Quality Assurance for Multichip Modules with AMI Techniques

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Abstract

The complex nature of Multichip Modules requires specialized quality assurance techniques and proper planning to minimize the losses during fabrication. Guidelines for the use of Acoustic Micro Imaging (AMI) techniques for the analysis of various sub-assemblies and assemblies throughout the fabrication process are discussed.

Specific areas of concern during the fabrication of Multichip Modules include, but are not limited too; substrate integrity, attachment of substrates into hermetic containers, multi-layer substrate metallization continuity, IC attachment to substrates directly or indirectly, IC interconnections (TAB or Flip Chip (C4 & BGA) types), evaluation of passive components, overmolding and hermetic seal analysis. Some actual examples of AM images from past experiences are provided for these areas of discussion.

Related standards from IPC, ANSI, ASTM and the Military are provided where applicable. These standards outline the evaluation criteria and the procedures for the use of AMI techniques such as SLAM (Scanning Laser Acoustic Microscopy) and C-SAM (C-Mode Scanning Acoustic Microscopy) for the various sub-assemblies and assemblies.

Background

Many people are still not aware of the capabilities of AMI technologies. For practical purposes, the review of AMI techniques will be limited to the capabilities best suited to the examination of Multichip Modules. Additional information on AMI techniques can be obtained through the references.

The two major AMI technologies are SLAM and C-SAM. Each of these technologies has several useful features for Multichip Module Quality Assurance (QA) analysis. The SLAM is basically a real-time through transmission acoustic imaging system analagous to the through transmission of x-ray. However, SLAM is sensitive to material continuity and the bonding between materials, whereas x-ray only detects density variations. As indicted in Figure 1, acoustic energy (ultrasound) is introduced into the sample from one side of the sample and received on the opposite side by a scanning laser detector. Internal flaws are viewed with SLAM throughout the entire thickness of the sample.

The SLAM can also produce interferograms, which display speed of sound variations through the sample. This feature is especially useful for characterizing the basic materials used. The SLAM's scanning laser detection system can also be used to produce laser scanned optical images or to induce current in a die to check for "dead" or cracked regions with the SLIC (Scanning Laser Induced Current) Mode. This is also refered to as OBIC (Optical Beam Induced Current).

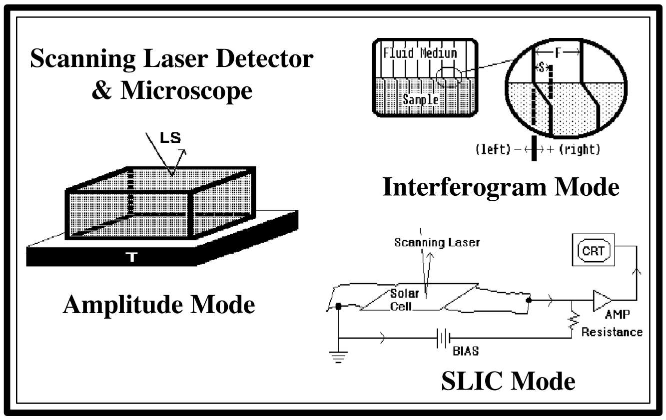


Figure 1: Block diagrams for SLAM Modes

The C-SAM is a reflection mode acoustic imaging system. As indicated in Figure 2, a pulse of acoustic energy is sent into the sample and then the returned echoes at each point are examined. It is basically a complete AMI tool for the analysis of samples since it can provide images at bond interfaces (C-Mode), non-destructive cross sectional views (Q-BAM™), through transmission images (THRU-Scan™), bulk material analysis and can be programmed to obtain the images of multichip module components or PC boardson an automated basis (UltraBoard™).

