Production Test

Using acoustic micro imaging to inspect MCMs

Various types of electrical testing can detect chip-level defects in MCMs, but packaging and assembly defects are generally hidden and can often be catastrophic. Acoustic micro imaging (AMI) provides a viable solution.

By Tom Adams

Multi-chip modules (MCMs) offer the significant advantages of shorter interconnect distances and a smaller footprint. For these reasons, many manufacturers are switching from board assemblies to MCMs. As each component is added to an MCM during manufacture, the value of the unit increases. It is important, therefore, to find defects and investigate process control problems that may have caused the defect as early in the assembly of the MCM as possible.

The individual components in MCMs sometimes have internal defects. There are two types of internal defects:

- chip-level defects such as saturation and gate dielectrics, which can be found by various types of electrical testing; and
- packaging and assembly defects, which electrical testing does not frequently reveal, unless they are catastrophic.

The second group of MCMs defects, often termed "hidden defects" because they are hard to find, is discussed here.

Hidden defects in MCMs (and in individual components) are a serious reliability concern because they tend to grow with repeated thermal cycling. Also, visual inspection, electrical testing, and even x-rays, fail to find most hidden defects. These defects include internal disbonds, delaminations, cracks, and voids. For example, voids in the die-attach material may cause no change at all in initial electrical testing. In use, however, the voids are likely to grow. Eventually they may reduce the heat-sink capabilities of the die paddle until the chip overheats and fails. Or the voids may grow in such a way that they actually cause internal movement, which rips wire bonds loose. Hidden defects have many other consequences, all of which tend to be lethal to the device.

AMI can usually image and analyze internal defects in MCMs and in individual components. AMI uses non-destructive ultrasound at very high frequencies (ranging from 5 to 200 MHz or more). At these frequencies, ultrasound has very useful properties. As it travels through a device, some of the ultrasound is reflected back from internal interfaces, and some of the ultrasound travels through the bulk of a device.

There are therefore two main types of AMI instruments. Through-transmission instruments (called SLAM by Sonoscan, Inc.) create an acoustic shadowgraph from the exiting ultrasound. Reflection-mode instruments (C-SAM) create images from the reflected ultrasound. SLAM is useful for the rapid screening of parts to detect internal defects at any

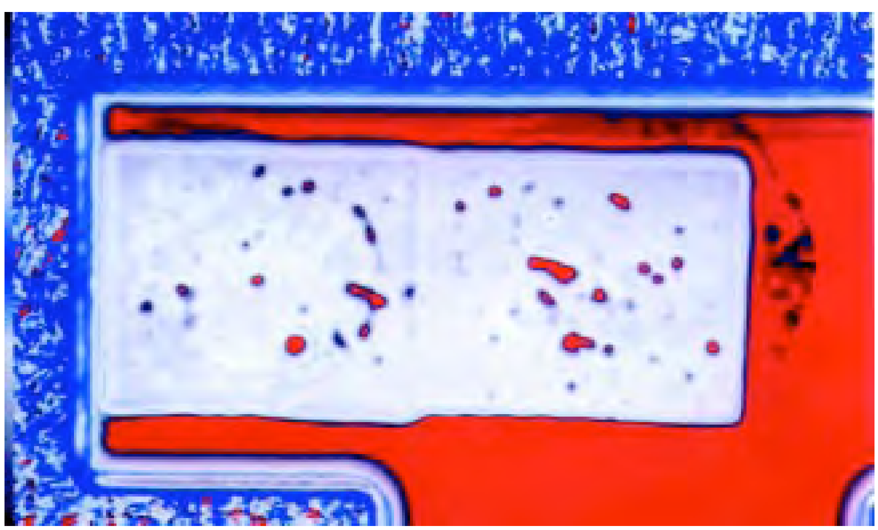

Figure 1: Side-by-side die acoustically imaged at 100 MHz from bottom side, through metallization pad and substrate. Red areas within the die are voids in the die-attach material.

level within the part. C-SAM, which requires access to only one side of the part, receives return echoes from the interior of the part.

