

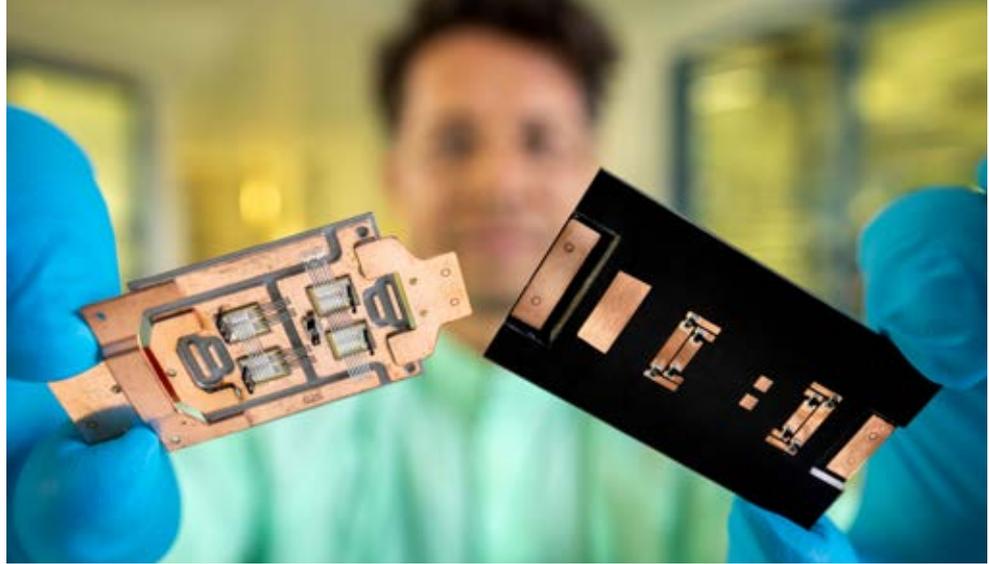


Fraunhofer
IZM

Fraunhofer Institute for Reliability
and Microintegration IZM

From Chip to Application

Power Electronics and
Packaging Development



Packaging Technologies



Power module with substrate water cooling for Formula 1

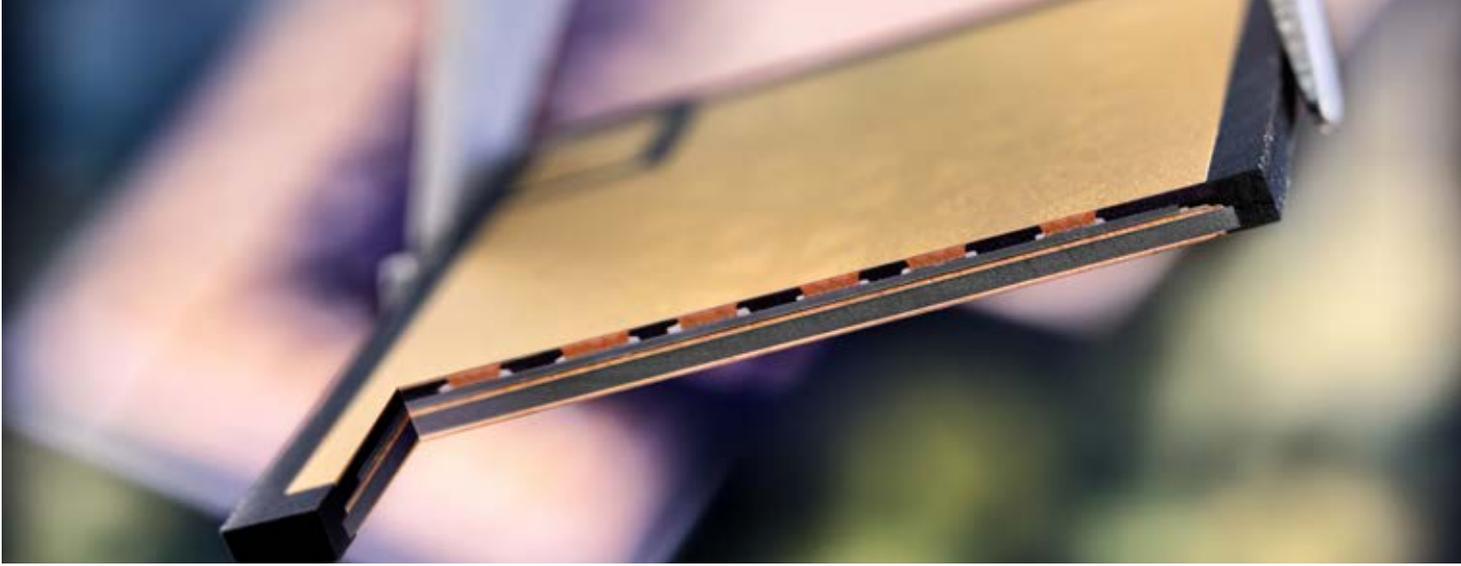
Fraunhofer IZM offers state-of-the-art assembly and interconnection technologies for the most demanding thermal requirements in power electronics. These include:

