# IPC/JEDEC J-STD-035A

# Acoustic Microscopy for Non-Hermetic Encapsulated Electronic Devices

A joint standard developed by the B-10a IPC Plastic Chip Carrier Cracking Task Group and the JEDEC JC-14.1 Committee on Reliability Test Methods for Packaged Devices

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Users of this standard are encouraged to participate in the development of future revisions.

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# ACOUSTIC MICROSCOPY FOR NON-HERMETIC ENCAPSULATED ELECTRONIC DEVICES

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# ACOUSTIC MICROSCOPY FOR NON-HERMETIC ENCAPSULATED ELECTRONIC DEVICES

(From JEDEC Board Ballot JCB-22-59, formulated under the cognizance of the JC-14.1 Subcommittee on Reliability Test Methods for Packaged Devices.)

## 1 Scope

This test method defines the procedures for performing acoustic microscopy on non-hermetic encapsulated electronic devices. This method provides users with an acoustic microscopy process flow for detecting anomalies (delaminations, cracks, mold compound voids, etc.) nondestructively in encapsulated electronic devices while achieving reproducibility.

## 2 Definitions

**A-mode -** Acoustic data collected at the smallest X-Y-Z region defined by the limitations of the given reflective acoustic microscope. An A-mode display contains amplitude and phase/polarity information as a function of time of flight at a single point in the X-Y plane. See Figure 1 - Example of A-mode Display.

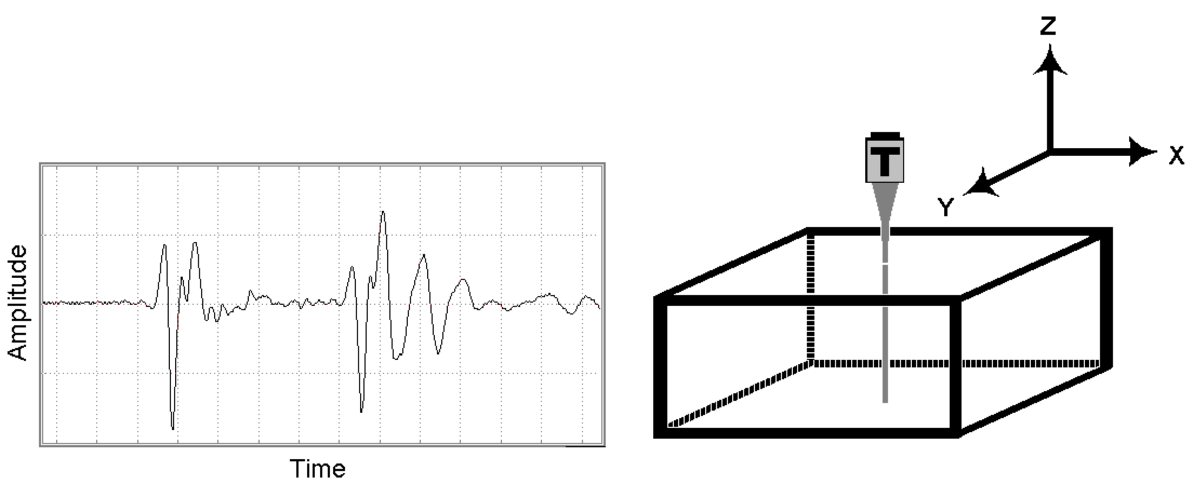



**Figure 1 — Example of A-mode Display**

**B-mode -** Acoustic data collected along an X-Z or Y-Z plane versus depth using a reflective acoustic microscope. A B-mode scan contains amplitude and phase/polarity information as a function of time of flight at each point along the scan line. A B-mode scan furnishes a two-dimensional (cross-sectional) description along a scan line (X or Y). See Figure 2.

## 2 Definitions (cont'd)

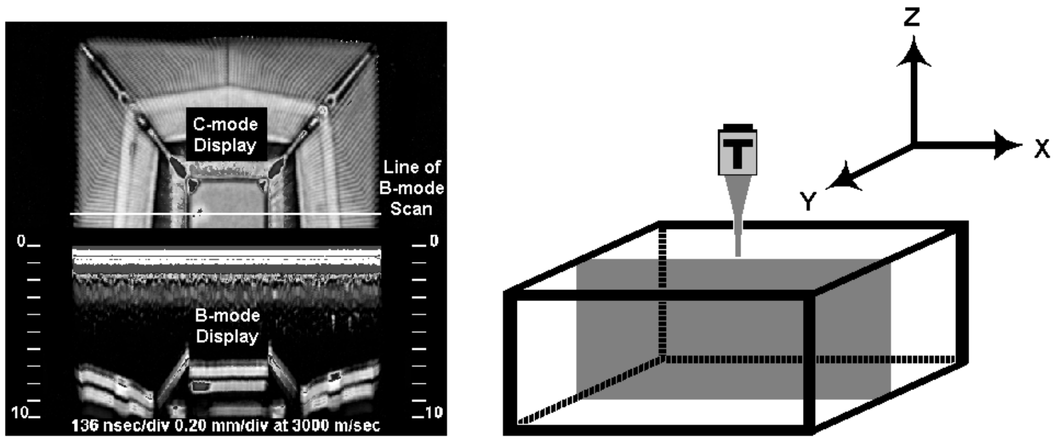



**Figure 2 — Example of B-mode Display**

**Back-Side Substrate View** Area (Refer to Annex A, Type IV) - The interface between the encapsulant and the back of the substrate within the outer edges of the substrate surface.

**C-mode -** Acoustic data collected in an X-Y plane at depth (Z) using a reflective acoustic microscope. A C- mode scan contains amplitude and phase/polarity information at each point in the scan plane. A C-mode scan furnishes a two-dimensional (area) image of echoes arising from reflections at a depth (Z). See Figure 3.

