Identifying IC package anomalies with acoustic solids

Planar acoustic images do not provide adequate data to identify defects within IC packages. To overcome this limitation, create and manipulate an acoustic solid—a virtual presentation of the package in 3D, which contains information about the interior of the device.

By Tom Adams

The number of internal anomalies, which may exist in a semiconductor package, is large. Conventional plastic IC packages can have at least 20 different defects, none of which is visible at the surface, and few of which are visible by X-ray. At least 18 internal defects can affect the performance of flip chip packages.

The conventional method for imaging and analyzing hidden internal defects has been acoustic micro imaging, which is both nondestructive and sensitive to differences in the elastic moduli of various materials. The very high frequency ultrasound used is especially sensitive to internal gaps such as cracks and delaminations.

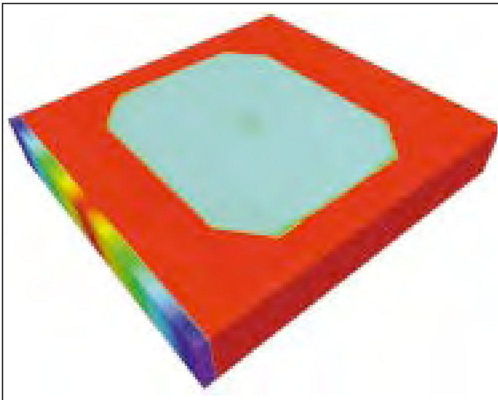

Figure 1: An unsectioned acoustic solid of a plastic ball grid array (PBGA) contains all the acoustic data about the internal features of the device.

Acoustic micro imaging uses a reflection-mode transducer that both pulses ultrasound into the package and picks up the return echoes from the interior of the package. Most acoustic images are planar images, straight-down acoustic views showing a desired level or interface within the package. A planar acoustic image might display, for example, only the die attach layer.

3D acoustic imaging

In recent years, researchers at Sonoscan have developed several variations of the planar image. The virtual cross section method manipulates the return signals to provide a nondestructive cross section of the device. The through-scan technique uses two transducers (one below the device) to image its entire thickness—a fast way of learning whether a defect is present.

However, a latest innovation gives acoustic micro imaging a usefulness it never had before. The innovation hinges on the creation of an acoustic solid, which is the virtual representation of the package in 3D. The acoustic solid is opaque, but it contains all of the acoustic data about the package (**figure 1**). More specifically, it contains data points (or return echoes) from all levels within the package. The acoustic color map, which relates color to the intensity of the returned signal, is at the lower left of the acoustic solid. The value of the acoustic solid is that it can be sectioned not only in various dimensions but according to the acoustic properties of the various materials and anomalies within the package (**figure 2**).

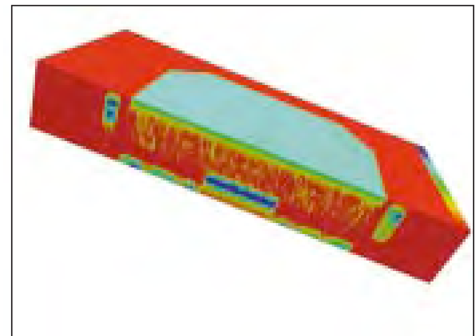

Figure 2: The FR4 substrate (blue) lies on either side of the die (also blue). Above the die, scattered tiny voids are present in the molding compound.

The first step in creating an acoustic solid is to acoustically slice the package into horizontal pieces. You can select the number of layers desired, which can range from 2 to 200; somewhere between 10 and 40 slices is adequate for most semiconductor packages.

The scanning transducer then scans the device once for each slice. The transducer is automatically op-

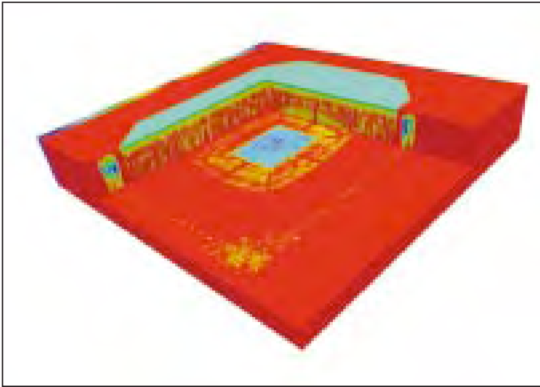

Figure 3: A 3D sectioning of the same acoustic solid shows the die and lead wires leading from the die.

timized for both focus and gating on each slice (gating is the electronic exclusion of all echoes except those from the defined level in the package).

During scanning, the transducer switches thousands of times per second between its pulse mode and its receive mode. When ultrasound from the transducer travels downward into the package, it is not normally reflected back by the bulk of materials such as the molding compound or the die. However, some of it is partly reflected back to the transducer by interfaces between materials. The intensity of the reflection, and the polarity of the reflection (whether positive or negative) depends on the acoustic properties of the materials on either side of the interface.

Ultrasound reflects back when there is an anomaly (one or more interfaces) in the bulk of a material. Molding compound, for example, can contain voids; each void represents an interface between the molding compound and the air in the void. The same is true of cracks in the die, or delaminations in the die attach. Gap-type anomalies (cracks, voids, delaminations, and the like) have the important property of reflecting all of the ultrasound back to the transducer. Their return echoes therefore have the greatest acoustic intensity.

