

ENGINEERING PRACTICE STUDY

TITLE:

MIL-STD-883-2, TEST METHOD 2030

**"ACOUSTIC MICROSCOPY (ULTRASONIC) INSPECTION OF
DIE ATTACH, FLIP CHIP UNDERFILL, AND THERMAL INTERFACE MATERIALS"**

**PROPOSAL TO DEVELOP A DRAFT TO ADD ACOUSTIC MICROSCOPY (ULTRASONIC) INSPECTION
OF DIE ATTACH, FLIP CHIP UNDERFILL, AND THERMAL INTERFACE MATERIALS; STANDARDIZE
FORMAT, AND LANGUAGE USAGE FOR CLARITY AND CONSISTENCY**

JUNE 17, 2026

EP STUDY PROJECT NUMBER: 5962-2026-003

FINAL REPORT

**STUDY CONDUCTED BY DLA WEAPONS SUPPORT (COLUMBUS)
Document Standardization Division (VA)
Microelectronics Branch (VAS)**

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- I. OBJECTIVE: The purpose of this Engineering Practice (EP) Study is to obtain input/feedback from the military services, manufacturers, users, and other stakeholders concerning the current usage and potential improvements to MIL-STD-883-2 test method 2030, "Ultrasonic inspection of die attach"
- II. BACKGROUND: Defense Logistics Agency (DLA) Weapons Support (Columbus) published MIL-STD-883-2 test method 2009, on 12 January 2022 and have made minimal changes to the method to date. The intention is to ensure that this test method is keeping up with the current requirements of the other test methods in MIL-STD-883.
- III. RESULTS: The EP Study project was opened, and an initial draft was posted on the web and distributed on January 23, 2026 for review and comments. Inputs were solicited from all interested parties, including the military services, microcircuit manufacturers, original equipment manufacturers, and user communities concerning the test method.
- IV. CONCLUSIONS: Definitions of terms should be clarified throughout the method. The changes to the test method (see attachment 1) should be proposed for incorporation into the next standardization document change action to MIL-STD-883-2.
- V. RECOMMENDATIONS: The findings of this EP study are sufficient to support updating the method. Prepare an initial draft of MIL-STD-883-2 using the results of this study for the draft of test method 2032.

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ACOUSTIC MICROSCOPY (ULTRASONIC) INSPECTION OF
DIE ATTACH, FLIP CHIP UNDERFILL, AND THERMAL INTERFACE MATERIALS

1. PURPOSE:

The purpose of this document is to nondestructively detect unbonded regions, delaminations, cracks and/or voids in the die attach, flip chip underfill, or thermal interface materials and at interfaces within devices through the measurement of acoustic continuity. It establishes Acoustic Microscopy (AM)/Ultrasonic inspection methods to measure the contact area(s) and/or bulk material anomalies of devices with considerations for mechanical, thermal, and electrical properties. Certain criteria shall be considered on a historical basis.

For certain device structures or attach materials, a dramatic distinction between well-bonded and poorly bonded conditions may be difficult to achieve. This factor should be considered in relation to the design of each device when application of this test method is specified. As examples, devices with lids, heat sinks, intentional air gaps and/or hermetic may be accessible for AM inspection from only one side nondestructively, while devices that are encapsulated, bare die, and/or non-hermetic may be AM inspected from multiple sides and/or through it.

2. DEFINITIONS:

2.1 Acoustic Microscopy (AM) – Generic term used to describe various types of high frequency ultrasonic imaging utilizing 5 MHz or higher frequencies for typical microelectronic applications. Equipment that creates an image using ultrasound to view a specimen's surface or subsurface features, including defects and damage. Also see "Ultrasonic Inspection".

2.2 Bulk Material - The term "bulk material" as used in this test method refers to the entire thickness within a specific layer of material. For die attach, flip chip underfill and/or thermal interface material, the material by itself is considered a bulk material.

2.3 Crack - A separation within a bulk material. See also "Delamination."

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

2.5 Die Attach (DA) - The term "die attach interface" as used in this test method refers to the entire bulk area between the die and the substrate to which it is bonded. For die attach interfaces, this includes the interface between the die attach material and the die, the interface between the die attach material and the substrate, plus the die attach material itself.

2.6 Flip Chip (FC) – There are various types of flip chip structures, as indicated below, that include an underfill material to help support and bond the die to a substrate.

