Bodo´s Power Systems®

The Next Step: Sintering is the Key to Future Power Electronics

In modern power electronics applications, requirements are becoming more demanding. Soldered connections are reaching their limits. Sintering is increasingly becoming indispensable. Dennis Ang, sintering expert at Heraeus, knows what challenges the new technology introduces and what users must consider when making the transition.

By Roland R. Ackermann, Correspondent Editor Bodo's Power Systems

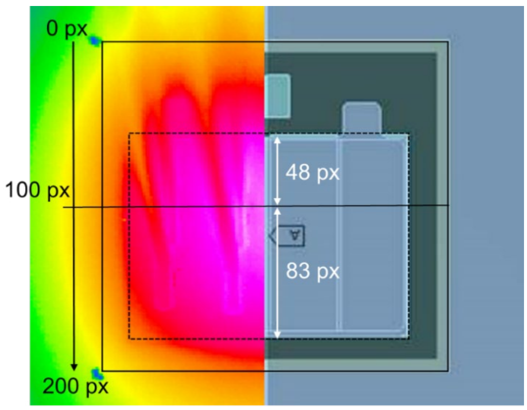
Q: What is the significance of sintering for modern power electronics?

Manufacturers of power electronics still rely on soldering. Standard power electronics modules are typically assembled by soldering with lead-free SnAg solder and wire-bonded with thick aluminum wire. In these techniques, the simple handling, low material costs and flexible integration into various processes offer an advantage. But what is enough for many standard applications is reaching its limits in modern technologies. This is because the demands made by new applications such as electromobility or renewable energies have risen enormously. Even a perfect solder joint may no longer meet the requirements. The materials used must support higher power densities and switching frequencies, and at the same time, the demands on the reliability of high-performance electronic modules are growing. Automobile manufacturers, for example, require the supplier industry to make products with a service life of at least 15 years or 250,000 km. Sintering with silver offers a solution. It also can overcome higher operation temperature restriction. A solid material until 961 °C, silver has a significantly higher melting point than tin-based, lead-free solders. Incorporating filler technologies, sinter supports higher thermal operating temperatures of more than 250 °C, as they remain thermomechanically stable and show almost no signs of aging. This is what makes high operating temperatures possible in modern power electronics. The silver particles of the sinter paste densify by means of diffusion processes. When heated above 230 °C and together with applied pressure of between 5 MPa and 30 MPa the density increases. The pressure ensures that porous areas in the compound layer are reduced, which is particularly important for large-area semiconductors.

Q: What experience does Heraeus have with sintering?

In the field of sintering, we have gained comprehensive know-how from more than a decade of experience in working with this technology. As a result, we have developed and refined an extensive range of solutions for a wide variety of applications. We have also developed a performance material portfolio covering almost every aspect related to improve device robustness – from various DCB substrates, sinter pastes optimized for copper surface and aluminum-copper bonding wires. Of course, we also share our accumulated experience with our customers - through comprehensive advice and hands-on experience in our application center in Hanau. Here we simulate their sintering processes and we offer sinter seminars and hands-on training to get to know the technology.

To establish the use of sintering in the production of high-performance electronics, the technology group Heraeus has accelerated a further development step. A die connection to a microchip substrate can already be made with sintering, but the core problem is surface contacting. Many years of expertise in material and bonding techniques



