Counterfeit identification method of plastic encapsulated microcircuits using scanning acoustic microscope

Yao Qiu\(^1\), SuJuan Zhang, ZhengPing Chen, Yanruoyue Li and Maogong Jiang
School of Reliability and Systems Engineering, Beihang University, Beijing, China
\(^1\) E-mail: qiuyao@buaa.edu.cn

Abstract. Scanning acoustic microscope (SAM) is usually used to detect whether the chips, substrate and pins of PEMs have delamination, cracks, voids and other defects. In this paper, a method of identifying surface treatment counterfeit components using SAM was proposed. In the proposed method, the suspicious components were scanned respectively using scanning modes of A-scan, X-scan and C-scan to focus on different depths of interface. The final image was obtained to identify the fake features. Finally, based on the actual case, validity and accuracy of the method to identify the counterfeit components were analyzed and verified. SAM operates non-destructively and proved to be an extremely useful tool complementing current state-of-the-art methods for counterfeit identification.

1. Introduction
As the supply chain of electronic components grows more complex due to globalization, due to be driven by interest, the counterfeit components appeared in many industrial sectors, including computers, telecommunications, automotive electronics, and even military systems [1]. The poor quality of the counterfeit components will cause a lot of problems, which will threaten the safety and reliability of their electronic products. The most common method of generating counterfeit components is surface treatment, such as relabeling. Many illegal traders product the relabeling of the counterfeiting electronic components to gain high profits, because this kind of counterfeit technology is low in technical requirement and cost of production.

In SAE AS5553B-2016 [2], “Counterfeit Electrical, Electronic, and Electromechanical (EEE) Parts; Avoidance, Detection, Mitigation, and Disposition”, the definition of counterfeit components are: (1) An unauthorized copy, imitation, substitute, or modified part, which is knowingly misrepresented as a specified genuine part of the manufacturer; (2) Or a previously used EEE Part which has been modified and is knowingly misrepresented as new without disclosure to the customer that it has been previously used. In many cases, the original marks of components are removed by grinding, then relabel new mark after coating. The surface of the components can be observed by optical microscope. However, it is difficult to identify residual marks of the original mark.

The scanning acoustic microscope (SAM) makes use of acoustic waves to create images of microscopic objects and provides nondestructive imaging of physical defects [3]. SAM has the unparalleled advantages in detecting material performance and internal defects compared with other technologies. However, in domestic related standards, SAM technology has not been used to identify counterfeit components.

In this paper, the SAM that had a high Z axis resolution feature was used to inspect the component package surface. By focusing on different depth of the package, ultrasound images of different depth
were generated and analysed, which can effectively detect if there were relabelling components. In the second and third section, the working principle of SAM was introduced, and the specific counterfeit identification method of PEMs was summarized. In the fourth section, an actual case was analysed by the method proposed in this paper, which verified the validity and accuracy of the method.

2. Principle of SAM

The SAM uses a single piezoelectric transducer both to send and receive the acoustic pluses [4]. The basic principle of SAM is to convert electrical signals to acoustic signals by transducer. The acoustic wave is then sent via liquid coupling medium (such as deionized water) to be focused to a spot at the depth of the sample. When the acoustic wave is transmitted from one medium to the other medium, during which some amount of sound energy is reflected at the interface between two media, because two materials have different acoustic impedances, as is shown in figure 1. Lastly, received echo signals have been digitized at a sampling rate of 1 GS/s with a resolution of 8 bit and stored on the microscope’s internal hard disc drive and were transferred to a workstation computer for additional off-line analysis [5].

![Figure 1. Figure with principle of SAM.](image1)

In this paper, three main modes of SAM were used, including A-scan, C-scan and X-scan. To be specific, the A-scan mode is presented that the real-time acoustic echo waveform of a certain spot is generated in the direction of the Z axis from transducer, illustrated in figure 2. The scanning process is done by synchronously moving the lens in the x-y plane while rapidly switching the driving electronics state between sending and receiving acoustic waves [6]. In figure 3, the C-scan mode presents a certain depth of the plane image determined by the location of the red line. In X-scan mode, a large number of C-scan images are obtained, that reflects different depth of the component plane, as is shown in figure 4.

![Figure 2. Figure with A-scan of SAM.](image2)
Figure 2 is an example to explain the functions of the individual buttons in the diagram generated by the SAM300 equipment (PVA TePla Analytical Systems GmbH, Westhausen, Germany). The X axis indicates the time when the acoustic wave is transmitted inside the sample, and the Y axis indicates the amplitude of the reflected echo. The blue line is mainly set for the unevenness of some samples. The width of the blue line indicates the surface trigger gate, and the surface signal should be positioned in the middle of the blue gate, which directly affects the image effect of the scanned picture of the sample. In X-scan mode, the scanning depth range is depended on the starting position and width of the green line. The red line represents the time gate, and its initial location determines the depth range of the C-scan image. Meanwhile, the time gate is usually set based on the depth range of the Z direction at the interested interface of the sample. Furthermore, the waveform of the blue circle shows the surface of the sample, and the waveform of the red circle shows the inside of the sample. In order to obtain useful images and waveform, these parameters are set in actual test according specific requirement.

3. Methodology

SAM can be used to detect chip voids, die delamination, solder cracks, pin delamination and a number of other defects generated by process. Therefore, the red line is usually set on the interface wave of the chip, pin and substrate. In an actual case, the C-scan image given the interface between the pin and substrate, as is shown in figure 5. And the surface mark of the sample is found in this picture, and it can’t be clearly identified because of the C-scan image is focused on the inside of the sample.

