Acoustic micro imaging systems are based on a scanning ultrasonic transducer that pulses ultrasound into the sample as it moves, and then detects the return echo signals. Ultrasound signals are pulsed and detected several thousand times per second, and the system converts the return echo signals into pixels that make up an acoustic image.

The return echo signals are reflected only by material interfaces inside the part. In multilayer devices, the ultrasonic waves are reflected at the boundary of the various layers, and the acoustic image reveals the exact internal structure.

On the other hand, ultrasound pulsed into a homogeneous material sends back no return echoes. In this case, the purpose of acoustic imaging is to ensure that the part contains no internal cracks or other gap-type defects. The three most frequent internal defects are cracks, delaminations, and voids, all of which contain air or another gas. Ultrasonic transducers make vivid, high-contrast acoustic images of these defects because an internal interface between a solid and a gas is a very powerful reflector of ultrasound.

This article describes how acoustic imaging can reveal internal structures and identify flaws in a complex ceramic chip capacitor and a flip chip device.

Ceramic chip capacitor

Figure 1 is the acoustic image of a ceramic chip capacitor. Such capacitors sometimes harbor internal defects that may cause immediate electrical problems, if they intersect a sufficient number of electrode plates; or cause electrical problems only later, in the field, if the defect grows over time. The bright white circular feature is an internal void (sometimes thought of as a flattened air bubble) inside the capacitor. The acoustic image reveals the x-y location of this defect, and makes possible the subsequent informed sectioning of the part. This sequence of processes was developed at Sonoscan, and has become known as “acoustically guided destructive physical analysis (DPA).”

A more complex example

Depending on the thickness and structure of a given sample, the acoustic image may include only a fairly thin specific depth, or it may encompass nearly the entire sample thickness. For example, the acoustic image of a multi-chip module frequently displays return echoes from nearly the
entire thickness, with only the top and bottom surfaces omitted. For more complex or thicker samples, the acoustic image may include only those return echoes from a specific depth of interest, while return echoes from all other depths are excluded.

The specific-depth approach was used to make the acoustic image in Fig. 3, which demonstrates that internal anomalies can be complex in nature. The sample consists of two side-by-side silicon chips, mounted in a package that includes several layers that are labeled in Fig. 4.

The black and white acoustic image in Fig. 3 displays only those return echo signals from the die-attach depth, from just above the top of the die-attach material to just below the bottom of the die-attach material. The acoustic image thus includes the interface between the die-attach material and the silicon die, and the interface between the die-attach material and the copper plate. The ultrasound was pulsed into the sample from below the silicon chip as it is oriented in Fig. 4.

The large white area in the right-hand chip in Fig. 3 is a large delamination at the interface between the silicon die and the die-attach material. Although quite wide, this delamination is very thin. It is hardly visible in the optical image in Fig. 4 as a dark line between the silicon die and the die-attach material. However, a delamination can be imaged acoustically even if it is as thin as 0.01 micron.

Because it reflects essentially all of the ultrasound, this very large delamination prevents ultrasound from reaching the die-attach material and the interface between the die-attach and the copper plate over the area of the delamination. Numerous other smaller delaminations or voids are visible as white features at the die-attach level in both dies, and it is very likely that the very large delamination over the right-hand die hides additional defects that may exist within the die-attach material or between the die-attach material and the copper plate.

Visible in the optical view of the DPA section in Fig. 4 are two air-filled voids (yellow arrows) in the die-attach material. These voids were probably air bubbles in the fluid die-attach material before it cured.

Fine precision

For some parts, the target area for finding a possible internal defect is very small, and greater precision is required in determining exactly where to cut to section the specimen. A good example is the integrated circuit device known as a flip chip. The face of the silicon chip is connected to a substrate by very tiny solder bumps whose size is measured in microns. Defects in flip chips often take the form of cracks through a solder bump, or between the bump and either the chip or the substrate.

Figure 5 is the acoustic image of a portion of a portion of a flip chip, and shows a classic situation: good solder bumps (the green arrow identifies one) are gray because they have good bonding throughout the solder bump, with no gaps. The bump and surrounding structures do not reflect much ultrasound. Bad solder bumps (red arrow) are bright because they contain a crack or gap that reflects ultrasound strongly.

In this instance, the acoustic image very precisely located the vertical plane through which the flip chip was to be sectioned. After sectioning and polishing, the flip chip was imaged via an SEM.

The results are shown in Fig. 6, which shows that the solder bump itself is intact and contains no cracks. Instead, a delamination shows as a dark line (marked by the arrow) between the passivation layer and the chip itself. This delamination is the gap that causes the solder bump to reflect ultrasound and appear white in the acoustic image. Looking back at Fig. 5, it can be seen that the white area indicating a gap actually extends beyond the area of the bump itself.
of this flip chip, precise acoustically guided DPA paid off because it avoided the waste of resources that would have followed if engineers had been looking for a process flaw that was causing cracks in the solder bump.

Other applications

Making acoustic images to serve as guides for physical sectioning provides several advantages. First, it can greatly improve both the speed and precision of physical sectioning because the locations of suspicious areas are known in advance. Second, acoustic imaging can produce an acoustic cross-sectional image that is analogous to the optical image resulting from physical sectioning, and it permits on-screen measurement of the depths of features within the part. Third, the ability to know precisely where to cut through a part makes it easier and more cost-effective to grind through a critical defect in several small steps, making a sequence of optical images that show the overall structure of the defect.

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