

Silver sintering wire-bonding less power module for high temperature applications

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Purpose of Work

Integrity of the power module is mainly provided by interconnections between the different components. Due to RoHS restrictions, conventional lead-based solders cannot be used anymore. New solutions of die attach have been investigated such as transient liquid phase bonding or silver sintering which is currently the most advanced alternative technology¹²³⁴. Furthermore, the increase of electrification in transportation system requires a high thermal management because power electronics systems can be located in severe thermal environment and have to dissipate high self-heating. Double-side cooling power modules do not use wires bonding anymore (fig. 1b), highly responsible for many failures. To match such requirements, a new structure combining silver sintering and double side cooling system has been developed and characterized. A prototype of single-phase bridge rectifier has been investigated.

Keywords: Nano-scale silver sintering, 3D assembly, wire-less power module, thermal and mechanical characterizations, high-temperature applications

Approach

Figure 2 illustrates our easy and fast three-step process for producing a 100 % double-side cooling wire bonding less sintered module in one step using nano-silver paste (Argomax® 2020 series), substrate and silicon dice. First of all, 100µm of nano-silver paste is screen-printed on the top of the metalized substrate and dried below 150°C. Then, the power die is placed on silver deposit and finally the assembly is performed under low pressure (10 MPa) at 250°C for one minute using a press equipped with specific heating plates (figs.3a & 3b). This approach has then been used to design a single die prototype⁵ and also a single-phase bridge rectifier using 4 silicon diodes and Insulated Metalized Substrate (IMS) for an easier prototype design. DBC substrates based single-phase bridge rectifier is also considered in a future optimization step.

Results and Significance

Analysis of cross-sections shows that sintered die-attaches are homogeneous, with regular thickness all along the joint and no void can be observed. We can also see that the two joints are identical (figs.4a & 4b). The thickness of the joint is about 26µm, which is similar to single back-side die-attach previously realized with the same silver paste⁵. Morphologically, silver sintered joints are the same whatever the process followed. The output I-V electrical characteristics of a single diode have been obtained for the two types of sintered assemblies (back-side and double-side) and it has been pointed out that these electrical characteristics are very similar whatever the process used to attach the die⁶. This clearly shows that the experimental procedure developed for 100% silver sintered double-side cooling module is reliable and repeatable. Figures 5 and 6 present a picture of the wire bonding less single-phase rectifier bridge and the electrical output waveform validating its electrical function respectively. These results are very promising. Additional full module thermal characterization has been realized to fully characterize such a wire bonding less module. More results will be presented in the full paper.

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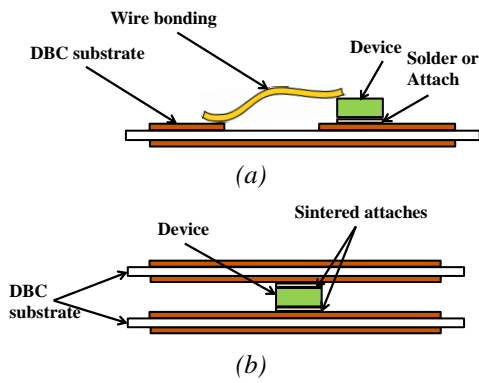


Figure 1 - Structure of a (a) conventional assembly using Direct Bonded Copper (DBC) substrate and a die (b) 100% sintered double-side cooling power module using two DBC substrates and a die.

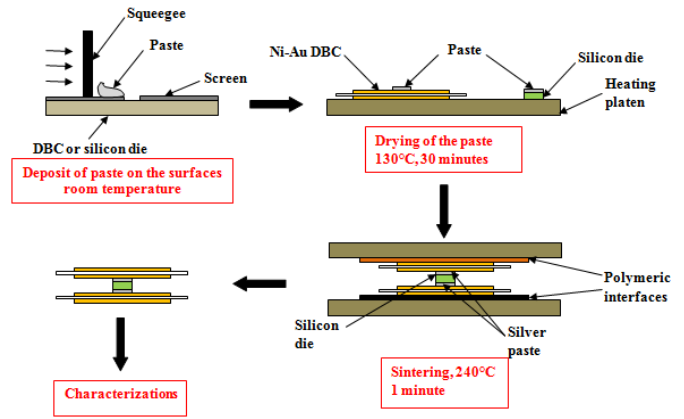


Figure 2 -Steps of the sintering process for the wire bonding less powerpackage

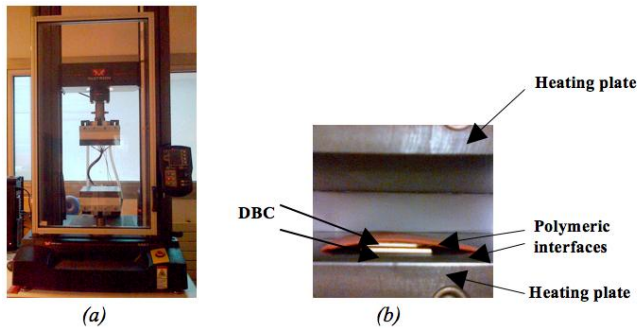


Figure 3 -Experimental process apparatus (a) Heating press used for nano silver sintering process (b) Assembly before sintering : silicon die is between the two substrates

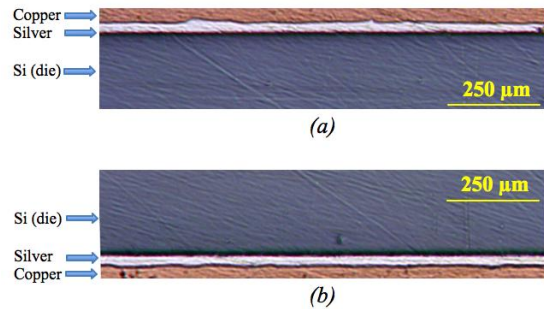


Figure 4 -Cross-section of the two die-attaches of the double side module based on DBC substrate (a) top of the die and upper substrate (b) backside of the die and lower substrate

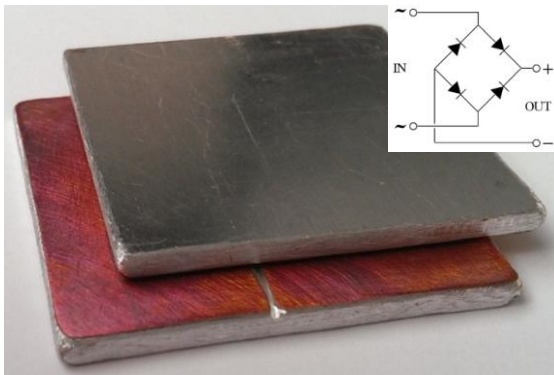


Figure 5 -Picture of the wire bonding less single-phase rectifier bridge using IMS. A shift on the geometry substrate allows the interconnections

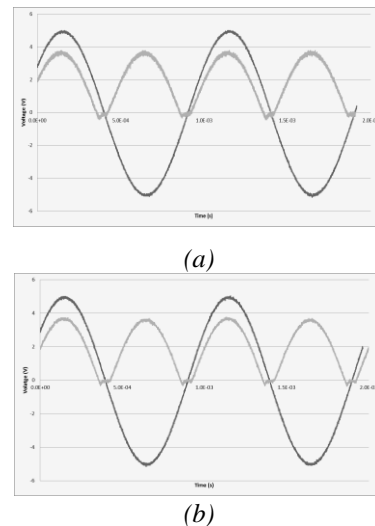


Figure 6 -Electrical characterization of the single-phase rectifier bridge using (a) wire-bonding less package and (b) wire bonding based package