds, base plates, housings, terminals, interconnections, windings, dielectrics
- Improve life time and reliability of packaging concepts
- Reduce development time and costs

Research and applications

- Temperature dependent characterization of mechanical properties including creep-, fatigue-, fracture- and failure-investigations
- Material property mapping by spatially resolved nanoindentation at small scales
  Application examples: Intermetallic phases, die-attaches, bond wires, phase boundaries and spatial property gradients
- Thermal analysis of materials: Specific heat of semiconductors, die-attaches, solder pastes (evaporation of fluxes, melting temperature, solidification behavior), sintering pastes (drying and sintering time, temperature, and atmosphere), substrates, TIMs

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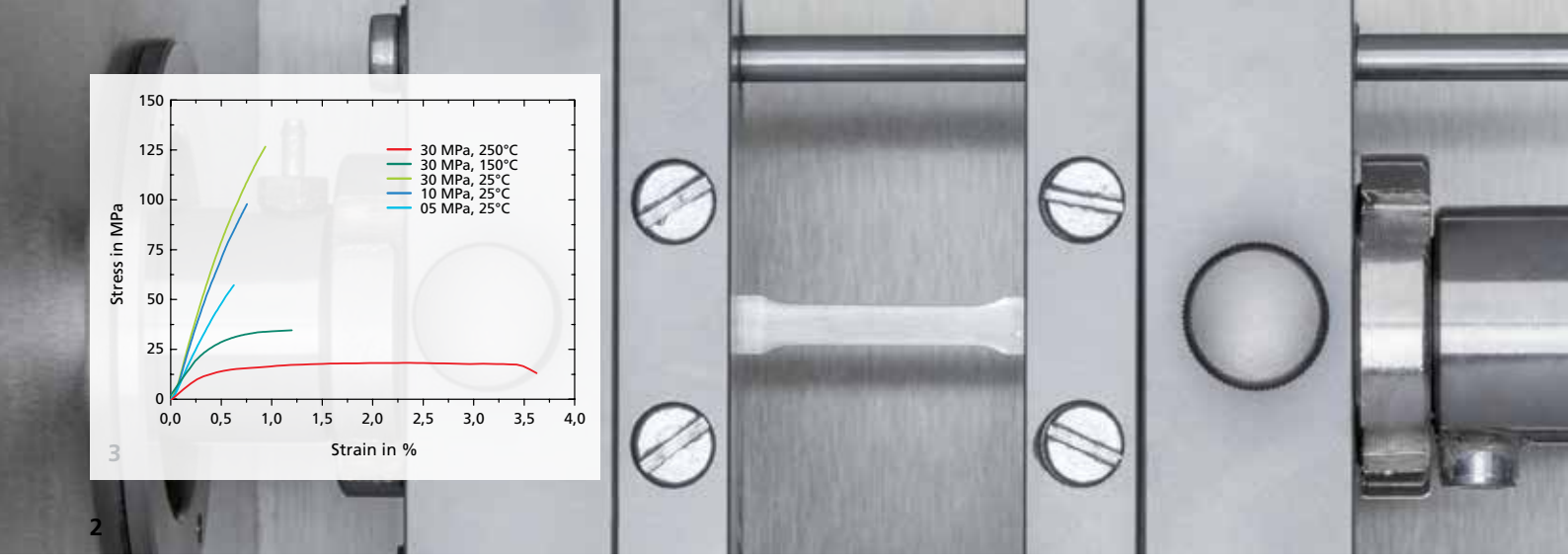


Assembly of test specimens

- Soldering: All kind of solders (lead-free, lead, gold, etc.)
- Silver-sintering: Representative specimens for tensile tests and nanoindentation
- Wire ultrasonic bonding and resistance welding
- Polishing, Etching, Micro machining

Tensile and compression testing

Global mechanical material parameters:

- Temperature dependent
- Elastic properties, tensile-, compressive-, yield-, creep- and fatigue strength
- Different strain rates for time-dependent material behavior
- Stress-strain curves for nonlinear FEM
- Special data for material models, e.g. Ramberg-Osgood, Anand, Garofalo

Nanoindentation

Local, global and gradients in mechanical material parameters:

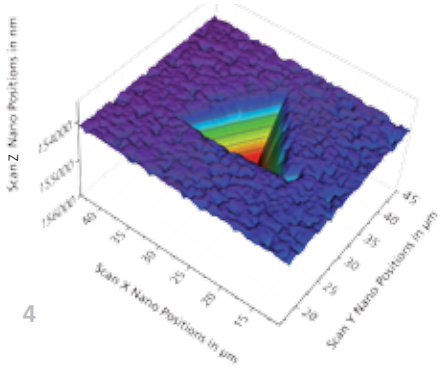
- Temperature dependent
- Elastic modulus, hardness, creep parameters
- 3D-Mapping of material properties
- Quantitative scratch and wear testing
- According to test standard ISO 14577

Simultaneous thermal analysis STA

Thermal material parameters:

- Characteristic temperatures (sintering, melting, formation of inter-metallics, decomposition, oxidation, glass transition)
- Temperature dependent specific heat capacity measurements
- Analyse of peak areas in dependence of mass change
- Kinetics of reactions, for instance oxidation and sintering
- Evaluation of mass change steps, for instance leakage of organics and debinding