Based on the principle of SAM technology, in order to identify the mark of sample, the red line should be set on the surface wave of the sample. Because many kinds of counterfeit components were produced by repeating marking, SAM was used to present and observe images of the different depths on the surface of the component, which was determined whether there was relabelling. The specific steps of the counterfeit component identification method based on SAM technology are as follows:

- Step 1: In A-scan mode, the blue line is set on the surface waveform of the sample. Then the starting position of the green line should be set on the depth scope of sample mark. And the
width of the red line is usually set on 30ns. Furthermore, in X-scan mode, a number of C-scan images are obtained at the same time.

- Step 2: The images containing the mark are selected from multiple C-scan images. Meanwhile, the corresponding waveforms of the interface are found in A-scan mode. Then, in A-scan mode, it is further focused on the depth of the mark.

- Step 3: In C-scan mode, the clear image of the identified interface is obtained and observed whether there is relabelling. If there is, it is judged to be a counterfeit component.

- Step 4: As for counterfeit component determined by Step 3, in order to determine the original identification mark, the width of the red line (time gate) should be shortened to the depth of the interface of the original mark. The time gate should be reduced gradually, such as 20ns, 10ns, 5ns and 1ns. Then, step 1, step 2 and step 3 are repeated. Finally, the clear C-scan image is obtained, which can further verify the source of the counterfeit component.

In the next section, a specific actual case was mentioned and analysed by the counterfeit identification method in this paper.

4. Case application
The component of SM320F2812PGFMEP manufactured by TI is a plastic encapsulated enhanced digital signal processor, as is shown in figure 6. In external inspection, it was found that the surface of the component had a mark of grinding, and the component was seen as a suspicious component.

![Figure 6. The image of the suspicious component.](image)

Then, SAM was used to inspect the surface of the suspicious component whether there was relabelling based on the counterfeit identification method presented in this paper. The results are as follows:

- Step 1: In X-scan mode, a number of C-scan images were obtained. Figure 7 was found out that there were other characters besides the original observed marks, but it was too vagueness to distinguish.

![Figure 7. The C-scan image in SAM.](image)
Step 2: First of all, the blue line and green line were set on to trace the wave of surface. Then, in A-scan mode, the width of the red line located in the interface between the two marks was set on 30ns. Finally, the clear C-scan image and waveform was presented in figure 8.

![Figure 8. The clear C-scan image and waveform in SAM.](image)

Step 3: From figure 7 and 8, the surface of the suspicious component was seen that there was relabelling. Therefore, it could be accurately determined as a counterfeit component.

Step 4: Based on step 3, in order to confirm the original logo, the blue line was set on to trace the wave of surface. And the green line should be located in the interface of the two marks. Moreover, the width of the red line was gradually set on 20ns, 15ns, 10ns and 5ns. And above steps were repeated. Lastly, when it was set on 5ns, the original logo, “TMS320F2812-PGFA”, was clearly shown in figure 9.

![Figure 9. The clear original logo of image and waveform in SAM.](image)

According to the information referred from the official website, the quality grade of “TMS320F2812PGFA” was industrial, but the “SM320F2812PGFMEP” was enhanced type. Meanwhile, the two types could be substituted for each other in circuit function and electrical parameters in table 1. To sum up, the counterfeit component was produced to gain more benefits by changing the quality grade. If the counterfeit component was used in electrical equipment, the reliability of the equipment will be declined.
Table 1. Comparison of two types.

| NO. | substance       | TMS320F2812PGFA | SM320F2812PGFMEP   |
|-----|----------------|-----------------|-------------------|
| 1   | Quality grade  | Industrial      | Enhanced type     |
| 2   | temperature    | -40°C~85°C      | -55°C~125°C       |
| 3   | Price          | $14.25          | $29.75            |
| 4   | Package        | LQFP176         | LQFP176           |
| 5   | producing area | Philippines     | Philippines       |
| 6   | Electrical performance |  | They can be substituted for each other. |

5. Conclusions

In this paper, a counterfeit identification method of PEMs was summarized. The method could be used to inspect whether there was relabelling based on SAM. By focusing on the different height range of the package interface, C-scan images and waveform were obtained, from which the suspicious component could be determined. In the actual case, a suspicious component was inspected and analyzed by this method to verify the validity of the method. In the usual screening or DPA tests, the counterfeit identification method using SAM should be added to test items to remove counterfeit components.

References

[1] Guin U, Huang K, Dimase D, et al 2014 Counterfeit Integrated Circuits: A Rising Threat in the Global Semiconductor Supply Chain Proceedings of the IEEE 102(8):1207-1228
[2] SAE AS5553B. Counterfeit Electrical, Electronic, and Electromechanical (EE) Parts; Avoidance, Detection, Mitigation, and Disposition [S]. 2016.09.
[3] Qiu Y and Zhang S 2017 Study on the Pin Delamination of Plastic Encapsulated Microcircuits Using Scanning Acoustic Microscope in 2017 Prognostics and System Health Management Conference (PHM-Harbin). IEEE pp.1-5
[4] Moore T M and McKenna R G 2014 Characterization of integrated circuit packaging materials [M] Harbin Institute of Technology Press
[5] Brand S, Tismer S, Moe S T, et al. 2015 Non-destructive wafer-level bond defect identification by scanning acoustic microscopy Microsystem Technologies 21(7):1385-1394
[6] Khaled A, Brand S, Kögel M, et al. 2016 Investigating stress measurement capabilities of GHz Scanning Acoustic Microscopy for 3D failure analysis Microelectronics Reliability 64:336-340