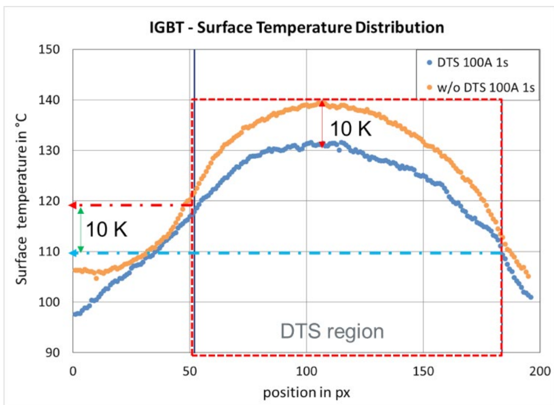


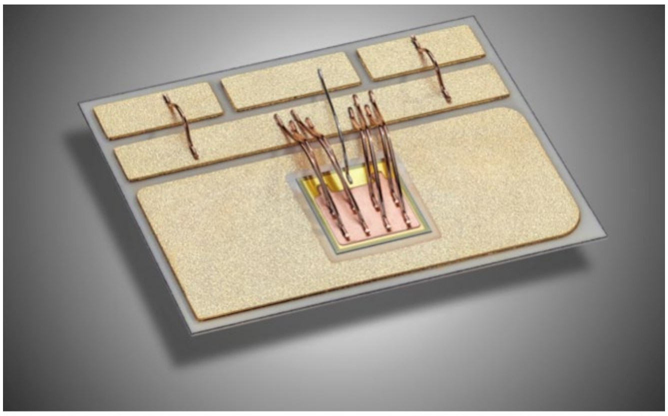
Figure 1: Fewer Hot Spots: The excellent thermal and electrical conductivities of the Cu foil and the Ag sintered layer ensure a lower temperature distribution on the top side of the chip, as this comparison of heat distribution with and without DTS shows.

such as sintering have resulted in several patented solutions for the manufacture of electronic modules -- from DCB substrates for a wide variety of applications to the most resilient wires made of the latest materials to sinter pastes to reliably hold all components together. We know almost every aspect of sintering and offer both products and advice. We don't just want to supply individual parts; we always have the holistic solution in mind.

Q: What difficulties arise when switching from soldering to sintering?

Sintering has not yet established itself completely as a technology in power electronic modules despite the outstanding physical properties of sintered layers. This is because sintering requires different machines and processes than soldering. Many manufacturers are reluctant to use the technology due to the complexity of the production changeover, and that converting to the sintering process involves significant investment in new production machines. In addition, the sintering process is still considered to be a complex mechanical engineering process. But these objections are increasingly diminishing, or even disappearing entirely. Sintering will be the standard for high performance material in the future. We are constantly working on making this future possible today - with cost-effective solutions and more easily accessible innovations.

The result of our efforts is the Die Top System (DTS®) - a material system for assembly and connection technology that was developed jointly with the technology company Danfoss and is based on its bond buffer technology. The conversion to new material systems such as DTS requires a manageable amount of investment. Therefore, Heraeus worked toward making its industrialization straightforward. With the pick & place system, chips and copper foils are put in place automatically. Since the sinter paste has already been pre-



Die Top System

*Layout by courtesy of Fraunhofer IISB

Figure 2: Flexible in use: The DTS enables the use of Cu wires instead of Al, which results in better performance and higher operating temperatures. The process can also be used for a wide variety of substrate layouts.

applied to the copper plate, the paste no longer must be applied by the customer. Furthermore, optional fixation points ensure that the applied copper plates do not slip before sintering, thus speeding up DTS placement during production. Next, chips and copper plates are sintered together. The copper wires are usually applied using thermosonic ball wedge bonding. A key advantage of the DTS is the flexible applicability of the material system. The process can be adapted to any shape. For example, if the chip layout is changed, no new tool is required.

A similar approach is followed by clip systems in which metal plates are used instead of wires. However, these also pose further challenges: The additional plates influence the bending stiffness, and the asymmetrical design can cause greater mechanical loads. Furthermore, the clip systems require two sintering processes. By using DTS in the joining process, the connection can be completely produced in one process. Coating systems are also a well-known alternative to DTS. Instead of a copper plate, copper coating is applied to the chip. However, copper coating on both sides is necessary to guarantee the mechanical strength - a complex process to ensure the necessary layer thicknesses of 40 µm.

Q: Which parts of the power electronics benefit from sintering?

Power Modules benefit most from sintering. They operate in the top end drawer of the power spectrum, requiring innovative solutions to enable high operation temperature and improve device lifetime exponentially. An example for this is the automotive market where the future will be autonomous, connected and electric. The proliferation of electronics control systems will intensify these challenges, and the demands on the material are constantly increasing. To meet these scenarios, newly developing power platforms can integrate SiC (silicon carbide) and adopt sinter technology to increase power capacity and overall performance. So sinter technology will primarily benefit automotive electronics systems such as power inverters and onboard chargers to deliver superior performance.