	Uniaxial Testing	Nanoindentation	STA
Specimen	Rectangular cross section from sheets to bulk materials	Thin layers, multi layers, bulk materials	Liquid or solid objects
Temperature	RT to 300 °C	RT to 500 °C	RT to 1500 °C
Atmosphere	N_2, Ar, Air	N_2, Air, Ar	N_2, Air, Ar, O_2



2 Micro scale thick silver-sintered dog bone immediately before hot tensile test

3 Mechanical behavior of silver-sintered dog bone in tensile test at different test temperatures and sintering pressures

4 Berkovich nanoindent on a silver-sintered bond line obtained by nanomechanical microscopy

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1 *Double sided silver sintering of power semiconductors; design study of various top side ribbons for extended life time and processability*

PACKAGING FOR ELECTRONICS

HIGH LIFE TIME, HIGH TEMPERATURE AND EXCELLENT RELIABILITY

Conceptional investigations

- Evaluation of cooling concepts, liquid and air, single and double sided cooling, heat spreading
- Life time improvement by matching and minimization of material's coefficients of thermal expansion (CTE)
- Designs with and without baseplate
- Design for electrical, thermal, mechanical and life time constraints
- Low parasitic inductance commutation cells especially for SiC and GaN
- High temperature applications up to 300 °C junction

Silver sintering

- Pressureless and pressure assisted (up to 75 kN) process for small and large areas
- Single and double sided semiconductor devices
- Multichip power modules using pre-attaching
- Selective sintering on populated circuit boards or in cavities of busbars
- Sintering of active and passive components
- Sintering on DBC, PCB and leadframe
- Screening of different sinter material

Soldering

- Standard lead free tin based and high temperature alloys
- Void free soldering with paste and preform material

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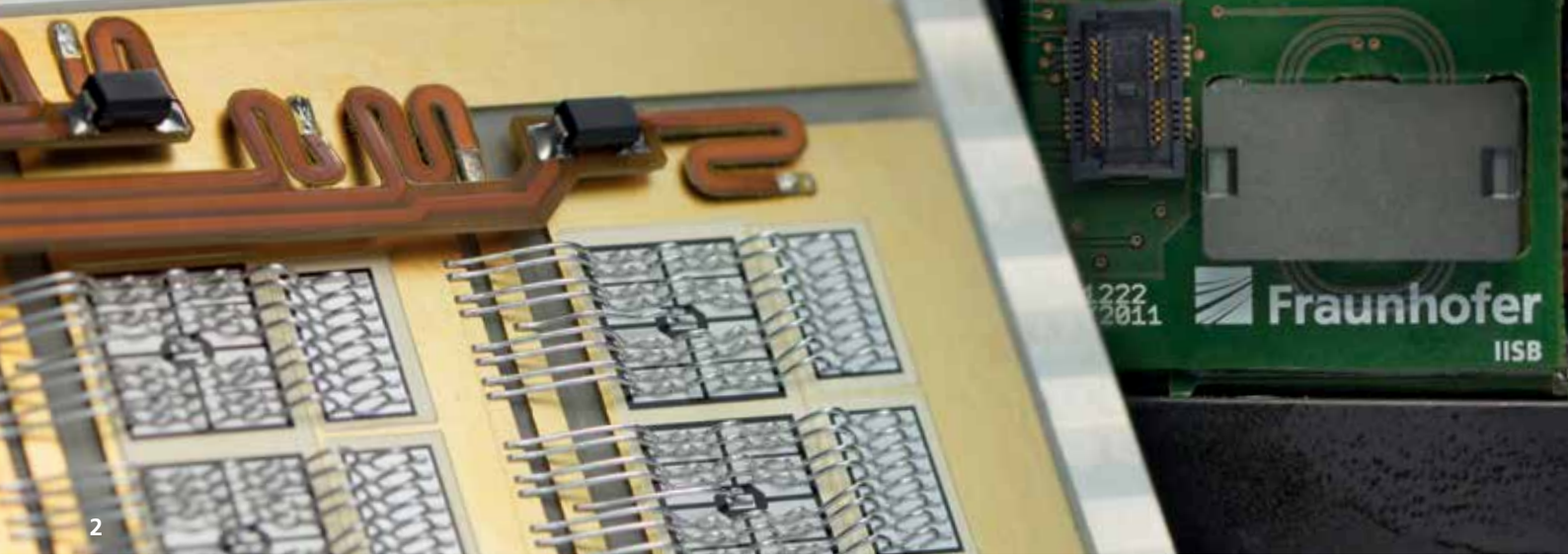


Wire and ribbon bonding

- From 25 µm gold wire to 500 µm copper wire
- Different materials such as gold, aluminum, copper and composites

Prototyping

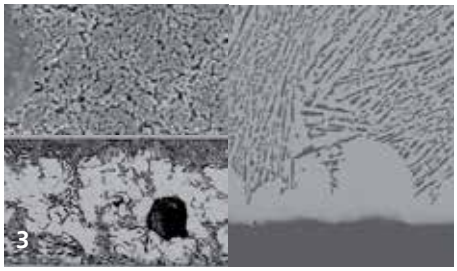
- Material selection including housing and potting
- Procurement of material
- Small-scale production and qualification