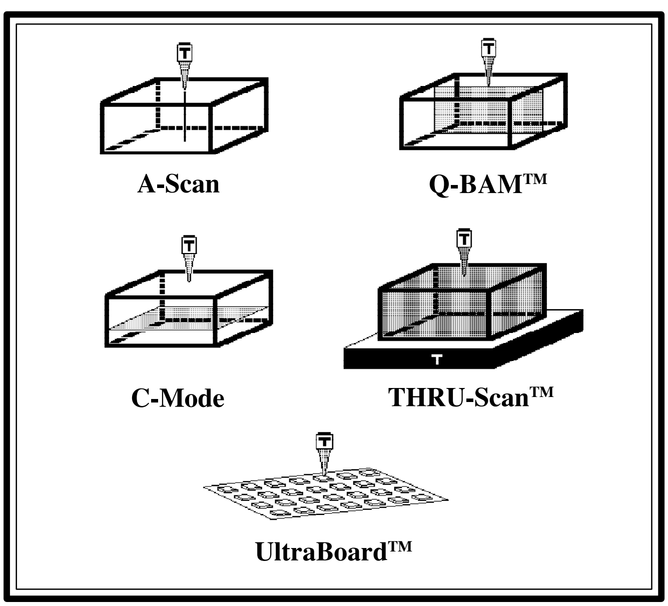


Figure 2: Block diagrams of C-SAM Modes.

Basics of Multichip Module (MCM); Quality Assurance (QA)

Through various standards organizations, military and commercial, there are guidelines published for the manufacture and utilization of MCM technologies. While it is true that new developments are being made on a daily basis, most of the basic requirements for MCM quality assurance are covered by the following standards:

IPC-MC-790, Guidelines for Multichip Module Technology Utilization [3]

IPC-SM-784, Guidelines for Chip-on-Board Technology Implementation [4]

SMC-TR-001, An Introduction to Tape Automated Bonding and Fine Pitch Technology [5]

MIL-STD-883, Method 2030, Ultrasonic Inspection of Die Attach [6]

MIL-STD-883, Method Proposed, Ultrasonic Inspection of TAB Bonds [7]

ASTM Proposal, Standard Test Methods for Non-Destructive Test of Tape Automated Bonding (TAB) Interconnections [8]

Other guidelines for quality assurance can be obtained from related technologies for surface mount (SMT), hybrids and ceramic packages such as;

IPC-D-279, Reliability Design Guidelines for Surface Mount Technology Printed Board Assemblies [9]

ANSI/IPC-A-610A, Acceptability of Electronic Assemblies [10]

SEMI Document #2044C - Specification, Cofired Ceramic Packages [11]

SEMI Document #1576D - Specification, Cerquad Package Construction [12]

When deciding when and where QA procedures should be enacted in the manufacturing process of MCMs there are several factors that need to be considered . The most obvious and probably the most important is cost. How much does the sub-assembly cost early in the manufacture cycle and how much will be lost if bad devices or components are not detected until completion of the module.

Substrates; Single and Multi-layer

There are various types of substrate materials and configurations that can be utilized for MCM constructions. The following are some of the more common substrates;

