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Non-destructive imaging of defects in Ag-sinter die attach layers – A comparative study including X-ray, Scanning Acoustic Microscopy and Thermography

P. Dreher[a,*], R. Schmidt[a], A. Vetter[b,c], J. Hepp[b,c,d], A. Karl[b], C.J. Brabec[b,c]

[a] *SIEMENS AG, Frauenauracher Str. 80, 91056 Erlangen, Germany*
[b] *Materials for Electronics and Energy Technology (iMEET), Martensstr. 7, 91058 Erlangen, Germany*
[c] *Bavarian Center for Applied Energy Research (ZAE Bayern), Immerwahrstr. 2, 91058 Erlangen, Germany*
[d] *Erlangen Graduate School in Advanced Optical Technologies (SAOT), Paul-Gordan-Str. 6, 91052 Erlangen, Germany*

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ABSTRACT

In typical power electronic modules several semiconductor dies such as MOSFET or IGBT are soldered to a DBC substrate. During module production the quality of the solder layers can be monitored by the use of X-ray inspection and the void rate can be determined. Recently, the more robust Ag-sinter technology is deployed for attaching the power dies to the substrate, especially for high reliability or high temperature requirements. Besides voiding also adhesion problems can occur during sintering due to multiple reasons (e.g. contamination). In contrast to volume defects, pure adhesion problems cannot be detected by means of X-rays. Accordingly, other methods have to be applied for process monitoring. The present investigation compares the advantages and disadvantages of different non-destructive imaging techniques towards the detection of defects in sinter layers. Besides X-ray, Scanning Acoustic Microscopy (SAM) and Lock-in Thermography methods (DLIT + ILIT) were studied and evaluated in terms of suitability for detecting different defect types, resolution (minimum defect sizes), inspection time and possible integration into the assembly process.

1. Introduction

For producing high quality and robust power electronic devices, process monitoring of certain production steps is essential, as not all problems occurring during assembly can be identified by means of a final electrical test. For example, a process deviation in joining technologies (e.g. soldering, ultra-sonic welding, wire bonding etc.) does not necessarily have a direct impact on the electrical functionality of the device. Nevertheless, it can severely reduce the robustness and/or the lifetime of the device. Especially voids in the die attach can lead to local hot spots and to overheating of the device, which can trigger additional failure modes or directly lead to final destruction.

Accordingly, non-destructive testing methods should be integrated into the production line for monitoring the quality of the different assembly processes. Specific requirements are high detection rates of failures, short test times (cycle times), in-line imaging and no negative impact on the following assembly processes.

Standard solder processes are usually monitored by means of X-ray inspection, which yields good access to void rates and allows the detection of severe joining failures. Recently, the Ag-sinter technology [1] was introduced to power module packaging, where it is mainly used for attaching the semiconductor dies to the substrate [2]. This joining technique is of special interest for power electronic applications that require high power cycling capability and/or high operating temperatures. It is therefore also a good candidate for assembling wide band gap semiconductors into power module packages. In recent studies it was proven that Ag sinter technology can provide an excellent die attach for SiC dies [3], while solder layers suffer from reduced power cycle capability due to the stiffness of the SiC material [4].

During the Ag sintering process, the semiconductor die is joined to the substrate by applying temperature and high pressure. The Ag sinter paste containing micron-sized Ag flakes and organic solvents is thereby gradually densified. Depending on the process parameters a certain porosity remains in the sinter layer. Besides voiding (predominantly present in wet paste sinter processes) also adhesion problems can occur during this process due to multiple reasons (e.g. contamination of the mating surfaces).

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* Corresponding author.
E-mail address: patrick.dreher@siemens.com (P. Dreher).

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detected by means of X-ray imaging. Therefore other methods have to be applied for efficient process monitoring.

In [5], Rudzki et al. investigated the usage of SAM and X-ray on Ag sintered semiconductor dies with artificially introduced voids. Also promising first results of IR-Thermography imaging were presented. All three methods provided good efficiency in detecting the relatively large voids of several mm^2. Nevertheless, smaller voids and the important aspect of adhesion problems were not considered in this study.

In our present study four different imaging techniques were compared regarding the provided quality of images, the suitability for detection of different defect types, acquisition speed and potential integration into the production process. The investigated methods are X-ray, Scanning Acoustic Microscopy, Dark Lock-In Thermography (DLIT) and Illuminated Lock-In Thermography (ILIT). Small volume defects (voids) and interface defects (adhesion problems) were investigated.

2. Materials and methods

The following paragraph provides information about the materials and methods used to achieve results with X-ray, SAM, DLIT and ILIT.

