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Size Up Component Defects Nondestructively

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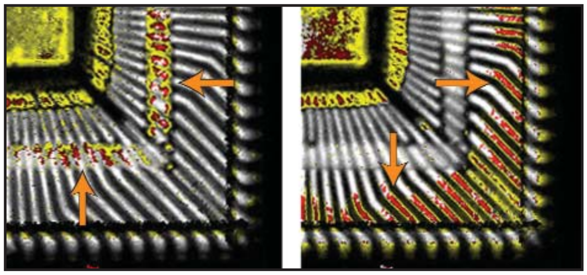
Acoustic microscopic imaging can locate internal defects in packaged integrated circuits (ICs) and other components without physically damaging the package.

The microscope's transducer sends a pulse of ultrasound into the sample. The pulse is reflected, partly or entirely, by material interfaces. It is just this action at the interface of two materials that enables Sonoscan's C-SAM® systems to detect package and device defects without damaging the device being examined.

It is the differences in material compositions, and how ultrasound is reflected by the different materials and spaces between them, that helps find unwanted spaces in electronic components. If an ultrasound pulse strikes the interface between mold compound and silicon, part of the ultrasound is reflected as an echo signal that will be picked up by the ultrasound transducer, while the remainder of the ultrasound will cross the interface and travel deeper. The echo from the mold compound-silicon interface will be of medium amplitude, and will look more or less gray in a monochrome acoustic image. But if there is a gap (such as from a delamination or void) between the mold compound and the silicon, the interface is between a solid and a gas such as air. Nearly 100 percent of the ultrasound will be reflected at a gap, and the echo will have the highest possible amplitude. In an acoustic image, it looks bright white. None of the ultrasound penetrates through the gap to go deeper into the sample because of the tremendous mismatch in the material properties of mold compound and air.


The acoustic image of gate 24 in this plastic IC package revealed delaminations (left) in red while gate 25, 92 microns deeper (right), showed delaminations on the lead fingers.

Nearly all internal structural anomalies in components are gaps of some type, including delaminations, nonbonds, voids, and cracks. The scanning transducer launches thousands of pulses per second from thousands of x-y locations and uses the return echo signals to make an acoustic image of the component. This process, called reflection-mode acoustic microscopy, is the most common of several imaging modes. But other imaging approaches are sometimes better at finding internal defects in components.

PolyGate™ Imaging Mode

The operator of an acoustic microscope such as a Sonoscan C-SAM system performing reflection-mode imaging usually specifies a time zone, or gate, within which arriving echoes are used for imaging. Return echo signals from interfaces within the gate are used for imaging; those from outside the gate are ignored.

The gate for a relatively thin plastic IC package may exclude the top and bottom surfaces of the packages but include echoes from any and all interfaces between the two surfaces. The result is that the acoustic image will reveal all of the internal features and defects, but not their relative depth. Knowledge of the component structure can provide information about the depth, but is not always a trustworthy approach.

PolyGate, as the name suggests, enables an acoustic microscope operator to create multiple gates to image a sample. Each gate will produce its own acoustic image. For example, a plastic IC package can be thought of as sliced horizontally into multiple layers, with an acoustic image for each layer. The individual images help tell the exact depth of a defect or anomaly. The maximum number of gates that can be set in PolyGate is 200, which may be excessive. Usually, 10, 20, or at most 50 gates are more than adequate to image a plastic IC package.

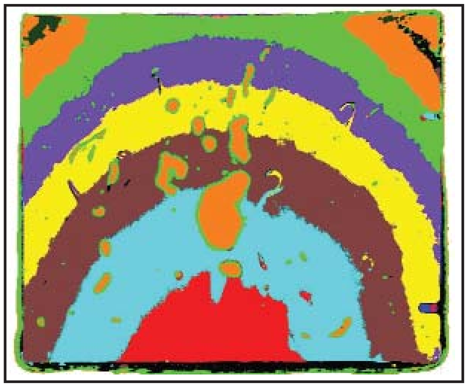
In imaging performed on a plastic IC package, a gate total of 50 gates was set on the microscope, each 92 microns in vertical extent. Imaging was performed on the package gates 24 and 25; most of the gates above 24 showed mold compound only, or mold compound and parts of the wire loops. The examination of gate 24 revealed delaminations chiefly along the KAPTON® lead frame tape. The images from the microscope indicate gaps typically by means of a red color. When the lead fingers were studied, they appeared to have no defects, although the die face appeared somewhat suspicious.