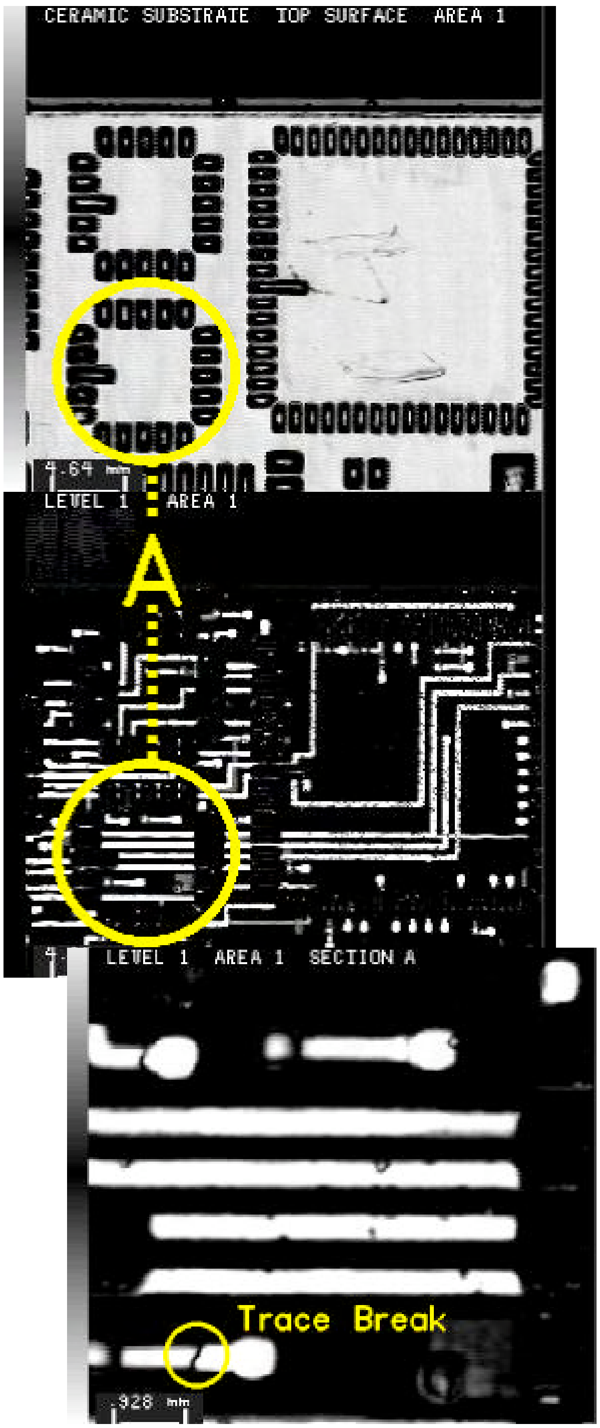
MCM-C - Ceramic substrates of either single or multilayer construction and usually using Alumina (Al_2O_3) or Beryllia (BeO) materials.

MCM-D - Deposited, unreinforced dielectric materials on underlying substrates of ceramic, silicon, copper or other metal/metal composites. The actual substrate material utilized will depend on performance requirements, such as high-frequency (Si), or size and strength (metal composites).

MCM-L - Laminated substrates with either a single or multiple conductive/laminate layers and usually using reinforced or unreinforced polymer materials such as epoxies and polyimides.

Each of the substrates has its unique capabilities and limitations. On a QA basis the biggest concerns are the proper bonding of the laminates or multiple layers and the continuity of the conductive traces or pads. An example of a trace discontinuity is provided in Figures 3 through 5.

In addition, brittle substrate materials such as ceramics and silicon should be checked for physical defects, such as cracks or voids, that could cause failure in the long term. Typical defects include cracks extending from holes or vias, punched or drilled, that will grow due to thermal cycling. Partial chipouts in a trace or pad area that may become completely dislodged due to shock, vibration or thermal cycling should also be considered a reliability problem.



Figures 3 through 5: MCM-C type substrate examined with C-SAM at the surface (upper left), at the first layer interface (lower left), and zoomed within the area outlined with the circle (lower right). Notice the broken trace marked in the lower right zoomed image.

Die Attach

Most MCM constructions utilize solder, eutectic or silver/glass die attach materials. Conductive or non-conductive epoxies may also be used for MCMs that will not see elevated temperatures. In any case, all of these die attach materials are relied upon for their thermal transfer and adhesive or mechanical strength properties. AM methods are very sensitive to voids, cracks and delaminations within the die attach material no matter which type is utilized.

In Figure 6 below the attachment of a Gallium Arsenide (GaAs) die to a ceramic substrate is examined for proper bonding. The white regions within the die attach indicate regions of poor attachment. The lower die is very poorly attached in comparison to the upper die.

Through MIL-STD-883, Method 2030, guidelines have been provided for die attach acceptance or rejection based on strength requirements. Based on that standard, the upper die attach in Figure 6 would be acceptable and the lower die attach would not be acceptable. The diagram in Figure 7 outlines the military guidelines.

Even if the die attachment does meet the strength requirements the thermal requirements should also be considered. If a void , crack or delamination in the die attach material is located under a "hot" location in the die the long term reliability of the MCM should be evaluated. Some work has been done in this area by Yerman, see reference 13.