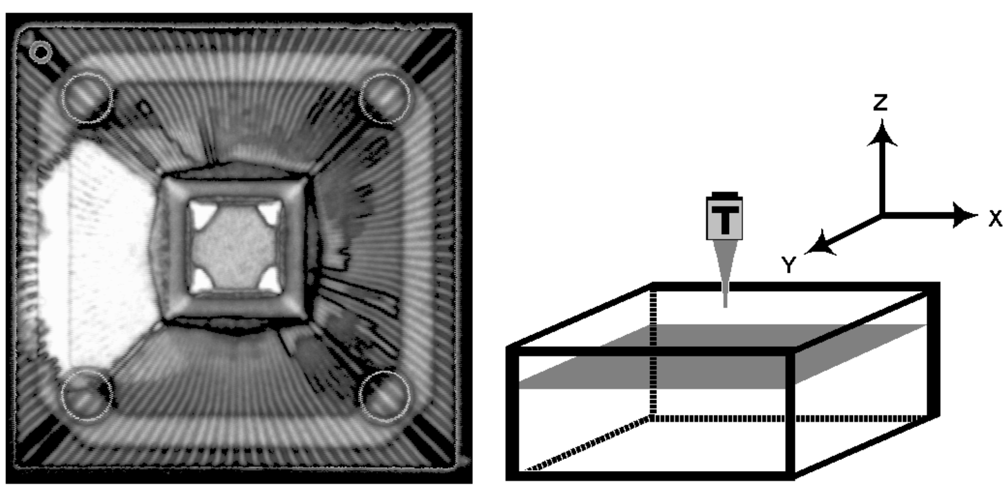



**Figure 3 — Example of C-mode Display**

**Crack -** A separation within a bulk material. See also ''Delamination.''

**Delamination -** An interfacial separation between two materials intended to be bonded. See also ''Crack.''

## 2 Definitions (cont'd)

**Through Transmission Mode -** Acoustic data collected in an X-Y plane throughout the depth (Z) using a through transmission acoustic microscope. A Through Transmission mode scan contains only amplitude information at each point in the scan plane. A Through Transmission scan furnishes a two-dimensional (area) image of transmitted ultrasound through the complete thickness/depth (Z) of the device. See Figure 4.

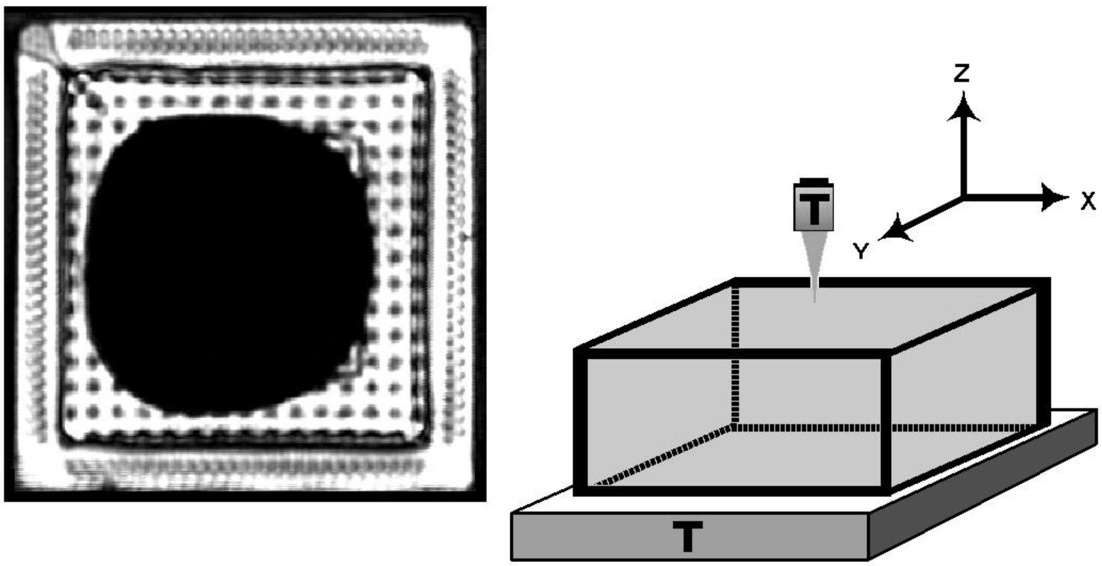



**Figure 4 — Example of Through Transmission Display**

**Die Attach View Area** (Refer to Annex A, Type II) - The interface between the die and the die attach adhesive and/or the die attach adhesive and the die attach substrate.

**Die Surface View Area** (Refer to Annex A, Type I) **-** The interface between the encapsulant and the active side of the die.

**Focal Length (FL) -** The distance in water from the face of the transducer to the location where the beam's diameter is at a minimum (also known as its spot size). The mathematical relationship between focal length and spot size is shown in Figure 5.

