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The Non-Destructive Test Method as A Simple Way to Evaluate The Quality of Metal Core PCBS for High Power Micro-Assemblies

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Abstract

The article describes the necessity of an incoming quality control of the delivered power electronics elements especially at the stage of choosing a reliable supplier. In particular, in the field of the metal core PCBs production, there is a need to control not only its heat sink parameters, but also to control the quality of the joint interface of the metal core PCBs. Since the use of poor-quality materials or the violation of the technological process by the manufacturer can lead to the defects in the PCBs structure. Thus it can affect the heat sink efficiency and the reliability of the entire assembly. The article proposes and describes the method of nondestructive incoming quality control of metal core PCBs. This method is based on the use of ultrasonic layer-by-layer scanning for obtaining the internal structure of PCBs. The article presents the results of applying this method for the PCBs of various manufacturers. The data of the structure visualization and the influence of environment temperatures changes were also obtained. The result pictures of the tested samples before and after the thermal circling were obtained to study the possible degradation of the PCBs structure and its parameters.

***Keywords**: metal core PCB, micro-assembly, power electronics, ultrasonic scanning method, non-destructive testing, incoming quality control*

1. Introduction

One of the main tasks in power electronics is to organize an effective heat dissipation and sink which especially important for miniature power assemblies. One of the most popular methods to dissipate the excess of heat is to use printed circuit boards on a metal base (so called metal core PCBs, Figure 1). In such a PCB a metal plate is used as the heat sink and one or more conductive layers of copper foil with a glass fiber cloth impregnated with resin (prepreg) are pasted on it. The most often used metals for heat dissipation are aluminum, copper or steel. The thermal conductivity of the aluminum base is about 150 W/m·K, and for copper it is about 400 W/m·K. However, despite such a difference in thermal conductivity, for the most cases the boards are manufactured on the aluminum base because it is the cheapest option of manufacture. The steel base is mainly used for screening electrical signals or for the mechanical hardness of the structure [1].

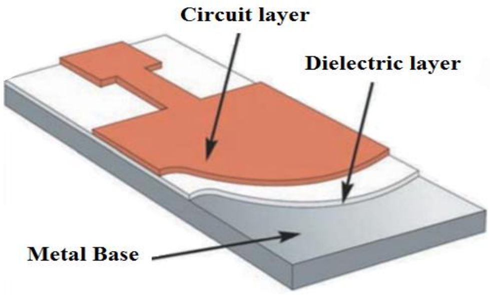

Figure 1. Metal Core PCB

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Such PCBs are manufactured in two stages: first of all one-layer or multi-layer printed circuit board is manufactured. Then a stack of multi-layer PCBs with a metal base interleaved with cushioning material is placed between the press plates (Figure 2). The PCBs are bonded with the metal substrate through a heat-conducting insulating layer. The most used materials with which you can attach the PCB to the metal base are prepreg and adhesive.

The chamber of the press machine must be hermetically sealed and the pressing process itself takes place after the air is pumped out to the pressure of at least 0.1 of atmospheric pressure. This vacuum value gives several positive effects at once. Firstly, the residues of the epoxy solvent that can lead to the gas voids in the structure are volatilized from the prepreg during the process. Secondly, during the pressing between the elements of the PCS there will be very little air, which will also lead to the good quality filling of the gaps with epoxy resin. Thorough fulfillment of the technological operations at these stages largely determines the quality of the producing PCBs [2,3]

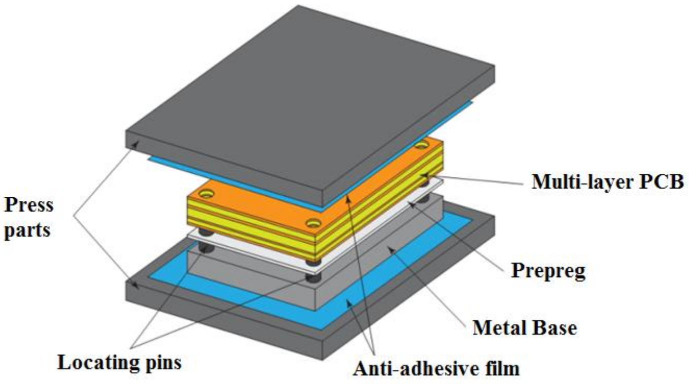

Figure 2. The assembly of multi-layer PCB stack with metal base

In result one of the important parameters in this case affecting the final thermal conductivity, will be the quality of the interface between the dielectric and the metal base. The real picture can be like the following on the Figure 3.