2.6.1 Flip Chip Microcircuits (Hermetically Sealed):

Devices or assemblies that have hermetically sealed metal or ceramic lids with Flip Chip mounted to substrate.

2.6.2 Flip Chip Microcircuits (Bare Die on Substrate):

Non-hermetic exposed backside Flip Chips mounted to substrates.

2.6.3 Flip Chip Microcircuits (with Lids):

Non-hermetic Flip Chip devices with lids designed for heat dissipation.

2.6.4 Flip Chip Microcircuits (Plastic Encapsulated):

Devices or assemblies that have non-hermetically sealed encapsulated Flip Chip.

2.7 Reflected - The term "reflected" as used in this test method refers to the change in direction of an ultrasound wave front at an interface between two different media so that the wave front returns via the medium from which it originated.

2.8 Reflection Mode - The term "reflection mode" as used in this test method refers to an ultrasonic scan or acoustic

microscope that uses one transducer as both the pulser and receiver. (This is also known as a pulse/echo system.)

2.9 Thermal Interface Material (TIM)– Is typically a solder or polymer material used to act as a thermal path. A common use is heat dissipation, in which the TIM is inserted between a heat-producing device (e.g., an integrated circuit) and a heat-dissipating device (e.g., a heat sink).

2.10 Transmitted - The term “transmitted” as used in this test method refers to the propagation of an ultrasound wave through a media or an interface between media that allows it to continue through the structure.

2.11 Transmission Mode - The term “transmission mode” as used in this test method refers to an ultrasonic scan or an acoustic microscope that transmits ultrasound completely through the sample from a sending transducer to a receiver on the opposite side.

2.12 Ultrasonic Inspection - The term “ultrasonic inspection” as used in this test method refers to high frequency ultrasonic visualization (imaging), which produces a gray or color scale output such as may be provided by ultrasonic scanning (US) or acoustic microscope (AM) techniques. The most common mode utilized for die attach, flip chip, thermal interface material inspection is an X-Y plane scan at specified depth(s) in Z, which is commonly referred to as C-Scan or C-mode imaging. Other ultrasonic techniques may also be utilized to obtain the die attach (DA), flip chip (FC), and/or thermal interface material (TIM) integrity data.

2.13 Void – A cavity (absence of material) within a bulk material.

3. APPARATUS:

The apparatus and materials for this test shall include:

3.1 AM/Ultrasonic Inspection Equipment:

The ultrasonic inspection equipment shall have a test/transducer design sufficient to penetrate to the die attach, FC and/or TIM material and interface(s). If a device to be inspected is non-hermetic, a sealed hermetic that can be opened to allow access or inspectable prior to hermetic, the ultrasonic equipment shall be capable of detecting an acoustic signal that transmits through the device structure (Transmission Mode) or enters the top and/or bottom or back of a package and is reflected by the desired bulk material or interface(s) of interest (Reflection Mode). In the case that the opening of a sealed hermetic or non-hermetic device with a known air cavity is undesirable, the ultrasonic equipment shall be capable of detecting an acoustic signal that enters the top and/or bottom or back of a package and is reflected by the desired bulk material or interface(s) of interest (Reflection Mode). The test/transducer design shall be capable of measuring a delamination, void, or anomaly of 1% of the region of interest (ROI) area being evaluated at minimum, but this may not be feasible in all cases due to the construction of the device. In such cases, the test/transducer design shall be chosen to ensure penetration down to the desired material interface with the achievable resolution being a secondary consideration. It is desirable to have the AM system resolution to be at least 2x better than the feature/defect size desired to be observed reliably and repeatably. A gage R&R study should be done when feasible. There is a tradeoff between the time to collect data and the size of the mechanical step/transducer resolution, so this should be considered when deciding upon the resolution used for imaging a specific device.

3.2 Output Method:

The output provided shall be used to produce an image for analysis (manual or automated). The dynamic range of the output image shall be at least 256 discernible colors or levels of gray scale. The appropriate gray/color scale shall be included in each image. The image, hard copy or digital, shall be large enough to achieve a resolution capable of measuring a minimum delamination, void, or anomaly of 1% of the region of interest (ROI) area being evaluated, or the best feasible resolution for the inspection application.