## 2 Definitions (cont'd)

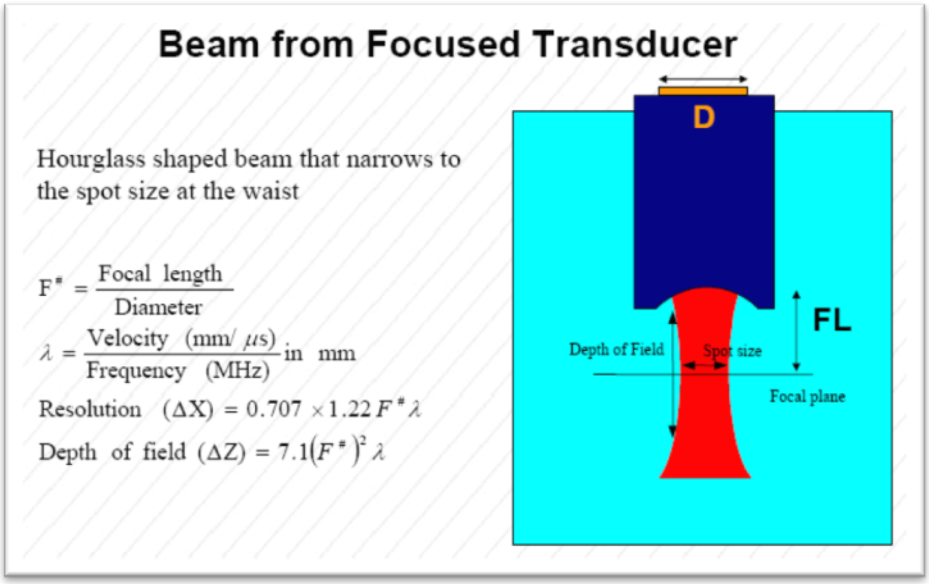



**Figure 5 — Relationship of Properties for Focused Transducers**

**Focus Plane -** The X-Y plane at a depth (Z), which the amplitude of the acoustic signal is maximized.

**Leadframe (L/F) View Area** (Refer to Annex A, Type V) - The imaged area which extends from the outer L/F edges of the package to the L/F "tips" (wedge bond/stitch bond region of the innermost portion of the L/F.)

**Reflective Acoustic Microscope -** An acoustic microscope that uses one transducer as both the pulser and receiver. (This is also known as a pulse/echo system.) See Figure 6.

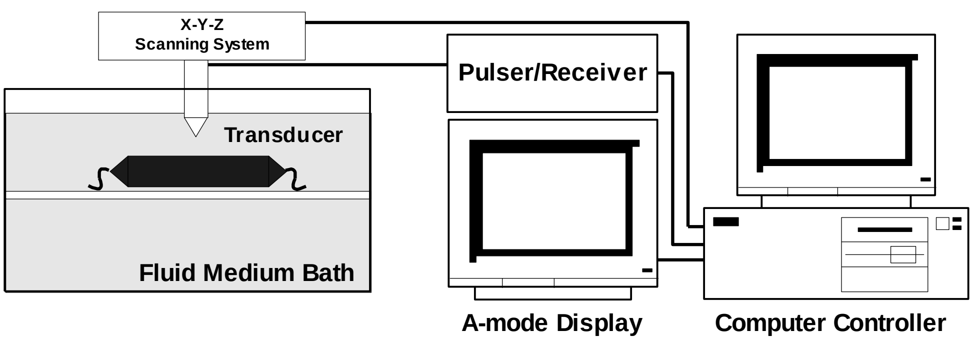



**Figure 6 — Diagram of a Reflective Acoustic Microscope System**

## 2 Definitions (cont'd)

**Through Transmission Acoustic Microscope -** An acoustic microscope that transmits ultrasound completely through the device from a sending transducer to a receiver on the opposite side. See Figure 7.

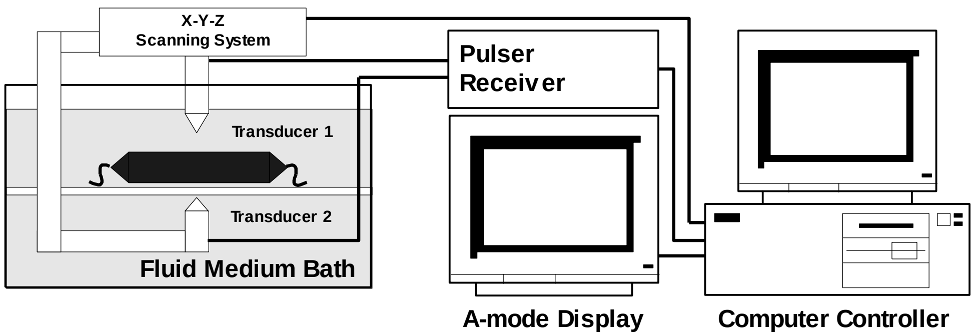



**Figure 7 — Diagram of a Through Transmission Acoustic Microscope System**

**Time-of-Flight (TOF) -**

a) In reflective mode, the time of flight is the time it takes for the acoustic pulse to travel from a single transducer/receiver to the interface of interest and back.

b) In through transmission mode, the time of flight is the time it takes for the acoustic pulse to travel from the sending transducer through the device to the receiving transducer.

**Top-Side Die Attach Substrate View Area** (Refer to Annex A, Type III) - The interface between the encapsulant and the die side of the die attach substrate surrounding the die.

## 3 Apparatus

### 3.1 Reflective Acoustic Microscope System (see Figure 5) Comprised of:

1) Ultrasonic pulser/receiver.
2) A display of the echo amplitude and phase/polarity versus time (A-mode display).
3) A computer-controlled display system for image display (B-mode and C-mode), storage, retrieval, printing and analysis.
4) An electromechanical X-Y-Z (typically computer-controlled) scanning system for moving the acoustic probe over the device and for setting the focus plane within the device.
5) A fluid medium bath, such as deionized water, to provide acoustic coupling between the device and the transducer.
6) A broad band acoustic transducer with a center frequency in the range of 5 to 400 MHz for subsurface imaging.

## 3 Apparatus (cont'd)

### 3.2 Through Transmission Acoustic Microscope System (see Figure 7) Comprised of:

1) Items listed in clause 3.1 above
2) Ultrasonic pulser (can be a pulser/receiver as in clause 3.1, 1)
3) Separate receiving transducer or ultrasonic detection system

### 3.3 Reference Packages or Standards

These include packages with delamination and packages without delamination, for use during equipment setup. Refer to clause 4.3.1.3. for a standard, Reference Bonded Wafer Sample per SEMI 3D17.

### 3.4 Sample Holder

The sample holder shall position the devices in the proper place, keep the devices from moving during the scan, and maintain planarity.

## 4 Procedure

This procedure is generic to all acoustic microscopes. For operational details related to this procedure that apply to a specific model of acoustic microscope, consult the manufacturer's operational manual.