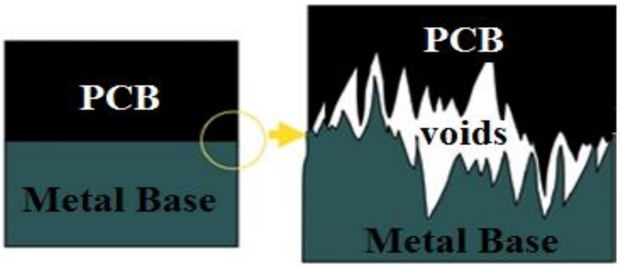

Figure 3. The quality of PCB and metal base interface [4]

Therefore, when choosing a supplier of metal core PCBs, it is very important to perform a primary incoming inspection to evaluate the quality of the materials used and the manufacturer's compliance with the process. Since a poor-quality interface can affect not only the efficiency of the heat sink, but also the temporary stability of the thermal parameters, and the reliability of the entire high power assembly.

2. Task and research method description

The task of the experiment was to carry out an incoming quality control of the samples of metal core PCBs from three different manufacturers for determining the possibility of using products in a high power micro assembly. The tested PCBs are shown in the Figure 4.

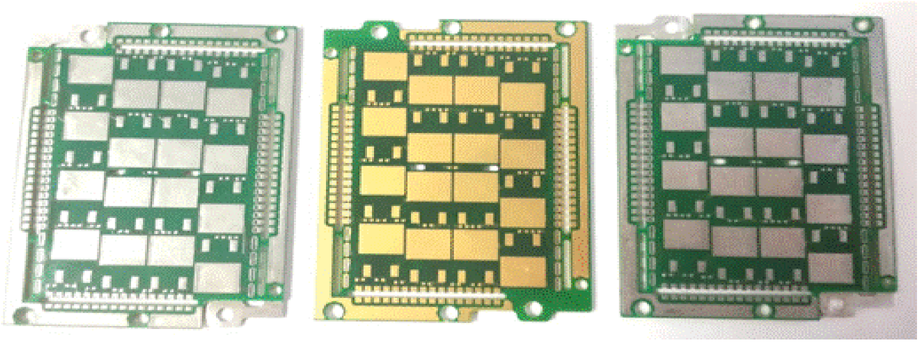

Figure 4. The tested samples of three different manufactures

In addition, it was necessary to investigate the influence of the environmental changes on the samples quality within the operating temperature range.

The standard peel-methods can not always be used for the incoming testing at the customer's enterprise due to lack of necessary equipment. In addition to the fact that they relate to the destructive control method, peel methods can only be used to judge the strength of the adhesive bond. But it is impossible to determine the interfaces of the bonding parts, the internal structure, and the presence of voids and delamination. The above defects may not affect the adhesion strength, but, as already mentioned, may affect the efficiency of heat dissipation.

This paper presents a usage of nondestructive input quality control of metal core PCBs using the method of layer-by-layer ultrasonic scanning.

The principle of operation of ultrasonic scanning method is based on the different reflectivity of materials. The ultrasonic wave passing through the sample can be absorbed, scattered or reflected depending on the elastic properties of the material. The wave reflected from the obstacles in the depth of the sample returns at different times, indicating the features of the material. Moreover, the higher the difference in resistances along the material interface, the greater the amplitude of the response and the greater the contrast of the visualized image will be. Some responses with a negative polarity in most cases indicate the presence of cracks and voids (Figure 5). Using a sound wave allows you to examine the samples layer-by-layer at different depths, visualizing its internal features [5,6].