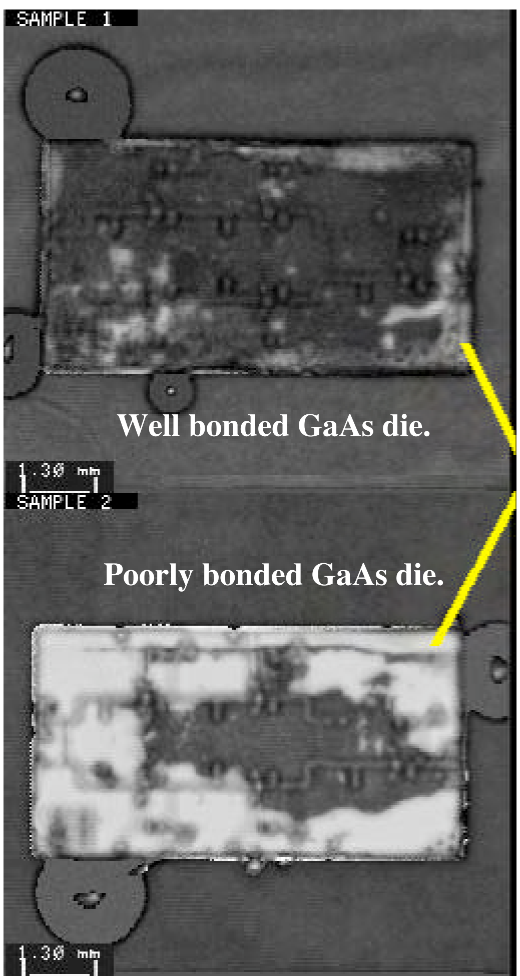


Figure 6: GaAs die attach to MCM-C substrates.

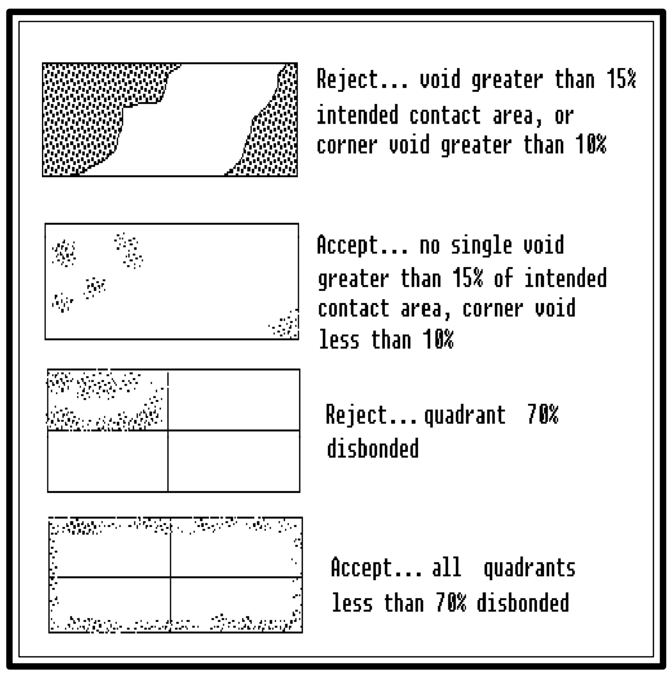


Figure 7: MIL-STD-883, Method 2030; Ultrasonic Inspection of Die Attach Guidelines.

Die Interconnections

One of the most common defects associated with MCMs is poor interconnects. Several forms of interconnect types are commonly used for MCMs. They consist of wire bonds, TAB (Tape Automated Bonds), Flip Chip (C4 or BGA) or some variation of one of these standard interconnect techniques.

Interconnects may be "bad" do to poor attachment techniques that cause "cold" solder joints, the improper amount of bond area, electrical shorts, the misalignment and/or the up-lift of leads.

TAB ILBs and OLBs are easily inspectable with SLAM or C-SAM type systems. Typically the ILBs are inspected with SLAM at 200 or 100 MHz, while OLBs are inspected with C-SAM at 100 to 50 MHz, depending on their size. Figure 8 provides an example of OLBs examined with C-SAM at 50 MHz.

