EVALUATION OF THIN PLASTIC PACKAGES USING ACOUSTIC MICRO IMAGING

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ABSTRACT:

Acoustic microscopy has become an accepted and now often required method for the evaluation of plastic encapsulated IC devices. The encapsulant thickness of standard devices is typically around 3mm so frequencies in the range of 10 to 25 MHz are normally used for acoustic inspection. Recently, the technology is being driven to provide thinner packages in order to accommodate tight space requirements for the applications for these devices. The TSOP and TQFP packages are approaching 1mm and less in thickness. The compact internal spacing between the layers requires better axial (z axis) resolution in order to individually distinguish the layers. This requires higher frequencies (as high as 100 MHz) and some modification of methods in order to analyze the parts.

Two types of acoustic microscopes were used in this study: the Scanning Laser Acoustic Microscope (SLAM), which operates in the shadowgraph through transmission mode, and the C-Mode Scanning Acoustic Microscope (C-SAM), which is a focused reflection/transmission mode instrument. In general, acoustic microscopes use high frequency ultrasound (5 to 500 MHz) to image the internal features in materials or components. The ultrasound is sensitive to variations in the elastic properties of materials and is particularly sensitive to locating air gaps (delamination or void). The material in this paper will provide an overview of experiences in the evaluation of thin packages. The concerns and different types of defects (die cracks, pad tilt) will be discussed along with the best frequencies and methods for the detection of these problems. Difficulties and limitations of acoustic inspection of thin plastic packages, generally imposed by the type of molding compound, will also be discussed.

KEY WORDS:

BACKGROUND - ACOUSTIC MICROSCOPY

There are two types of acoustic microscopes which can be used to study and evaluate thin plastic packages. The Scanning Laser Acoustic Microscope (SLAM) and the C-Mode Scanning Acoustic Microscope (C-SAM). Both instruments utilize high frequency ultrasound to detect internal discontinuities in materials and components.

The SLAM is a shadowgraph through transmission technique (Figure 1), operating at frequencies between 10 and 500 MHz. In SLAM analysis, a continuous plane wave of ultrasound penetrates the entire thickness of the sample. The pattern of transmitted ultrasound is then detected by a rapidly scanning, finely focused laser beam which acts like an ultra sensitive point-by-point "microphone". The transmission of ultrasound is affected by internal features and defects, discontinuities and material properties. Images which are produced in real time, 1/30 of a second, simultaneously reveal bond integrity of all interfaces throughout the entire sample thickness.

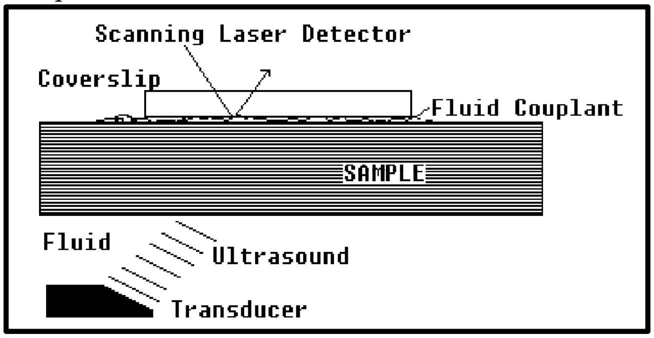

Figure 1: Block Diagram of a Scanning Laser Acoustic Microscope (SLAM)

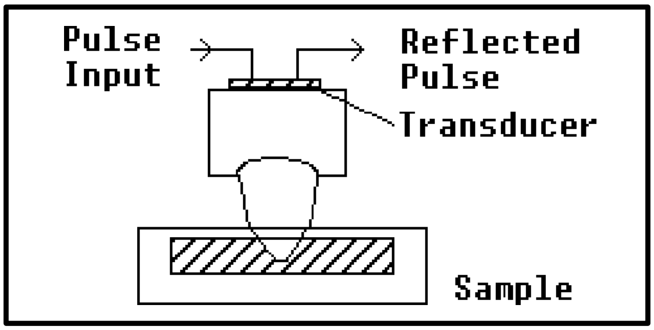

Figure 2: Block Diagram of a C-Mode Scanning Acoustic Microscope (C-SAM)

The C-SAM operates in the pulse-echo mode, typically over a range from 5 to 200 MHz, to produce level specific images of a sample (Figure 2). A focused ultrasonic transducer works alternately to send, and, recieve reflected signals within the sample. An electronic gate is used to select a specific depth, or, interface. A very high speed mechanical scanner is used to index the transducer across the sample and produce images in tens of seconds.

