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E L E C T R O N I C S

Informationpaper

Ceramic heatsink in e-mobility

Ceramic heatsinks for e-mobility power electronics

E-mobility is the collective term for electrically powered vehicles. This group of vehicles includes electric cars, electrical rail transport, e-bikes, electric scooters, trolley buses and other electrically powered vehicles.
The main focus is on electric cars. Here, the need for innovative solutions is very high in many areas: starting with the transmission of electricity from the grid to the car, the storage of electrical energy in batteries and the conversion back to alternating current to drive the electric motor.

The main differences between conventional and electric vehicles are in the areas of propulsion and energy storage. An electric vehicle typically has two DC on-board electrical systems with associated DC/DC converters. The electric powertrain consists of the HV battery, the inverter and the electric motor. This increased complexity poses new challenges for the coordination of all components. Depending on the vehicle, these can vary according to the topology of the vehicle electrical system and the voltage level on the low and high voltage sides. Rising vehicle electrical system voltages and increasing drive system power levels with corresponding load fluctuations due to driving dynamics place the highest demands on the system.

1 Electric motors

In today's all-electric cars, a wide range of motor power options are available. The powertrain must provide the power dynamically and safely for all operating modes. CeramTec offers insulation and bearing solutions for electric motors, for example.

2 Power electronics

Power electronics is one of the most important components of an electric vehicle. This includes controllers for motor control and DC/DC converters. CeramTec offers innovative solutions with ceramic cooling systems and substrates for circuit carriers. Cooling is discussed in more detail below. CeramTec has developed innovative and leading solutions in this area.

3 HV battery

The battery is the heart of the electric vehicle. They come in many different forms, ranging from small cars to high-performance batteries in sports cars. Technical ceramics can open up further potential here, for example as an insulating material for solid-state batteries.

3.1 HV battery management system

The battery management system protects the battery from overvoltage, overheating and deep discharge. Ceramic components, heatsinks and substrates are available for the power circuits.

4 Vehicle electrical system

This is where the electronic engine control unit is connected to the vehicle electronics and the CAN bus. This enables the control and power supply of assistance systems such as ESP and ABS. Technical ceramics also provide support in the form of cooling systems, circuit carrier substrates and electrical components.

5 Heating + air conditioning

The passenger compartment is supplied by PTC direct heating or electric air conditioning compressors. Technical ceramic insulators, heating elements and circuit carriers can provide support.

6 Charger

Whether the HV battery needs to be charged quickly in less than an hour or over several hours, as is the case with normal AC charging, technical ceramics provide support in the form of insulators, circuit carriers and electrical components.

The use of ceramic heatsinks in e-mobility

High voltages and currents are used in e-mobility to provide the required motor power. Road traffic and the associated rapid changes in speed require a highly dynamic power supply. This places correspondingly high demands on the powertrain and all its supply and control elements. Electronic powertrain control plays a key role in ensuring that the electrical energy supplied is used efficiently. The DC voltage supplied by the HV battery must be converted to AC for the electric motor. The efficiency of the main inverter has a significant impact on the range of the electric vehicle and the distance that can be travelled on one charge of an HV battery.

The inverter electronics are designed to minimise switching losses. The heat dissipation of the inverter electronics plays a key role. The more heat that can be dissipated, the higher the power density of the electronics can be. The size of the electronics can also be minimised and the total number of electronic components can be reduced. With good heat dissipation, the potential of modern SIC semiconductor chips, which have a high switching frequency and improved thermal properties, can be better exploited.

SiC inverter power module on ceramic heatsink

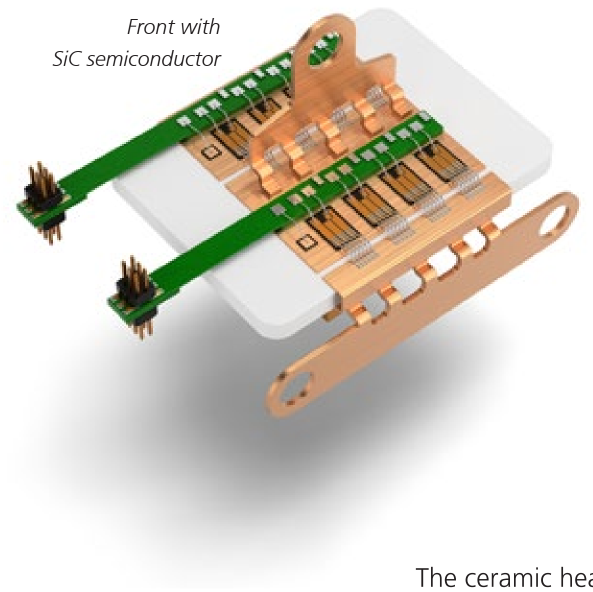
The figure below shows the power module for the inverter.