3.3 Holding tank:

A holding tank for containing the coupling fluid and locating fixtures (as needed) to ensure accurate and repeatable placement of the devices inspected. The holding tank, locating fixtures and any auxiliary supporting hardware shall be constructed of materials that will be unaffected by corrosion or other reactivity in the presence of the coupling fluid.

3.4 Coupling Fluid:

Commonly DI water is used as a coupling fluid between the ultrasonic transducer and the part being inspected, but other fluids may be utilized as needed. In all cases the fluid coupling shall be kept clean or changed on a regular basis to prevent contamination of the devices being inspected.

4. PROCEDURE:

The ultrasonic inspection instrument shall be selected or adjusted as necessary to obtain satisfactory images and achieve maximum image details within the sensitivity requirements for the device or defect features the test is directed toward. In the case of reflection mode or transmission mode images, care must be exercised to ensure that the ultrasound penetrates and is sensitive to the entire die attach, FC and/or TIM interface or bulk material area of interest.

4.1 Mounting and handling:

The devices shall be mounted in the holding tank so that the devices are not damaged or contaminated and are in the proper plane for inspection. The devices may be mounted in any type of fixture providing the fixtures do not block the view from the ultrasonic transducer to any portion of the body of the device in the region of interest. The coupling fluid in the holding tank shall be DI water or other suitable noncorrosive liquid. The devices shall remain in the coupling fluid for as short a time as possible. After the ultrasound inspection, proper cleaning and drying of the samples are required. Refer to IPC J-STD-033 for the recommended bake out times and procedures to remove any ingressed moisture within a non-hermetic surface mount device (SMD).

4.2 Views:

All devices shall have at least one image view made with the ultrasound penetrating the device in a direction perpendicular to the plane of the material interfaces, and for which there is acoustic continuity from the device exterior surface to the die attach, FC and/or TIM interface or bulk material area of interest. Generally, the Z-axis direction with the die attach, FC and/or TIM parallel to the X-Y plane. For devices with no sealed air gap above the die (unlidded or non-hermetic devices), an image view made with the ultrasound directed from (reflected) or through (transmitted) the surface of the die, FC and/or TIM interface or bulk material to the material interface(s) may be specified (see Figure 2030-2 for examples).

4.3 Recording image data and marking:

The ultrasonic image shall be stored in a digital file format by the equipment or printed using paper and with at least a resolution of 300 data elements per inch nominal. The image shall be identified by unambiguously marking the paper on which the image is printed or stored within the digital file format with, but not limited to the following information:

- 4.3.1 Device manufacturer's name or code identification number.
- 4.3.2 Device type or part number.
- 4.3.3 Production lot number or date code or inspection lot number.
- 4.3.4 Ultrasonic image view number and date.
- 4.3.5 Device serial or cross reference numbers, where applicable.
- 4.3.6 Ultrasonic laboratory identification, if other than device manufacturer.
- 4.3.7 Mounting material family type utilized for the die attachment (DA), flip chip (FC) and/or thermal interface material (TIM), if known.

4.4 Recording with nonprint techniques:

The use of documentation techniques, other than paper recording techniques is preferred (e.g., digital data files) provided that the equipment can store results of at least equal quality when compared to printed recording techniques, and all requirements specified herein, except those pertaining to the actual paper recording. If possible, the digital file name should incorporate a unique device identifier, such as a serial number, as part of the file name.

4.5 Serialized devices:

When device serialization is required, each device shall be readily identified by a serial number.

4.6 Set up verification:

4.6.1 Lidded Device(s):

When imaging lidded (sealed) devices, one open lid device of the same type and construction should be available to help set up the equipment. The device may be a scrapped, nonoperational device or a known set up sample with known voids which will be used to identify internal landmarks and ensure the equipment is properly operating. If an open lid device is not available, knowledge of the internal structure and layout will help confirm the AM images are at the correct depth and area.

4.6.2 Plastic Encapsulated Device(s):

When imaging plastic encapsulated devices, also known as PEMs (Plastic Encapsulated Microelectronics), while it is also ideal to have a device of the same type and construction with known defects at the level of interest to help set up, it is not likely practical. Therefore, having knowledge of the internal structure and layout will help confirm the AM images are at the correct depth and area.