Operating frequencies ranging from 15 to 100 MHz were used for the data in this study. In general the higher the frequency the higher the resolution in the acoustic images. Lower frequencies, however, provide more transmission through materials. A frequency which provides the best compromise of resolution and penetration can be found to suit most applications.

There are several different imaging modes of Acoustic Microcopes. A discussion of the modes which will be referred to in the text of this paper follows.

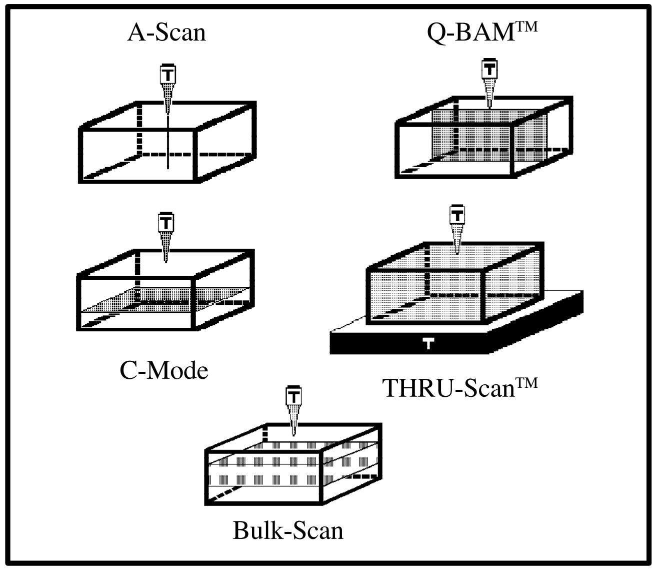

Figure 3: Various modes of C-SAM system used for BGA and Flip Chip analysis.

EXPERIMENTAL METHODS AND DISCUSSION

THRU-Scan™
THROUGH TRANSMISSION MODE

Through transmission imaging modes rely on sending the acoustic signal through the entire thickness and/or multiple layers of a sample and detecting the transmitted signal using a seperate reciever. The SLAM (see Figure 1) uses a scanning laser as the detection method. The C-SAM, THRU-Scan™ mode (see Figure 3) uses a second transducer as the detector. Defects, if present, block the ultrasound from the detector, appearing as dark shadows in the acoustic image.

A-SCAN

Reflection mode acoustic microscopes can aquire information in several different ways (one of which, the Thru-Scan, is mentioned above). The fundamental information, using the reflection mode, is contained in the A-Scan (see Figure 3). The A-Scan displays the depth information in the sample at one x,y coordinate. Echos displayed in the A-Scan correspond to different interfaces in the device being examined. The distance between the echos relates to their depth in the device (V= 2d/t). The amplitude and phase information of the echos is used to characterize the condition at the interface. The equation which describes the interaction between materials at an interface is as follows:

$$\frac{R}{I} = \frac{Z2 - Z1}{Z2 + Z1}$$

INTERFACE SCAN TECHNIQUE (C-Mode)

The basic imaging method commonly used to evaluate devices for delaminations and voids is the interface scan. This method involves gating the echo specific for the interface to be investigated. The focus of the acoustic beam is optimized for the interface as well. Figure 3 describes the interface scan technique. The acoustic image of the interface displays both the amplitude and phase (polarity) of the gated echos via the AIPD™ (Acoustic Impedance Polarity Detector).

BULK SCAN TECHNIQUE

This technique is used to picture the acoustic appearance of the "bulk" of a material as opposed to a specific interface. A diagram of the "Bulk Scan" technique appears in figure 3. The gating of the acoustic signal within the material begins immediately after an interface echo, and, includes all of the area up to the next internal interface echo. The focus is at a level within the thickness of material. If the material is entirely homogeneoeus, there will be little or no signal to be displayed in the image. Voids, or, other discontinuities will cause signal reflections which appear as bright areas in the image. This imaging mode is typically used in material characterization application, such as characterization of molding compounds. However, it also has utility in applications where the exact level of a defect can vary slightly.

