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Post-Reflow Acoustic Micro Imaging

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Before plastic-packaged ICs and other component types are mounted on a board, they are frequently inspected by a variety of methods including acoustic micro imaging tools to ensure quality. Ultrasound is able to reveal structural defects in ICs, flip chips, ceramic chip capacitors and other components whose materials and geometry (typically, with at least one flat surface) make acoustic imaging possible.

Acoustic imaging is usually carried out on products for military, aerospace, medical and high-end consumer applications. Imaging systems such as those found in Sonoscan's C-SAM® series image and analyze internal structural defects so that the offending components can be removed from production.

Pre-screening acoustic imaging, usually in large quantities of a single component type, finds the delaminations and other gap-type defects that form during component fabrication or handling. Internal gaps in components present two dangers: they may expand through thermal cycling and mechanical shock until they break a connection, and they are natural collection points for water and other chemicals that percolate into packages, where they form corrosive cells that may break connections.

Spotting Trouble

Occasionally, defects can occur after acoustic screening. The first hint of trouble may come when an unusually large number of boards fail electrical tests. If optical, visual inspection of the board and of the components shows no obvious cause, the mounted components can be inspected again acoustically. The assumption is that something went wrong between initial acoustic inspection and end-of-line electrical testing. In the past, the culprit was often local overheating during reflow, but today, the defects are more likely to also be caused by improper handling. One possibility is that the auto placement/insertion may have damaged the components. In some failures, the problem is simply that no acoustic inspection was performed before mounting.

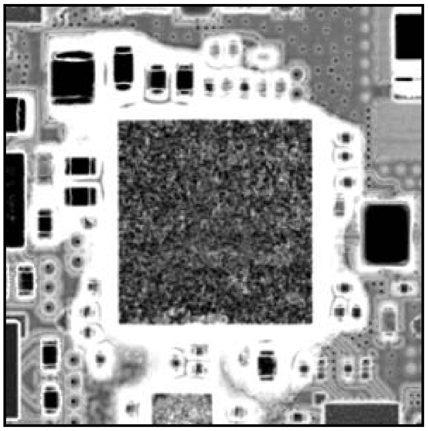

Figure 1: Surface scan C-SAM image of a portion of a populated board.

Scanning a populated board differs substantially from scanning a JEDEC-style tray of loose components. In a tray, all parts are identical and on the same plane. The ultrasound-pulsing transducer can remain at the same height throughout the scan. On a board, however, the components and other structures have varying heights. Gating of the return echoes may also differ. In a tray, the user may gate on (accept for imaging) only those echoes from material interfaces within a depth of interest — the interface between the mold compound and the die face, for example, in a package type that has a history of defects at that interface. But in scanning a populated board, gates are likely to be wider to encompass components of different thicknesses.

Acoustic Imaging

When a pulse of ultrasound leaves the transducer, it does its work in a few millionths of a second. It enters the layer of water that couples the transducer to the sample; at this water-to-solid interface, a portion of the ultrasound is reflected back to the transducer and a portion crosses the interface into the mold compound (to use a plastic-packaged IC as an example).

As the ultrasound passes through the mold compound, it is absorbed to some degree, but there are no large material interfaces. The mold compound also sends back smaller echoes from particles and voids in the material, and these echoes are then used to help characterize the mold material.

As the ultrasonic pulse approaches the die face, one of two things may happen. First, if at a given x/y scanning coordinate there is a delamination or other air-filled gap on top of the die, the ultrasound will never reach the die itself. Instead, it will almost all be reflected by the interface between the mold compound and the air, even if the air-filled gap is only 20 nm thick. Second, if the mold compound is firmly bonded to the top of the die, a portion of the ultrasound will be reflected back to the transducer, while another portion will cross this material interface and travel deeper into the package, sending back echoes from deeper material interfaces.

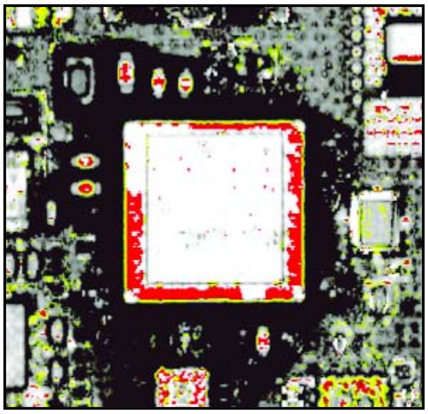

Figure 2: Subsurface C-SAM image of the same area as Figure 1. In the large IC package, delaminations (red) of the mold compound from the die paddle nearly surround the die.