- Large-area joining by soldering or sintering
- Die attachment by soldering, Ag sintering or Cu sintering or transient liquid phase bonding (TLPB)
- Thick wire and ribbon bonding for top-side contacting of power semiconductors
- Connection to control electronics and housing/encapsulation
- Laser and ultrasonic welding of load connections
- Quality assurance through X-ray and ultrasonic microscopy
- Solutions for heat dissipation/cooling concepts

Fraunhofer IZM has tested and proven various design concepts and processes for encapsulating power electronic assemblies:

- Potting processes for soft and hard casting
- Embedding of bare power semiconductors – Si, SiC, GaN – in the assembly layers of printed circuit boards or in epoxy mold compounds using compression molding
- Extending the use of compression molding to the encapsulation of assemblies
- Use of leading-edge printed circuit boards and mold materials
- Highly compact modules with short conductor paths to enable high switching frequencies
- Modules for optimized integration or connection to heat sinks
- Modular design of complex power electronic systems

*top:
Scalable low-inductance
molded power module before
and after encapsulation*

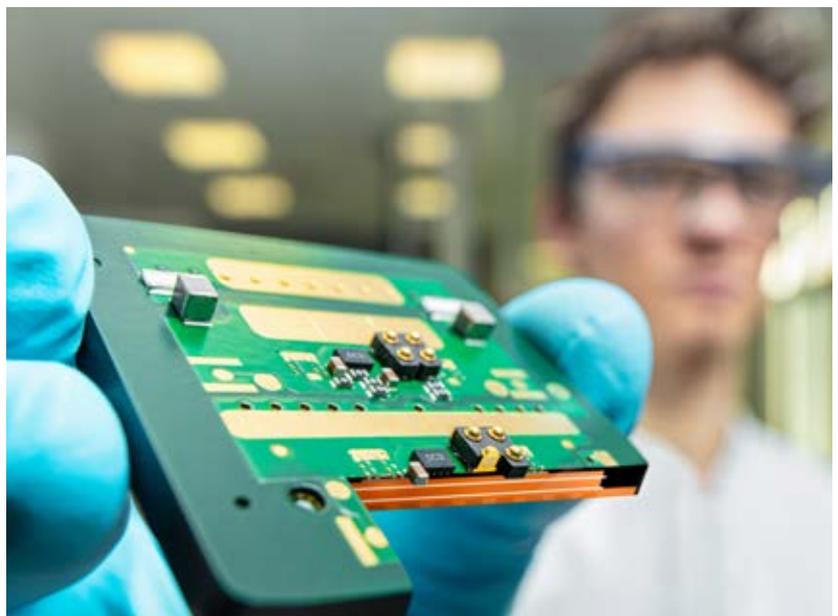


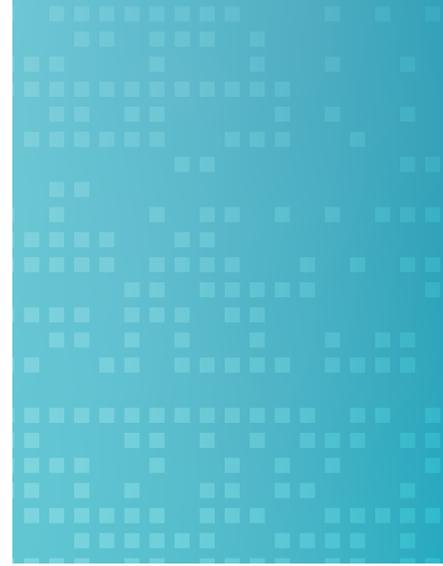
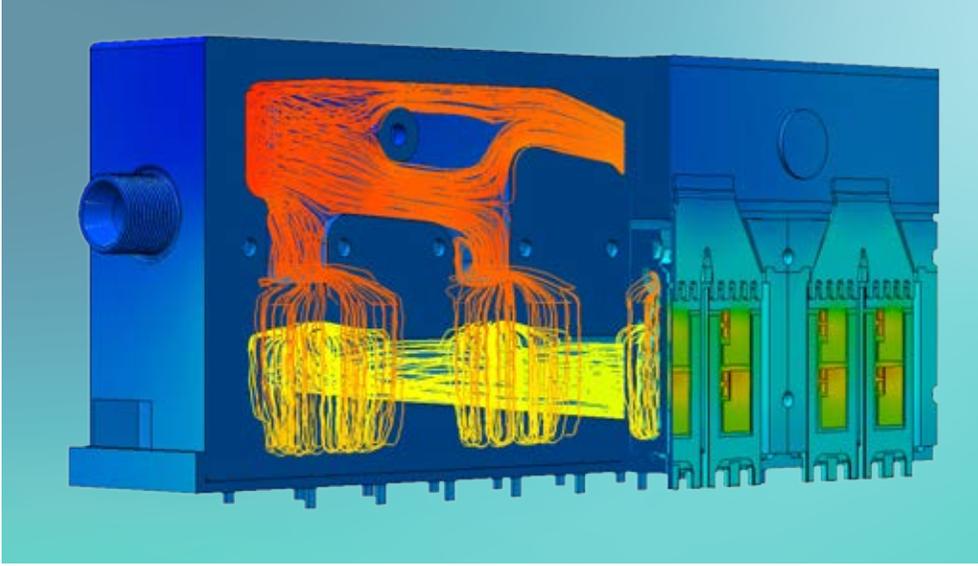
Industrial customers benefit from our systematic technology transfer: Every process is further developed for industrial use with the aim of creating reliable, highly integrated systems for demanding applications. The corresponding activities include:

- Development of materials and soldering processes that enable an increase in the remelting temperature (transient liquid phase soldering)
- Cooperation with material manufacturers (e. g., DCB/DAB/AMB, heat spreaders, TIMs, sintering and soldering pastes) for improved processability, cooling, and reliability
- Development of alternative technologies such as flip chip, ultrasonic bonding, Cu thick wire or ribbon bonding, sandwich structures (double-sided chip cooling)
- Development of Ag sintering technologies for chip and heat sink assembly
- Development of innovative soldering technologies for pore-free large surfaces
- Die soldering with thin layers (e. g., Au/Sn) to improve thermal performance
- Optimization of bonding techniques with ICA [isotropic conductive adhesive] and HCA [insulating, thermally conductive adhesive], which are used for lower power densities
- Thick wire and ribbon bonding processes (Cu, Cu/AIX)
