Effect of Environmental Factors on Ultrasound Detection of Plastic Encapsulated Microcircuits

Hailong Zhao*, Kui Zhang, Zhenhua Zhou, Shanbin Xi, Lijing Yin, Jie Huang and Hao Peng

The 13th Research Institute, CETC, Shijiazhuang, Hebei, 050051, China

*Corresponding author’s e-mail: zhaohl@cetc13.cn

Abstract. Based on the problems encountered in ultrasonic detection of Plastic Encapsulated Microcircuits (PEMs), the relationship between storage environment, immersion time, baking treatment and temperature test and other environmental factors and the stability of PEM are studied for the characteristics of plastic encapsulated materials that are susceptible to temperature changes and moisture. And its effect on the results of ultrasonic testing, the reasons for the inconsistency of ultrasonic testing results are analysed, and storage, transportation, immersion time, baking treatment requirements before and after the test, and device use recommendations are put forward.

1. Introduction

Plastic encapsulation is a form of encapsulation in which plastic is used as the package. Common plastic encapsulated materials include epoxy resin and silicone resin. Plastic Encapsulated Microcircuits (PEMs) are thinner, smaller and lighter than airtight packages because they have no internal cavity volume. Compared with other packages, PEMs have obvious advantages in size and weight.

However, PEMs are temperature and humidity sensitive devices. In the process of storage and use, temperature changes can easily lead to delamination, cracking and even explosion of devices, and the invasion of moisture will further aggravate this phenomenon, which has a great impact on the ultrasonic detection of PEMs. The inconsistent test results are often encountered during the test, mainly including the following:

(1) The results of ultrasound detection from different testing institutions for the same batch of devices are inconsistent;
(2) The same batch of devices are detected by ultrasound again at intervals, and the results show great changes.
(3) The first sample of ultrasound testing is qualified, and after a period of time the second sample testing is not qualified;
(4) The pre-screened qualified devices are unqualified in a large number of ultrasonic testing after the temperature cycle test.

Common environmental factors that easily lead to the change of the state of PEMs include the storage environment conditions of the device, the immersion time of ultrasonic detection, the baking treatment before and after ultrasonic detection, and the influence of temperature test. Due to the instability of PEMs, these factors will lead to changes in the state of PEMs, which will affect the ultrasonic detection results.
2. Effect of Storage Environment
The non-airtight nature of plastic encapsulated materials determines that PEMs are susceptible to water vapor, especially when the environmental humidity is high and necessary moisture-proof storage measures are not taken, the moisture absorption of PEMs is more serious. Water vapor intrusion will make the internal parts of the device layered due to the expansion of water vapor, which makes the qualified device unqualified when re-checked. In addition, excessive water vapor will often fill the already layered interface, so that the ultrasonic cannot detect the delamination.

The thermal expansion coefficients of the various components of PEMs vary greatly, which determines that PEMs are susceptible to temperature changes. Once PEMs encounters temperature changes during storage, compression or tension stress will be generated at the interface of different materials. If there is bad bonding or poor bonding performance due to water vapor in the device manufacturing process, it will lead to package delamination. Temperature changes in the storage process will further expand the small layers into large layers, which will affect the ultrasonic detection results.

Therefore, if the temperature and humidity conditions are not properly controlled during storage and transportation of PEMs, the state of devices with higher Moisture Sensitivity Level (MSL) is prone to change. As a result, the results of ultrasound testing will change greatly after a period of time, and the conclusions of different testing institutions will also be different.

3. Effect of Immersion Time
During ultrasonic testing, when PEMs are immersed in the coupling liquid (generally deionized water) for a long time, it will be found that the detectability of detects becomes lower. The immersion time will cause the deviation of the ultrasonic detection result, which is more obvious for some devices with higher MSL grade and those with defects. This is mainly due to the moisture inhalation inside the device during the test and the state of the device has changed. After the PEM with delamination absorbs moisture or enters water, the delaminated area fills with water, and the ultrasonic detection image is similar to that of the non-delaminated device, which shows the false appearance of delamination "disappearing", as shown in Figure 1 and Figure 2.

![Figure 1. Ultrasound detection image of PEMs just immersed in water](image1)

![Figure 2. Partial delamination of PEMs "disappear" after 3 hours of immersion](image2)

In order to obtain more accurate test results, it is necessary to minimize the time that PEMs are immersed in water during ultrasonic testing, and necessary measures such as drying should be taken before and after the test.