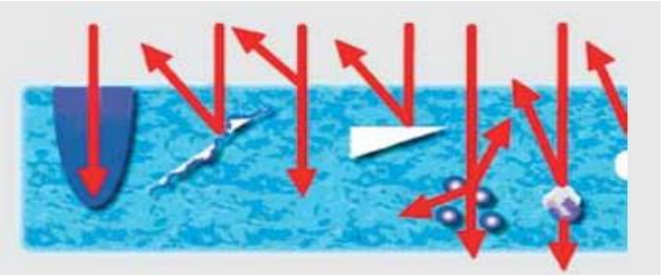

Figure 5 .The principal of Ultrasonic Scanning method

The non-destructive ultrasonic scanning method described above was selected for the incoming quality control using the Sonoscan system [7]. This system can capture the internal structure of micro-assemblies, the volume under the case, it can determine the quality of adhesive joints and detect the presence of hidden voids and structure defects (like delamination, cracks, cavities) etc. Wherein the sample will not be destroyed during the inspection. The resolution of the used Sonoscan system allows the operator to visualize the defects as small as 25 μm.

In addition to the experiment it was necessary to take into account the influence of the operating temperature range of the whole micro-assembly. Thus according to the technical requirements of regulatory documents, a serial of tests were conducted to determine the ability of the products to maintain their appearance and parameters after exposure to a multiple fast change in ambient temperature from -60 to + 150°C.

In this experiment, the two-chamber method was used for a rapid temperature change. The samples were exposed to 20 consecutive thermal cycles. The samples were held in each chamber for 20 minutes to stabilize the temperature. The time of samples transfer from one chamber to another was no more than 2 minutes.

As a result, the layer-by-layer visualizations of samples of metal core PCBs were obtained for the state before and after the thermal cycling process. The collected data allow us to judge not only about the quality of the PCBs, but also about the possible degradation of the samples structure and parameters.

3. Research results

The results of layer-by-layer scanning of metal core PCBs samples from three different manufacturers were obtained (sample No.1, sample No.2, sample No.3). To estimate the reliability of the samples and to identify the degradation of the bonding joint quality, the studies were carried out before and after thermal cycling in the operating temperature range.

Figures 6 and 7 show the obtained images of PCB and metal base interface of sample No.1 before and after the thermal cycling relatively.

Figures 8 and 9 show the obtained us-scanning results for sample No.2 before and after the thermal cycling relatively.

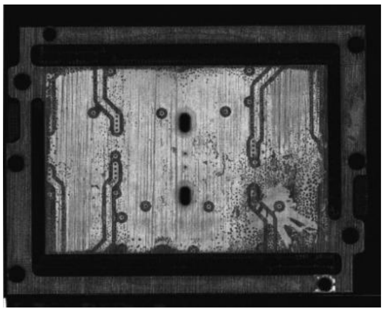

Figure 6. Before thermal cycling results of sample No.1

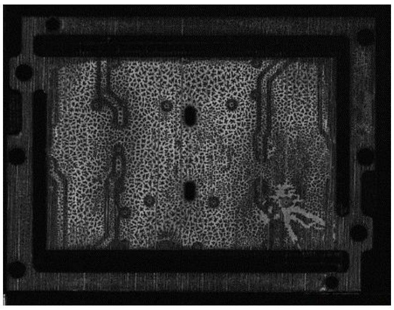

Figure 7. After thermal cycling results of sample No.1

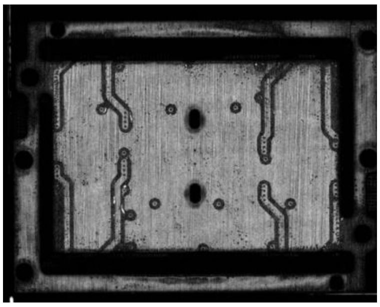

Figure 8. Before thermal cycling results of sample No.2

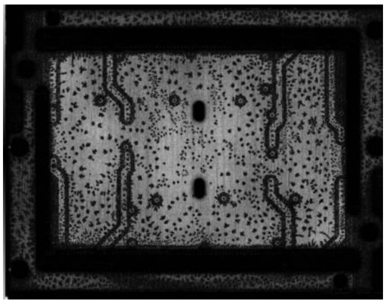

Figure 9. After thermal cycling results of sample No.2

Figures 10 and 11 show the obtained us-scanning results for sample No.3 before and after the thermal cycling relatively.