- 3D multi-layer integration for extended functions and modularization (chip in polymer, stacking solutions, embedding of power chips in PCB embedding technology)
- Assembly technologies for GaAs, InP, SiC, and GaN as well as thinned semiconductors
- Optimization of encapsulation and packaging technologies for thermally optimized structures with high dielectric strength and temperature stability

*top:
Power module with
PCB-embedded
WBG semiconductors*

*Low inductance SiC power
module with mold technology
and direct cooling*





Reliability and Thermal Management

To ensure product reliability, Fraunhofer IZM offers comprehensive support in design for reliability – from early modeling to life cycle testing. The goal is to achieve the highest possible reliability with minimal resource expenditure. Using simulation-based methods, we evaluate the effects of temperature, humidity, and mechanical stresses on materials, geometries, and processes as early as the design phase. By analyzing the aging characteristics of materials, we can develop appropriate life cycle models.

We also design tests for power components or complete systems according to customer-specific requirements. Automated test systems are used to perform lifetime studies through active performance cycling based on the automotive standard AQG 324.

Based on our broad system expertise in microelectronic systems – from packaging to product level – we work with our customers to develop robust, durable solutions, from individual components to complete systems.

The following measurement and test environments are available for this purpose:

- Active and passive thermal cycling for lifetime evaluation
- Characterization and analysis of thermal behavior
- Methods for condition monitoring and field data acquisition
- Test benches for combined and accelerated lifetime testing (vibration, temperature, temperature change, humidity)
- Modeling of failure mechanisms
- Analysis of novel material combinations
- Metallography, EBSD, FIB, SEM, EDX
- Ultrasound and X-ray microscopy as well as X-ray CT
- High-resolution deformation measurement (non-contact and with temperature variation)
- Determination of (transient) material behavior and material aging

*top:
Fluid simulation to optimize
the power module's heat
dissipation*



Power Electronics at Fraunhofer IZM

Drive Inverter with 600 kW Continuous Power

Fraunhofer IZM offers customized solutions along the entire value chain in power electronics—from chip assembly and circuit design to prototype production, including control, housing, and cooling. Design with a focus on reliability and testing completes our services.

