Analysis of Scanning Acoustic Microscopy Problems for Plastic Encapsulated Microcircuits with Complex Structure

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Abstract. In order to keep up with the development trend of plastic encapsulated technology and effectively improve the Scanning Acoustic Microscopy (SAM) capability of Plastic Encapsulated Microcircuits (PEMs) with complex structure, the structural characteristics of complex packaging devices, the limitations of ultrasonic technology and the applicability of testing standards are systematically studied. The influence of complex package structure and chip coated structure on SAM detection is analysed. The influence of the limitation of ultrasonic technology on the thickness and number of layers of PEMs is studied. Finally, the applicability of SAM test standards is discussed. Through the research, many problems in the SAM detection of PEMs with complex structures are pointed out, and some test requirements and suggestions on test standards are given.

1. Introduction

Plastic Encapsulated Microcircuits (PEMs) have long dominated in commercial and industrial applications due to their small size, light quality, low cost and easy procurement [1]. However, due to the special structure and material of PEMs, there are some potential defects, such as voids, cracks and delamination between parts, etc. as shown in Figure 1. Because plastic encapsulated structures usually have relatively flat surfaces, they are very suitable for ultrasonic detection. Ultrasound can detect the size and various defects of the internal structure of the encapsulation. Therefore, Scanning Acoustic Microscopy (SAM) is widely used in the field of electronic packaging [2].

![Figure 1. Schematic diagram of the structure and defect form of PEMs](image-url)
2. Challenges of Complex Structures
Since the 21st century, there have been some new trends in packaging, including some new system-level and 3D packaging, the typical of which are SiP, SoP, PoP and stacked CSP [3], as shown in Figures 2 and 3.

![Figure 2. Chip stacked 3D BGA package [4]](image1)

![Figure 3. Dual-sided chip stacked 3D package [5]](image2)

For complex structures and high density PEMs, many interfaces are formed between different materials within the device, and the interface distance is very close. In the process of ultrasonic detection, if you are not familiar with the structure of the device and the components of each structure, it is easy to cause missed judgments and misjudgments. Therefore, for these devices with complex structures, it is necessary to know the structure of the devices by other means such as X-ray before scanning them, and then select the appropriate transducer and scanning mode to scan and discriminate them.

3. Chip Coated Problem
In order to protect chips and shield radiation, some PEMs are coated with a layer of organic materials on the surface of chips. This method is simple in process and effective, and has been widely used. When this coated device is scanned, all the scanning waveforms are phase-inverted, and the SAM image is displayed in red, which is very similar to delamination, as shown in Figure 4. If the engineer is not familiar with the structure of this device or has insufficient experience, it will be judged as unqualified, causing a misjudgment.

![Figure 4. SAM image of chip coated device](image3)

When chip surface delamination is more serious and chip coated is suspected, this kind of structure can be distinguished by several simple and effective verification methods such as sampling microscopy, X-ray examination and chemical opening [6]. Generally, the most effective verification method is to do a section examination after the sample is sealed. If the validation results confirm that there is a layer with coated material on the chip surface, then it cannot be judged that the SAM detection is not qualified.
4. Limitations of Ultrasound Technology

4.1. Thickness Limit
SAM uses the principle of reflected wave imaging of ultrasound to detect the internal defects of PEMs, and the resolution of the ultrasound is inversely proportional to the depth of penetration. Limited by these characteristics of ultrasound, SAM has the following limitations for devices with large thickness:

4.1.1. Limited resolution
Ultrasound resolution includes Z-axis longitudinal resolution and X-Y lateral resolution. The Z-axis vertical resolution is a function of the transducer frequency. The higher the transducer frequency, the higher the resolution. However, the higher the frequency, the faster the attenuation of the ultrasonic signal with the increase of the depth. In order to ensure the penetration depth, the Z-axis resolution must be reduced. The X-Y transverse resolution is determined by the transducer characteristics (frequency, diameter, focal length, etc.), the absorption and scattering of ultrasonic waves by sample materials, and the electromechanical characteristics of the X-Y carrier station, all of which limit the X-Y transverse resolution.

4.1.2. Difficult to analyse thicker packaged devices
The attenuation of the ultrasonic signal is related to the depth of the signal entering the packaging material and the frequency of the transducer. The deeper the signal enters the device, the more severe the signal attenuation; similarly, the higher the frequency of the transducer, the more severe the signal attenuates with depth. For thicker packages, the ultrasonic signal is completely attenuated after reaching a certain depth, so it cannot be detected and analysed.

4.2. Multidimensional Effects
According to the principle of ultrasonic detection, the SAM image will show whether there is any defect in the sample, the type of defect, the location of the defect and the size of the defect. However, for complex packaging structures with multiple interfaces, the ultrasonic signals between interfaces interfere with each other, and some defects may not be displayed in the scanned image, or the defects shown in the scanned image may not be the actual defects of the sample.

For delamination defects, due to the large number of complex packaging interfaces and thicker thickness, the transducer selected has a lower frequency, which results in the overlap of the surface and internal scanning surface echo signals, and delamination phenomenon cannot be seen in the acoustic scan image of the delaminated PEM. In addition, due to the multi-layer interference effect, there is a delamination phenomenon in the acoustic scan image of the PEM without delamination.

Therefore, every time a complex structure PEMs is scanned, the abnormality in the scanned image should be carefully examined to determine whether the abnormality is caused by packaging defects or artificial or equipment factors in the detection process. For samples with different packaging forms (such as shape, thickness, structure, etc.), the working conditions of the acoustic scanning equipment should be adjusted to ensure that the defects displayed by the scanned image are accurate and true, and to avoid missed judgments and misjudgments.

5. Standard Applicability Issues
At present, the main commonly used test standards for SAM of PEMs at home and abroad mainly include GJB 4027A-2006 "Methods of Destructive Physical Analysis for Military Electronic Components" [7] and MIL-STD-1580B "Destructive Physical Analysis for Electronic, Electromagnetic, and Electromechanical Parts" [8]. The inspection contents and methods required by the standards only applicable to the most basic forms of encapsulation.

With the rapid development of plastic encapsulated technology, some new types of encapsulation appear continuously, but the development of SAM test standards cannot keep up with them in time. Among the current effective sound scanning standards at home and abroad, there are only the testing
standards for ordinary plastic-packaged integrated circuits, and there are no testing standards for various new plastic-packaged devices and modules. In order to better guide the SAM detection of PEMs, the standard terms for the detection of BGA, Flip-Chip and other common new PEMs and hybrid packaging modules (Figure 5) should be added, and at least some standards system with macro guidance should be formulated.

Figure 5. Hybrid encapsulated module

6. Conclusion
SAM is an effective means to detect the internal defects of PEMs without damage. However, with the development of packaging technology, many new packaging structures become more and more complex, and there are many problems in the SAM test. The complexity of the device structure and the limitations of ultrasound technology put forward higher requirements for the detection engineers; otherwise, they are prone to detection errors or undetectable defects. In addition, it is particularly prominent that the SAM test standards cannot keep up with the development of packaging technology, so it is urgent to formulate more applicable standards and specifications.

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