These echoes are separated in time. You can gate echoes electronically to ignore all echoes except those from a defined level within the part. You can image a single interface (mold compound to die face, for example) or a single-layer structure (the die-attach material, for instance). To include multiple interfaces and structures, you can gate the echoes more broadly. Research and development at Sonoscan, where both SLAM and C-SAM were developed, has resulted in numerous useful ways for manipulating the return echoes, including 3D acoustic images and non-destructive cross-sectional images.

Nearly all production materials, including silicon, epoxy, die-attach materials, and metal lead frames, transmit ultrasound well and make good images. Disbonds, delaminations, cracks, and voids all constitute "air gaps." Air gaps do not transmit ultrasound at all; instead, they reflect the ultrasound back to the source. If a part contains one of these defects, you will see a black area in a through-transmission image. The area is black because no ultrasound has emerged from the part in this area. Using reflection-mode instrument, you will see the defect as a brightly colored area because the defect has reflected all of the ultrasound back to the source.

As an MCM moves through production, there are at least six stages where you can use AMI to image and analyze internal defects before further value is added to the MCM. These stages are

- the MCM substrate before components are mounted;
- the die-attach of components mounted in the MCM;
- the solder bumps and underfill beneath flip chips on the MCM;
- wedge-type (but not ball-type) wire bonds in the MCM;
- the seal of the lid that covers and protects MCMs on ceramic substrates; and
- passive components such as ceramic chip capacitors.

MCM substrates

MCM substrates can be made of several materials, including alumina, beryllia, and PCB materials. You can easily image alumina and beryllia substrates. Some types of PCB substrates are opaque to ultrasound and may be difficult to image acoustically.

It is useful to image alumina and beryllia substrates before components are put in place. The physical integrity of the substrate can be evaluated; cracks in the substrate show up strongly in acoustic images. Punched or drilled holes may have adjacent microcracks that will grow over time. Acoustic imaging will easily distinguish these defects. Some substrates also have vital subsurface traces, which can also be imaged.

Die-attach layer

The die-attach layer of components mounted onto an MCM may contain both delaminations and voids. Delaminations can occur at either the top or bottom surface of the die-attach material, in areas where the material is not well bonded to either the die itself or to the die paddle. Small delaminations may be unimportant, but larger delaminations can easily grow and impede heat dissipation from the circuit. Voids within the die-attach material are caused by bubbles within the die-attach material in its fluid form. Like delaminations, voids can grow over time.

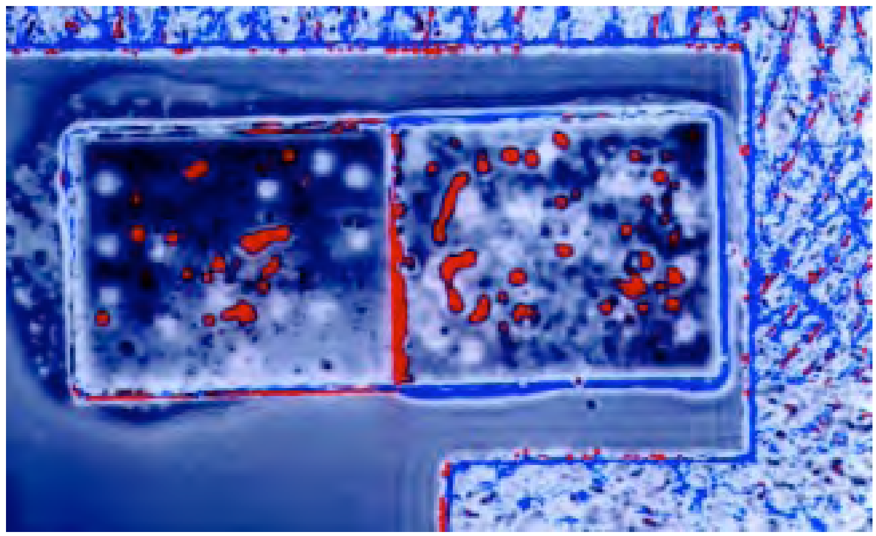

Figure 2: The same MCM, but imaged from the top side. The outline of each void is somewhat different because electronic gating is at a higher level, but the void pattern is the same as in figure 1.