Q-BAM™
(QUANTITATIVE B-SCAN ANALYSIS MODE)

Q-BAM™ is an imaging mode that provides a cross-sectional view of the sample along a designated line through the device. Each pixel of the cross section is in the correct focus for that depth in the sample. The distances between the internal depth levels is related to the sonic velocity in the material.

ANALYSES OF TSOP AND TQFP PACKAGES

As with any package type, through transmission imaging can be used to obtain a rapid assessment of the overall package condition in thin devices. Through transmission techniques are also valuable to confirm the presence of delaminations in cases where the interpretation of the waveforms in the reflection mode is ambiguous. Since through transmission imaging is not level specific lower frequencies (10 MHz to 25 MHz) are typically used in order to provide unobstructed transmission of the

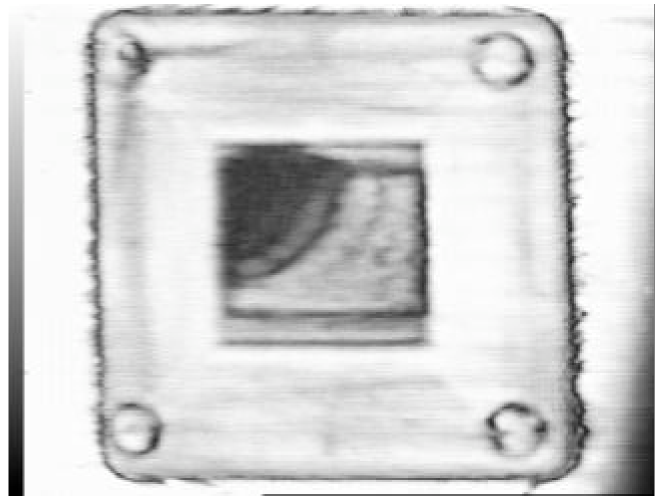

Figure 4A: SLAM 10 MHz Through transmission image of a TQFP.

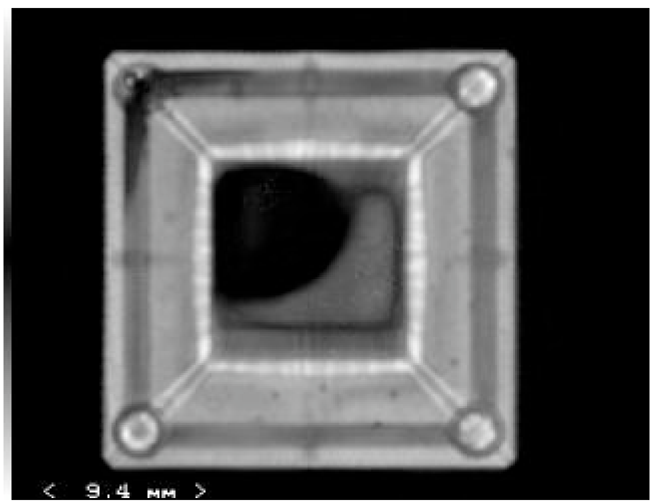

Figure 4B: THRU-Scan™ Through transmission image of the same TQFP.

ultrasonic signal through the encapsulation material causing defects free areas to appear relatively bright in the acoustic images. By contrast, the air gaps created by voids and delaminations will obstruct the ultrasound even at these frequencies and appear dark in the images. Figure 4A shows a stillframe image taken from the real-time SLAM system. The image displays a 10 MHz shadowgraph projection of a TQFP device. A large portion of the die/die pad area appears dark indicating a defect in this region. Through transmission imaging can be accomplished on the pulse/echo type systems as well, though not at real-time speeds. Figure 4B shows a C-SAM Thru-Scan image of the same TQFP. Similar to the SLAM image, a dark area (delamination) is detected in the die/die pad area. The through transmission images can be used as maps to guide the level specific interface scan analysis to determine the exact depth of a defect using the reflection mode.

Using reflection mode techniques, a factor which becomes of great importance in acoustic evaluation of thin plastic devices is axial (z dimension) resolution. As mentioned in the background section there is a relationship between the frequency of the ultrasound and the resolution available in the acoustic images. This is true not only for spatial resoluton but for axial resolution as well. The higher the frequency, the thinner the layer which can be discriminated. Table 1 gives some typical dimensions at several frequencies. It is not always a straightforward matter to simply use the highest available frequency when evaluating encapsulated devices. The type of molding compound has a significant influence on the frequency which can be used for analysis. Certain formulations are attenuating to the ultrasound and necessitate lower frequencies for penetration through to the interface in question. For the thin encapsulated devices a compromise between resolution and penetration is usually found in the 30 MHz to 100 MHz range.

