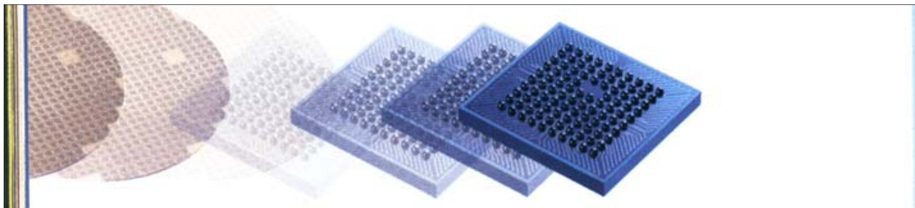

Acoustic Micro

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At a Glance

Acoustic imaging can locate internal defects, such as delaminations, cracks and voids.

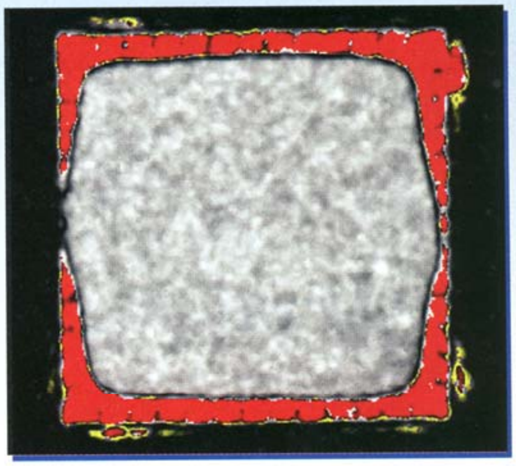
From their status as novelties only a few years ago, stacked-die configurations have become more robust and are now routinely used in many applications. They represent a very useful form of vertical miniaturization, but the thinness of the die and the stack structure still carries a degree of risk.

The geometric complexity of stacked-die configurations creates the opportunity for internal structural anomalies that may impact long-term reliability. While some anomalies may result in immediate electrical failure, other anomalies may have no immediate effect on performance, but may change over time and cause a failure at a later date. In this latter category are delaminations, cracks and voids.

With some limitations, these internal anomalies can be imaged and analyzed by acoustic micro imaging (AMI), although they are out of the reach of most other inspection methods. The multilayer structure of stacked die is generally somewhat similar to the structure of standard AMI targets such as plastic IC packages and multilayer ceramic chip capacitors. An important aspect of AMI is the ability to guide imaging to a specified depth within the stacked die.

Acoustic imaging of stacked die differs in two respects from the imaging of IC packages: The number of internal interfaces is greater, and it may be more difficult to receive adequately strong signals from the deeper layers. The transducer used in AMI alternates several thousand times a second between pulsing ultrasound and receiving the return echoes from various depths. Most imaging modes use a time window (electronic gate) in order to receive only those echoes from the depth of interest.

The pulsed ultrasound is reflected only from internal interfaces, and not from homogeneous bulk materials such as silicon or the molding compound. At each interface, a portion of the ultrasound is reflected, while the remainder travels deeper into the sample and is again partly reflected by the next interface. A stacked-die configuration may contain a large number of interfaces. Even though the reflection for a single interface may subtract only a variable fraction of the energy from the pulse, little or no signal may be returned from the deepest interfaces. Reflection from gap-type anomalies (delaminations, voids or cracks) is nearly 100%. Gap-type anomalies are therefore imaged in high contrast; on the other hand, features directly beneath such an anomaly are generally not imaged because no pulsed ultrasound reaches them.



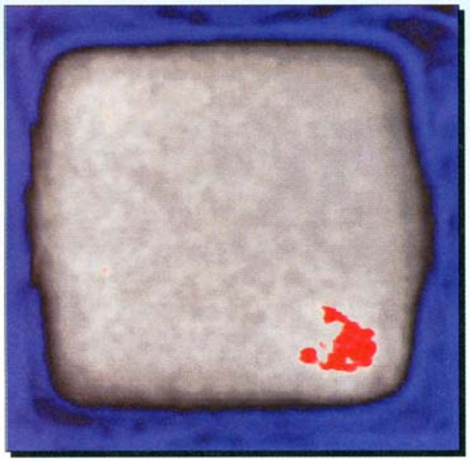
Switching from the reflection mode to the transmission mode gives at least a partial work-around for the imaging limitations caused by the numerous internal interfaces in stacked-die configurations. In the transmission mode, ultrasound is pulsed entirely through the stacked-die configuration, and the emerging signals — which may be significantly stronger than reflected signals — are picked up by a sensor below the sample. Since gap-type defects at any depth still reflect 100% of the ultrasound, the resulting transmission image shows areas of defects as dark regions where no signal arrived at the sensor. The absence or presence of defects, along with their X-Y extent, can thus be determined.