Reflection-mode C-SAM imaging, which requires access to only one surface of the sample, is frequently used to image the die-attach. If the MCM has an acoustically transmissive substrate such as alumina or beryllia, you can image it from either the top or bottom side.

Figure 1 is the C-SAM image of two die mounted side-by-side on a metallization pad within an MCM having a ceramic substrate. Because this substrate is acoustically transparent, this image was made from the bottom side, through the substrate and the metallization pad. Electronic gating was on the interface between the die-attach material and the metallization pad. The acoustic frequency used was 100 MHz.

In figure 1, the metallization pad appears red, while the die-attach material appears gray-white. Within the die-attach material are numerous red features. These are voids.

In figure 2, the same portion of the same MCM has been imaged at the same frequency—but this time from the top side, through the die. Electronic gating in this image is at the top interface of the die-attach material, where it touches the bottom surface of the die.

In this image the metallization pad is gray (colors in acoustic images are selected arbitrarily from several color maps). The die-attach region is mottled dark gray, and the voids within the die-attach material are red. This image is nearly a mirror image of figure 1—the same voids are present in the same positions. The size of the individual voids has changed, however, because gating in figure 1 was on the interface attaching substrate to die, while gating in figure 2 was on the interface attaching die to die. The larger size of the voids in figure 2 suggests that the voids may have migrated upward while the die-attach material was in a fluid state.

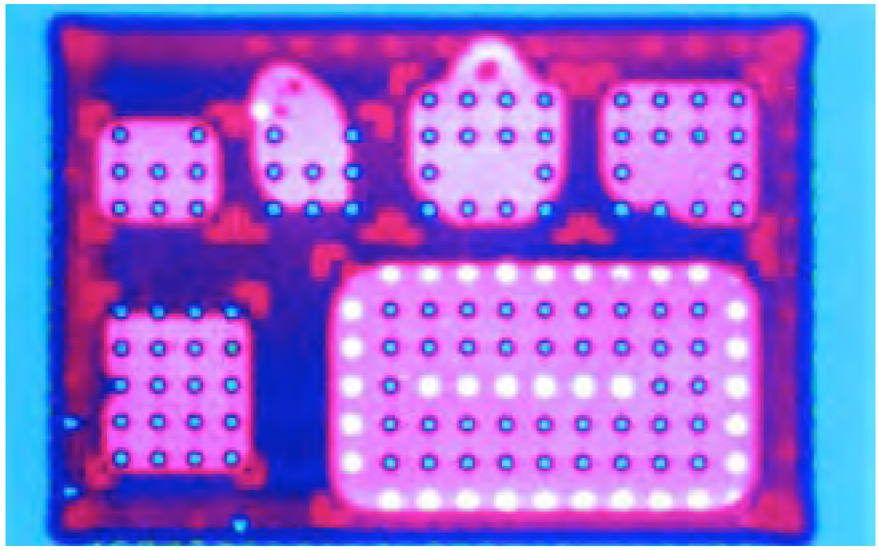

Figure 3: Multi-component MCM imaged from bottom side through substrate at 100 MHz. Electronic gating is on the bond of the solder bumps to the substrate. Bumps appearing blue are well bonded; white bumps are disbonded.

Attachment of flip chips in MCMs

In MCMs that use flip-chip configurations, the integrity of the solder bumps is important. You can use acoustic inspection to tell whether individual bumps are missing, and whether adjacent bumps have bridged. When an individual bump is present, it can be inspected for three parameters:

- the bond of the bump to the die face above it.
- defects (voids or cracks) within the bump itself.
- the bond of the bump to the substrate beneath it.