### 4.1 Equipment Setup

#### 4.1.1 Select the Transducer

Select the transducer with the highest useable ultrasonic frequency, subject to the limitations imposed by the media thickness and acoustic characteristics, package configuration, and transducer availability, to analyze the interfaces of interest. The transducer selected shall have a low enough frequency to provide a clear signal from the interface of interest. The transducer shall have a high enough frequency to delineate the interface of interest.

Through transmission mode may require a lower frequency and/or longer focal length than reflective mode. Through transmission is effective for the initial inspection of devices to determine if defects are present.

#### 4.1.2 Verify Setup

Verify setup with the reference packages or standards (see 3.3 above) and settings that are appropriate for the transducer chosen in clause 4.1.1 to ensure that the critical parameters at the interface of interest correlate to the reference standard utilized.

#### 4.1.3 Place Devices in the Sample Holder

Place devices in the sample holder in the coupling medium such that the upper surface of each device is parallel with the scanning plane of the acoustic transducer. Remove air bubbles from the devices' upper surface and from the bottom of the transducer head.

### 4.1.4 Align the Transducer

At a fixed distance (Z), align the transducer and/or stage for the maximum reflected amplitude from the top surface of the device. The transducer must be perpendicular to the device surface.

### 4.1.5 Focus

Focus, as shown in Figure 8, by maximizing the amplitude, in the A-mode display, of the reflection from the interface designated for imaging. This is done by adjusting the Z-axis distance between the transducer and the device.

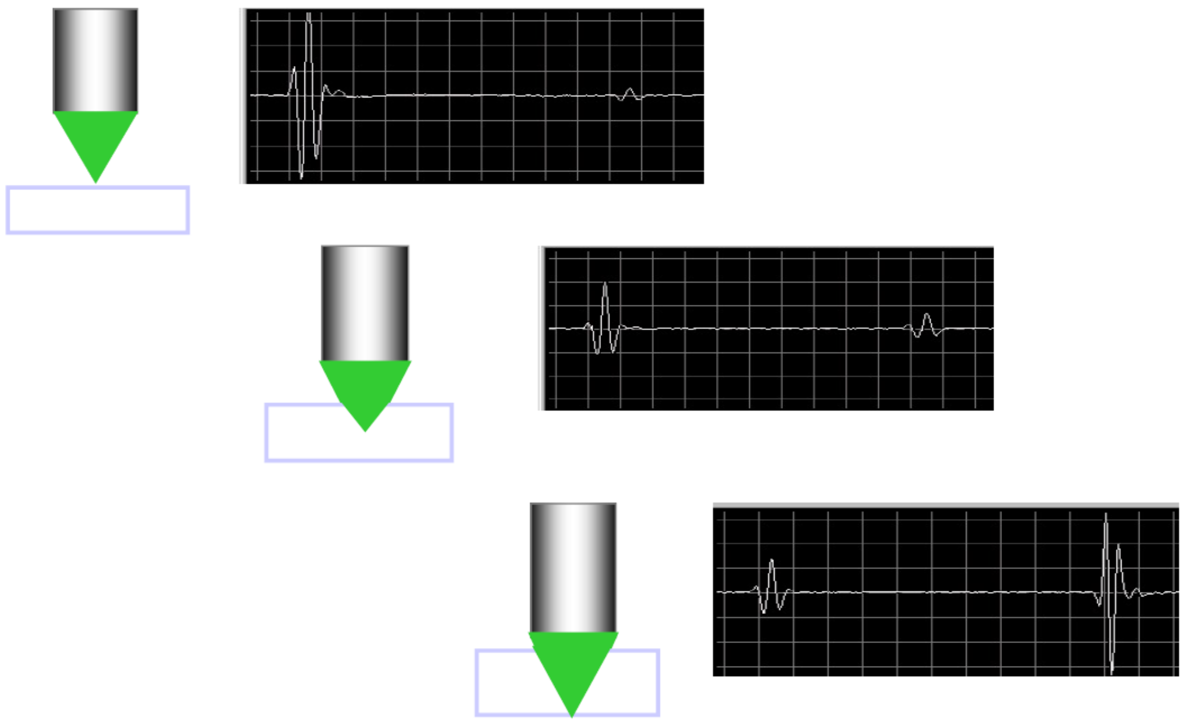


**Figure 8 — Example of Maximizing the Focus for the Top Surface, Approximate Middle and Bottom Surface of a Homogeneous Device.**

## 4.2 Perform Acoustic Scans

### 4.2.1 Inspect for any Anomalies

Inspect the acoustic image(s) for any anomalies, verify that the anomaly is a package defect or an artifact of the imaging process, and record the results. (See Annex A for an example of a check sheet that may be used.)

To determine if an anomaly is a package defect or an artifact of the imaging process it is recommended to analyze the A-mode display at the location of the anomaly. Physical analysis of the package may also be required to confirm the nature of the anomaly.

#### 4.2.2 Consider Potential Pitfalls

Consider potential pitfalls in image interpretation listed in, but not limited to, Annex B and some of the limitations of acoustic microscopy listed in, but not limited to, Annex C. If necessary, make adjustments to the equipment setup to optimize the results and rescan.

#### 4.2.3 Evaluate

Evaluate the acoustic images using the failure criteria specified in other appropriate documents, such as J-STD-020.

#### 4.2.4 Record

Record the images and the final instrument setup parameters for documentation purposes. An example checklist is shown in Annex D.

### 4.3 Characterization of AM Reflection Mode System

The philosophy of the characterization is to provide an assessment of an Acoustic Microscope (AM) system for practical applications. It should be noted that because of the variations in AM system performance from manufacturer to manufacturer, it is not intended to specify an exact set of operating parameters for use on all manufacturer's systems to obtain identical images.

The objective of the characterization procedure is to ensure reproducibility of operation of each individual microscope to a known reference standard. It is not useful to calibrate parts of any one AM system in isolation from the rest of the AM systems. In particular, the characterization of a transducer shall be performed together with the pulser/receiver of the AM system with which it will be utilized.