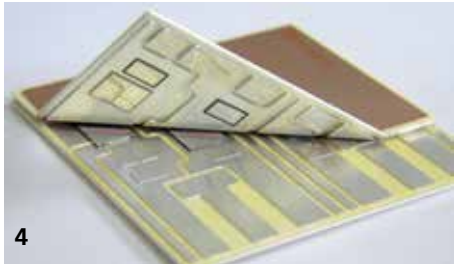
Testing

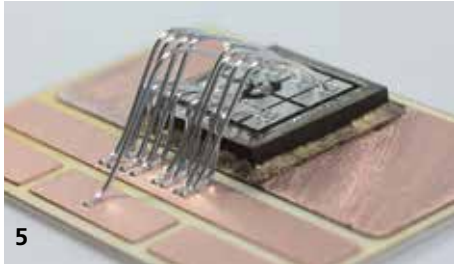
- Static and dynamic thermal measurements from chip to coolant
- Thermal measurements with thermography
- Static electrical characterization
- Dynamic switching characterization
- Scanning acoustic microscopy
- Shear, pull, peel test
- Active power cycling
- Passive temperature cycling

Equipment

- Multi-physics simulation tools (electro-thermo-mechanical), CAD
- Plasma cleaning and activation of surfaces
- Printer for paste material
- Vapor-phase vacuum soldering
- Formic-acid-activated infrared vacuum reflow
- Hydrogen activated infrared vacuum reflow
- Full automatic die placer with high temperature and extended tool force capability
- Automatic wire and ribbon bonders (aluminium, copper, composites, and gold)
- Servo press for sintering
- Ultrasonic and resistance welding machines for electric terminals







2 *Inverter Building Block for the IISB electric vehicle technology demonstrator; robust concept with direct cooled CTE matched baseplate, full aluminium approach, integrated gate driver, current sensor and DC link capacitor (600 V IGBT half bridge)*

3 *Cross-section of a silver sintered, gold-germanium, aluminium-zink and high lead soldered bond lines*

4 *Double sided cooled sintered power module*

5 *Head spreading and CTE matching by graphite*

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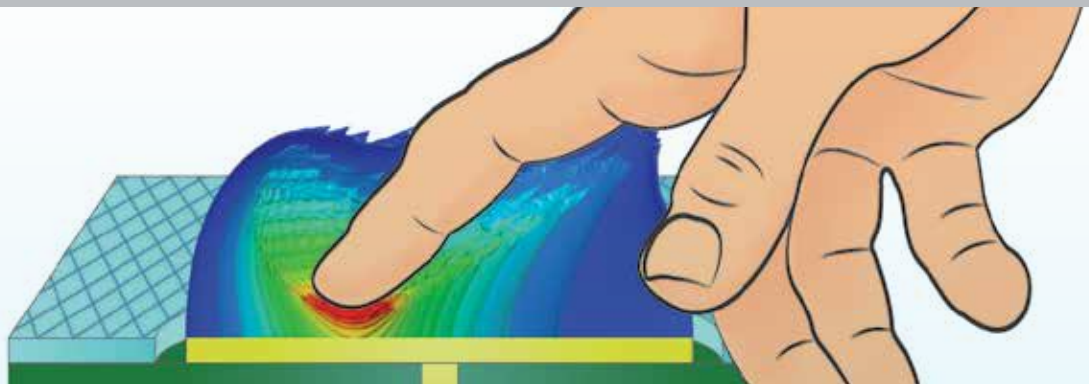

1

1 *Distribution of the electric field strength: finger close to the sensoring electrode and extraction of L and C possible*

SIMULATION OF ELECTRIC PARASITICS AND FIELDS

Simulation opportunities

- Parasitic electric effects – extraction of capacitance, conductance, inductance and resistance matrices
- Electric and electromagnetic simulation
- Circuit simulation of complex power electronics
- Simulations not limited to power electronics

Parasitic extraction

- 3D and 2D extraction of parasitics in electronic packaging
- Computation of the capacitance, conductance, inductance and resistance matrices
- Generation of a netlist by extracted LCR parameters of any design, for instance SML or SPICE format
- Calculation of the inductance and capacitance values of PCB or standard power module designs as well as of sensors and other similar applications

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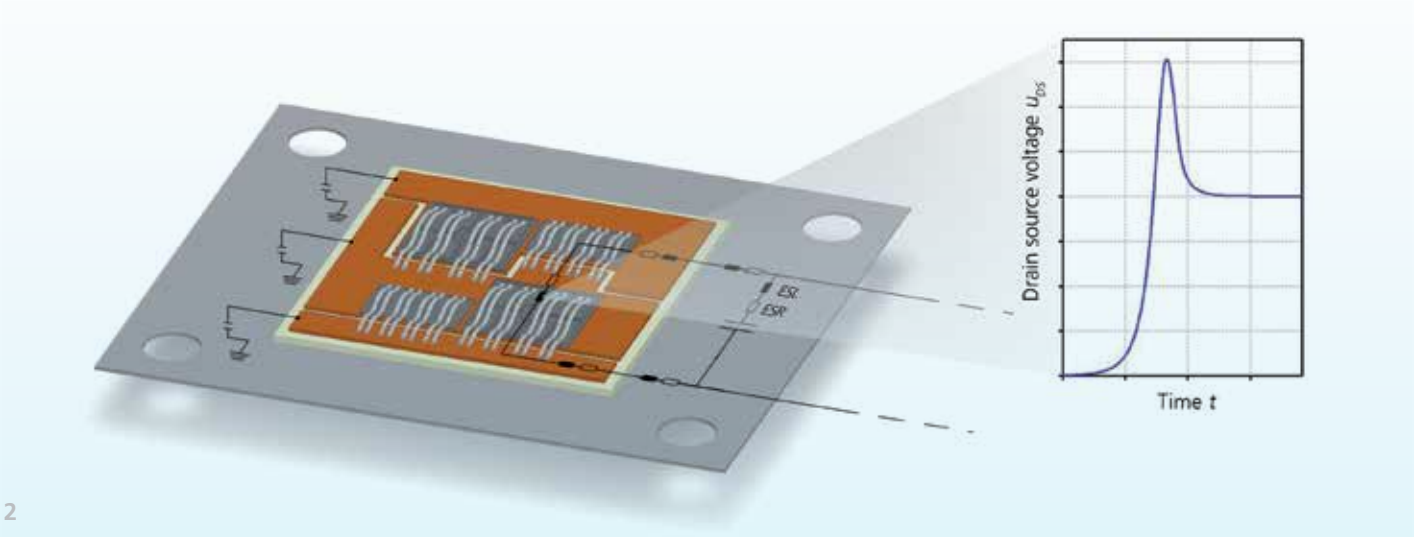


