A new application of SAM in the non-destructive inspection for SIM card

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Abstract. Scanning Acoustic Microscopy (SAM) is a typical inspection method in the semiconductor IC manufacturing industry. Because the die thickness is a key parameter for SIM card, a new method to measure the internal die thickness of SIM card is proposed with SAM’s reflective scanning mode. Using this method the internal die thickness of SIM card can be accurately measured without introducing any damages to SIM card. The thickness model and methodology based on the SAM signals have been established. The model was properly verified and calibrated by two real test cases.

1. Introduction
Scanning Acoustic Microscopy (SAM) is a typical instrument used to examine the adhesion between two different materials in a non-destructive way [1, 2]. Frequencies in the range of 5-300MHz are typically used for semiconductor applications. Ultrasonic frequency is related with penetration depth and resolution. The resolution is higher with increasing ultrasonic frequency, while the penetration range is shorter [3].

Based on the features of short time, high efficiency and non-destructiveness, SAM has become a significant inspection tool as non-destructive way and widely applies in the Semiconductor encapsulation industry. However, to my knowledge, SAM rarely appears as the inspection tool of SIM card, especially the measurement of the thickness of the inner die.

The die thickness is one of the key parameters for SIM card. It is highly necessary to monitor this parameter in the process. The conventional measurement of die thickness in the SIM card has to get the die out from the SIM card. It will unavoidably damage the SIM card. On the other hand, the conventional method will typically take about 1 hour, and even more, to complete the die thickness measurement due to the preparation processes. Therefore, the inspection sample size is limited due to the inspection cost and time.

In this paper, a new non-destructive method was proposed to measure the thickness of the internal die in SIM card. The inspection function of SAM has been expanded further.

2. Principle and methodology
2.1. Principle of SAM
The ultrasonic, a pulse signal of high frequency (5MHz - 300MHz), has good directivity and constant speed in the uniform material.

Generally SAM is used in two scanning mode, which is reflection and transmission [4]. The reflective scan mode takes advantage of the reflective signal from the interface and defect to analyze the location and size of failure spot. The ultrasonic which is generated by the transducer will penetrate the couplant into the sample. When the acoustic pulse hits the interface between two materials, parts of the signal get reflected. The degree of reflection depends on the acoustic impedance of the two materials, and the value of acoustic impedance is related to the characteristic of two materials [5]. Analyzing phase and amplitude of the reflected signal can be used to characterize the examined interface.

2.2. Method for thickness measurement
The reflective ultrasonic between the incoming and outgoing interface can be detected by the transducer, as shown in Figure 1. The peak of reflective signal in Figure 2 presents the location of the incoming or outgoing interface. As shown in Figure 2, the transmission time, from the incoming to outgoing interface of the material, is able to be determined exactly. As well known, the value of acoustic velocity is material related. Some typical values are listed in Table.1. Therefore, the thickness of the material can be expressed by equation (1),

\[ T = \frac{V_{\text{material}} \cdot t}{2} \]  

Where T is the thickness of the internal die, \( V_{\text{material}} \) is acoustic velocity of the test material, and t is the transmission time from the incoming to outgoing interface of the material.

| Material            | Acoustic velocity (mm/µs) |
|---------------------|---------------------------|
| Aluminium           | 6.350                     |
| Steel, common       | 5.920                     |
| Steel, stainless    | 5.740                     |
| Brass               | 4.399                     |
| Copper              | 4.720                     |

**Figure 1.** The reflective signal between the incoming and outgoing interface is detected by the transducer.

**Figure 2.** The peak of the reflection presents the location of the incoming or outgoing interface. The transmission time from the incoming to outgoing interface is counted.

**Table 1.** The value of acoustic velocity.
3. Results and discussion

3.1. SAM front-side scanning mode

The front-side scanning mode is employed to the SIM card’s module as shown in Figure 3. The SAM image and waveform are generated by reflection scanning mode of SAM as in Figure 4. The SAM image by the front-side scanning is shown in Figure 5, including internal die.