4.6.3 Device(s) utilizing Thermal Interface Material (TIM):

When imaging thermal interface material (TIM), the interface of interest is the lid (heatsink) to TIM to confirm proper contact for heat transfer. Knowledge of the lid thickness and/or areas where TIM should be in contact will help confirm the AM images are at the correct depth and area.

4.6.4 Bare Die Device(s):

When imaging die attach or underfill under a bare die, the interface of interest is the die to die attach or underfill interface to confirm proper bonding. Knowledge of the die thickness and type of material in contact will help confirm the AM images are at the correct depth and area.

4.7 AM/Ultrasonic Imaging Equipment Settings:

Transducer frequency, gate width, receiver amplification/attenuation, and other equipment settings shall be selected to achieve the resolution desired for the type of inspection being accomplished and documented. The equipment/transducer design shall be capable of measuring a delamination, void, or anomaly of 1% of the region of interest (ROI) area being evaluated at minimum, but this may not be feasible in all cases due to the construction of the device. In such cases, the equipment/transducer design shall be chosen to ensure penetration down to the desired material interface with the achievable resolution being a secondary consideration. Optimize the ultrasonic signal reflected from the material level or interface of interest and distinguish image features with as great a contrast as possible. AM/Ultrasonic images shall be made for each view, interface, and/or depth required.

4.8 Operating Personnel:

Personnel who will perform AM/ultrasonic inspection shall have training in ultrasonic imaging procedures and techniques so that defects revealed by this method can be validly interpreted and compared with applicable standards.

4.8.1 Specific Personnel Training:

The following requirements shall be met to qualify personnel.

4.8.1.1 Level 1 (Typically Operator):

Trained by the supplier or subject matter expert to operate the system.

4.8.2 Proficiency of Personnel:

To establish the proficiency of personnel for AM/Ultrasound testing the combination of written procedures, inspection setting/parameter selections, and inspection data collection and reporting should be evaluated. Some guidance for this can be provided in J-STD-035 for PEMs and AS6171/6 for general AM inspection of EEE Parts.

4.9 Interpretation of AM/Ultrasonic Images:

AM/Ultrasonic images shall be inspected to determine that each device conforms to this standard and any defective device shall be rejected. Interpretation of the image shall be made under moderate light level conditions without a glare on the display monitor or the recording paper's surface. The image shall be viewed at a magnification to capture the expected feature and/or defect to determine acceptance as specified herein. Automated percentage void or bond area calculations can be utilized instead of visual analysis upon confirming that the automated method is at least equal to the accuracy of the visual method (see Figure 2030-3 for example of an automated method).

4.9.1 Die Attach (DA) examination and acceptance criteria:

In the examination of devices, the following aspects shall be considered unacceptable die attach interface, and devices that exhibit any of the following defects shall be rejected. If heat transfer is a concern, defects directly under the "hot" regions of the attach interface may be an issue and should be evaluated further with thermal assessment or reliability testing.

4.9.1.1 Voids and Unbonded Areas of Hermetic Devices:

When imaging devices ultrasonically, certain types of mounting material may not give true representation of voids; therefore, the mounting material shall be noted on the inspection report, when known.

1. Total of voids in excess of 50 percent of the total intended interface region (see Figure 2030-4).
2. A single void in excess of 15 percent of the total intended interface region (see Figure 2030-4).
3. A single corner void in excess of 10 percent of the total intended interface region (see Figure 2030-4).
4. When the interface region of interest is divided into four equal quadrants by bisecting both pairs of opposite edges, any quadrant exhibiting interface region voids in excess of 70 percent of the intended interface quadrant region (see Figure 2030-4).
5. In case of dispute, the percent of voiding shall be determined by actual measurement from the digital image using percentage void and bond image analysis functions with at least two threshold levels, i.e., B&W.

4.9.1.2 Voids and Unbonded Areas of Plastic Encapsulated Devices and PEMs:

It shall be noted if the devices are power or non-power for evaluation. Defect criteria are typically more critical for power devices than other devices with respect to their performance and reliability as indicated in Table 1 below.