2

Circuit simulation

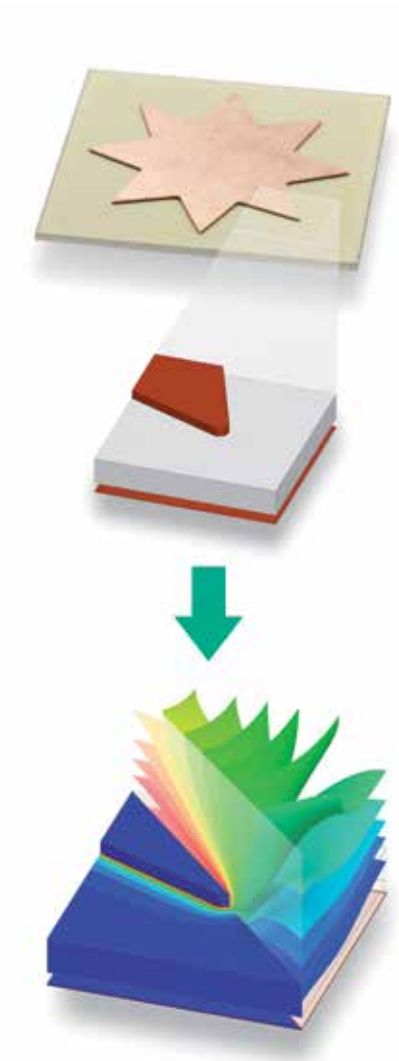
- Circuit simulation of power modules, for instance half-bridge or commutation cells
- Circuits based on designed layouts, the extracted parasitics serve as input parameters
- Realistic answers of the system to applied voltage and current wave forms

Electric and electromagnetic simulation

- Static and transient simulations (2D and 3D)
- Electric field strength distribution
- Identification of critical areas on the modules due to enhancement of the electric field strength
- Parametric studies of dependencies with respect to the field distribution
- Electromagnetic losses in high frequency applications
- Wide parameter studies of power coupling through coils
- Illustration of the magnetic field distribution

Software used for simulation

Always up-to-date versions of simulation software for multiphysics and electromagnetic simulation, for instance ANSYS Emag, Maxwell, Q3D



3

2 *Parasitic extraction (inductance, capacitance) of a power module as input parameter for circuit simulation - turn off overshoot due to the inductance (right)*

3 *Star-shaped copper on a ceramic (DCB) and the simulated electric field strength (left) and the electric potential (right) due to an applied voltage on the upper copper layer*

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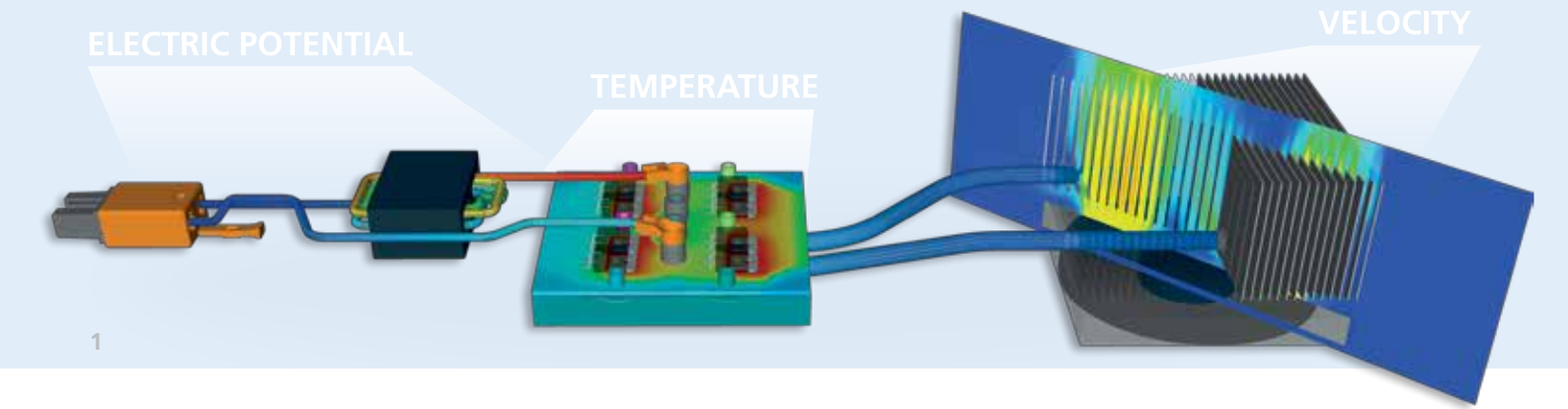

1 *Electronics simulation of Joule heating, component losses and forced convection*

SIMULATION FOR POWER ELECTRONICS

DEVICE, MODULE, AND SYSTEM SIMULATIONS

Supporting the development of power electronics, all simulations are closely linked to application and verified by measurements. Our measuring equipment is described in detail in extra information sheets.

