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Pressureless Silver Sintering Die-Attach for SiC Power Devices

S. Hascoët^a, C. Buttay^a, D. Planson^a, R. Chiriac^b, A. Masson^a

Email: cyril.buttay@insa-lyon.fr

^aUniversité de Lyon, INSA-Lyon, lab. Ampère, CNRS UMR 5005, F-69621, France

^b Université de Lyon, Université Lyon 1, LMI, CNRS UMR 5615, F-69622, France

Silicon carbide power devices are extremely attractive for high temperature applications [1]. Many converters, based on SiC power devices, have been demonstrated to operate at ambient temperatures ranging from 200°C to 400°C [2,3]. However, the power devices themselves are no longer the only limiting factor for the increase in operating temperature. Their packaging has become the main stumbling block for high-temperature, reliable operation [2]. Different degradation phenomenon can be observed: fracture of the package during large thermal cycling (due to mismatch in the Coefficient of Thermal Expansion of the various materials), diffusion of chemical species, phase change...

Die attach is one of the packaging function that must be redesigned for high temperature. The standard die attach technique uses lead-based solders with a melting point (T_M) around 300°C, or 573 K [4]. It is considered that a die attach material should not operate above a temperature equal to 0.8 T_M [5] (above this temperature, most of the mechanical strength is lost, leading to premature failure). This means that the standard solders alloys are limited to an operating temperature of $0.8 \times 573 = 458$ K, or 185°C. Alternative techniques have been proposed, including solders with higher melting temperatures, adhesives, silver glass, diffusion bonding, and silver sintering [6].

This latter solution is very promising: silver has the higher thermal conductivity of all metals (429 W/m.K, on par with that of SiC). Its electrical conductivity is also excellent. It is non toxic, and has a melting point much higher than that of the soldering alloys (961°C). Silver sintering has been demonstrated with process temperatures ranging from room temperature [7] to 300°C [8]. Currently, most of the sintering processes require some pressure (from a few MPa to 40 MPa) to be applied on the devices during the process. This is unpractical, as it requires dedicated apparatus and may damage the devices. In this article, we present a pressureless process which takes place in an oven, much like a standard soldered die attach.

Experimental procedure: The test vehicle used for this study is presented in fig. 1: 25x30 mm DBC substrates are cleaned using ethanol/acetone/diluted sulfuric acid/deionized water/ethanol and then dried using a nitrogen blow nozzle. Silver paste (Heraeus 117-02P2) is printed on the substrates using a 50 μ m-thick stencil. 3x3 mm Si dummy chips are then placed on top of the silver deposit using a die bonder to control the force applied during die placement (JFP PPOne). A Design-Of-Experiment study was performed to find the optimum bonding parameters (Fig. 2). *(more details will be given regarding the analysis of the DOE in the final paper)*. Calorimetric analysis (SDTA/DSC) was performed (figure 3) on some paste samples to find out reasonable values for the process profile before optimizing it

Results: For each of the 12 configurations of the DOE, 15 dies were shear-tested. The results given in figure 4 show that most configurations satisfy the MIL-STD 883 standard [9] (2.72 MPa on a 9 mm² die). Configurations 2 (35 min drying, 70°C/min ramp, 250°C and 15 min sintering) and 6 (identical, with 300°C sintering) give the best results. *The results will be discussed. In particular, we will address the effect of a protective atmosphere (nitrogen)*

Conclusion: A very simple sintering process has been presented (performed in air, without any pressure applied on the devices, and with process times comparables to that of soldering). This process is well suited to SiC power devices, as it offers much higher operating temperature capability, better electrical and thermal performance than soldering.

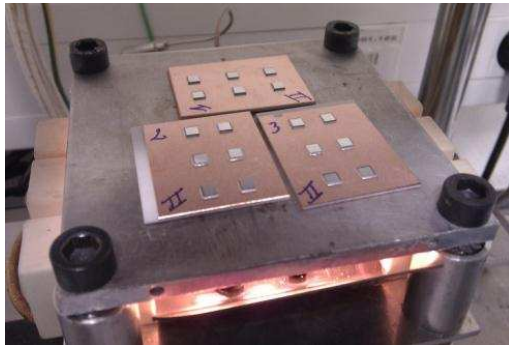


Figure 1: attachment of 18 3x3 mm diodes on DBC substrates. The size of the hot plate is 80x80 mm

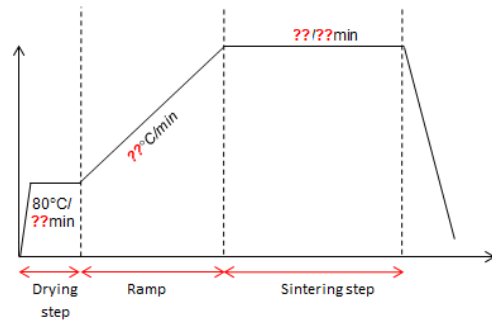


Figure 2: The 4 parameters (factors) of the temperature profile: duration of the drying step, ramping time, sintering temperature, sintering time.

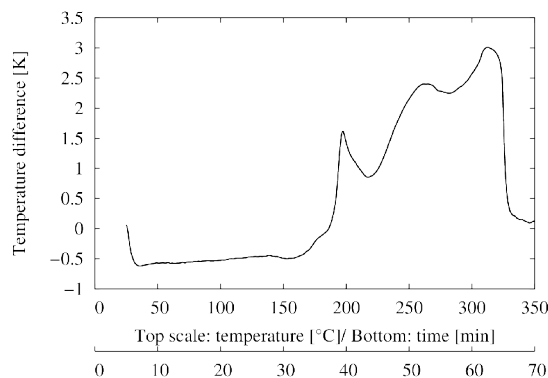


Figure 3: Simultaneous Differential Thermal Analysis (SDTA) measurement obtained for a sample of paste, in air, showing that reactions start around 200°C, up to 300°C.

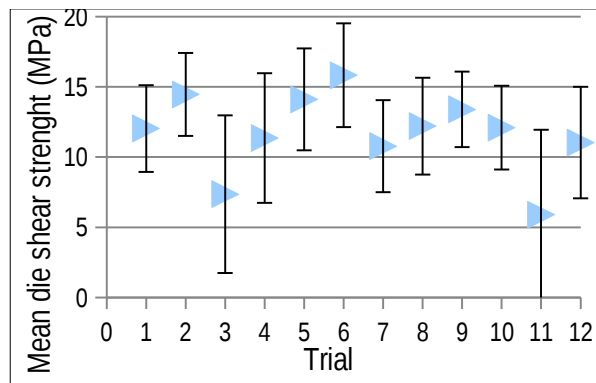


Figure 4: shear strength (mean and dispersion) for the 12 configurations of the DOE (details will be given in the final paper)

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