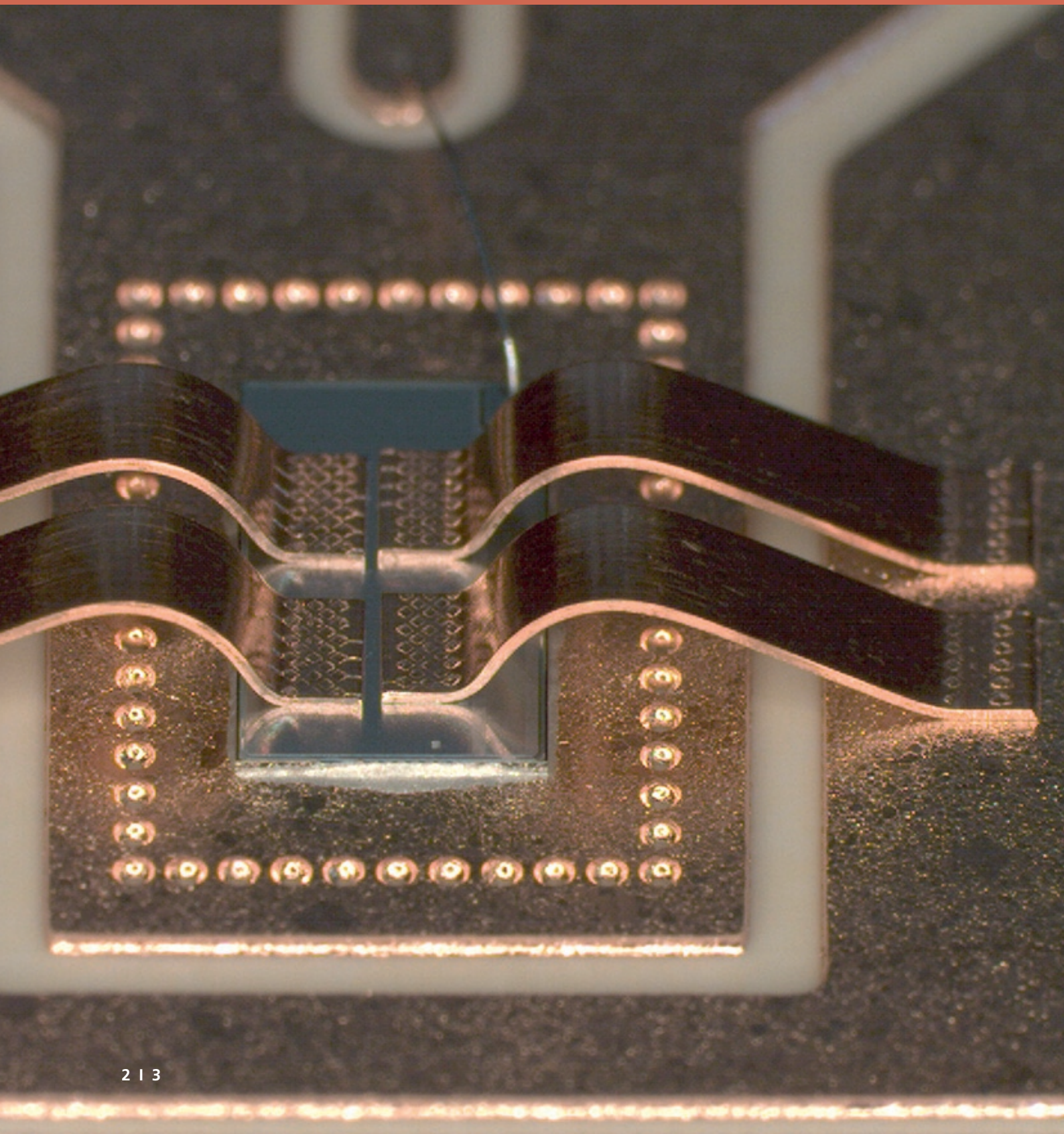
Fraunhofer
IZM

FRAUNHOFER INSTITUTE FOR RELIABILITY AND MICROINTEGRATION IZM

POWER ELECTRONICS

FRAUNHOFER IZM – POWER ELECTRONICS IS OUR PASSION



Life without electrical energy is simply unimaginable, but our natural resources are limited. Increasingly, we have to use regenerative sources in existing power networks intelligently and flexibly, and devices and machines that use electricity, from switching power supplies, to electric and hybrid cars and railways, through to large industrial drives, have to be as energy-efficient as possible. Power electronics is the technology to meet these challenges.