It has the following characteristics:
- 1200V full SiC half bridge with sintered semiconductor devices
- Low Rth′= 0.15 K * cm^2 / W with simultaneous high current capability
- Low module inductance due to module-integrated ceramic capacitor on the back of the ceramic heatsink
- Non-critical interfaces for easy system application
- Scalable module design to meet current requirements

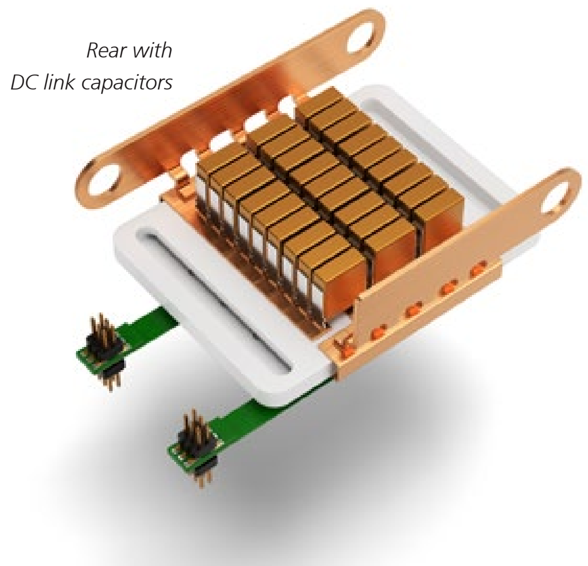
Chip-on-heatsink technology using the example of a drive inverter

CeramTec's chip-on-heatsink cooling technology, which is designed for inverters in e-mobility powertrains, was presented at the power electronics trade show PCIM Europe 2021.
The requirements profile for the heatsink is based on the requirements described earlier. In addition to the ability to generate maximum electrical power, low weight, compact design and maximum heat dissipation are also required.
CeramTec has developed a heatsink made of aluminum nitride (AlN) with chip-on-heatsink technology that meets these requirements. The heatsink is a circuit carrier and cooling structure in one component. This results in a significant increase in power density and a considerable reduction in the size of the power module.

Front with SiC semiconductor



Rear with DC link capacitors



The ceramic heatsink is designed to optimise heat dissipation from the SiC semiconductors on the front of the heatsink. On the rear of the heatsink, the low-inductance DC link capacitor is integrated into the power module via metallisation around the heatsink.

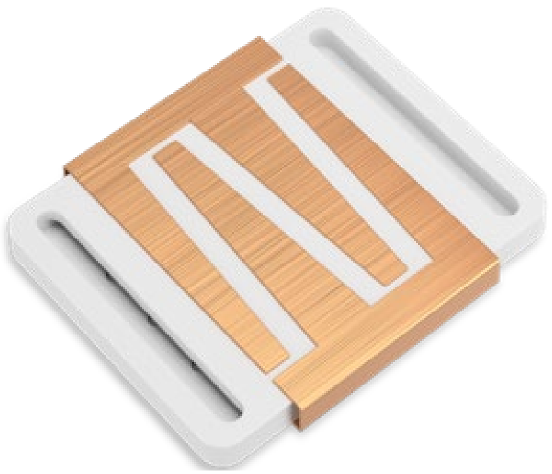
Cooling structure

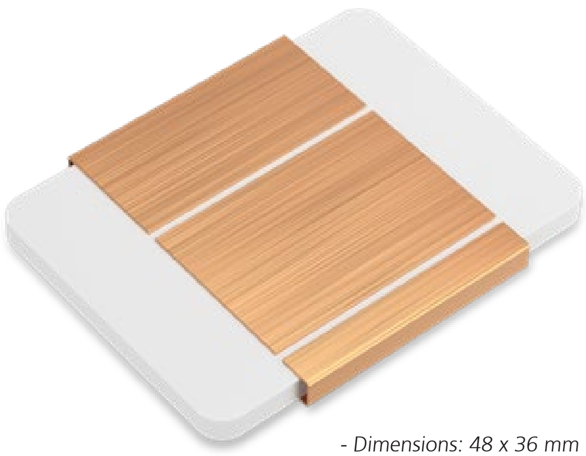
The ceramic heatsink has an internal cooling structure. This is designed as a pin-fin structure, with inlets and outlets for the cooling fluid already provided in the base body. The pin-fin design fulfils several main functions. It significantly increases the heat transfer surface area of the heatsink. The pin fins are arranged in such a way as to ensure uniform circulation across the surface, which enables good heat dissipation. At the same time, the pin-fin structure ensures high mechanical strength of the heatsink, which can absorb compressive, torsional and bending forces well.