#### 4.3.1 AM System Setup

**Operating Mode -** Select the C-mode operating mode of the system for this characterization.

**Coupling Medium and Temperature -** The coupling medium shall be de-ionized water maintained within the temperature range 25°C ± 2°C during scanning. Since the attenuation and velocity of sound in water is temperature dependent, it is necessary to maintain the temperature as a constant when comparing scanned images from various occasions.

In some cases, the temperature of the coupling medium may not be controlled directly by activate thermal regulation. In these cases, when performing AM on the same devices from various occasions (e.g., pre- and post-stress testing), it shall be necessary to institute procedures which ensure that the TOF, gain and gate position & width settings are adjusted to compensate for the difference in temperature between pre- and post-test. This is more critical for higher frequency transducers, typically above 100 MHz, due to the changes in the speed of sound and attenuation of ultrasound in water with temperature fluctuations.

**Reference Sample** – The Reference Bonded Wafer Sample as per SEMI 3D17 is described in Figure 9, Figure 10 and Figure 11. The Reference Bonded Wafer Sample was designed to determine the resolution/detectability of an AM system/transducer for the evaluation of voids, delaminations and cracks in structures.

**4.3.1 AM System Setup (cont'd)**

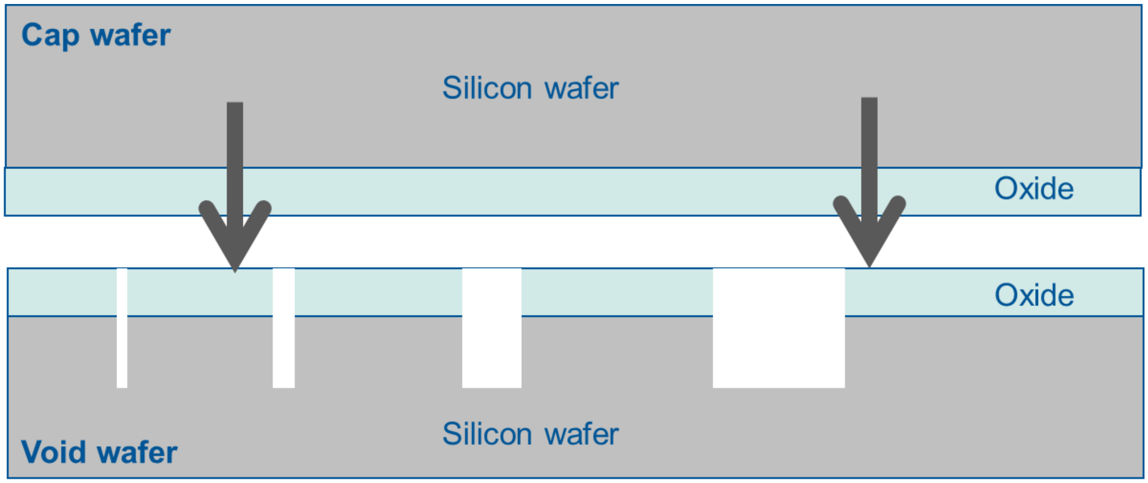



**Figure 9 — Example Structure of Reference Bonded Wafer Sample per SEMI 3D17**

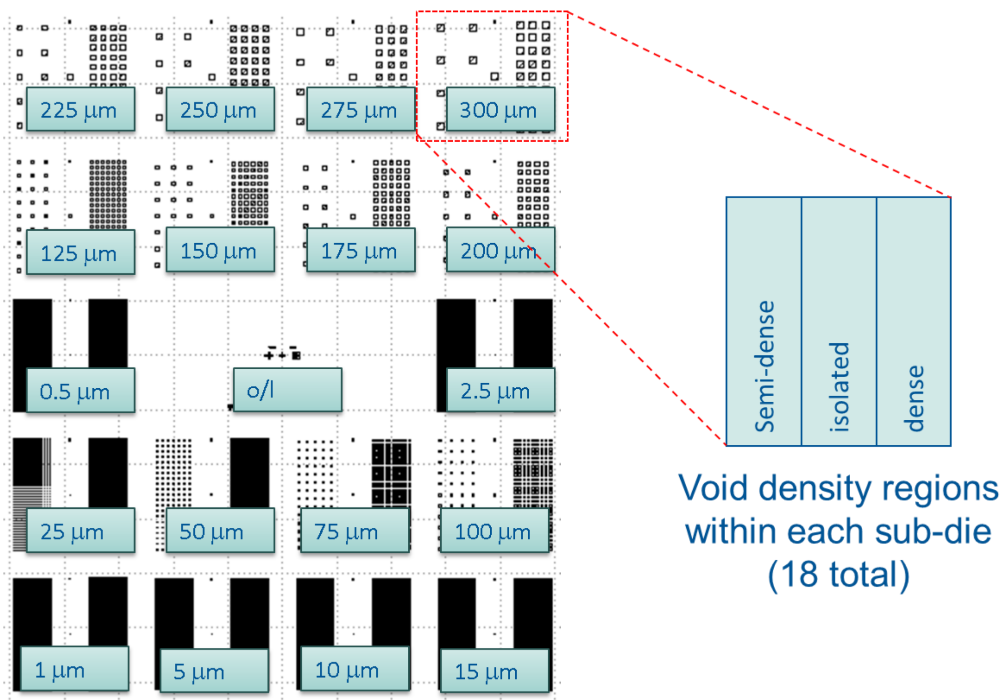



**Figure 10 — Layout of the Artificial Voids of Different Sizes and Densities in a Die-sized Array per SEMI 3D-17**

**4.3.1 AM System Setup (cont'd)**

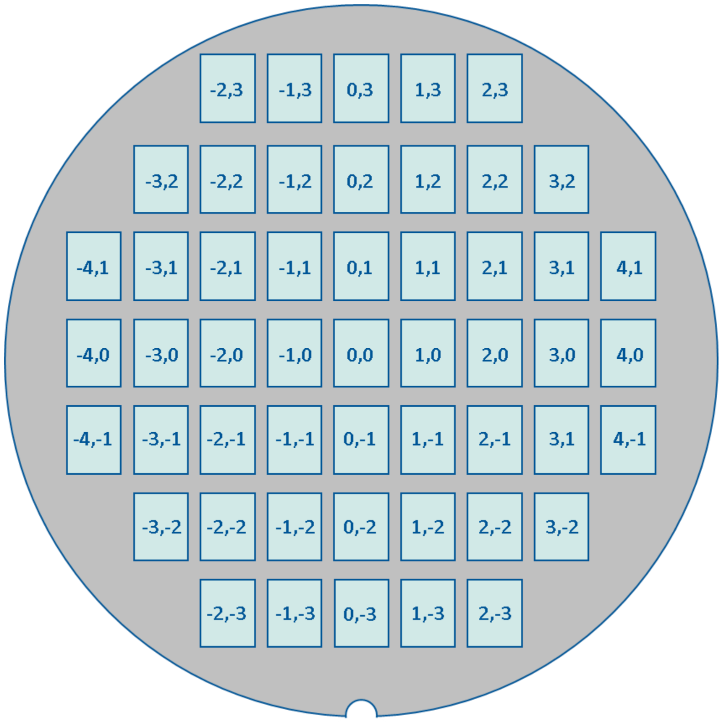



**Figure 11 — Example of a 300mm Diameter Reference Bonded Wafer Sample with the Die Numbering System and Layout for the Die-sized Arrays per SEMI 3D-17**

**Image Data -** The image/data analysis is limited to the examination of a single interface depth (gate setting) that is in focus.

**Parameters to be Documented:**

- **General Parameters -** The data recorded for each scan shall include:
  - The S/N or ID number of the reference device.
  - The date of the scan and the identity of the operator.
  - The manufacturer and model of the AM system used.