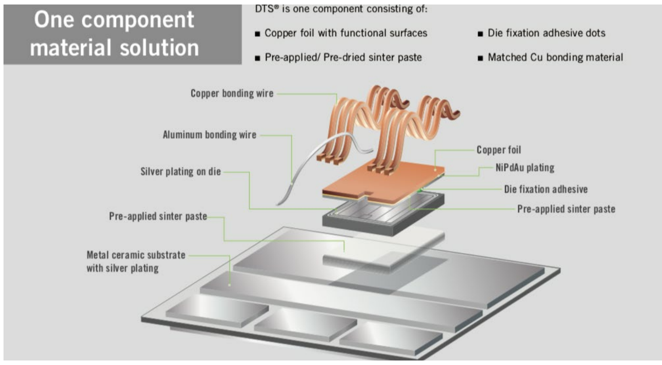


Figure 3: Structure of the Die Top System

Q: What advantages does copper wire offer over aluminum?

Compared to soldered chips with aluminum bonding wire, a 50-fold higher number of cycles is achieved before faults occur. At the system level, this was experimentally proven at a temperature swing of DT=130°K. To conduct the heat generated by the chip in a targeted manner, the copper layers are specially structured to produce an

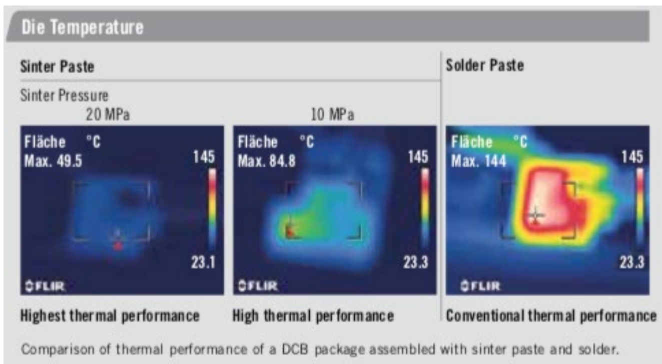


Figure 4: Better heat distribution: A comparison of the two methods shows that the heat is distributed better with sintered DCBs than with soldered ones.

optimum topology. The foil protects the chip from the high mechanical loads during wire bonding. Thus, copper bonding wires with much better conductivity can be used instead of the previously used aluminum bonding wires. These make it possible to significantly reduce module derating or to use smaller modules while maintaining the same performance. The challenge: Since copper does not bond sufficiently with the silver contained in the sinter pastes, the Cu plates must be coated with a precious metal (NiAu, NiPdAu or Ag). Heraeus has further developed its sinter pastes for this purpose: A targeted addition of additives ensures that the copper oxide is reduced to copper during the sintering process of the paste, thus optimally diffusing into the sinter layer and creating a solid bond.

Q: What is the future of sintering?

The increasing demand for high-performance electronics along with rising performance requirements for electronic components make the use of modern sintering technology indispensable. The further development of electromobility - in response to technical advances as well as political conditions - is one of the factors driving further growth in the field of high-performance electronics. This can already be seen in the example of China: There, a quota has already been introduced for e-cars and plug-in hybrids, according to which domestic and foreign car manufacturers must meet minimum targets for the share of alternative transmissions in production and sales. In addition to e-mobility, renewable energies are also being promoted in Europe. The use of DTS thus represents an important success factor in competition on the global market. Sintering is indispensable and is the technology of the future needed to achieve this aim.

www.herae.us/sintering

About the Author

Dennis Ang, Global Product Manager - Sinter Products, Heraeus Electronics

Dennis is a well-travelled profession in the field of engineering. At Heraeus Electronics, his area of focus is in power electronics systems where he applies his invaluable industrial knowledge accumulated from past appointments in product development, process engineering and business development to bring to market cutting-edge performance material to energize power electronics industry.

Dennis graduated from Australia with honors in Electrical Engineering and is a Six Sigma Black Belt.