These two events, reflection and transmission, occur at thousands of x/y coordinates per second as the transducer scans a component. Each echo from within the gated depth of interest becomes a pixel in the completed acoustic image. As the transducer scans, it will collect high-amplitude echoes from the mold-compound-to-air interface, and medium-amplitude echoes from mold-compound-to-die interfaces. The first will be bright white in the grayscale acoustic image, while the second will be some shade of gray. By convention, published images often use a color map that displays gap-type defects as red.

Image Analysis

Figures 1 and 2 are C-SAM images of one small region of a populated PCB. This small, thin telecommunications board had over 100 components of various sizes. In Figure 1, only echoes from the first interface encountered by the pulse are used to make the acoustic image. This surface scan shows the surface of each feature, no matter at what depth it lies within the gate selected — the top surface of a large IC package, the top surface of a small capacitor, and the top surface of the PCB. A surface scan such as this is sensitive to the features about 50 µm below the surface. The large white area around the IC package reveals that the board surface in this region is significantly brighter than the other areas of the circuit board, a phenomenon that is typical of a multilayer board whose top layer may be delaminated, thus returning more of the ultrasound than if it were bonded.

Figure 2 is a C-SAM image of the echoes from material interfaces below the top surface of the highest component, but within the gated depth. The large die is at center. The area of the die paddle surrounding the die shows many red regions, indicating that the mold compound is delaminated from the substrate. The risk is that the delaminations will expand under the die and block heat dissipated. In addition, the board area surrounding the IC is black, which confirms that the top layer of the board is delaminated.

Also, surrounding this component are several small components imaged in red that may or may not be defective as the ultrasound needs to be focused at their depth to be sure. When the transducer is scanning a board, the single flat top surface that most components have is lacking. Instead, the transducer travels in its single plane and receives return echo signals from whatever the pulse strikes — the flat top of an IC package, the curved side of a capacitor, or the board texture.

Many of these return echo signals will not correlate well with the expectation, for example, that a red or yellow feature is definitely a gap-type defect. Red may simply be the software's interpretation of echoes from the curved side of an out-of-focus small component. In some cases, however, a small component may deserve a more detailed analysis.

The multilayer ceramic chip capacitor shown in Figure 3 was first identified as questionable in a whole-board scan. Ceramic chip capacitors present a special problem because they may contain vertical cracks that will cause failure by creating pathways between electrodes. Vertical cracks reflect very little ultrasound, so a different method was used for a high-resolution image of this capacitor — gating was limited to the back surface of the capacitor. No reflected echoes are collected from the body of the capacitor. Instead, the pulses are reflected from the back surface and display any cracks they encounter on the way back to the transducer. The cracks are imaged as highly visible acoustic shadows. The red arrows in Figure 3 show two cracks imaged in this way. There is a possible small crack in the lower left of the upper capacitor.

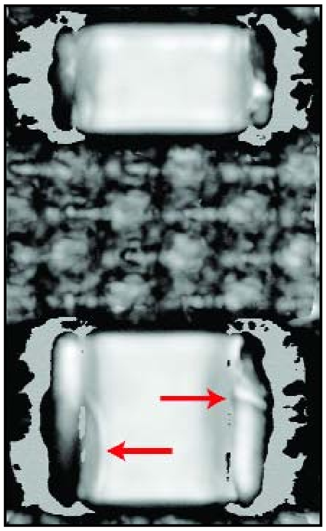

Figure 3: Arrows pinpoint cracks in mounted multilayer ceramic chip capacitors.

When problem solving requires additional diagnostic information, Sonoscan has developed numerous imaging modules that can be used without removing the components from the board. The Quantitative B-scan Analysis Mode (Q-BAM™) technique can be used to nondestructively cross-section a component through any vertical plane.

The Time Domain™ mode can be used to zero in on fine details of structural defects. The PolyGate™ mode can be used to image a component in thin nondestructive slices. Without removing the components from the board, a great deal can be learned about structural defects and their causes.

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