4. Effect of Baking Treatment
Ultrasound detection of moisture absorbing PEMs often fails to get accurate conclusions. In order to reduce the effect of moisture on ultrasonic detection of PEMs, it is necessary to bake and dehumidify
them, which are divided into pre-treatment before ultrasonic detection and baking treatment after ultrasonic detection.

4.1. Pre-processing before Ultrasound Detection
For PEMs that have not been stored for a long time and have just been taken out from the moisture-resistant bag, high-temperature baking pre-processing is not required before ultrasonic testing. For devices that are not used for long-term storage or exposed to air for a long time, in order to ensure the accuracy of ultrasonic detection results, the device should be dehumidified by pre-treatment. However, there is no clear requirement for pre-processing before ultrasonic testing in China.

4.2. Baking after Ultrasound Detection
During ultrasonic testing, PEMs will more or less absorb some water in deionized water. In order not to affect the accuracy of use and re-inspection results, in principle, the device should be baked and dehumidified after ultrasonic testing, and then placed in a moisture-proof bag for transportation. However, the current implementation of the baking process after ultrasonic testing in China is very different. The baking temperature implemented includes 70°C, 85°C, 100°C, 125°C, etc., and the baking time includes 0.5h, 1h, 2h, 24h, etc., and some even do not bake. There are three reasons for this difference:

(1) The importance of moisture resistance of PEMs is not well understood in China, and the requirements for storage, transportation and use of PEMs are not enough to be standardized.

(2) There is no standard for baking after ultrasonic testing. Baking conditions are not specified in the main ultrasonic testing standards such as GJB 4027A-2006 [1], MIL-STD-1580B [2]. Only PEM-INST-001 [3] stipulates that baking should be done for 1 hour at 125 C after ultrasonic testing.

(3) Baking has the possibility of causing defects to expand or even fail, as shown in Figure 3. In the absence of mandatory requirements, some device suppliers, testing institutions, users, etc. are not willing to risk the failure of the device to bake.

![Figure 3. Potential failure due to high temperature baking](image)

If the baking process is not thorough, different conclusions may be drawn when the ultrasound test is performed again. At the same time, incomplete baking may bring hidden dangers to the subsequent use of the device, which is contrary to the original intention of increasing the strength of ultrasonic detection screening in recent years. In order to reduce the risk of use and improve the effectiveness of ultrasonic testing, it is necessary to make clear requirements for baking after ultrasonic testing.

5. Effect of Temperature Test
The reliability of PEMs is usually tested by reliability tests such as temperature cycle, high-temperature storage, high-temperature life, etc. Temperature cycle is the most effective test to predict reliability [4]. Low reliability devices often fail to pass the test of ultrasonic detection due to severe delamination after temperature cycling.

During the temperature cycle test, under the impact of temperature change and high temperature, the thermal expansion coefficients of the plastic packaging material and the chip, lead frame and substrate are inconsistent, which will cause stress concentration at the junction of different materials in the plastic packaging. Once the stress level exceeds the yield strength or fracture strength of one of the packaging materials, delamination and cracking will occur. During the temperature cycle test, through
continuous thermal expansion and contraction effects, the interfacial delamination will continue to expand. Ultrasonic testing was performed after the temperature cycle test, which showed that a large number of devices were unqualified. The changes in the bonding area of a certain amplifier before and after the temperature cycle are shown in Figure 4 and Figure 5.

![Figure 4. PEMs with no delamination before temperature cycling](image1)

![Figure 5. PEMs delaminated after temperature cycling](image2)

The bonding area is a very critical area that is prone to delamination. It can be seen from Figure 4 and Figure 5 that there is no delaminated pins of the amplifier bonding area before the temperature cycle, but most of the pins appear delamination after the temperature cycle. The delamination of the pins in the bonding area may cause the bonding point to fall off or the bonding wire to break, which will invalidate PEMs and cause serious reliability problems.

6. Conclusion
Ultrasound detection is a non-destructive test method for obtaining sample information that is not available by other test methods. However, the non-airtightness of the plastic encapsulated material makes PEMs susceptible to temperature changes and moisture changes in the external environment, and the state of the device is not stable enough, which affects the accuracy of ultrasonic testing. In order to improve the significance of ultrasonic testing and reduce the risk of use, standardized storage and transportation of PEMs, reduction of immersion time in the process of ultrasonic testing, and necessary baking treatment before and after ultrasonic testing should be carried out. The use of PEMs that cannot pass reliability tests such as temperature cycle should be restricted.

References
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