# Acoustic Flatness Measurement Enhances Die Attach Analysis of Power Device

## *An ultrasonic transducer raster-scans the flat surface*

*Thermal management is always a concern when using power devices. Acoustic micro imaging looks nondestructively at the internal features of power devices; specifically, this method images the interfaces between materials. The quality of the bond at an interface, and the presence or absence of delaminations or voids at an interface, can give an engineer good insight into the thermal integrity of the device and its likely longevity.*

*By Tom Adams, Consultant, Sonoscan, Inc.*

A recent development at Sonoscan, the designer and builder of acoustic micro imaging systems, has added a second method of extracting information about the internal condition of a power device or another type of IC. This method is known as Acoustic Surface Flatness (ASF) measurement. It operates in conjunction with, and at the same time as, reflection-mode acoustic micro imaging, which is the primary technique for imaging the device. The two techniques are explained in detail below.

**Reflection-Mode Acoustic Micro Imaging**
This is the most commonly employed of several methods of using VHF and UHF ultrasound to image the interior of a device. An ultrasonic transducer raster-scans the flat surface of the device. While scanning, the transducer pulses ultrasound into the device and receives the return echo signals from material interfaces at a selected depth within the device - the die attach depth, for example. The moving transducer carries out its pulse-echo function several thousand times per second because the round-trip travel time for a pulse is typically on the order of several microseconds.

A pulse traveling through a homogeneous material (mold compound, silicon, etc.) sends back no echo. A pulse striking a bonded material interface (mold compound to silicon, for example, or silicon to die attach) sends back a return echo that has what may broadly be described as moderate amplitude. But if the pulse strikes the interface between a solid material and an empty gap such as a crack, a void, or a delamination, more than 99.99% of the ultrasound is reflected. Cracks and other gap-type defects are therefore the brightest features in the acoustic image. The high speed of operation and the great sensitivity of the transducer to amplitude variations explain why acoustic micro imaging systems can achieve high accuracy in nondestructive internal inspection.

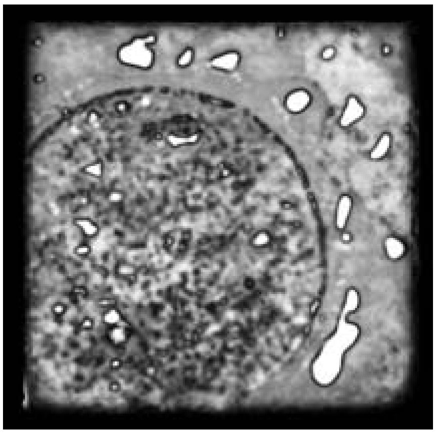

*Figure 1: Acoustic image of the die attach material under a silicon die in a power device. White features are voids (trapped air bubbles) in the die attach. Large circular feature formed when the droplet of fluid material cured slightly before the die was put on.*

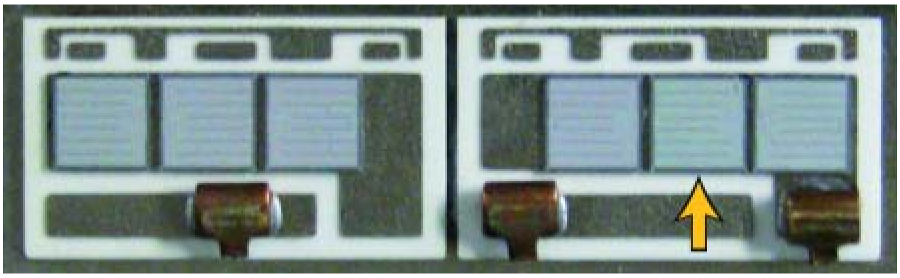

*Figure 2: Optical photograph of the power device assembly. The die imaged in Figure 1 is marked by an arrow.*

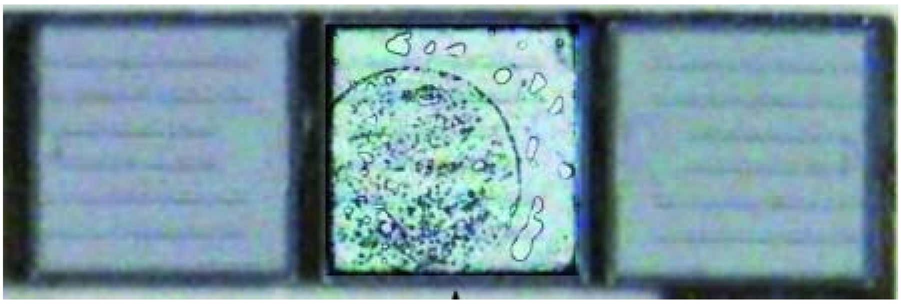

*Figure 3: Overlay of the acoustic image of the die attach layer and the optical photo of the die.*

Figure 1 is the reflection-mode acoustic image of the die attach depth underneath one of six similar die arranged in two groups of three in a power device assembly. An optical photo of the device itself is in Figure 2; the die imaged acoustically is the second from the right. The acoustic image is superimposed on the die in Figure 3.

Acoustic imaging was performed before encapsulation of the device because there were concerns about the die attach process, and the users of the device wanted to obtain a very clear image showing the condition of the die attach. Although most power devices are imaged acoustically after encapsulation, imaging the bare die is an approach often used in the development of power devices in power rectifiers, lighting control, explosives fuses, and other applications.