Processing/manipulating acoustic data

When the process of creating the acoustic slices has been completed, each slice contains all of the acoustic data for that particular narrowly defined horizontal slice. Some slices—those through defect-free molding compound, for instance—will contain essentially no data. Others, such as those running through both the die attach material and a delamination will be rich in data.

Since it employs a collection of software tools, creation of the acoustic slices is very nearly an automated process. Software enables the transducer to look for and find the package, and to measure its x, y, and z dimensions before slicing begins. You need to merely specify the number of slices and initiate the process.

At the conclusion of slice production, the slices are displayed as thumbnail images on-screen. You can view them in this form, or in sequence as in a slide-show format.

At this point the virtual volumetric imaging software takes over and stacks the acoustic slices into the 3D acoustic solid. The acoustic solid appears on-screen as a rectilinear solid. Since it is visually opaque, it is essentially featureless, except where an internal acoustic feature such as a crack happens to intersect a sidewall. The important property of the acoustic solid is that it contains electronically all of the acoustic information about the interior of the package.

As a first step, rotate the acoustic solid into a position that will provide better viewing when it is sectioned. This means a low oblique view; you should be looking down at the horizontal plane of the acoustic solid from an angle of roughly 20° to 30°.

In the simplest form of sectioning, you can remove rectilinear solid sections of the acoustic solid. If it is known, for example, that there is a delamination in the die attach material, you can remove a rectilinear corner section whose bottom plane intersects the die attach layer. Removal of this section can expose part or all of the die attach and the accompanying delamination. Carry out the same procedure to display die

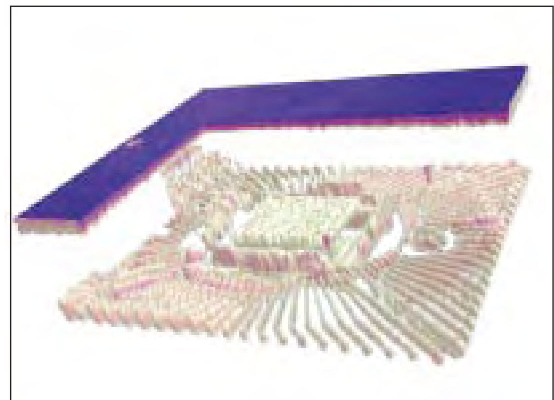

Figure 5: The acoustic solid of a PLCC has had several "slices" of molding compound removed retaining a popcorn crack reaching the surface.

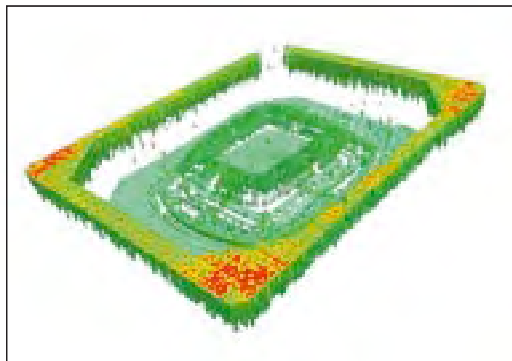

Figure 4: Extensive removal of molding compound created this view . Note the wires leading from the die and the stepped topography of the substrate.

face delaminations and other essentially horizontal defects (**figure 3**).

In addition to rectilinear sections, you can also extract whole slices. Slices are numbered from the top, beginning with slice number 00. If the molding compound is unimportant for viewing particular internal features, you should do away with those slices containing the molding compound. Slice 00 might provide a “roof” giving you an understanding of the thickness of the package.

You can also remove parts of the acoustic solid, which correspond not to the slices but to the acoustic properties of the material. If the molding compound forms a very non-planar interface where it meets the lead fingers, you can easily remove the entire molding compound (**figure 4**). Specifying the removal of all acoustic data that matches the acoustic properties of the molding compound will achieve this end.

Figure 5 illustrates the results of the sectioning of an acoustic solid. The package is a plastic leaded chip carrier (PLCC) which contains a popcorn crack. The popcorn crack originates under the die and extends upward.

In figure 5, the entire molding compound has been removed except for layers 00 and 01. Note the mold mark at the top surface of the package. By defining removal according to acoustic properties rather than by slice numbers, the largest portion of the popcorn crack, which extends upward until it reaches the top surface of the package, has been preserved. The more modest vertical structures, which surround the die, are smaller extensions of the same popcorn crack.

What does this new acoustic solid technique accomplish? Primarily, it makes all of the acoustic data of the interior of the package available for visual representation. It allows you to select the data to be viewed according to multiple definitions—by slice number, by various vertical or diagonal slices, or even by acoustic properties. Other choices are also available, as in figure 5, wherein a suggestion of the sidewalls of the acoustic solid (and therefore of the device package) has been retained as a translucent vertical layer.

You can create an acoustic solid and slice it in a way to realize two objectives simultaneously: 1) the desired features, both normal and defect, inside the package can be seen; and 2) these features can be seen in their proper spatial relationship to the whole package. ee

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