Fraunhofer IZM has all the necessary expertise in the entire development chain, from system design, packaging, thermal management, electromagnetic compatibility, through to reliability and damage analysis.

WE DEVELOP COMPLETE POWER ELECTRONIC SYSTEMS – FROM DESIGN TO PROTOTYPE

ELECTRICAL SYSTEM AND CIRCUIT DESIGN

Applications for power electronic components are endless – in industrial drives, to generate renewable energy, in transport and in innovative healthcare technology. Each of these areas poses different challenges to the system. For example, the automotive industry requires high switching currents, voltages and frequencies, and operating and coolant temperatures are rising. Other requirements are mechanical stability, strict EMC specifications, small build spaces, an extremely long lifetime and high reliability. Fraunhofer IZM is developing groundbreaking solutions for these demands. We support our customers in the development of customized power electronic systems in the areas:

- Circuit technology and prototype construction
- Control of power electronic components
- Use of a broad range of simulation tools in all design phases, including Matlab, Simplorer, Solid Works, FEM and PEEC tools
- EMC-compatible design using prediction and modeling of electromagnetic interference phenomena
- Testing and characterization of prototypes in in-house laboratory

COVER

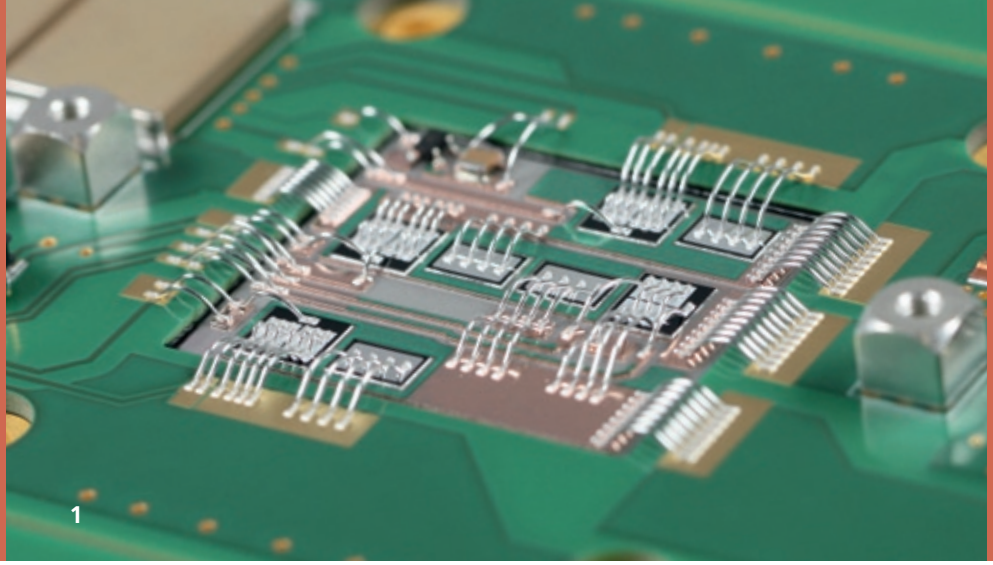
Electric vehicle: Fill up at the socket

LEFT

Cu ribbon bonding for power electronics

TOP

Converter for controlling a helicopter's rotor blades which meets high reliability requirements at small volume, even under tough climatic and mechanical conditions