Structure of the heatsink

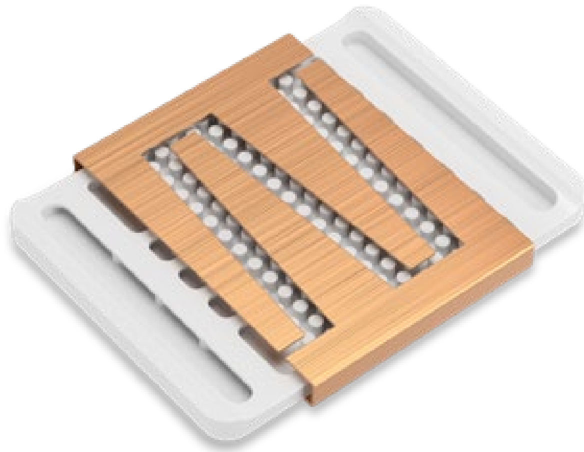
The structured copper sheets are applied directly to the ceramic heatsink. Their dimensions and arrangement are determined by the requirements of the components and the electrical power to be generated.
The structure of the heatsink allows both sides to be used as circuit carriers and both sides to be cooled.

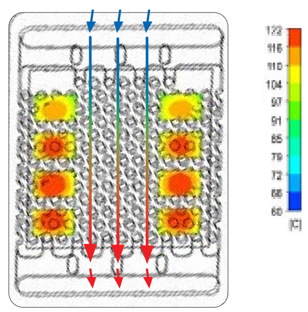
• Heatsink consists of two layers
• Inlet and outlet on the back of the ceramic
• Easy connection to the cooling circuit via gaskets
• Free choice of coolant
• Resistant to electrochemical and mechanical corrosion
The structure of the heatsink allows both sides to be used as circuit carriers and both sides to be cooled.





- Dimensions: 48 x 36 mm
- Metallisation thickness 0.3 mm
- Weight of the ceramic heatsink ~ 10 g





Another major advantage is that the pin-fin structure can be matched to the footprint of the SiC semiconductors, so that the same number of cooling pins are located below the cooling area. This enables optimum cooling of all chips.

With CeramTec's chip-on-heatsink technology, the direct metallisation of heatsink and integrated cooling structure, CeramTec provides a cooling system for e-mobility that can be used efficiently and effectively to cool power modules in many areas.

Module properties

Module-integrated AlN ceramic heatsink with chip-on heatsink technology

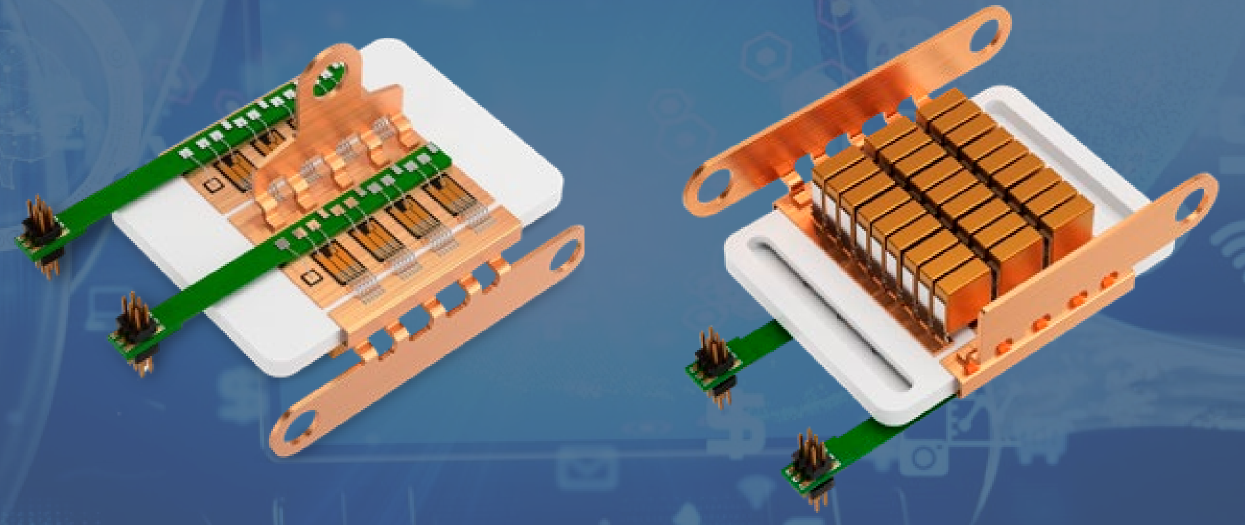
- Maximum power density with minimum weight
  - » No additional metal heatsink required
- Ceramic heatsink can be used on both sides
- Internal structure optimized for the sintering process of SiC semiconductors
- Scalable for different performance classes