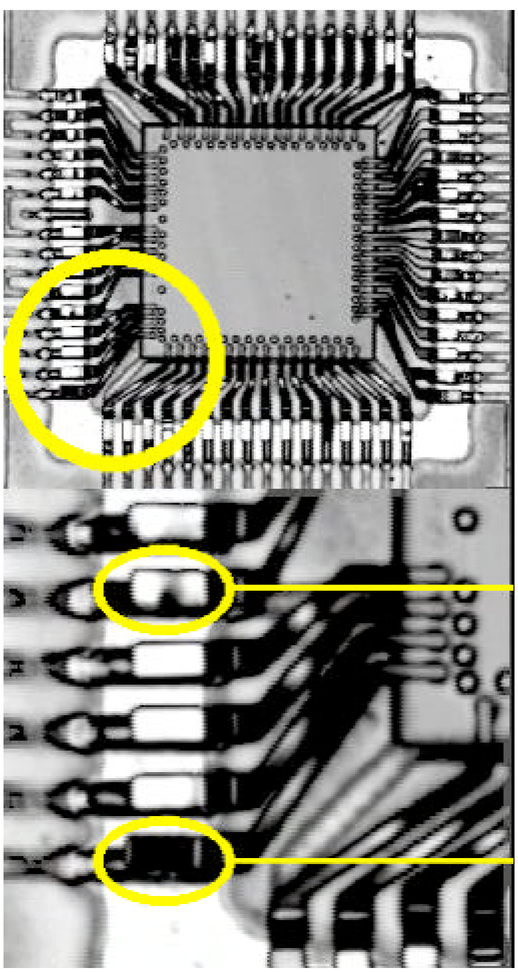


Figure 8: TAB OLBs with overall view and enlarged region showing good, partial, and bad bonds.

While some of these defects can be observed visually, such as misalignment, up-lifting and shorts for wire bond or TAB type interconnections, none can be observed visually for Flip Chip type bonds unless they are at the very edge of a die. However even the visual inspection of the bonds at the edge can be obscured by other components or devices.

An example of examining Flip Chip devices for proper bonding of the BGA (Ball grid array) solder joints is provided below. Notice that all the joints along the edge are well formed and bonded. However, several of the joints near the center of the device have voids or are completely absent as indicated.

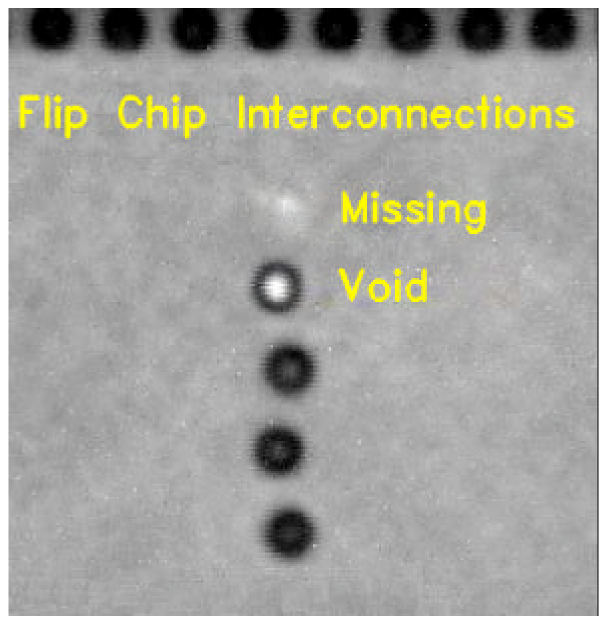


Figure 9: Flip Chip solder joint bond evaluation.

Assuming that all the BGA, C4, or Flip Chip type bonds are perfectly formed and bonded there is another problem. The strength of the interconnections may not be adequate for long term reliability. Epoxy back fill may be utilized to help anchor the die to the substrate. However, the capillary action of the epoxy between the die and the substrate is not always perfect, causing voids to occur.