1

PACKAGING FOR POWER ELECTRONICS

INTEGRATING BIG SYSTEMS INTO SMALL SPACES

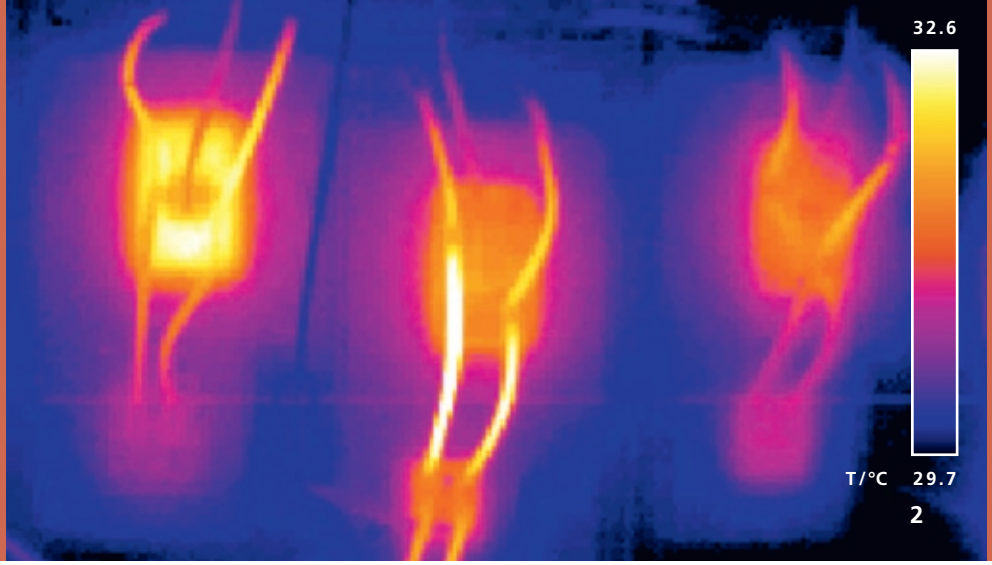
Today's power electronics has optimal thermal features and is extremely reliable. The technology is used in the following techniques:

- Large-area joining with solder preforms and pastes, by means of Ag sintering or diffusion soldering
- Heavy wire and ribbon bonding for connecting power semiconductors
- Connection to power electronics and housing / encapsulation
- X-ray and ultrasonic microscopy, visual inspection and mechanic testing

Fraunhofer IZM systematically examines each processing step and develops it further to ensure that technology transfer to industry is always as simply and smooth as possible. Our work includes:

- Developing materials and soldering processes that increase the remelting temperature (Transient Liquid Phase Soldering)
- Cooperation with material manufacturers (e.g. DCB/DAB/AMB, heat spreaders, sinter and solder pastes) to improve processability, cooling and reliability
- Development of alternative technologies like flip-chip, ultrasonic bonding, Cu heavy wire and ribbon bonding, sandwich assemblies (double-sided cooling of chips)
- Development of innovative large-area soldering technologies free of pores
- Die soldering with thin layers (e.g. Au/Sn) to improve thermal performance
- Optimization of gluing technologies used for low power densities
- Alternative heavy wire and ribbon bonding processes (Cu, Cu/Al)
- 3D multilayer integration for increased functionality and modularization (chip-in-polymer, stack solutions, embedding of power chips)
- Assembly technologies for GaAs, InP, SiC and GaN and thinned semiconductors
- Optimization of encapsulation and housing technologies for thermally optimized assemblies with high dielectric strength and temperature stability

Some of our primary aims in this include minimizing weight and size, simplifying the technologies used and reducing cost, without impairing thermal management. A key future packaging challenge will be achieving operating temperatures of more than 200 °C.



2

3

THERMAL MANAGEMENT

Heat generated in power electronic components has to be dissipated reliably. A system's entire heat path must be taken into account: The heat is dissipated from the chip though various interfaces, thermal interface materials, spreaders and substrates, before being released into the environment by a heat exchanger (cooler). All of the specified points influence thermal resistance and have to be optimized to meet the application's requirements.