  - The version number of the operating software.
  - The temperature and type of coupling medium.
  - The data as requested in Appendix D.
- **Transducer Parameters -** The data recorded for the transducer used shall include:
  - S/N or ID number of the transducer
  - The manufacturer and model of the transducer
  - Focal length of the transducer
  - Center frequency of the transducer
  - F# of the transducer

## Annex A Acoustic Microscopy Check Sheet

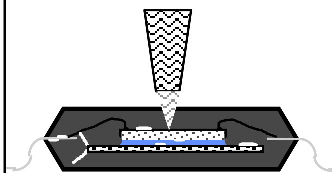
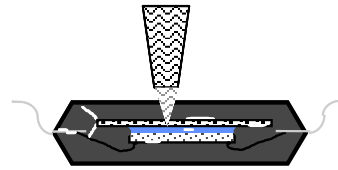
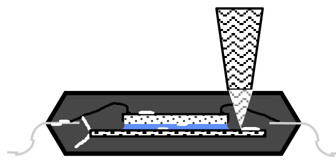
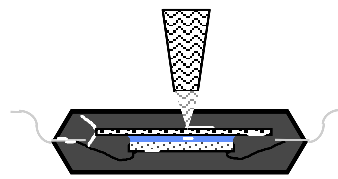
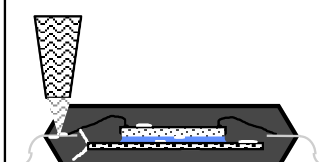
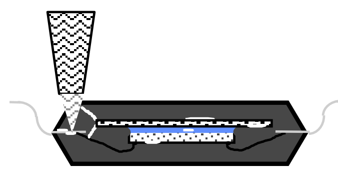
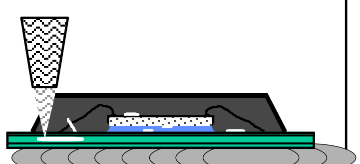
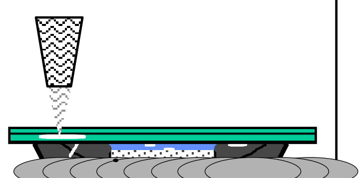
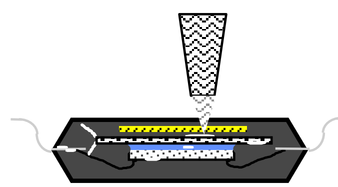
| | Circuit Side Scan | Non-Circuit Side Scan |
|---|---|---|
| Type I Delamination: Encapsulant/Die Surface |  | |
| Type II Delamination: Die Attach Region | |  |
| Type III Delamination: Encapsulant/Substrate (Die Side) |  | |
| Type IV Delamination: Substrate/Encapsulant (Backside) | |  |
| Type V Delamination: Encapsulant/Lead Interconnect |  |  |
| Type VI Delamination: Intra-Laminate (Laminate Substrates Only) |  |  |
| Type VII Delamination: Heat Sink/Substrate | |  |

**Figure 12 — Delamination Types from Circuit and Non-Circuit Side Scan**

**Annex A Acoustic Microscopy Check Sheet (cont'd)**

**CIRCUIT SIDE SCAN**

Image File Name/path:________________________________________________________

**Delamination**

(Type I) Die Circuit Surface/Encapsulant number affected: __________ Average. % ________
Location: ☐ Corner ☐ Edge ☐ Center

(Type II) Die/Die Attach number affected: ________ Average. % __________________
Location: ☐ Corner ☐ Edge ☐ Center

(Type III) Encapsulant/Substrate number affected: ________ Average. % _______________
Location: ☐ Corner ☐ Edge ☐ Center

(Type V)
Interconnect tip number affected:______________ Average % ______________________
Interconnect number affected: ______________ Max. % length ____________________

(Type VI) Intra-Laminate number affected: ________ Average. % _______________
Location: ☐ Corner ☐ Edge ☐ Center

Comments:

**Cracks**

Are cracks present: ☐ Yes ☐ No If yes:

Do any cracks intersect: ☐ bond wire ☐ ball bond ☐ wedge bond ☐ tab bump ☐ tab lead