It is easy to evaluate the quality of the epoxy back fill with AM techniques. By using the same

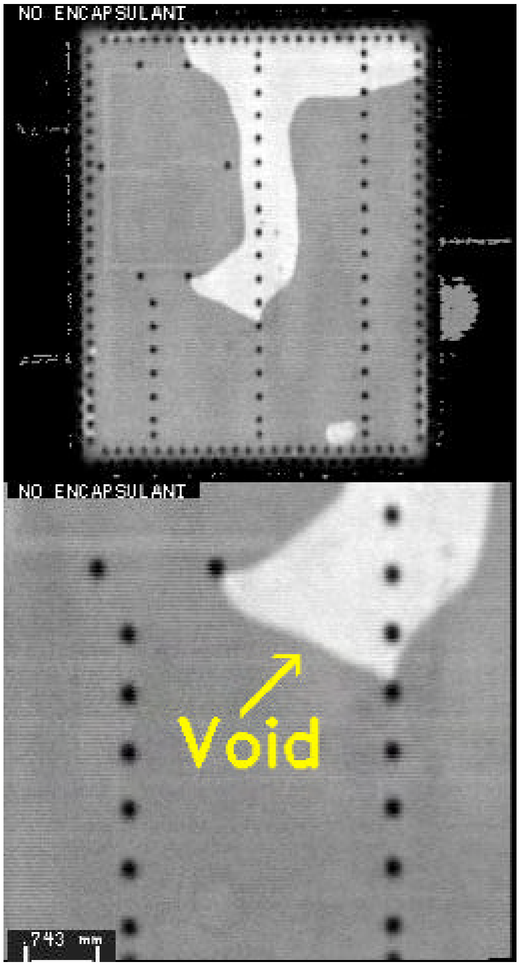


Figure 10: Flip Chip attachment with epoxy back fill for stability. Note the large void with the epoxy material, as indicated.

test parameters utilized for the interconnection analysis the percentage or the quality of the back fill can also be determined. As shown in Figures 10 & 11, the interconnections and the back fill can be observed. The amount of back fill voiding allowed will need to determined based on the environment of use and the location of the voids.

AM techniques are also applicable to the analysis of wedge type wire bonds. From the AMI point of view wedge type wire bonds are somewhat similar to TAB interconnections, due to their flat bond surface. The graph provided in Figure 12 indicates the relationship between the area of bond to actual pull strength data for several TAB bond systems. Similar relationships for wedge type wire bonds can also be developed for the various metallurgical configurations.

The analysis of ball type wire bonds is not usually a good application for AM techniques due to the geometry of the joint. The spherical shape of the ball joint reflects most of the acoustic wave energy away from the interface of interest and away from the receiving transducer.

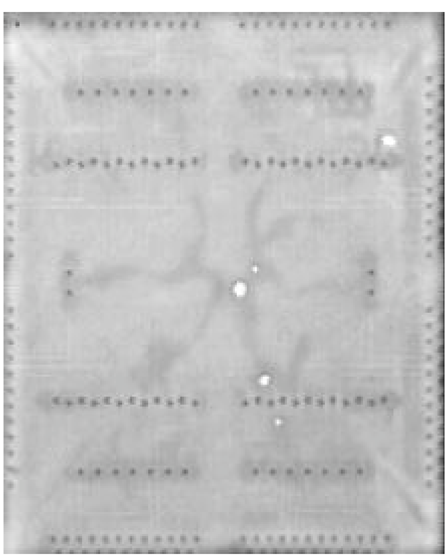


Figure 11: Flip Chip with epoxy back fill and a minimal amount of voiding, as indicated by the white regions.

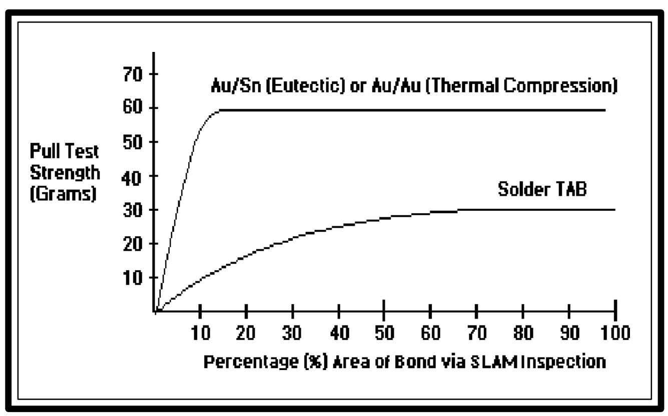


Figure 12: Relationship of AM bond area vs. bond pull strength for various TAB interconnection metallurgy.