Die Attach Critical Function	Delamination Criteria: Power Applications <i>For devices that require thermal and/or electrical contact to the backside of the die (e.g., such as power MOSFET, IGBT and diodes)</i>	Delamination Criteria: Other applications
Thermal conductivity	The acceptable delamination % change requirements for thermal die attach used in power applications should be determined between device suppliers and users as a function of potential thermal coupling efficiency loss.	No delamination/cracking > 50% of the die attach area
Electrical continuity	The acceptable delamination % change requirements for electrically conductive die attach used in power applications be determined between device suppliers and users as a function of potential electrical characteristic degradation (e.g., increase of RdsON).	No delamination/cracking > 50% of the die attach area

Table 1: Void and Nonbond Criteria for Plastic Encapsulated and PEMs

4.9.2 Flip Chip (FC) examination and acceptance criteria:

The level of acceptable voiding, delamination, or cracking within the underfill or between the underfill and substrate or die within flip chip devices is dependent on end-use reliability. In some highly critical cases, lower percent voiding may be required. Two adjacent solder bumps that have a connected void may bridge during subsequent thermal processing. In critical applications, the customer may request that the supplier perform a full review of the impact of shorting between adjacent non-common solder bumps. Additional requirements for voiding may be needed as a result of this review.

4.9.2.1 All the following acceptance criteria apply:

1. Maximum 1% total allowable voiding/missing underfill material under the entire Flip Chip die area, unless otherwise specified.
2. No delamination between the underfill and device surface or substrate allowed
3. Underfill must surround all of the peripheral solder joints (0% voiding on device perimeter) (See Figure 2030-1 below), unless otherwise specified.

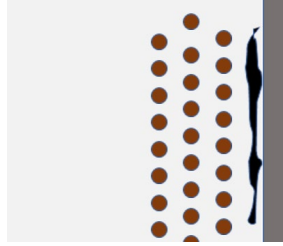


Figure 2030-1: Void (black) in underfill at perimeter of the solder joints and edge of die

4. No evidence of chip-outs, cracks, or damage to the device or substrate, such as those caused by the dispensing process, unless otherwise specified.
5. No evidence of solder splash on substrate side of Flip Chip device
6. No voiding in the underfill bridging between two (2) solder bumps
7. No die cracks
8. No die metal stack delamination or cracking (within the metal stack of the die itself)

4.9.3 Thermal Interface Material (TIM) examination and acceptance criteria:

The level of acceptable voiding, delamination, or cracking within the TIM or between the TIM and heat sink or die for packages with TIM is dependent on end-use requirements. The non-interfacial contact area (bulk material) within the heat path, void, delamination, and cracking limits should be determined by modeling of the thermal and thermal-mechanical properties of the device and there may be localized hot spots of higher concern. The specific limits shall be provided by the requestor of this TM to the testing facility.

5 REPORTS OF RECORDS:

5.1 Reports of inspection:

When specified by the Requestor, the manufacturer or laboratory shall furnish inspection reports with each shipment of devices. The report shall describe the results of the ultrasonic inspection, and list the purchase order number or equivalent identification, the part number, the date code, the quantity inspected, the quantity rejected, and the date of test. For each rejected device, the part number, the serial number when applicable, and the cause for rejection shall be listed. Additional information should include, but not limited to, how was the devices were inspected, setup parameters, and/or criteria used for accept/reject.

5.2 Ultrasonic image and report retention:

When specified by contract, the manufacturer or laboratory shall retain a set of the ultrasonic images and a copy of the inspection report. These shall be retained for the period specified by the procuring activity in the acquisition document.

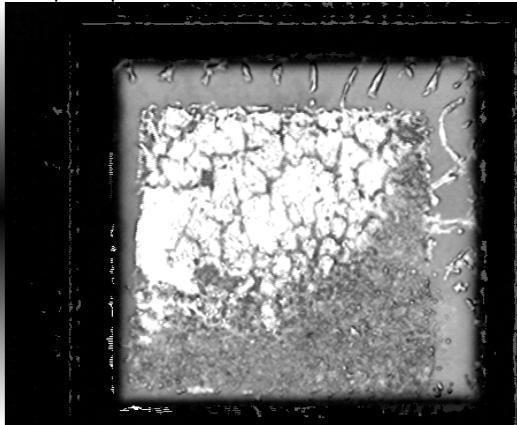
6 SUMMARY:

The following details shall be specified in the applicable acquisition document:

