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How Acoustic Microscopes Became Smart

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The evolution of acoustic microscopes in recent years has enabled them to extend their nondestructive data-collecting and image-making capabilities in several directions. By doing so they have made possible new kinds of analytical and screening techniques and become smarter. The changes in acoustic microscope technology involve both hardware and software.

Typically acoustic microscope systems seek out subsurface features, including anomalies, by pulsing ultrasound into the sample and turning the return echoes into pixels. Defects such as delaminations, voids and cracks send back the highest amplitude echoes and are bright white in the acoustic image; other material interfaces are some shade of gray. Laboratory microscopes image and analyze small numbers of components, while automated systems are used to scan large quantities of components to sort out the bad ones.

Lately, though, acoustic microscopes have quietly been adding capabilities that find and image internal features better, faster, or in ways not possible before. There are four recent game-changers: customized transducers, scanning stacked die, adding transducers, and precise selection of pixel size.

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Customized ultrasonic transducers.

Customized transducers. Generic transducers have fixed frequencies, focal lengths and other fixed parameters. They are fine for many applications, particularly at low frequencies up to about 50MHz. At higher frequencies, the relationship between focal length (the distance from the transducer at which resolution is highest) and the lens's numerical aperture — in other words, the lens's F-number is just as it is in optical systems. A transducer with a longer focal length gives up some resolution. At frequencies of 75MHz and above, the length of the water couplant path begins to affect performance because it absorbs more of the high-frequency ultrasound. A particular application may need, for example, a customized 180MHz transducer that has a relatively short focal length but that can still reach the required depth in the sample.

Changed Focal Length

Or the focal length may be changed in other ways. Typically the focal length of a standard high frequency transducer is 0.5 inches (12.7mm), but a microscope user who needs very high resolution at a high frequency may require a different focal length.

This is why Sonoscan designs and manufactures all of its C-SAM® system transducers from 50MHz up to the industry's high of 400MHz. The company has also designed and manufactured over 2,500 customized transducers that have been optimized for specific applications.

Engineers at Sonoscan have even turned out transducers with a frequency of 10MHz — a very low frequency at which ultrasound penetrates farther into materials — and with very long focal lengths. Such a transducer has been used to look through samples of silicon carbide that are 12 inches (304mm) thick. The image resolution is low, but when it is necessary to find internal features and defects without destroying the sample, they are the tools that work.

Scanning stacked die. This is a particularly difficult task, one that defied solution for years. Recently Sonoscan, in cooperation with the Technical University of Dresden, has developed software that permits successful imaging.

The problem with stacked die is that they are very efficient at creating very large numbers of echoes that cannot easily be sorted out. Suppose a manufacturer has designed an 8-die stack, and wants to be sure there are no gap-type defects in the adhesive between any of the die. His target has 8 die, 8 layers of adhesive, and a substrate.

A pulse of ultrasound travels through the first die and strikes the top of the first adhesive layer. Part of the ultrasound is reflected, and part travels deeper, where it meets the interface between the bottom of the adhesive and the top of the second die. Here part of the ultrasound travels into the second die, but part is reflected upward. And of that part that is reflected upward, a portion is reflected downward by the bottom of die #1. This process is repeated as the pulse travels deeper, and soon the number of echoes arriving at the transducer is very large. How to sort out the right echo for imaging, let us say, the interface at the top of die #4?

The very short distances between the material interfaces in a die stack also mandated customized transducers.

Virtual Die Stack

The new system uses information about the materials and dimensions in the stack to create a virtual die stack that simulates as closely as possible the physical die stack. The virtual die stack is "imaged" by a C-SAM system to narrow down the parameters that will best image the physical stack. These parameters are used on the physical stack and further refined. A few more transitions between the virtual stack and the physical stack give the precise parameters that are needed for the interface at the top of die #4 or any other depth in the physical die stack.

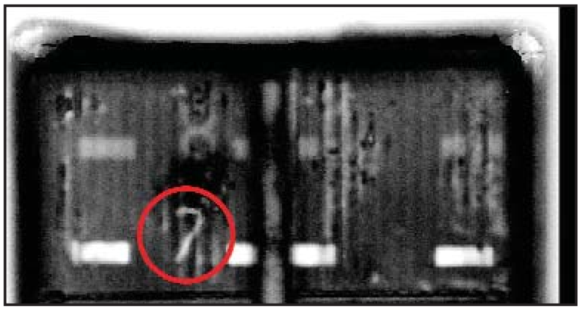
During development of the software, an 8-die stack was created in which an identifying number and three rectangular trenches were etched into each die. The shallow trenches, being gaps, served as intended "defects," as did the number that identified the die. This arrangement let developers know when the return echoes were indeed gated on the right interface.

In the acoustic image from one portion of a physical stack of eight die, the image was made by establishing initial imaging parameters with the virtual die stack, and refining them on the physical stack. The goal in this case was to image the features etched into die #7. Two numbers are visible: the "8" from die #8, and more brightly the "7" of die #7, circled in the image. The trenches etched into the silicon to the left and right of the numeral 7 are especially conspicuous. When used on a production die stack lacking intentional gap and etched numbers, this method will find real defects such as delaminations, and allow the needed process adjustments to be made.

The very short distances between the material interfaces in a die stack also mandated the development of customized transducers that could handle the echoes that are very closely spaced in time.

Adding transducers. Newer automated acoustic microscopes may have multiple scanning stages, with a transducer for each stage. If you are screening trays of components and have two stages, the automated system will image twice as many components as a single-transducer system in the same amount of time. But if the tray contains relatively large items whose area of interest is relatively small — lead frames, for example — the automated system can tell the transducer to scan only the areas of interest (the die and die attach) and skip all other areas. To date, Sonoscan has received reports of speed improvements of as much as 7X using this technique.

A tray that has been scanned is moved out immediately to the drying area, permitting the scanning of the next tray to begin at once. The batch and lot data are available immediately, in the form of spreadsheets or visually in the form of tray maps. Accept/reject criteria can be applied by software, or components can be sorted into other categories.



Acoustic image of die #7 of the eight dies in a test stack. A numeral and rectangular trenches have been etched into each die.

Precise Selection of Pixel Size. In the past, a standard field of view might have been composed of 1000 lines of 1000 pixels each, and yielding an acoustic image having 1 million pixels. If higher resolution were needed, the size of the field of view remained the same, but the pixel count was increased to 2000 x 2000, producing an acoustic image having 4 million pixels. If even higher resolution was required, the count could be further increased to 4000 x 4000, but there were no intermediate steps in resolution.

This restriction was abandoned in order to allow the user to determine the pixel size and the number of pixels. A microscope user needing to find subsurface defects 25 microns wide can benefit by selecting 25 micron pixels, and a field of view of any appropriate size. The acoustic images will show the defects, and time will be saved by not scanning at a lower pixel size. But a user who requires much higher resolution can select pixels sizes down to 1 micron.

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