We have a comprehensive approach to reliable and cost-efficient thermal management solutions. This includes:

- Technology and process know-how
- Material characterization
- Thermal design (simulation)
- Measurement technology

HEAT DISSIPATION FROM CHIP TO SYSTEM

The following measurement technologies are available in our thermal laboratory:

- High-resolution transient IR thermography
- Wind channel
- Water cooler measurement station
- Thermal characterization of materials (e.g. glues, pads, metal joints)
  - … Interface resistance
  - … Thermal conductivity
  - … Thermal impedance
- Thermofluidic simulation on system-level

Fraunhofer IZM is expert in combining simulation and experiments. This means that the heat path can be laid out optimally to meet application-specific parameters as early as in the design phase.

Other current research includes thermoelectric cooling and the behavior of thermal interfaces during aging.

1
Power converter

2
Results of the TIM measurement shown on the right

3
Transient temperature measurement of a MOSFET module using IR thermography

1

2

ELECTROMAGNETIC COMPATIBILITY

Electromagnetic compatibility (EMC) becomes more and more important for preventing functions from failing as power electronic systems are integrated into very different environments. That the methods used to date are unable to address these problems adequately is exemplified in the case of hybrid and electric vehicles.

We at Fraunhofer IZM specialize in this area and provide consulting and research for all phases of product development. Starting with basic research into interference phenomena in specific applications, we cover the entire spectrum, including troubleshooting after product delivery. We use in-house simulation processes developed specifically for frequent problems, as well as sophisticated measurement series.

INTERFERENCE-FREE SYSTEMS FROM MILLIHERTZ TO GIGAHERTZ

Typical focus areas include:

- Research into EMC phenomena and filter topologies
- Simulation of interferences on system-level
- Cost optimization on system-level
- Development of EMC concepts, filters and shielding
- Troubleshooting

We have a comprehensive set of measurement technologies available for verification, including an absorber chamber and a laboratory for network and impedance analysis. Circuit simulators and 3D-field calculation programs are used for simulation.

RELIABILITY

Thermally induced mechanical strain and expansion lead to power electronic systems failing and reduce their lifetime.The decisive parameters can already be optimized in the design phase to ensure the best reliability possible.

The damage behavior of materials and components are carefully analyzed and characterized in experiments; selected material and geometry parameters can be manipulated in advanced in computer modelling. Technology-specific material properties are a particular focus of measurement technology at Fraunhofer IZM.Among other things, such properties are key extending the lifetime of a solder joint or a wire bond, and for measures that improve reliability.

All reliability-dependant aspects of power electronics can be targeted with these techniques, including:

- Solder, sinter or glued joints
- Wire bonds and ribbon bonds
- Thermal and electrical vias
- Encapsulations
- Substrates and composite materials

We have all the necessary test equipment at hand:

- Active and passive thermal loading cycling to evaluate lifetime
- Techniques for condition monitoring and field data collection
- Measurement station for combined and accelerated lifetime tests (vibration, temperature, temperature cycling and humidity)
- Metallography, EBSD, FIB, SEM, EDX
- Ultrasonic and X-ray microscopy
- High-resolution deformation measurement (contactless and with temperature variation)

Current research is focusing on condition monitoring methods, the integration of transient material behavior and aging as analysis factors, failure mechanisms in innovative material combinations and contact measurements, as well as combined loading.

Thanks to our expertise in systems reliability, we can provide technology solutions that are optimized in terms of materials and processing cost-efficiently, and thus improve lifetime optimization.

DESIGN FOR RELIABILITY

1
Example of failure occurring in an electric car

2
EMC measurement station in an absorber chamber

3
Crack in a heavy wire wedge

4
Crack in an Ag sinter layer

5
Measurement assembly to evaluate the reliability of thermally conductive packaging materials (TIM)

YOUR PARTNER: FRAUNHOFER IZM

FRAUNHOFER IZM'S SERVICES

Our services cover the entire assembly of power modules using the latest materials, technologies and research insights.We are also focusing strongly on developing alternative assembly technologies for power semiconductors. With us, you're at the right place for:

- Consultation and feasibility studies
- System design, development and testing
- Material characterization
- Simulation (electrical, thermal, fluidic and mechanical)
- Process development and optimization
- Prototype and small series manufacturing
- Quality and reliability analyses
- Failure and damage analyses
- Know-how and technology transfer

YOU HAVE A PROBLEM? WE ARE THE ANSWER.

CONTACT US!

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