Simulation subjects

- Electrical, thermal, and mechanical simulations on device, module, and system level
- Electronic cooling design, thermal management
- Coupled and multiphysics simulations
- Extraction of electric parasitics and circuit simulations
- Simulation – design – optimization – verification by measurement

Electrical, thermal, and mechanical simulation

- Electric current, potential and field strength distribution analysis
- Identification of critical areas of the insulation due to high field strengths
- Electromagnetic simulation
- Fundamental assessment of the temperature distribution
- Steady-state and transient temperature behavior
- Investigation of the temperature distribution of operating electronics
- Computation of the deformation due to temperature loads of the fabrication process or during operation
- Illustration of the internal stress of the attached materials in a stacked arrangement

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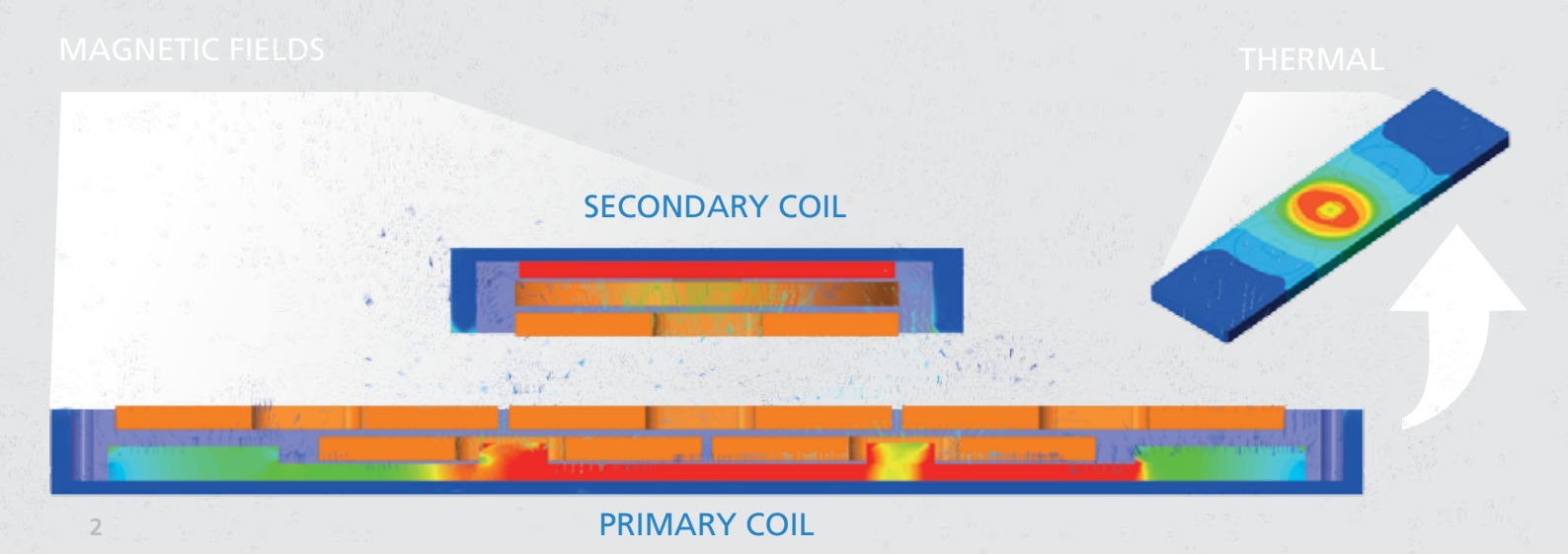


2

Electronics cooling design

- Computational fluid dynamics (multi-fluid)
- Radiation and Joule heating
- Steady state and transient simulation
- Detailed chip, board, and system level within one simulation
- Complex geometries and 3D component assemblies

Multiphysics simulation

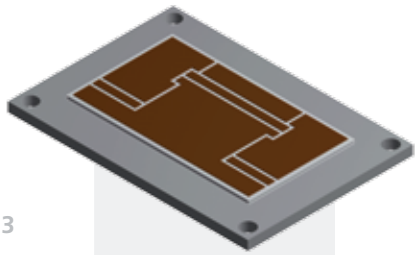
- Multiphysics coupling of simulation
- Coupled structures via electromagnetic fields
  - Coupling of coils – contactless energy transfer
  - Inductive heating of conductive components
- Coupling of simulation software – FEM calculations linked with circuit simulation

Electronic simulations

- Parasitic extraction of electronic setups – capacitance, conductance, inductance and resistance matrices
- Circuit simulation of electric circuits