Hermetic/Protective Seal Integrity

Normally the final step in the process of a MCM structure is to provide a protective or hermetic seal for the assembly.

Since some of the MCM-L type assemblies are very similar to COB (Chip-on-Board) in construction a form of "glop top" or encapsulation is sometimes utilized to protect the mounted die. Depending on the type of encapsulation, AMI techniques can be used to evaluate the adhesion of the encapsulant to the die, the analysis of the die attach, the interconnection quality and/or the epoxy back fill. Figure 13 shows a set of C-SAM images of a Flip Chip type device that has been protected by an epoxy encapsulant.

The selection of the AMI technique or frequency will depend on the surface contour of the encapsulant and its loading of filler materials.

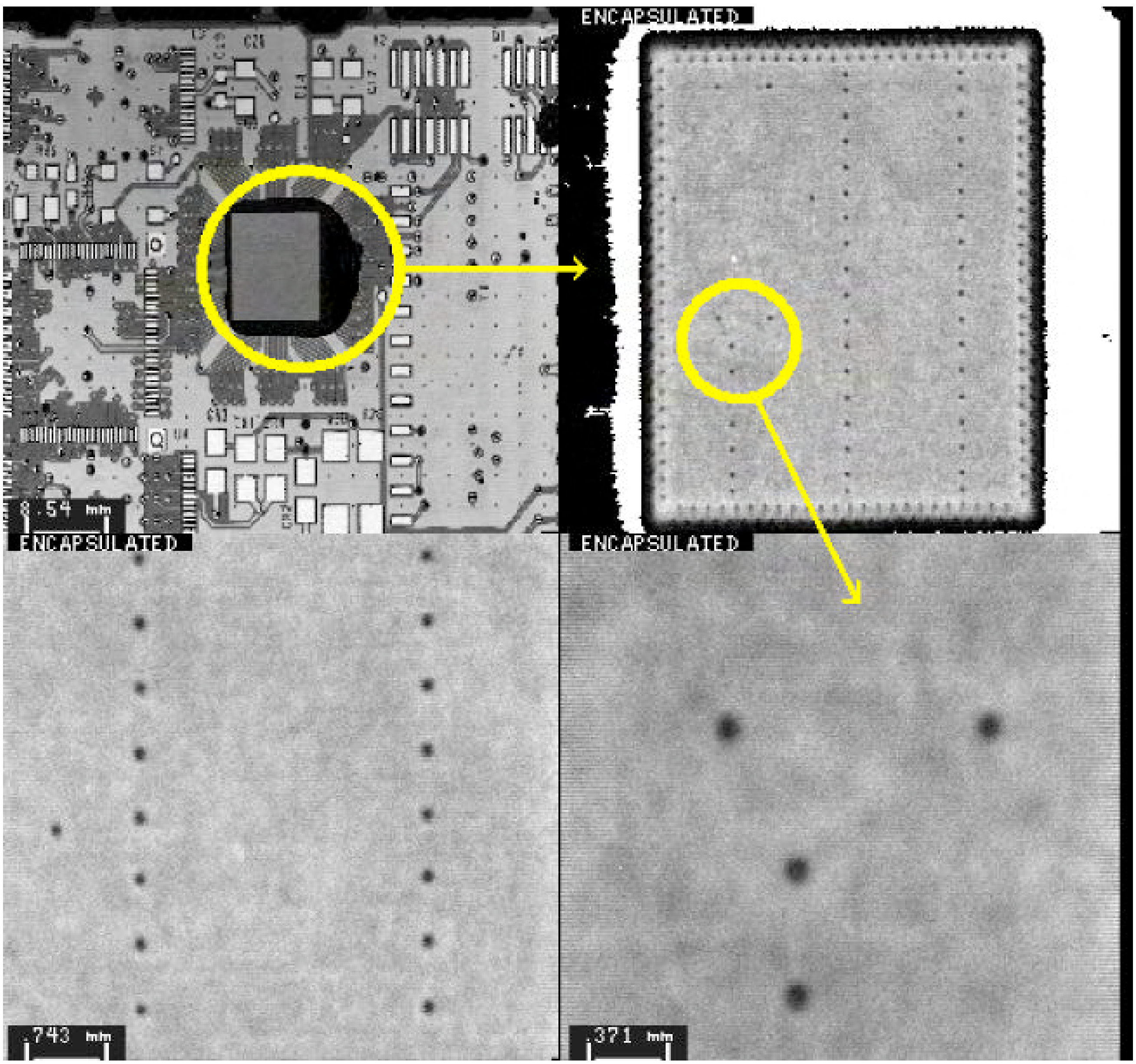
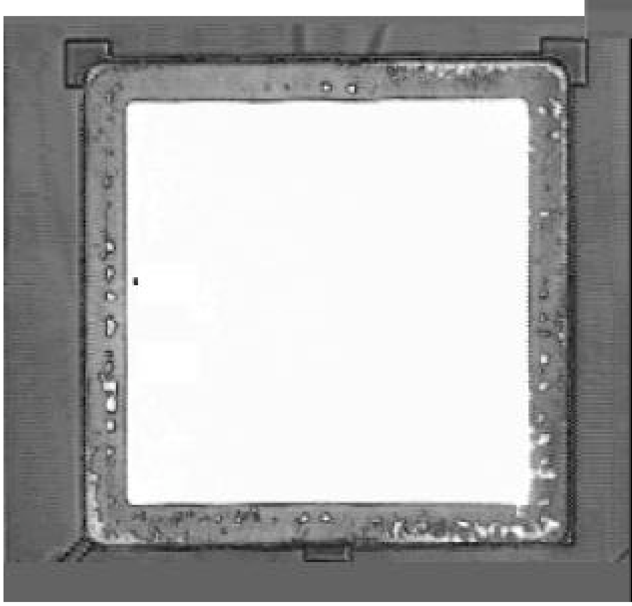