2.1. Production process flow

Fig. 1 contains the first relevant production steps of a sintered power module, including the necessary material and possible assembly problems with their origin. In a first step, the sinter paste has to be applied to the DBC (direct bonded copper) substrate by using a stencil printing process. Afterwards the power die is picked from the wafer or waffle pack and placed onto the paste. The substrate is then transferred into the sinter press and the joint is formed. The sinter process is sensitive to various parameters such as pressure, temperature, process gases etc. Also the quality of the mating surfaces and the sinter paste plays an important role for a good, reliable joint. If any of the process parameters is not controlled properly, or contamination occurs, adhesion problems or voiding may happen. After sintering, the die's top side can be connected with heavy Al wire bonds by using a standard ultrasonic bonding process.

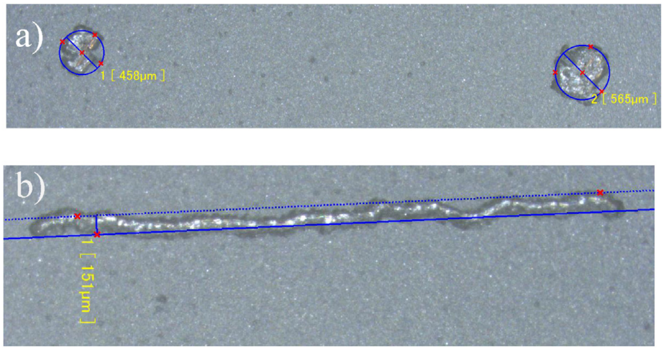

Fig. 2. Manipulated sinter paste after printing for simulating volume defects. Every induced defect was measured in size. a) circular volume defect; b) long extension volume defect.

2.2. Sample preparation

All samples used for the present study were built up following the process described above. A 650 V, 200A Si-IGBT (Infineon SIGC100T65R3E) with noble backside metallization was sintered onto the test DBC substrates with silver finish. 300 µm Al wire bonds were used for electrical top side connection. To have free vision to the surface (necessary for the IR-measurements) only a minimum number of wire bonds (two) were used.

For a quantitative evaluation of the resolution limit of the non-destructive imaging methods, it is important to investigate defects of known size and type. Two different types of defects were brought in by either scratching out a certain amount of sinter paste (volume defect) or by etching the metallization of the IGBTs. Removing the noble metal (Ag) surface of the die's backside inhibits the sinter joint formation between the silver paste and the die, producing an interface defect.

Fig. 2a) shows a microscopy image of two artificial volume defects of circular shape taken directly before drying the paste and placing the die. The size of the artificially produced voids ranged from 427 µm to 924 µm in diameter. To simulate scratches or chatter marks in the paste, also long extension defects of widths ranging from 120 µm up to 432 µm were fabricated (an example is shown in Fig. 2b). A total number of

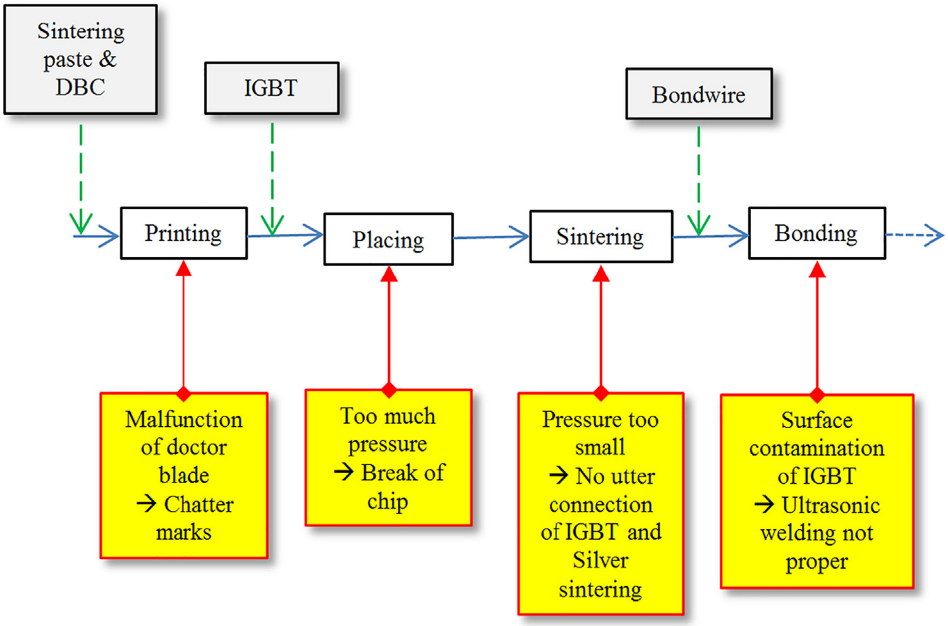

Fig. 1. First production steps of a sintered power module showing the relevant processes (center), the flow of material (top) and potential defects (bottom). Processes are limited to those that matter in this study.