In this case, the original SAM signal is shown in Figure 6. In the waveform, the peak of the 2nd reflection presents the incoming interface, and the peak of the 3rd reflection stands for the outgoing interface. We can extract the transmission time t from the SAM reflection signal in Figure 6. Then the thickness of the internal die can be obtained based on the equation (1). In order to verify the thickness model, two SIM cards with different die thicknesses are tested. The actual die thicknesses are measured by conventional method also. The die thicknesses are summarized in Table 2. It can be seen that the die thickness measured by SAM method is quite consistent with the actual die thickness.

| Material | Value |
|----------|-------|
| Iron     | 5.930 |
| Silver   | 3.607 |
| Gold     | 3.251 |
| Zinc     | 4.170 |
| Tin      | 2.960 |
| Silicon  | 8.400 |

Figure 3. The top image of SIM card used in measurement.

Figure 4. The schematic diagram of SIM card’s drawing. The different reflective signals are generated from several layers when the ultrasonic pulse penetrate SIM card’s module.

Figure 5. The SAM image of front-side scanning mode.

Figure 6. The reflective waveform and transmission time from the incoming to outgoing interface.
Table 2. Spec and measured internal die thickness of SIM card module

| Type    | Spec Thickness | SAM test Thickness | Real Thickness |
|---------|----------------|--------------------|----------------|
|         |                | Transmission time  | Thickness      |
| Card-A  | 150±10um       | 0.039us            | 163.8um        | 159.2um        |
| Card-B  | 200±10um       | 0.049us            | 205.8um        | 204.3um        |

3.2. SAM backside scanning mode

Unlike the previous SIM card module measurement, due to the existing air among the interfaces in the SIM card, the thickness of the internal die can’t be measured using front-side scanning mode. To inspect the reflective acoustic, the exposed backside die is necessary. To open a window, the center metal contact of SIM card needs to be removed by manual uncovering as presented in Figure 7 and Figure 8. The test method is described following.

The SAM image and waveform are generated by reflection scanning mode of SAM as shown in Figure 9. In the waveform shown in Figure 10, the peak of the 1st reflection presents the incoming interface, and the peak of the 2nd reflection stands for the outgoing interface. From the SAM reflection signal in Figure 9, the internal die thickness can be obtained with same data processing as previously described front-side scanning mode.
The thickness summary is shown in Table 3. The SAM test results are calibrated and verified in a conventional and destructive way. The accurate SEM results are shown in Figure 11 and Figure 12 for two cases.

**Table 3.** SAM measures the thickness of the internal die of SIM card’s module, and compares to spec thickness and real thickness.

| Type  | Spec Thickness | SAM test Thickness | Real Thickness |
|-------|----------------|--------------------|----------------|
|       |                | Transmission time  | Thickness      |                |
| Card-A| 150±10um       | 0.038us            | 159.6um        | 159.2um        |
| Card-B| 200±10um       | 0.048us            | 201.6um        | 204.3um        |

*Figure 11. In the conventional and destructive way, the real thickness of Card-A is shown by SEM.*

*Figure 12. In the conventional and destructive way, the real thickness of Card-B is shown by SEM.*

From the results we can conclude that the SAM backside scanning mode can measure the thickness accurately.

4. **Conclusion**

With the development of SIM card and smart card, it’s necessary to create an innovative method for measuring the thickness of the die in SIM card. A new application is proposed with SAM’s reflective scanning mode from front-side and backside. With non-destructive SAM measurement, we are able to demonstrate its advantage over conventional and destructive method. Preparation and measurement time by SAM can be shortened into a reasonable range. Therefore the cost is lower than the conventional method. The acceptable accuracy of SAM method was verified by physical measurement of SEM. SAM turns out to be an effective way of die thickness measurement in SIM card.

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