Simulation – design – optimization - verification

- Power module design based on simulation
- Optimization and analysis of structures and arrangements via simulation
- Verification of test structures by various in-house measurement possibilities, for instance static and Lock-In-Thermography, indirect thermal impedance and resistance (R_{th}, Z_{th}/ different coolants, flow rates, temperatures), etc.
- Material characterization for realistic material properties as input for simulations (for example nanoindentation, tensile tests at different temperatures)



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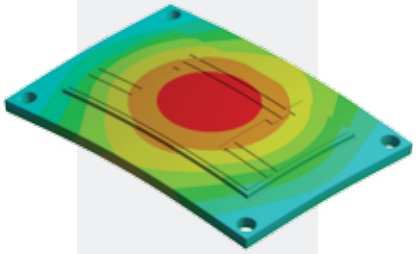
Ceramic substrate on baseplate



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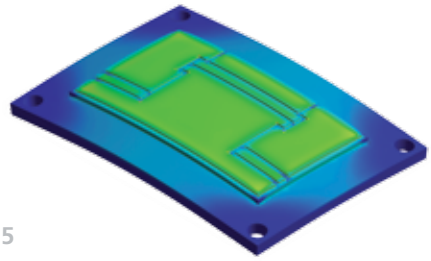
Deformation due to joining the temperature of substrate and baseplate



5

Resulting stress distribution of the arrangement at room temperature

2 *Magnetic field distribution of an inductive power transfer simulation; power losses lead to a heating in the coil arrangement*

3 *Ceramic substrate on baseplate*

4 *Deformation due to joining the temperature of substrate and baseplate*

5 *Resulting stress distribution of the arrangement at room temperature*

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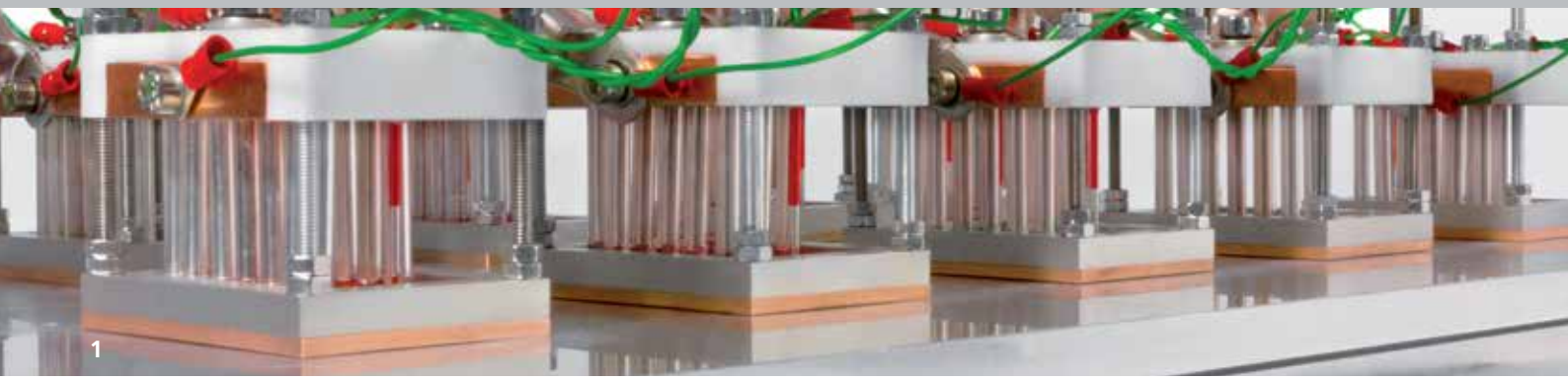

1 *Thermal characterization of power modules mounted on a water-glycol cooled heat sink*

THERMAL CHARACTERIZATION

RESISTANCE R_{TH} AND IMPEDANCE Z_{TH} MEASUREMENTS

Fields of research and service

- Thermal characterization of new packaging concepts, materials, devices and technologies for power electronic devices
- Static and dynamic thermal measurements (R_{th}, Z_{th})
- Heat sinks for single and multi devices (up to 20 samples per heat sink)
- Design and assembly of power modules for testing silver sintering, soldering, wire bonding)
- FEM-Simulation of thermal behavior from semiconductor to coolant
- Workshops for test result interpretation

Measurement system

- Temperature acquisition via device under test (indirect measurement principle)
- Direct temperature measurement by thermography, PT100 and thermo-couples
- Heating current from 0.1 A up to 2000 A
- Heating voltage up to 35 V
- Heating and cooling power up to 20 kW
- Coolant temperatures from - 60 up to + 350 °C possible
- Coolant flow up to 25 l/min
- Maximum pressure: 8 bar