Very good thermal properties for maximum current per SiC semiconductor area

- Rth '= 0.15 K*cm²/W
- Integrated pin style structure
- Integrated capacitors thermally connected to the heatsink

Low-inductance module structure for high switching performance

- Metallization around the edges
- Module-integrated ceramic capacitor
- Optimized for the use of 1200V SiC semiconductors



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CeramTec

ELECTRONICS

Advanced ceramic for e-mobility

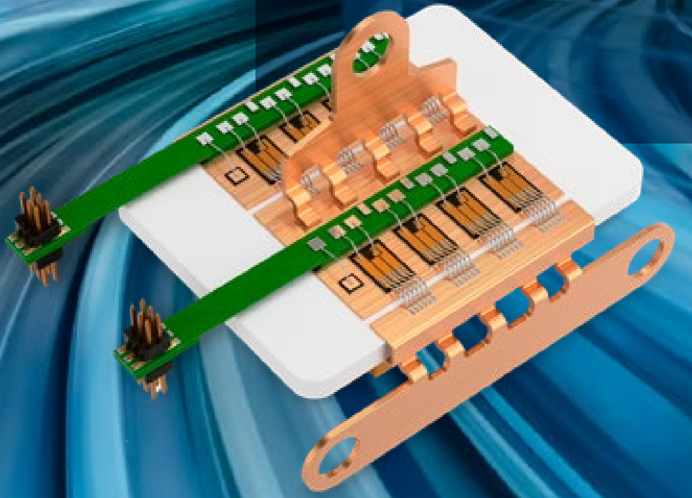
Thermal management with ceramic heatsink