Frequency	Plastic	Metal	Ceramic
10 MHz	0.225mm 0.009in	0.45mm 0.018in	0.675mm 0.027in
15 MHz	0.15mm 0.006in	0.30mm 0.012in	0.45mm 0.018in
30 MHz	0.075mm 0.003in	0.15mm 0.006in	0.225mm 0.009in
50 MHz	0.045mm 0.0018in	0.09mm 0.0036in	0.135mm 0.0054in
100MHz	0.0225mm 0.0009in	0.045mm 0.0018in	0.0675mm 0.0027in

Table 1: Sample Thickness Resolution (Optimistic)

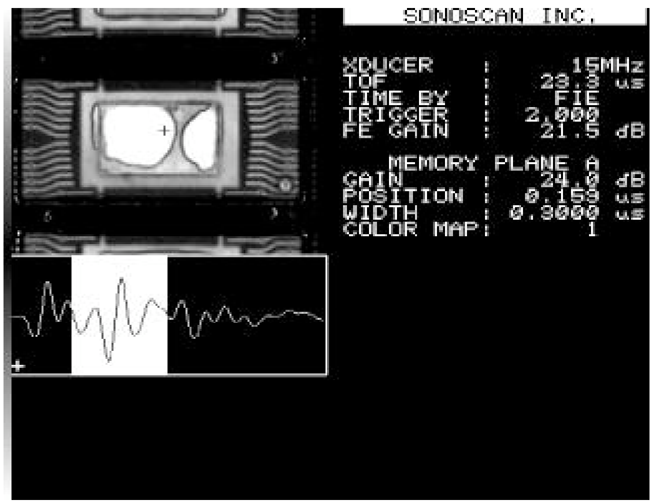

Figure 5A: C-Mode image and A-Scan waveform obtained at 15 MHz.

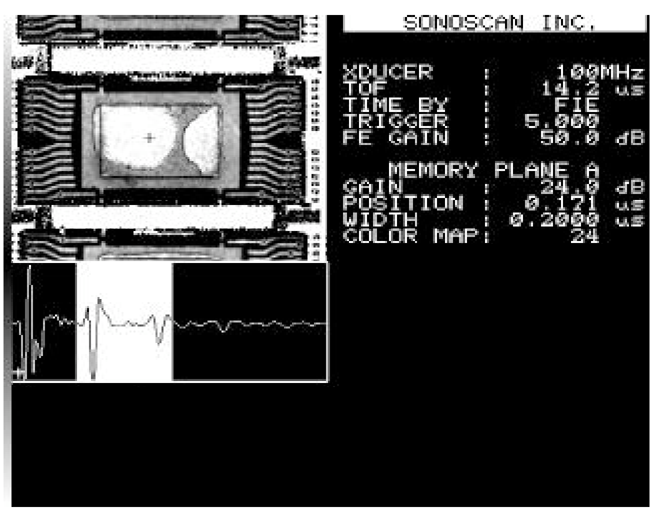

Figure 5B: C-Mode image and A-Scan waveform obtained at 100 MHz.

Delamination of the mold compound/die interface is of concern in all types of plastic encapsulated devices. Thicker plastic encapsulated ICs are evaluated routinely at a frequency of 15 MHz for die face delaminations. However, in the TSOP and TQFP devices the wavelength of the ultrasound at 15 MHz is too long to adequately separate the encapsulant/die interface from the front surface echo. The following example illustrates the relationship between frequency and axial resolution. Figures 5A & B compares the images and A-Scans for a typical TSOP device at 15 MHz and 100 MHz. The die surface in the package contains large delaminations (brighter areas). Although the delaminations are detectable at both frequencies, examination of the A-Scans shows the definition of the die surface echo to be much clearer at 100 MHz. At 15 MHz the echo for the front surface of the device nearly overlaps with the echo for the die surface. The 100 MHz image shows better detail due to the higher spatial resolution available.