Does crack extend from lead finger to any other internal feature: ☐ Yes ☐ No

Does crack extend more than two-thirds the distance from any internal feature to the external surface of the package: ☐ Yes ☐ No

Additional verification required: ☐ Yes ☐ No

Comments:

**Mold Compound Voids**

Are voids present: ☐ Yes ☐ No If yes:

Approx. size __________ Location _______________ (if multiple voids, use comment section)

Do any voids intersect: ☐ bond wire ☐ ball bond ☐ wedge bond ☐ tab bump ☐ tab lead

Additional verification required: ☐ Yes ☐ No

Comments:

**Annex A Acoustic Microscopy Check Sheet (cont'd)**

**NON-CIRCUIT SIDE SCAN**
Image File Name/path:______________________________________________________________
_____________________________________________________________________________

**Delamination**
(Type IV) Encapsulant/Substrate number affected: _______ Average. %________________
Location: ☐ Corner ☐ Edge ☐ Center

(Type II) Substrate/Die Attach number affected: ________ Average. % _________________
Location: ☐ Corner ☐ Edge ☐ Center

(Type V) Interconnect number affected: ____________ Max. % length ___________________

(Type VI) Intra-Laminate number affected: ________ Average. % _________________
Location: ☐ Corner ☐ Edge ☐ Center

(Type VII) Heat Spreader number affected: ________ Average. % ___________
Location: ☐ Corner ☐ Edge ☐ Center

Additional verification required: ☐ Yes ☐ No

Comments:
_____________________________________________________________________________

**Cracks**
Are cracks present: ☐ Yes ☐ No
If yes:
Does crack extend more than two-thirds the distance from any internal feature to the external surface of the package: ☐ Yes ☐ No
Additional verification required: ☐ Yes ☐ No

Comments:
_____________________________________________________________________________

**Mold Compound Voids**
Are voids present: ☐ Yes ☐ No
If yes:
Approx. size _________ Location ______________ (if multiple voids, use comment section)
Additional verification required: ☐ Yes ☐ No

Comments:
_____________________________________________________________________________

## Annex B Potential Image Pitfalls

| OBSERVATIONS | CAUSES/COMMENTS |
|---|---|
| Unexplained loss of front surface signal | Gain setting too low<br>Symbolization on package surface<br>Ejector pin knockouts<br>Pin 1 and other mold marks<br>Dust, air bubbles, fingerprints, residue<br>Scratches, scribe marks, pencil marks<br>Cambered package edge |
| Unexplained loss of subsurface signal | Gain setting too low<br>Transducer frequency too high<br>Acoustically absorbent (rubbery) filler<br>Large mold compound voids<br>Porosity/high concentration of small voids<br>Angled cracks in package<br>“Dark line boundary” (phase cancellation)<br>Burned molding compound (ESD/EOS damage) |
| False or spotty indication of delamination | Low acoustic impedance coating (polyimide, gel)<br>Focus error<br>Incorrect delamination gate setup<br>Multi-layer interference effects |
| False indication of adhesion | Gain set too high (saturation)<br>Incorrect delamination gate setup<br>Focus error<br>Overlap of front surface and subsurface echoes (transducer frequency too low)<br>Fluid filling delamination areas |
| Apparent voiding around die edge | Reflection from wire loops<br>Incorrect setting of void gate |
| Graded intensity | Die tilt or lead frame deformation<br>Device tilt |

## Annex C Some Limitations of Acoustic Microscopy

Acoustic microscopy is an analytical technique that provides a nondestructive method for examining encapsulated electronic devices for the existence of delaminations, cracks, and voids. This technique has limitations that include the following:

| LIMITATION | REASON |
|---|---|
| Acoustic microscopy has difficulty in finding small defects if the package is too thick. | The ultrasonic signal becomes more attenuated as a function of two factors: the depth into the package and the transducer frequency. The greater the depth, the greater the attenuation. Similarly, the higher the transducer frequency, the greater the attenuation as a function of depth. |
| There are limitations on the Z-axis (axial) resolution. | This is a function of the transducer frequency. The higher the transducer frequency, the better the resolution. However, the higher frequency signal becomes attenuated more quickly as a function of depth. |
| There are limitations on the X-Y (lateral) resolution. | The X-Y (lateral) resolution is a function of a number of different variables, including:<br>• Transducer characteristics, including frequency, element diameter, and focal length<br>• Absorption and scattering of acoustic waves as a function of the sample materials<br>• Electromechanical properties of the X-Y stage |
| Irregularly shaped packages and surfaces are difficult to analyze. | The technique generally requires some kind of flat reference surface. Typically, the upper surface of the package or the die surface can be used as reference. In some packages, cambered package edges can cause difficulty in analyzing defects near the edges and below their surfaces. Figure 13 and Figure 14 indicate how ultrasound approaches and reflects from example surfaces. |

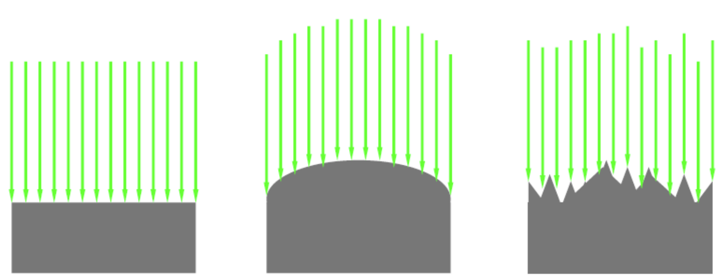
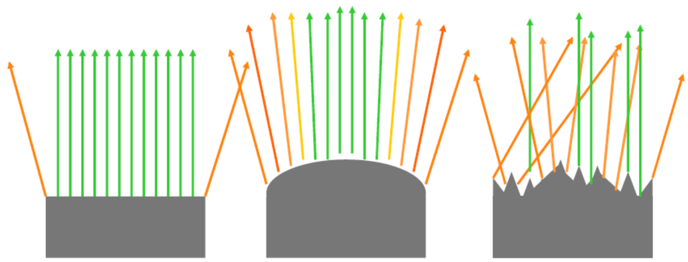


**Figure 13 — Ultrasound Waves Approaching Various Example Surfaces.**

**Annex C Some Limitations of Acoustic Microscopy (cont'd)**



NOTE As indicated, some ultrasound waves will not be received by the transducer.

