Acoustic Micro Imaging Finds Hidden Defects

By Tom Adams

Contract board assemblers must constantly control costs in order to show a profit. At the same time, the quality and reliability of finished boards are a growing concern; no one wants to be part of a horror story involving a notorious field failure.

As a final check on the reliability of finished boards, contract manufacturers are beginning to turn to acoustic micro imaging. Originally used almost exclusively to image and diagnose single unmounted components in failure analysis laboratories, acoustic micro imaging has recently evolved new automated tools capable of inspecting the internal features of board-mounted components.

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Acoustic micro imaging uses very high frequency ultrasound in a pulse-echo mode. Ultrasound pulsed into a mounted plastic-encapsulated IC is reflected by internal interfaces, such as the interface between the molding compound and the die face, or the interface between the die attach and the molding compound. Well-bonded interfaces produce an acoustic image having predictable intensity (the strength of the returned echo) and polarity (whether the acoustic impedance increased or decreased at the interface). But internal defects which will cause field failures — delaminations, voids, cracks, and the like — are gaps which cause far stronger reflections and are imaged in much higher contrast. In an acoustic image, gaps (think “defects”) are usually imaged in red. Acoustic micro imaging has not been adapted to image the attachment of external leads to the board. But it images all sorts of internal package features, including the solder bumps inside flip chips, and even defects such as cracks inside individual solder bumps.

Internal Packaging Defects

Internal packaging defects are very significant because they can cause field failures even if a board has passed final electrical testing successfully. One recent example: a component type that was experiencing scattered early intermittent field failures in a variety of products. Acoustic micro imaging quickly showed that there was a delamination between the molding compound and the lead frame near the edge of the package. Further examination showed that the delamination was causing moisture and contaminants to collect, and that dendrite metallization was growing between adjacent pins, causing a short. A close look at production processes showed that strips of this component tended to stick when being removed from the mold machine, and that the application of pressure by the ejector pin was causing the delamination. Acoustic imaging of the finished board would have found the delaminations before field failures had a chance to occur.

Much of the interest in end-of-line acoustic inspection is being directed toward the new Model D-24 from Sonoscan. Although both components and boards tend to grow smaller over time, there are still plenty of big boards, and this automated system scans an area up to 24 x 24 inches, which may represent a single large board such as a core router, or a non-singulated group of smaller boards.

The D-24 first learns the x, y, and z coordinates of each component. The transducer then goes to each component and scans it individually. If there are areas of components having the same elevation and the same internal features — a group of D-RAMs, for example — greater speed is achieved by scanning the group as though it were a single large component. Spatial resolution is maintained by advanced scanning techniques. The completed acoustic image of a whole board may be much too large to display in full resolution on a computer screen; instead, the operator zooms in on selected areas of interest.

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But acoustic imaging of all of the components on a board is usually too slow to keep up with the production beat. Furthermore, board assemblers usually have a good idea which components are likely to have internal defects. So the D-24 is more likely to be used selectively, and taught to image only those components judged most likely to cause a field failure. This speeds up the inspection process dramatically, and still generates high board reliability. But if the board itself has very high intrinsic value, and requires true high reliability, it may be a good cost-saving move to image the whole board.

The D-24, like Sonoscan's other reflection-mode C-SAM systems, is versatile. In addition to populated boards, it can image trays of components. One of the most frequent uses of C-SAM systems worldwide is the imaging of incoming components in order to remove those with internal defects before board mounting. This method has the advantage of spotting the occasional appearance of lots having a high percentage of internal defects — caused, for example, by the ejector pin problem mentioned earlier, and not known to the vendor. An even simpler method involves using a C-SAM merely to measure numerically the acoustic impedance (density times acoustic velocity) of the molding compound. This measurement takes only a few seconds, but tells the assembler whether the vendor has started to use a new molding compound. Many internal defects have been found early by this method, and by the knowledge that early runs with a new molding compound are often rich in internal defects.

Field failure-causing defects include die face delamination, delaminations along lead fingers, cracked die, voids and other gaps.

The types of internal packaging defects that can cause field failures form a nearly endless list. Die face delaminations are very significant because they often expand during normal thermal cycling and break wire bonds. Even if a die face delamination does not expand — and some never do — it will become a collection site for the moisture and contaminants that are absorbed by the plastic encapsulant. Even tiny amounts of moisture and ionic contaminants have a corrosive effect; on the die face, corrosion can attach the chip circuitry. Delaminations along lead fingers can lead to conduction paths between adjacent leads. Voids and other gaps in die attach material can compromise the heat sink function, and can grow via thermal cycling to cause loss of adhesion.

One type of defect observed recently is the cracking of the thinned die which are often used in small BGA packages. The basic problem is that the die are so thin that they cannot withstand even normal handling. The problem comes to light when the packages are tested electrically and fail. But it is very difficult to determine the cause of the electrical failure; the most reasonable guess is that one or more of the interconnects have broken. Electrical tests can't tell whether an open is being caused by a broken interconnect such as a wire, or by breaks in the circuitry on the face of the die. When this problem first appeared, packaging houses were very reluctant to perform the tedious and expensive physical cross-sectioning of these packages, in part because cutting and grinding by themselves can fracture the die. Acoustic micro imaging, though, solved the problem because it can image the die cracks nondestructively right through the molding compound, and can help to confirm that the problem is a cracked die rather than broken interconnects.

Cracked die are a somewhat unusual example of a defect which could be observed electrically, and which needed an immediate diagnosis. Most internal defects are not detected electrically, and are detected only when, through a combination of thermal cycling and the action of humidity and contaminants, they cause a field failure.

As long-term board reliability becomes more and more a part of running a contract manufacturing operation, it will become even more valuable to perform a final acoustic inspection to ensure that the components that have been mounted will actually perform without failure over the long term.

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