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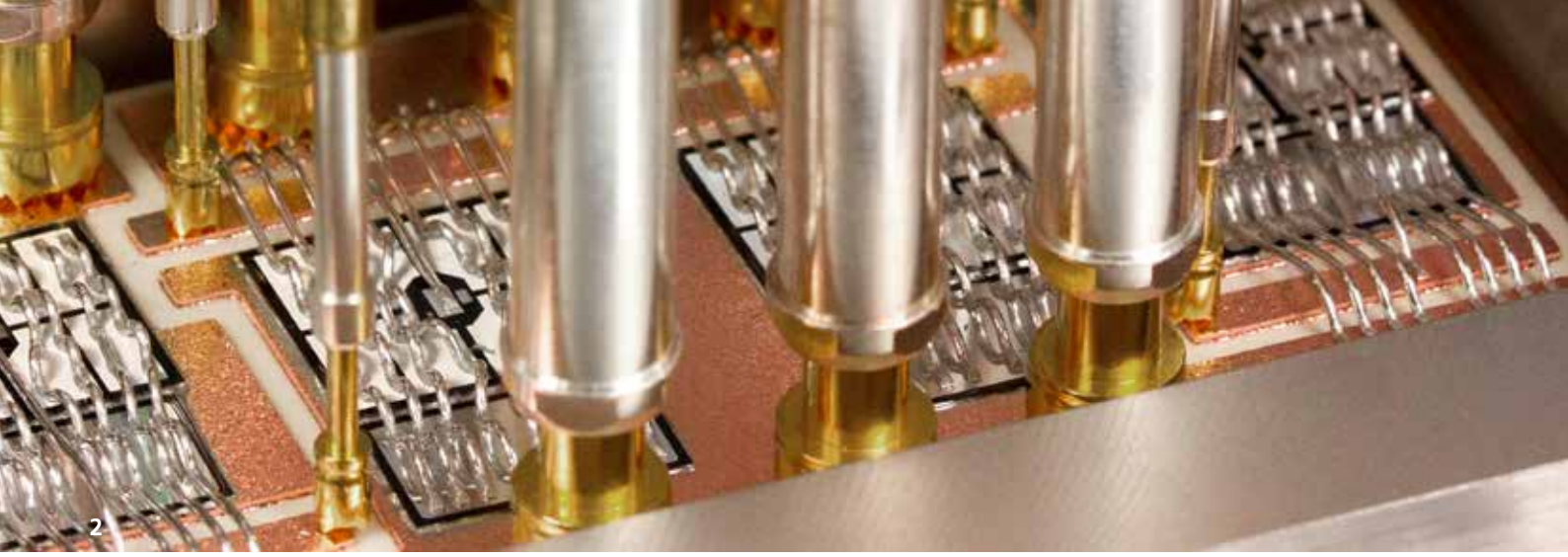
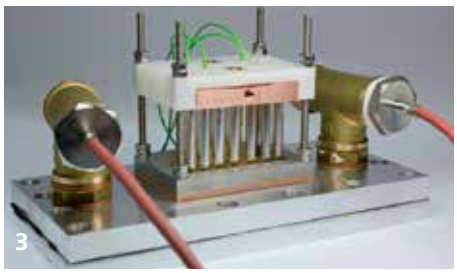


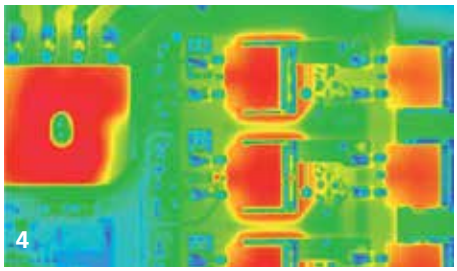
Devices for testing

- IGBTs, MOSFETs, JFETs, thyristors
- Resistors
- Schottky-diodes, pn-diodes
- Si, SiC and GaN devices



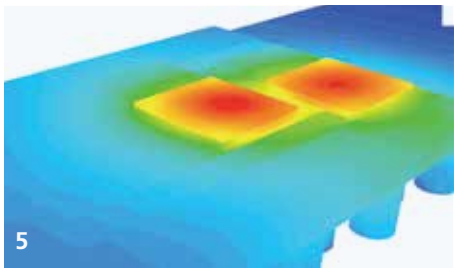
Packaging for testing

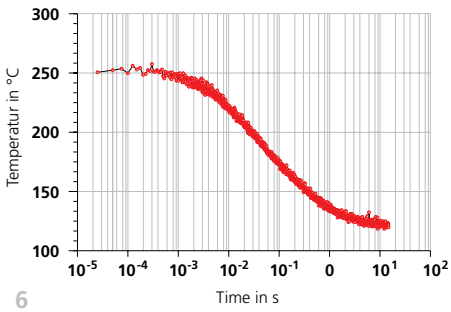
- Power modules with or without baseplate
- PCB-Boards with discretes (To-devices, D^2Paks, etc.)
- Direct or indirect water cooled systems
- Liquid and air cooled devices
- With or without housing or molding
- In-house test layouts and samples



Additional services

- Foster/Cauer network calculation
- Thermal management consulting
- FEM-simulations
- Statistical analysis





2 *Power module during thermal impedance measurement*
3 *Device under test*
4 *Thermography*
5 *FEM Simulation*
6 *Example of thermal impedance measurement*

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1 *Automatic wire bonding of power electronic modules*

WIRE BONDING

TOPSIDE CONNECTION FOR SEMICONDUCTORS

Research fields

- New materials for bond wires like copper, composites or alloys
- Improvement of application's life time by bonding parameters, geometry, material and others
- Metalization and surface optimization of semiconductors for best bondability
- Cleaning process to achieve a reliable bond connection
- Correlation between bonding parameters and lifetime using power cycling tests to life time

Our services

- Aluminum and copper wedge-wedge-bonding with diameters from 100 µm to 500 µm possible
- Ribbon bonding
- Gold ball-wedge bonding with diameters from 25 µm to 75 µm possible
- Heatable work holder for bond process under temperature for up to 200 °C
- Quality assurance by pull and shear tests
- Control of reliability and life time by active power cycling test, passive temperature cycling and vibration tests
- Design of experiments to optimize bonding parameters