Evaluation of the die attach is important in thin packages. Again, higher frequencies are needed to descriminate the individual layers within the packages. The position and duration of the electronic gate used to select the echo(s) for imaging must be restricted to the position and duration of the specific echo for the die attach otherwise extraneous waveforms will obscure the die attach information. Focus for the die attach interface is significantly different than the focus for the die surface. A frequency of 100 MHz was used in the

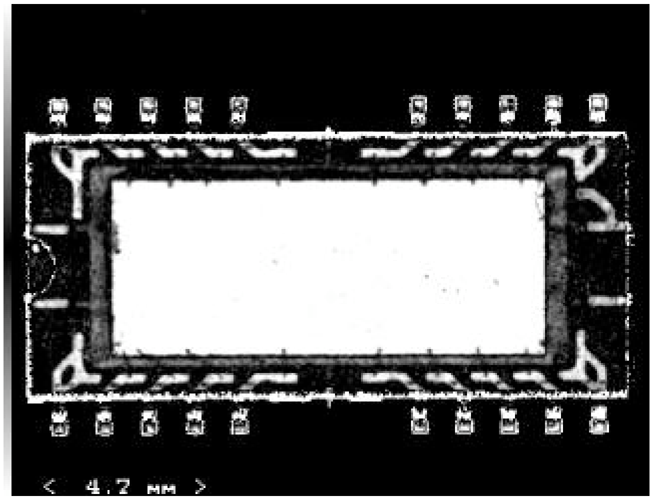

Figure 6A: C-Mode image at 100 MHz of the mold compound to die surface interface.

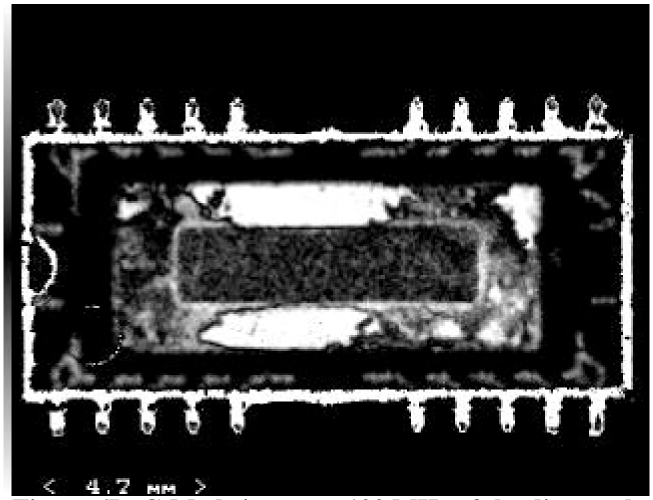

Figure 6B: C-Mode image at 100 MHz of the die attach level interface.

following example. Figures 6A & B compares the die surface image with an image of the die attach level. In the image of the die surface the gate could be wide enough to include the lead frame and die pad levels. The die surface is bonded to the encapsulant over the entire die area. The image of the die attach used a gate specific to the die attach interface. Large disbonds (white features) can be seen in the die attach. This sample contains a window frame die pad. The center area of the back of the die is bonded to the mold compound material.

In understanding the behavior of die attach materials it is not only necessary to locate delaminations and voids in the bond, but to specify if the defect is at the die/adhesive or adhesive/pad level. The following example (see Figure 7) shows a 100 MHz Q-BAM™ display of the die attach in a TQFP device. The upper half of the display shows the c-scan image for reference. A white line in the image describes the location for the cross sectional view. A large delamination is noticed in the die attach. (This is the same delamination which was detected in the through transmission image.) By observing the position of the echos on the A-Scan it was noticed that the delamination echo appeared at a slightly deeper level in the die attach, at the adhesive/pad level. The Q-BAM™ cross section of the sample, shown in the lower half of the display, shows the varying levels in the die attach. Direct depth measurements can be made for the scales shown at the sides of the image. The increments are scaled based on the velocity of the ultrasound in the encapsulant material. This information is given at the bottom of the display.