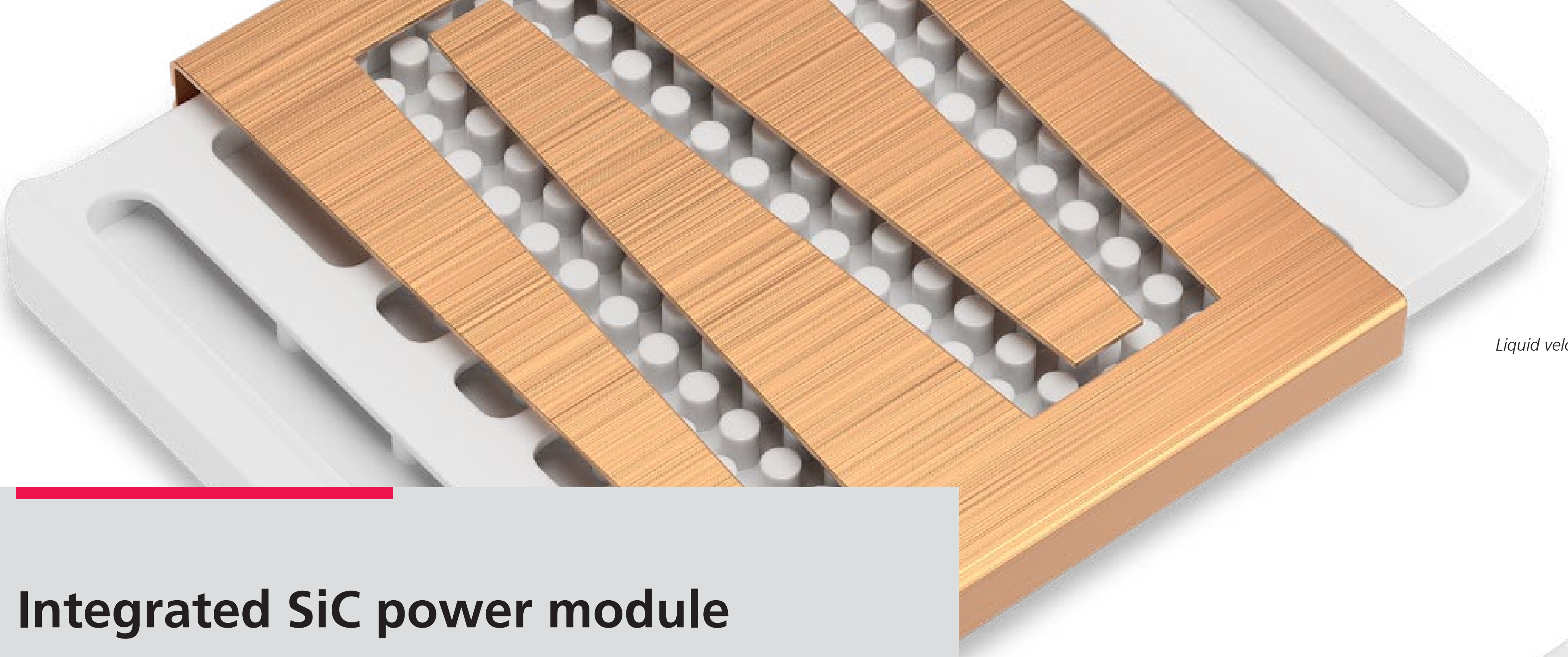
CERAMIC EXPERTS

Ceramic heatsink in e-mobility

The use of ceramic heatsink in power electronics, as used in various applications in e-mobility, offers significant advantages in terms of thermal and electrical performance as well as their power density compared to conventional heatsinks. For this purpose, CeramTec provides ceramic heatsinks with applied metallization, which make it possible to apply the electrical components directly to the ceramic heatsink (chip-on-heatsink) and thus make the best possible use of the chip surface.

High-performance ceramics offer several advantages over conventional materials such as metals and plastics. They are resistant to temperature changes, corrosion, and chemical resistance. In addition, they are characterized by a particular thermal conductivity and electrical insulation as well as strength and good tribological properties. High-performance ceramic solutions can therefore be used in a variety of ways in e-mobility.

