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Use of golden samples for the assessment of the quality and reproducibility of scanning acoustic microscopy images of electronics samples

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ABSTRACT

Scanning Acoustic Microscopy (SAM) is a widely used technology for non-destructive failure analysis in electronics samples. The primary information generated by SAM is a grey scale image, which is the basis for the interpretation by the failure analysis engineer. The quality of this primary image depends, amongst others, on the system setup by the operator and on the selected transducer. Therefore, if SAM analyses of a given sample are performed by several engineers using different types of SAM systems, then in general the obtained images differ.

In the present study we introduce specifically manufactured golden samples with single or stacked dice including known defects for assessing the image quality and reproducibility of SAM images. These golden samples represent a robust measurement standard. They are particularly suited for studying and then minimizing differences in SAM image quality obtained by different operators and/or different types of SAM measurement equipment. Ultimately, they will allow to homogenize the SAM image quality on different kinds of typical standard samples on a high level, and thus contribute to reliable failure identification independently of the specific operator or measurement system.

Preferred presentation:

[X] Oral

Preferred track (please, tick one or number 1 to 3 tracks in order of preference: 1 = most suiting, 3 = least suiting)

[2] A - Quality and Reliability Assessment Techniques and Methods for Devices and Systems
[1] C - Progress in Failure Analysis: Defect Detection and Analysis
[3] F - Packaging and Assembly Reliability

1. Introduction

Scanning Acoustic Microscopy (SAM) is a widely used technology for non-destructive failure analysis in electronics samples. SAM is used for a great variety of applications, such as defect analysis on electronic samples [1, 2], thin silicon via (TSV) verification by ultra-high frequency scanning [3], or identification of very small defects by nonlinear acoustic imaging [4, 5].

The capability of SAM to detect different failure modes in a given sample needs to be checked and validated. Therefore, in safety related applications, important effort is done to double check SAM (or other non-destructive testing) results for their relevance, accuracy, and probability of detection of a given defect [6]. However, to our knowledge, the systematic analysis of the detectability of given failure modes in electronic components has not been done yet.

The primary information generated by SAM is a grey scale image, which is the basis for the interpretation by the failure analysis engineer. The quality of this primary image depends, amongst others, on the system setup by the operator and on the selected transducer. Therefore, if SAM analyses of a given sample are performed by several engineers using different types of SAM systems, then in general the obtained images differ.

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In the present study we introduce specifically manufactured single or stacked die golden samples including known defects for assessing the image quality and reproducibility of SAM images. These golden samples represent a robust measurement standard, and are intended to be used in two different ways:

(1) In case reasonably similar SAM systems are used by different operators, the operator's skills and knowledge have the largest influence on the obtained image quality. Under these circumstances, a well-trained operator might be able to visualize an unknown defect in a given sample, whereas the less experienced operator might miss the same defect. In this case, the golden sample will constitute a test piece for correct system setup and use. The less experienced operator might use it before doing acquisitions on unknown samples, in order to validate the measurement system setup by visualizing a known defect in a known sample of similar structure.

(2) If the same sample is analysed with significantly different SAM systems, in particular with transducers of different frequencies or focal lengths, then the obtained images will vary in terms of image resolution, sharpness and contrast. While the image obtained with the "best suited" of these transducers might show a particular defect clearly, the defect signature might be less clear for other transducers. For particularly "poorly suited" transducers the defect might even not be visible at all. In this case, the golden sample will allow to obtain reference images for well-known defects in well-known sample structures for visualizing the influence of the acquisition system (mostly the transducer) on the obtained image quality. Knowing the influence of the measurement system on the obtained image is of particular importance for electronics components manufacturers with several (worldwide) production sites. Often these sites are equipped with different types of SAM systems (different manufacturer, model, manufacturing year, available transducers, …), resulting in different SAM images obtained on different sites on the same sample under test. The use of golden samples will allow to check to what extend differences in image quality are attributable to differences in the used acquisition system and is therefore part of the ISO IEC 17025 standard "General requirements for the competence of testing and calibration laboratories".

2. Experimental setup

2.1. Golden sample design

To be relevant for long term SAM image assessment, golden samples should fulfil the following requirements:

- Being as similar as possible to mass production components,
- Being able to reproduce a large variety of possible defects, with a large freedom in dimensions,
- Being long term stable (no warpage, no shrinking, no humidity soak over a long period).