A few of the types of internal anomalies that may be found in stacked-die configurations are described and illustrated in this article. Figures 1 and 2 were made from a stack of two die encapsulated in a plastic molding compound. Figure 1 was gated at the top-die top surface at the interface with the molding compound above the die.

The red area around the periphery of the die surface is a die-face delamination, where the molding compound is not bonded to the die. The color red indicates a very high-amplitude returned echo signal from this gap-type defect. Research at Sonoscan has recently shown that reflection from gaps is nearly 100%, even if the thickness of the gap is as little as 100-1000 Å.

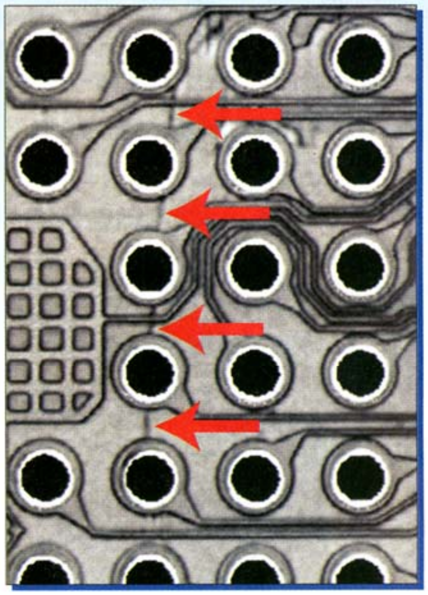
Imaging of Stacked Die

1. A two-die plastic package, imaged from the top side at the interface between the molding compound and the top of the first die (left). The red area marks the delamination of the molding compound, critical because the delaminated area encompasses the wire bonds.



2. The same two-die stack (left), imaged at the die attach level below the first die — note that the delamination above this level crops the imaging of the die attach. The small red area is a gap-type defect.

3. A different two-die package (right), imaged acoustically from the bottom side. The arrows mark a crack in the lower die.

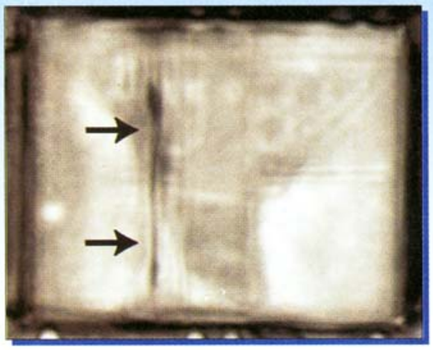


This delamination includes the wire bonds on the surface of the chip, and poses two long-term threats to reliability. First, relative motion of the chip and the molding compound (caused, for example, by thermal cycling) may break wire bonds. Second, the delamination is likely to become a collection point for moisture and contaminants that can corrode the wire bonds.

Figure 2 is the acoustic image of the die attach beneath this die. In this acoustic image, the die attach has a somewhat irregular shape because of the blocking of ultrasound by the delamination at the die surface above this depth, as shown in Figure 1. Most of the visible die attach region appears gray and homogeneous — that is, without defects. A small region at lower right is red, indicating some form of gap-type defect.

Figure 3 is the acoustic image of the bottom side of a different two-die stack, also encapsulated as a plastic package. This package was imaged before surface mounting, and could therefore be accessed from either the top or bottom surface. Figure 3 was made from the bottom side and shows, in addition to the traces on the interposer, a crack (arrows) in the lower of the two die.

4. The same package as in Figure 3, imaged acoustically from the top surface. Pulsed through four intervening interfaces, C-SAM ultrasound was able to image the die crack shown here from the top of the package.



Next, the package was flipped over and imaged from the top side. Imaging at various depths showed that there were no defects relating to the top die. Gating was then set at below the top of the second die, in the bulk of the silicon, in order to image the same die crack from the top surface of the package. In order to image the crack, ultrasound had to be pulsed through four interfaces above the crack: the top surface of the package, the interface between the overlying molding compound and the top of the first die, the interface between the bottom of the first die and the adhesive layer, and the interface between the adhesive layer and the top of the second die. Figure 4 shows the result of this deep image. The crack is indicated by the arrows.

Acoustic imaging of stacked-die configurations is similar to the imaging of plastic IC packages, in that there are multiple layers and multiple interfaces where features of interest may occur. The imaging of stacked die, though, may involve a greater number of critical interfaces. How well a given stacked-die configuration will respond to acoustic imaging depends in part on the materials involved and the geometry of the package. The information gained from acoustic imaging can be of considerable value in ensuring the long-term reliability of the device and, in particular, in locating internal defects that have not yet caused an electrical failure. •

Tom Adams is a freelance writer and photographer based in New Jersey. He has written numerous articles for technical and scientific trade magazines in North America, Europe and Asia.