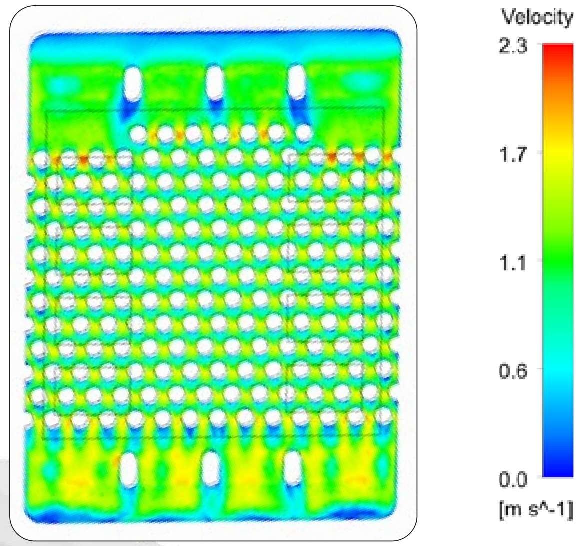




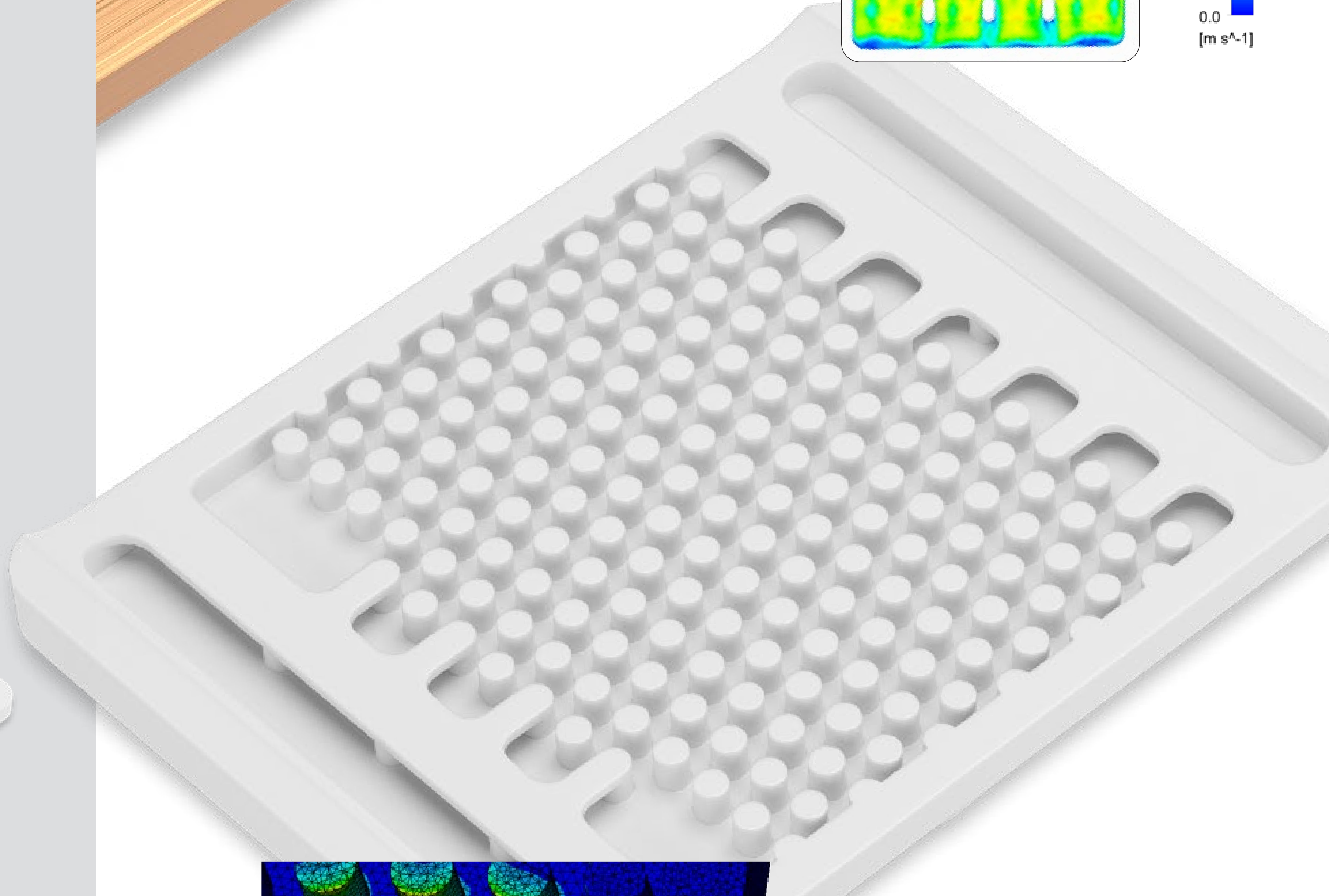
Integrated SiC power module on ceramic heatsink

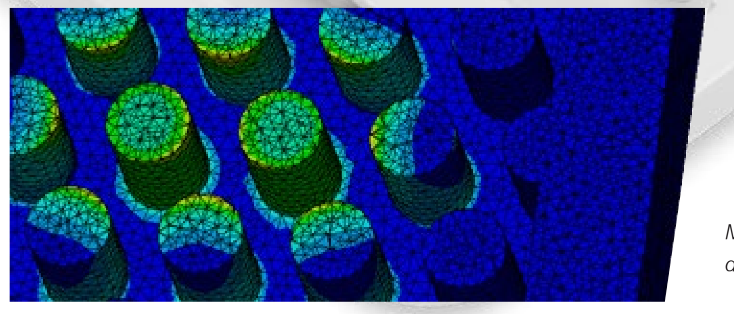
The integrated SiC power module is based on CeramTec chip-on-heatsink technology. The ceramic heatsink is a cooling structure and circuit carrier in one component, which leads to a significant increase in power density. The design of the ceramic heatsink enables optimized cooling of the SiC semiconductors on the top of the heatsink. On the underside of the heatsink, the DC link capacitor is integrated with low inductance in the power module via metallization around the edges of the heatsink.

Ceramic heatsinks metallized on both sides for low-inductance electronic assemblies



Liquid velocity distribution through the ceramic heatsink





Mechanical stress on the internal structure during the sintering process

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