**Figure 14 — Ultrasound Reflection from Various Example Surfaces**

**Edge Effects -** The edges cause difficulty in analyzing defects near the edge for any internal features. The typical return signal amplitude over edges and a sample surface is shown in Figure 15. How the edge effect is related to the depth of focus within a sample is shown in Figure 16.

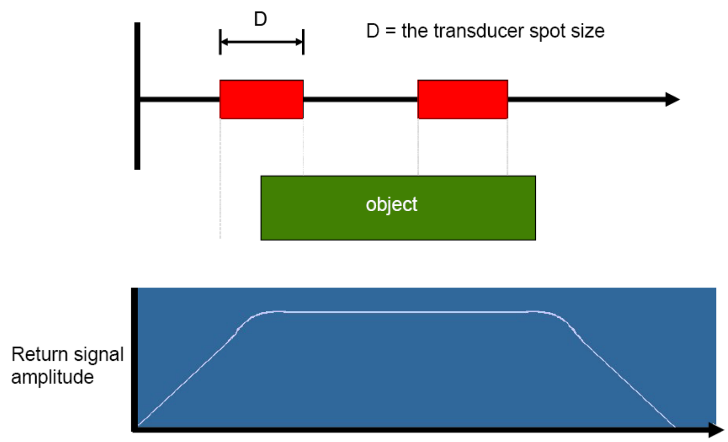



**Figure 15 — Edge Effect Causing Reduction in Returned Signal Amplitude Due to Edge.**

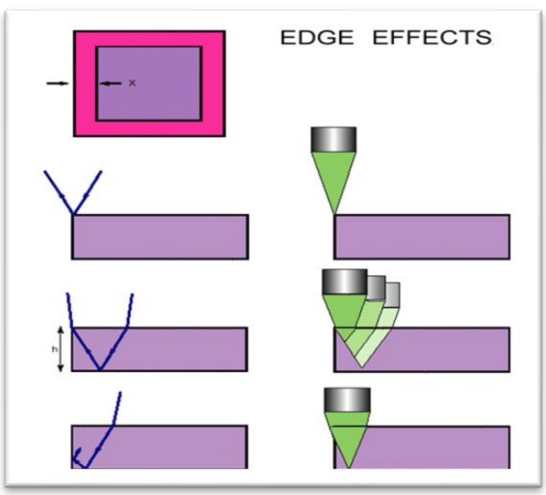



**Figure 16 — Edge Effect Due to Depth in a Sample.**

## Annex D Reference Procedure for Presenting Applicable Scanned Data

Most of the settings described may be captured as a default for a particular supplier/product with specific changes recorded on a device or lot basis.

**Setup Configuration** (Digital Setup File Name and Contents)

- Calibration Procedure and Calibration/Reference Standards used
- Transducer
  - Manufacturer
  - Model
  - Center Frequency
  - Serial Number
  - Element Diameter
  - Focal Length in Water
- Scan Setup
  - Scan area (X-Y dimensions)
  - Scan step size
    - Horizontal
    - Vertical
  - Displayed Resolution
    - Horizontal
    - Vertical
  - Scan speed
- Pulser/Receiver Settings
  - Gain
  - Bandwidth
  - Pulse
  - Energy
  - Repetition rate
  - Receiver attenuation
  - Damping
  - Filter
  - Echo amplitude
- Pulse Analyzer Settings
  - Front surface gate delay relative to trigger pulse
  - Subsurface gate (if used)
  - High pass filter
  - Detection threshold for positive oscillation, negative oscillation
  - A/D settings
  - Sampling rate
  - Offset setting

## Annex D Reference Procedure for Presenting Applicable Scanned Data (cont'd)

### Per Device Settings

Device Orientation (top or bottom (flipped) view and location of pin 1 or some other distinguishing characteristic)
Focus (point, depth, interface)
Reference Plane
Nonstandard parameter settings
Device identification information to uniquely distinguish it from others in the same group

### Reference Procedure for Presenting Scanned Data

Image file types and names
Gray scale and color image legend definitions
Significance of colors
Indications or definition of delamination
Image dimensions
Depth scale of TOF
Deviation from true aspect ratio
Image type: A-mode, B-mode, C-mode, TOF, Through Transmission

- A-mode waveforms shall be provided for points of interest, such as delaminated areas. In addition, an A-mode image shall be provided for a bonded area as a control.

## Standard Improvement Form IPC/JEDEC J-STD-035A

The purpose of this form is to provide the Technical Committees of JEDEC with input from the industry regarding usage of the subject standard. Individuals or companies are invited to submit comments to JEDEC. All comments will be collected and dispersed to the appropriate committee(s).

If you can provide input, please complete this form and return to:

JEDEC
Attn: Publications Department
3103 North 10th Street, Suite 240 S
Arlington, VA 22201

Fax: 703.907.7583

1. I recommend changes to the following:
   - [ ] Requirement, clause number ____________
   - [ ] Test method number ____________ Clause number ____________

   The referenced clause number has proven to be:
   - [ ] Unclear [ ] Too Rigid [ ] In Error
   - [ ] Other ____________________________________________

2. Recommendations for correction:

   ________________________________________________
   ________________________________________________
   ________________________________________________
   ________________________________________________

3. Other suggestions for document improvement:

   ________________________________________________
   ________________________________________________
   ________________________________________________
   ________________________________________________

Submitted by

Name: ____________________ Phone: ____________________

Company: ____________________ E-mail: ____________________

Address: ____________________

City/State/Zip: ____________________ Date: ____________________

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