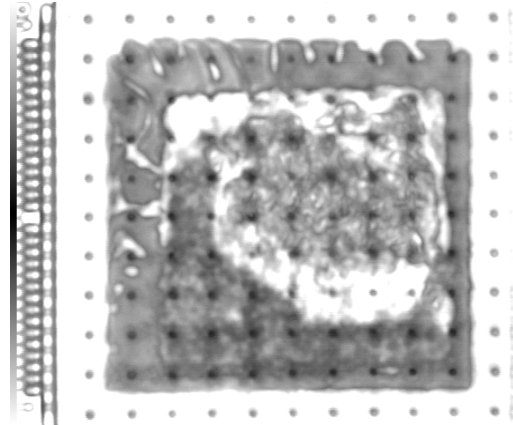
- 6.1 Number of views, if other than indicated in 4.2.
- 6.2 Image marking, if other than indicated in 4.3 or marking of samples to indicate they have been ultrasonically imaged, if required.
- 6.3 Defects to be sought in the samples and criteria for acceptance or rejection, if other than indicated in 4.9.

6.4 Image and report retention per 5.0.

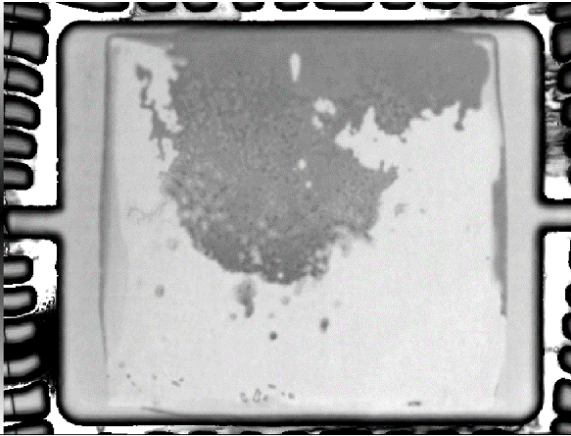
Test reports per 5.0.



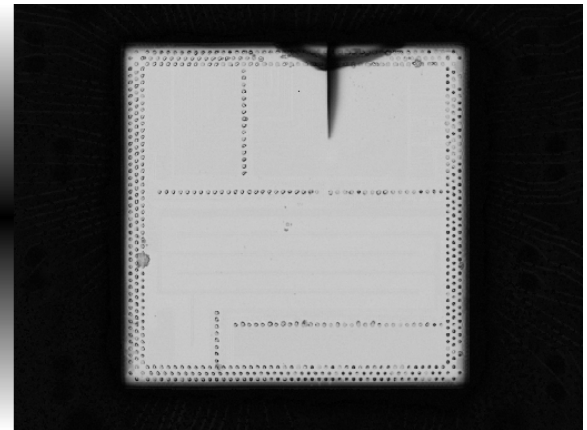
Example 2030-2a: Unlidded device reflection mode image through the die to die attach interface.



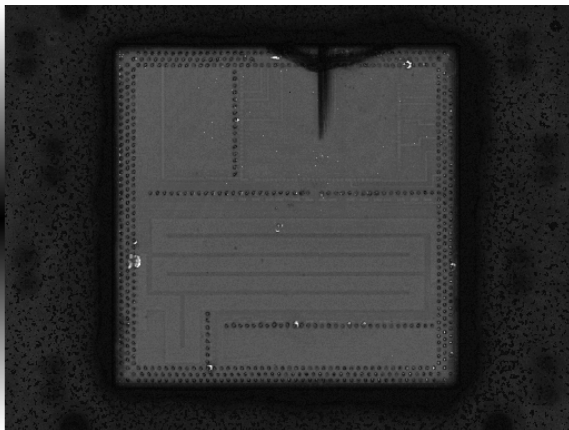
Example 2030-2b: Unlidded device reflection mode image through substrate side to die attach interface.



Example 2030-2c: Non-hermetic device reflection mode image through substrate side to die attach interface (see Figure 2030-2 for example automated method analysis).



Example 2030-2d: Bare die Flip Chip device reflection mode image through chip to the underfill interface.



Example 2030-2e: Bare die Flip Chip device reflection mode image through chip to the bulk underfill material.



Example 2030-2f: Lid to TIM reflection mode image through lid to the thermal interface material.

FIGURE 2030-2. Example Reflection Mode Grayscale Images of Die Attach, Flip Chip and TIM Interfaces.