In Figure 1, the bright white features at right and top are voids (air bubbles) in the die attach. Because air is such a good thermal insulator, voids are undesirable in the die attach of a power device; too great an area of voids can block heat flow from the die and cause the die to overheat. But in this case only about 3% of the die attach area is occupied by voids - not a problem unless one of the voids is relatively large and also happens to lie directly under a hot spot on the die.

The large circular feature at left is the outline of the fluid droplet of die attach material that was placed onto the substrate before the die was attached. The droplet cured slightly, forming the dark residual outline. Next the placement of the die caused the bulk of the droplet to flow across the interface between the die and the substrate. Ideally, the droplet should have been located in the center of the substrate, rather than near a corner, but on all six of the die in this device the droplet's circular residue is near the lower left corner.

There is nothing particularly unusual in this acoustic image. The voids are the sort of ordinary defect that the user of the device was concerned about. The circular outline of the fluid die attach material is often seen acoustically.

**Acoustic Surface Flatness**
In this case, however, the device was also imaged by the newly developed (patent pending) Acoustic Surface Flatness (ASF) method. This technique makes use of the same pulse of ultrasound, but in a much different way. In reflection-mode acoustic imaging, data is collected not only about the amplitude of a returned echo signal, but also about the time in nanoseconds that has elapsed since the pulse was launched. The elapsed time is used, among other things, for determining the depth of the feature being imaged. In nearly all reflection-mode imaging, imaging is limited to a specific desired depth within the sample by setting a time gate. Only return echoes within the time gate are used in imaging, which guarantees that the acoustic image will display only features from the internal depth of interest.

ASF uses only the elapsed time measurement data, and uses only the elapsed time of echoes from the top surface of the part. By measuring the elapsed time, the precise distance from the transducer to the top surface of the device at each x-y coordinate scanned can be measured. As the transducer scans the device, it collects from each pulse the exact distance to the surface of the part at that coordinate as well as the amplitude of the return echo from the internal depth of interest at that coordinate.

The result is two acoustic images. The reflection-mode image (Figure 1) shows material-interface features at the depth of interest inside the part. The ASF image shows the topography of the top surface of the part. ASF was developed for use along with reflection-mode imaging because the surface topography can often add to the data gathered from the interior of the part and make it easier to determine why and how a part failed or may fail in the future.

The ASF image of this die and the two die adjacent to it is seen in Figure 4. This is the group of die on the right in the optical image in Figure 2. ASF uses a color spectrum to show differences in elevation across the surface of the device. Here, the lowest points (A) are colored red, and the highest points (B) are colored white; the die are obviously tilted. Each of the three die thus slopes upward from northeast to southwest. The difference in elevation between point A and point B is 0.205mm - hardly a difference that would be noticed by casual observation.

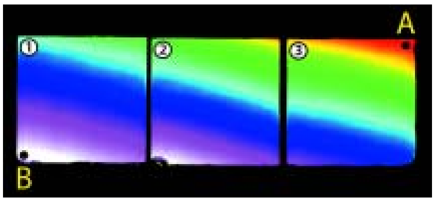

*Figure 4: Acoustic Surface Flatness (ASF) image shows topography of the top surface of three die. Lowest points are red; highest points are white.*

But why is the surface of the die tilted? It may be tilted because the die attach material is thicker at one corner. The acoustic image of the die attach material makes this explanation seem likely. On the other hand, the die attach may have the same thickness throughout, and the die might be tilted because the substrate beneath the die is tilted.

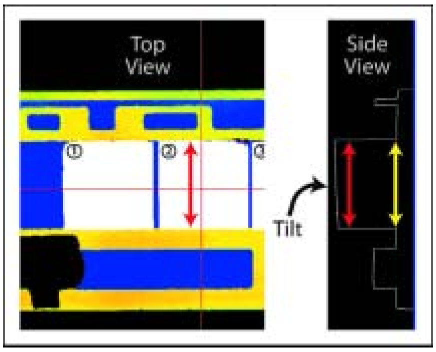

*Figure 5: ASF side view shows significant tilt in the profile of the top of the die (red arrow at right), but no tilt in the profile of the substrate (yellow arrow).*

To find out the real cause of the die tilt, the device was imaged in a variation of ASF called "side extension." The result is shown in Figure 5, where the white areas are the three die, yellow is the ceramic substrate, and blue is direct bonded copper on the ceramic. The red arrow in Top View shows the width of the die imaged in Figure 1. The side profile of this die is indicated by the red arrow in Side View. The top surface of the die is clearly tilted. The side view of the copper-ceramic substrate beneath the die is indicated by the yellow arrow. No tilt is evident here. The die is therefore tilted because of variation in the thickness of the die attach material. Separate direct measurement of the die attach thickness gave the same result. Apparently the off-center location of the partly cured droplet, which left the ring seen in Figure 1, caused the die to be tilted.

Where the die attach material is thickest, it will to some extent impede the flow of heat from the die. What the reflection-mode and ASF acoustic images reveal is that there are two conditions that may have negative impact on the transfer of heat from these die: 1) one or more voids may be aligned with a hot spot on the die; and 2) the die attach material, particularly toward the southwest corner of a die, may be thick enough to reduce the amount of heat transferred away from the die.

**www.sonoscan.com**