Given these requirements the first batch of golden samples was produced based on standard TO components (Fig. 1). The die (500 µm thick silicon) is soldered onto the paddle (thickness 1 mm) by a 50 µm thick die-attach layer. The component is then molded into a 5 mm thick resin.

Artificial defects of various dimensions have been created both in the die/die-attach interface and in the die volume, as described below. Additionally, stacked dice featuring a stack of paddle – die attach 1 – die 1 – die attach 2 – die 2 have been produced, with artificial defects in either one or both of the two die/die-attach interfaces.

2.2. Golden samples manufacturing

Manufacturing of the golden samples is done by using standard manufacturing steps of the micro-electronics industry. After having passed the frontside manufacturing steps, the Si die's back side (BS) is coated with a meta BS layer. Patterning by a ps Nd:YAG laser (355 nm) is used for removing some sections of the meta BS layer. Then the die is soldered onto the pad. Areas where the meta BS layer has been removed will not be soldered, and therefore constitute artificial defects at the die/die-attach interface as shown in Fig. 2. Finally, the samples are molded.

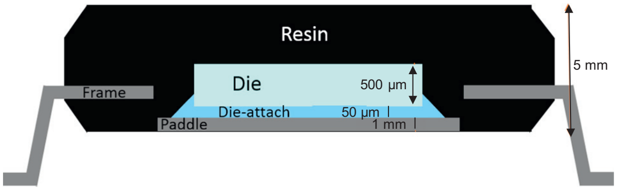

Fig. 1. Sketch of the golden sample structure.

In case of stacked dice, artificial defects are generated similarly in either one of the two or in both die/die-attach interfaces.

For simulating volume defects within the silicon, side drill holes are applied to one of the Si side walls before packaging of the die.

2.3. Scanning acoustic microscopy imaging

Scanning acoustic microscopy images have been obtained on the golden samples by using double channel scanning acoustic microscope (SAM) systems (model IS-202 and IS-350) from Insight kk company (Tokyo, Japan). These systems allow 3-axis (x,y,z)-scanning with a minimum pitch size of down to 0.1 µm on a (x,y) scan area of maximum 350 × 350 mm with a scan speed of up to 1000 mm/s along the x-axis. Ultrasonic transducers with frequencies from 1 to 300 MHz can be used.

All SAM acquisitions are done from the bottom side of the sample, through the exposed paddle, as is the standard measuring setup for characterisation of die attach or silicon volume defects in this type of component, as shown in Fig. 3. All images shown in this study are so-called C-Scan images. With the reference system as shown in Fig. 3, *x* is the so-called scan direction and *y* the so-called step direction. Typically, a pitch of 4 µm has been used in both scan and step direction.

The ultrasound wave is focussed on the die-attach interface in the sample. For doing so, prior to doing C-scan acquisition, the A-scan with the transducer being approximately placed above the centre of the die is visualized by the *Insight-Scan* control software of the SAM system, as shown in Fig. 4. Two peaks can be identified: The front surface echo, which is the first echo on the time scale, and the die/die-attach interface echo, the second echo on the time scale. Then the transducer is

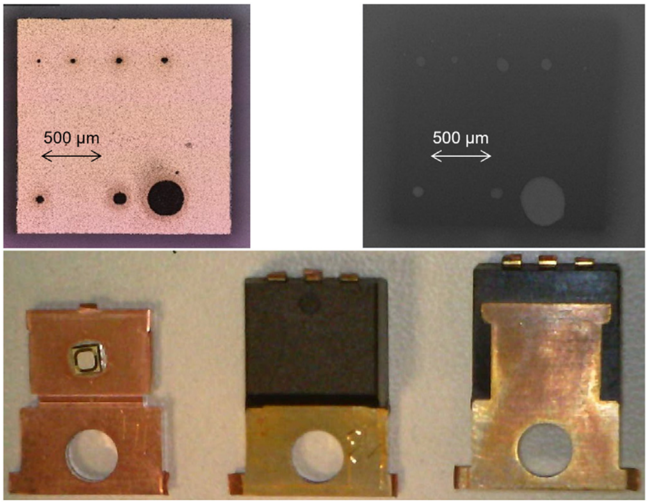

Fig. 2. Optical view of a meta BS layer with several structures removed by laser patterning (top left) and resulting artificial defects in the die/die-attach interface as seen by SAM (top right). The die dimension is 2 × 2 mm. Bottom images: Samples before molding (left) and molded in top and bottom side view (center, right).

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