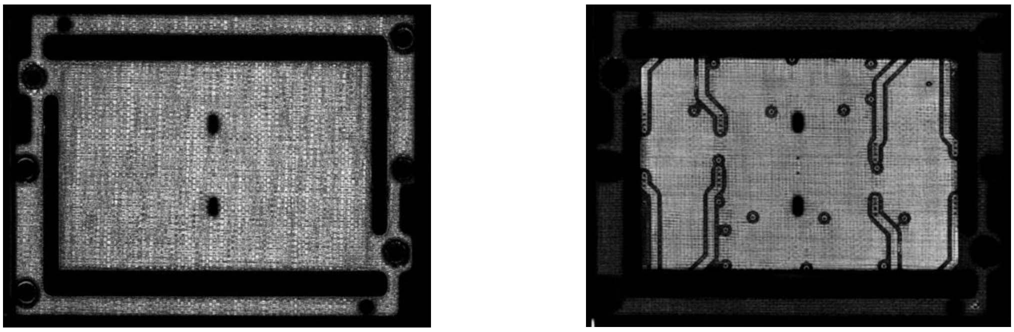

Figure 10. Before thermal cycling results of sample No.3 (layer-by-layer screening)

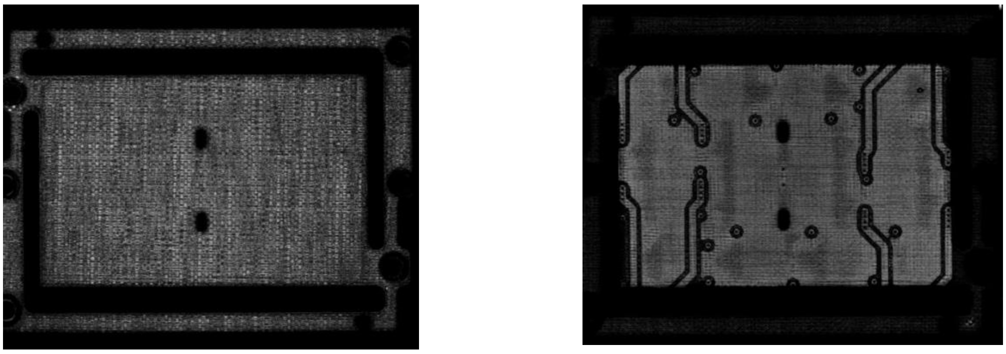

Figure 11. After thermal cycling results of sample No.3 (layer-by-layer screening)

4. Results Discussion

As it can be seen in Figures 6 and 7 of the sample No.1 results, several structure violations of the adhesive layer with small inclusions of air were found. Moreover after the thermal cycling process, the increase in the defect density and the degradation of the entire adhesive layer became evident. Apparently, the manufacturer violated the technology process or used poor-quality materials for manufacturing metal core PCB.

On the sample No.2 before thermal cycles (Figures 8), positive results were obtained at the bonding interface between the PCB and the metal base: a uniform pattern, no delamination or large air voids. However, after carrying out the thermal cycling process, a large number of air voids appeared at the interface, which most likely can be related to the use of poor-quality adhesive material.

The research of the sample No.3 showed a perfect picture, remained stable after thermal cycle process. The ultrasonic scanning system did not detect any defects at the interface either before or after the thermal cycling process, which is very clearly seen in the layered visualization of the structure in Figures 10 and 11. Based on the obtained experimental data, it is possible to judge about the good quality of the manufactured PCBs. In addition similar good results were obtained on the other samples ordered from this manufacturer.

Thus the samples of the third manufacturer can further be used in high power assemblies for effective heat sinking [8,9].

5. Conclusion

During the research three samples of metal core PCBs of different manufacturers were studied. For this study a non-destructive ultrasonic scanning method was applied using the

Sonoscan system. As a result of carried out research a layered visualization of the PCBs internal structure was obtained. The quality of the bonding interface between the PCB and the metal base were studied, the presence of defects, delamination, voids, indicating about the technological process violation or the use of poor-quality materials were investigated. In addition, the impact of environmental changes on the quality of the samples was tested within the operating temperature range. Ultrasonic scanned images of the test samples were obtained after series of thermo cycles. Based on the performed tests, the conclusions were made about the possibility of further use of certain metal core PCBs for high-power micro-assemblies.

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