According to the scale of this microscopy, gate 25 is 92 microns below gate 24 and imaging of gate 25 revealed red delaminations between the mold compound and the top surfaces of the lead fingers. The delaminations along the tape have disappeared because their echoes begin above this gate. The die face, however, displays at this depth an area of red that suggests that it is delaminated from the mold compound.

Mapping Solder Thickness

Assemblers of insulated-gate-bipolar-transistor (IGBT) modules such as those used to control power in electric vehicles often must determine the thickness of the solder that bonds the metal heat sink on the bottom of the module to the substrate (often ceramic plates) above the module. The plates can become tilted during assembly, and the thickness of the solder may vary significantly across a plate as a result. IGBT modules are power devices that must dissipate a great deal of heat. Variations in the thickness of the solder can degrade the heat dissipation capability and cause the die to overheat. Voids in the solder, typically formed as bubbles when the solder was in fluid form, also disrupt heat flow and can cause overheating.

Module assemblers are interested in knowing the thickness of the solder at each point across the plate, by a nondestructive means. Using the acoustic microscope, the IGBT module was imaged through the heat sink at the bottom, with the transducer scanning the external surface of the heat sink and with a mechanism to keep water away from the other parts of the IGBT module. The transducer pulses ultrasound energy into the heat sink as it scans it, but the amplitude of the returning echo signals is not analyzed; using Sonoscan's Time Difference tool, signal amplitude is ignored in this case. With this tool, a gate is set with its upper limit just above the solder-heat sink interface, and with lower limit just below the solder-plate interface. The gate thus encompasses the entire thickness of the solder layer.



In this mode, color equals distance, and thus tells the thickness of the solder attaching the heat sink to this IGBT module. The orange features near the center are voids: the color indicates that the top of the void - the interface between the air in the void and the solder above the void — is from 45 to 90 microns above the plate.

At each x-y location, the scanning transducer receives two return echo signals, one from the heat sink-to-solder interface and one from the solder-to-plate interface. The difference between the arrival times of the two echoes is measured and converted into the thickness of the solder at that x-y location. Scanning the entire area of the ceramic plate yields a map of solder thickness. Ideally, the thickness should be nearly the same at all locations.

Measuring Solder Thickness

The acoustic microscope was used to produce a Time Difference image showing the thickness of solder over one plate in an IGBT module having nine plates. Arbitrary nonadjacent colors have been assigned to a range of thicknesses to simplify accept/reject decision-making for these modules. Each color represents a vertical thickness range of 45 microns. Orange regions show solder thickness ranging from 45 to 90 microns, green regions represent thickness from 90 to 135 microns, and so on. The thickest solder, in red, is from 360 to 405 microns thick. Ideally, the color range would be narrow. An acceptable plate might have thicknesses ranging across three of the colors in the middle of the sequence, such as magenta to brown. But a plate where solder thickness dips near zero at two corners is clearly a reject. The curved color bands can also indicate such conditions as when the device's ceramic plate is somewhat curled.

Because the time difference between the two pulses arriving at each x-y location is being measured, this tool also images voids in the solder, but by depth rather than by their signal amplitude. A void will reflect all of the ultrasound, and no ultrasound energy will reach the ceramic plate. The acoustic microscope can locate variously shaped voids using the color scheme, where color can indicate the top of a void, such as the interface between the air in the void and the solder above the void, and the positioning of the voids.

Other new imaging tools from Sonoscan include the Sonosimulator™ which makes it possible to accurately image specific interfaces in stacked die assemblies, Frequency Domain Imaging™, which decomposes return signals into frequencies to solve truly subtle diagnostic problems, and many others.

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