A unique advantage of our institute is our in-house semiconductor packaging. In a cost-driven discipline such as power electronics, design-oriented packaging is crucial for market success. The close interlinking of manufacturing, system understanding, and user requirements enables unique, optimization across the board—from chip to application.

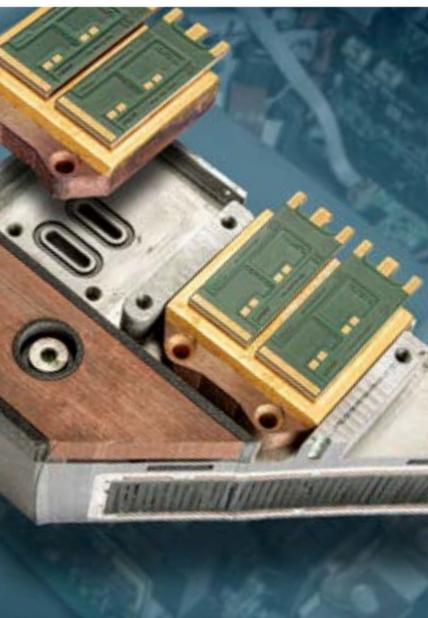
Our services are aimed in particular at customers in the automotive and energy industries, but covers the entire spectrum of electrical energy conversion – from medical implants and power-over-line supply to high-voltage direct current (HVDC) applications.

An example of our technological expertise: a 600 kW drive inverter with 200 kVA/l power density for the automotive industry. Embedded silicon carbide semiconductors on ceramic substrates were used here in our unique embedding technology – eight modules per switch, connected in parallel, silver-sintered and directly connected to a 3D-printed copper cooler. The result: minimal thermal resistance (R_{th}) with single-sided cooling.

Compact polyacrylate-based film capacitors further reduced the space requirement. Thermal simulation of all components ensured reliable continuous performance. The prototype successfully met its specifications in field testing – proof of our efficient, application-oriented development work.

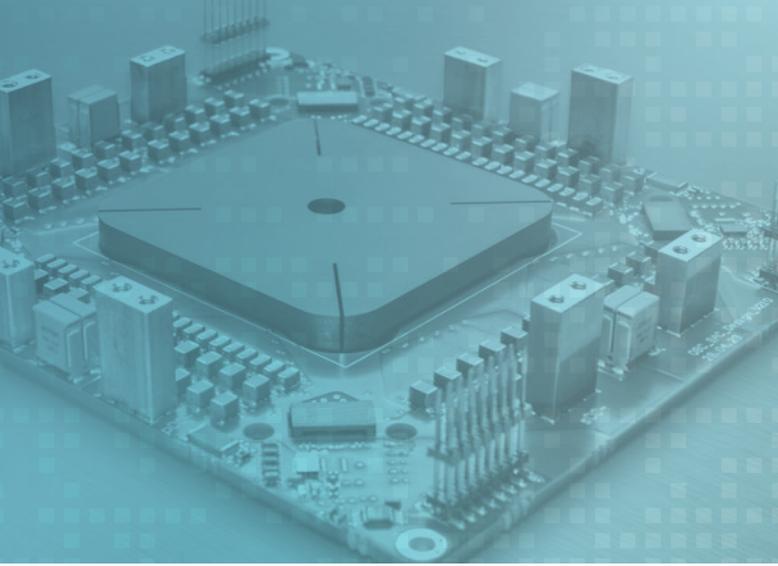
Technical specifications

- 3-phase drive converter
- 48 SiC semiconductors
- Approx. 3l volume of the power core
- 800 or 1200 V base
- Continuous power of 600 kW (835 V × 720 A_{RMS})
- Peak power of 720 kW (800 V × 900 A_{RMS})
- Power density of 200 kVA per liter
- Peak efficiency of 98.7 %



Section through one of the 600 kW inverter's three phase modules

*top:
Efficient and powerful thanks to PCB embedding and innovative cooling from the 3D printer – the "Dauerpower" inverter*



Cover:

*Bidirectional 11 kW sine-amplitude-
converter for on-board charger*

Contact

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