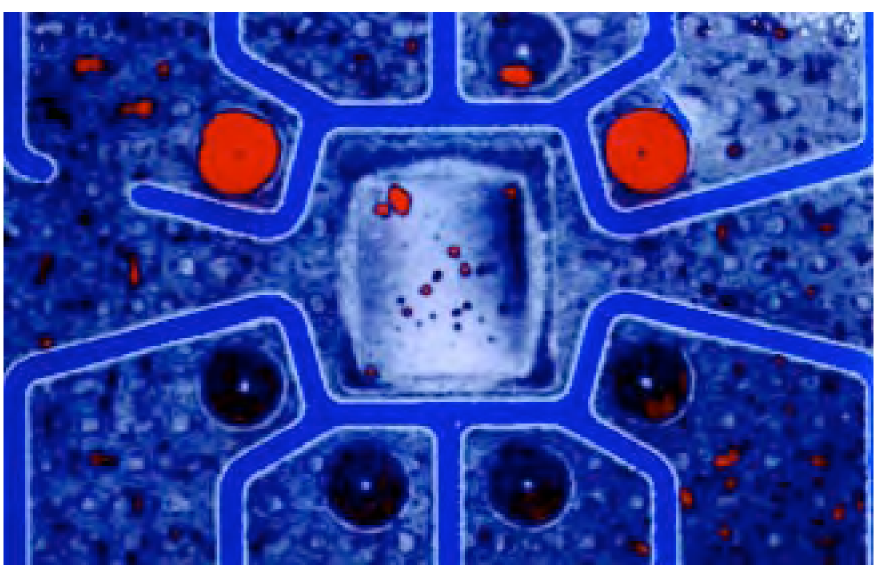

Figure 4: "Smart Card" imaged from bottom side through metallization at 100 MHz. Red areas in die-attach at center are voids. In addition, two circular bonds are disbonded (red).

Figure 3 shows a multi-component MCM imaged from the bottom side through its ceramic substrate at a frequency of 100 MHz with C-SAM. The image was electronically gated at the interface between the substrate and the solder bumps, and shows the integrity of the bond at this level.

Good bonds are blue in this image. Most of these bonds are also of uniform size. The size of the bond image is important, since bonds that appear smaller than normal in an acoustic image are generally partial bonds, and are likely to fail. In the large component at lower right, however, all of the peripheral bumps are white, which shows that no bond is present. A row of bumps running across the center of this component is also disbonded. The pattern of disbonds in this component suggests that a single process step is beyond the limits of control parameters.

Wedge-type wire bonds

Acoustic imaging of wire bonds is suitable for wedge-type bonds and for TAB bonds, both of which have laminar structures. Ball bonds tend to have a hemispherical surface that reflects ultrasound in all directions, making them difficult to image. The important feature is the bond of the wire to the bond pad.

Figure 4 shows part of a "Smart Card" imaged by C-SAM from the bottom surface at 100 MHz. The gray areas of the image are a metallization layer, similar to a lead frame. The die-attach material (and beneath it, the die) are at the center of the image. Several red voids are present in the die-attach.

Surrounding the die are seven circular bond pads to which the wires are bonded. Electronic gating is at the bond layer of the pads. Two bond pads (red) appear to be completely disbonded. You can see the wire itself at the center of each bond pad.

Lid seals

The acoustic inspection of the lids that cover MCMs is concerned with the seal of the lid to the substrate beneath it. This seal can be imaged from the bottom side (if the substrate is acoustically transparent) or from the top side. Breaks in the seal are another type of "air gap" defect and are easily imaged.

Passive components

MCMs of various types sometimes contain ceramic chip capacitors. The body of these capacitors consists of alternating layers of ceramic and dielectric material. At each end of the capacitor is a metal termination.

The chief defects in ceramic chip capacitors are delaminations between the layers, voids, and internal cracks. All of these are "air gap" defects and are easy to spot acoustically. Delaminations sometimes exist at more than one level within a capacitor. If electronic gating is on the entire thickness of the capacitor, these delaminations will appear to overlap.

Acknowledgement:
Images provided courtesy of J. E. Semmens, Advanced Applications Laboratory, Sonoscan, Inc. AEE

For more information you may fax
+1-708-7667088