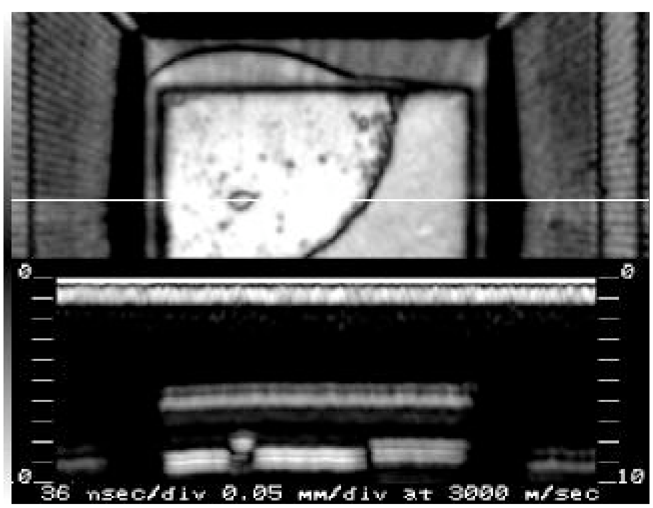

Figure 7: Q-BAM™ image of the die attach of the TQFP.

The Q-BAM™ cross sections are also very useful for tracking the planarity of the internal construction in thin packages. Needless to say, the tight size tolerances in the devices does not allow room for much die or die pad tilt. Even minor changes in planarity can be viewed in the acoustic cross sectional images. Figure 8 shows a Q-BAM™ image of a part containing die pad tilt.

Die cracks have been encountered in TSOP devices. Generally, the cracks result from improper mechanical handling during the packaging process. The best way to image cracks in the silicon die is to view the cracks at the die attach level. The opening of the cracks may be too small to be resolved when viewing at the mold compound/die interface. In some instances, the die cracks may originate closer to the die attach level, and not be open to the chip surface. However, any depth to the crack, or component of the crack internal to the die will create a shadow in the acoustic image when viewed at the die attach level. This renders the cracks

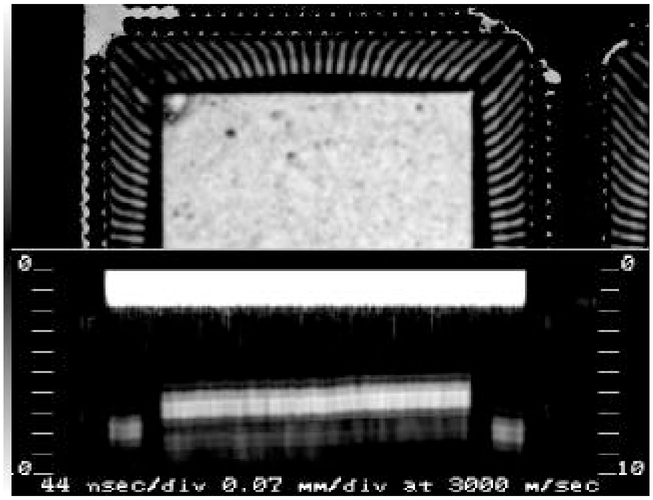

Figure 8: Q-BAM™ of a TQFP with die pad tilt.

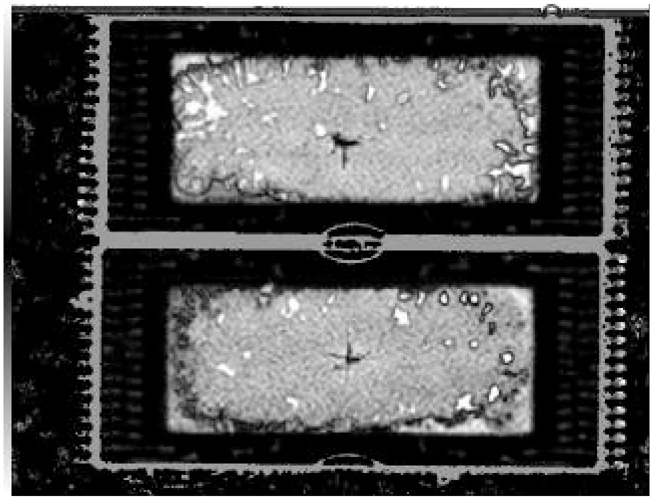

Figure 9: 100 MHz C-Mode image of TSOP devices with die cracks.

readily detectable within the resolution limits of the frequency being used for analysis. Figure 9 displays a 100 MHz acoustic image showing two TSOP packages. Cracks are present in the die as well as voiding in the die attach.

CONCLUSION

Defects can occur in thin plastic packages as a result of improper processing or handling just as they can in thicker devices. Acoustic micoscopy can be used successfully to evaluate these devices. However, the data presented in this study shows that the important factor in evaluating thin plastic packages is the capability to use higher frequencies in order to accomodate the compact internal dimensions in the devices.

REFERENCES