CeramCool® – Ceramic Simplifies Management in Electronic Systems

Electronic components are subject to limitations in performance and reliability due to their low thermal tolerance. Advancements with higher power densities generally focus on optimizing heat-sinks; less thought is given to the layers between them and the electronic components. A change of concept and material allows significant gains in thermal management and reliability along with a simplified system.

Introduction

Using ceramics as heat-sinks and circuit carriers as a visible part of the product design required fresh thinking and the willingness to overcome traditional approaches during the market launch just a few years ago. Now ceramic heat-sinks have reached development departments everywhere and are used in applications ranging from high-power electronics to lighting. To put it another way: Wherever things get hot!

What's hot?

Ultimately this is defined by the most thermally sensitive element in an assembly in the face of steadily rising power densities.

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Fig. 1
CeramCool® Honeycomb for light outputs of over 200 000 lm

Keywords
thermal management, heat-sinks, alumina, aluminium nitride

According to the law of energy conservation, thermal energy that is released must be transferred to the surrounding environment. Since the temperature gap between the hot spot and the ambient temperature is generally quite small, large surfaces and excellent thermal management are a prerequisite. Ideally, this is where directly bonded ceramics come in. After all, "the hotter it gets" the greater the advantages of the ceramic system.

The CeramCool concept

CeramCool® is an effective combination of circuit board and heat-sink for the reliable cooling of thermally sensitive components and circuits. It enables the direct and permanent bonding of components. Also, ceramic is electrically insulating per se and provides bonding surfaces by using direct metallization. This enables the printing of individual conductor path layouts on all dimensions. Direct Copper Bonding (DCB) and Structured Copper Technology (SCT) can be used for high power electronic applications and high current strengths. The heat-sink itself becomes a circuit carrier that can be densely populated with components just like a conventional circuit board. The system dissipates heat without creating thermal barriers and guarantees longer life for sensitive semiconductor components.

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Performance benchmarking

When comparing the performance of different systems it is important to take into consideration the influence that interface materials have. They create a mechanical bond between the electronic component and the heat-sink, provide electrical insulation and facilitate thermal transfer. These materials are essential as most thermally conductive materials also conduct electricity and virtually every electrically insulating material poses a heat barrier. Eliminating them from the system offers tremendous potential for optimization. Adding all of the thermal resistances R_t together yields the total thermal resistances R_{tt}. It enables an accurate comparison of thermal management solutions for initial efficiency estimates.

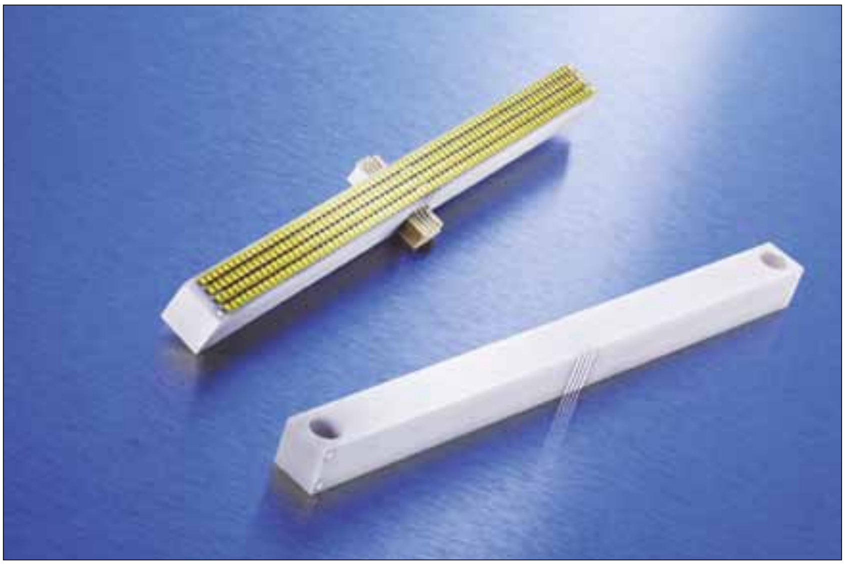

Fig. 2
This single-channel CeramCool® has been developed for low-depth installation