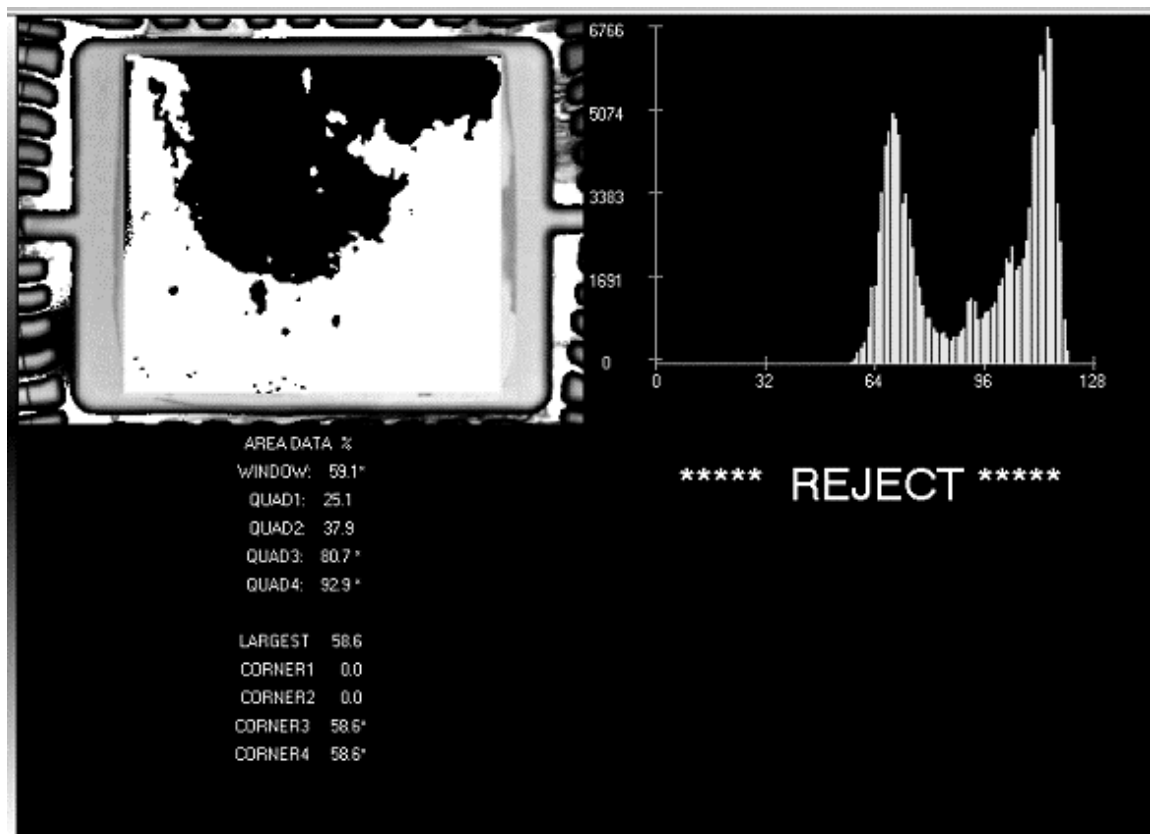


FIGURE 2030-3. Example Automated Method Analysis Report for Die Attach Interface.

Typical Transmission Mode Image Analysis
(Two threshold levels – B&W)



Reject: Single void larger than 15 percent (%) of total intended interface.
Reject: Corner void larger than 10 percent (%) of total intended interface.

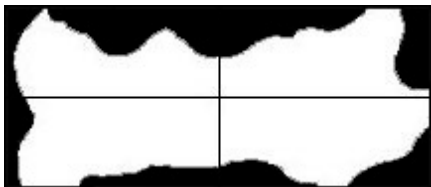
Typical Reflection Mode Image Analysis
(Two threshold levels – B&W)



Accept: No single void larger than 15 percent (%) of total intended interface.
Accept: Corner void of area less than 10 percent (%) of total intended interface.



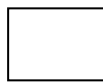
Reject: Quadrant more than 70 percent (%) unbonded.



Accept: All quadrants less than 70 percent (%) unbonded.



= Void or Unbonded area



= Void or Unbonded area

FIGURE 2030-4. Void criteria for die attach material interface inspection.