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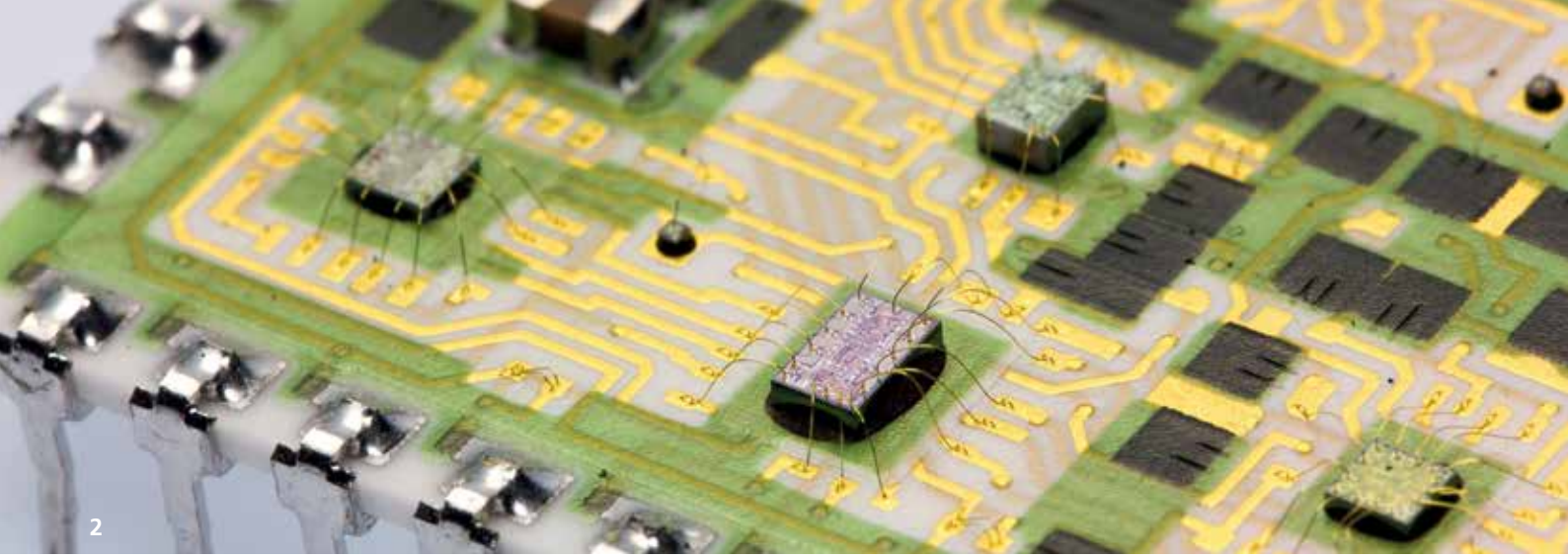


Functional principle

- Ultrasonic bonding works with high-frequency acoustic vibrations under pressure creating a solid-state welding
- For aluminum wedge-wedge-wire bonding ultrasonic energy is applied to the wire for a specific duration while being held down by a bond force
- Thermosonic gold bonding includes heat treatment and can be used to form solid-state bonds below the melting point of the mating metals
- For ball-wedge-bonding, a gold ball is formed before the bonding process by melting the end of the wire applying a high voltage

Devices and packaging

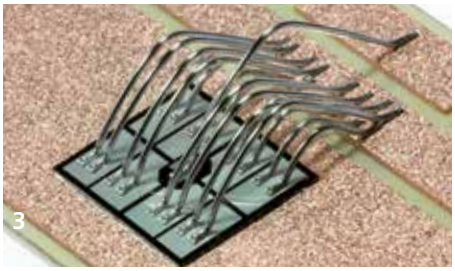
- Power electronic modules
- Single semiconductors
- Si, SiC, and GaN devices
- Surfaces providing best weld solutions:
  Aluminum, copper, gold, and silver
- Various material combinations of wires and surfaces - please refer to table below

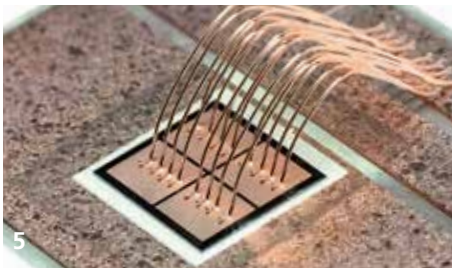
Bonding machine features

- Semi-automatic bonding process
- Programmable bond layouts
- Deformation limit control
- Image recognition of semiconductors and substrates
- Large area modules as well as small micro electronic devices bondable
- Fast switching of bond heads and pull or shear heads

Table of material combinations

Wires	Surfaces						
	Al	Cu	Au	Ni	Pd	Ag	Sn
Al	✓	✓	✓	✓	✓	✓	✓
Cu	✓	✓	✓	✓	X	✓	X
Au	✓	X	✓	✓	X	✓	X
Pd	✓	X	X	X	X	✓	X
Ag	✓	✓	✓	✓	✓	✓	X
Sn	✓	X	X	X	X	X	✓





2 *Gold wire (25 µm)*
3 *Aluminum wire (125 µm)*
4 *Aluminum wire (375 µm)*
5 *Copper wire (250 µm)*