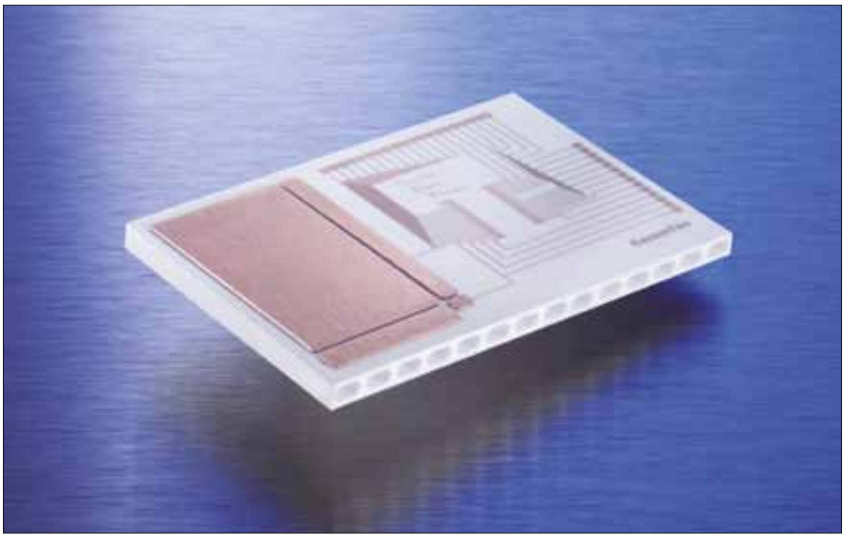

Fig. 3
The cooling agent flows very close to the hot spot – only 1 mm separates the two

Ceramics: Two in one

It is common to optimize only the heat-sink. Hundreds of designs are available, most of which are made of aluminum. In order to bring about a significant increase in performance, the bond must be improved between the heat-sink and the component that requires cooling. Advanced technical ceramics provide a solution: The heat-sink itself is responsible for electrical isolation. Advanced ceramics such as Rubalit® (Al_2O_3) or Alunit® (AlN) combine two crucial characteristics: good electrical isolation and thermal conductivity.

Rubalit® has a lower, Alunit® an almost comparable thermal conductivity to aluminum, although Rubalit® is a more affordable alternative to Alunit®. The thermal expansion coefficient of both materials corresponds to that of semiconductors. They are rigid, corrosion-resistant and ROHS compliant. Fully inert, they are the last system component to fail. The simplified construction (without glues, insulation layers, etc.) combined with a direct and permanent bond between the electronic component and CeramCool® create optimized operating conditions for the entire assembly. Put simply: What isn't there won't wear out and materials that expand in proportion to each other won't separate. The result is excellent longterm stability, secure thermal management and exceptionally high reliability.

Scope

Applications and designs for ceramic solutions are quite varied. They range from flat, passively cooled substrates to three-dimensional, actively cooled heat-sinks. LEDs are often applied to Alunit® ceramics, for example. They offer better thermal conductivity than PCBs and their thermal expansion coefficient equals that of semiconductors. Perlucor®, a highly efficient, transparent ceramic, will certainly play a role in lighting systems in the future. Three to four times harder than glass, featuring high thermal conductivity, metallization capacity and an optical grade of >92 % relative transparency from UV to IR, Perlucor® opens up entirely new markets in lighting. Double-sided metallized aluminum nitride substrates are also often used for thermal management in high frequency technology. The tungsten-nickel-gold metallization applied in this scenario ensures high adhesive strength along with good solderability. MELF resistors are manufactured from 96 % Al_2O_3. Rubalit® ceramics are used here amongst other reasons due to their thermal conductivity. These resistors are present in virtually every sector, from the automotive industry to satellite technology.

Air cooling can reach its limits when working with high power densities; liquid cooling is required.

Fig. 4
Perlucor® transparent ceramic offers new possibilities in lighting technology

Coolant just 1 mm from the heat source

One option is liquid cooling with CeramCool®. It benefits from the fact that ceramic is chemically inert, non-corrosive and resistant to salt, acid and lye, among other things. Electrolytic corrosion does not occur. This significantly expands the range of coolant options. Convection and liquid cooling work according to the same basic principle: Achieving the shortest possible distance between heat source and heat-sink. Ceramic is unbeatable here: The coolant is just 1 mm away from the hot spot. No other design can achieve this and still assure such a long lifetime. New production processes have made it possible to create linear cavities from Alunit® over the past few years. Since then, this exceptionally thermally conductive ceramic (≥170 W/m · K) has been a preferred material for liquid cooled systems.

CeramTec offers a variety of standard modules that are used in a number of different markets. The liquid coolers are extruded, dry pressed or – for more complex geometries – joined together using multiple parts, like the CeramCool® Liquid Cooling Box, for instance. The latter is used for packing densities of up to 75 W/cm^2. Performance is primarily limited by the size of the electronic components.

One power package is the CeramCool® Honeycomb. With its chip-on-heat-sink technology it cools packing densities of >170 W/cm^2. The module is easily scalable and offers space for around 1000 LEDs. This design has also been used in wind turbines since 2002 and has been a part of trains and subways for over 20 years.

The 1K-143 single-channel cooler features a simple, yet efficient geometry. Its surface can be fully populated. The connectors on the back make it possible to arrange it to form a seamless light band for lighting applications.

CeramCool® Multi K is found in a variety of applications. The flat, multi-channel system is characterized by its direct thermal connection, low wall thickness and direct metallization. Copper layers of up to 400 µm can be applied in power electronics. It is possible to achieve microline structures from pitch to pitch and line widths of 200 µm. Even subfineline structures can be realized on Alunit®.

Conclusion

CeramCool® technology opens the door to developers looking for new circuit architectures featuring the highest possible power densities. Thanks to efficient ceramic thermal management, it is also possible to achieve high reliably and an exceptionally long service life time.