Figure 13: A set of AM images of a MCM-L with a protective encapsulate over the die. The upper left show an overall view of the assembly. The upper right, lower left and lower right show a progression of zoom scans in the region of the Flip Chip attached die. Everything appears well bonded.

The surface contour will greatly affect the image quality if it has a tight spherical shape to it due to the reflection of the acoustic waves. If the surface is parallel to the surface of the die the image quality will be greatly enhanced. In addition an AMI technique called main bang (MB) triggering can also be useful in compensating for surface roughness. MB triggering allows the system to scan an interface if the surface roughness affects the first interface echo (FIE) triggering.

Many types of MCM assemblies are protected by a hermetic package, usually a metallic can type structure with a brazed or soldered lid. The assurance of a proper seal is a critical factor for a harsh environment and long term reliability.

While there are standard hermeticity and leak tests, the use of AMI techniques can provide immediate feedback on the quality of the lid brazing or soldering process. Figures 14 & 15 show two (2) solder lid seals. It is quite noticeable that both seals contain a significant number of voids and delaminations. However, only in one case does the void break through. AMI is useful for measuring the safety margin of the seal area.



Figures 14 & 15: Kovar lids soldered to ceramic packages. Notice the voids, white regions, within the solder seal areas of both packages. The circle indicates the location of a seal leak.

Passive Components

When evaluating the quality of MCM assemblies it is important to not overlook the less expensive and passive components that may be incorporated into them. Components such as ceramic chip capacitors and chip resistors can contain defects as manufactured or can sustain damage during handling or mounting processes.

Figure 16 shows a sampling of six (6) ceramic chip capacitors. Three (3) of them contain defects. The only defect that can be observed visually is the chipout, which is the least detrimental of the defects observed with AMI techniques. The other two (2) contain internal delaminations.

As previously mentioned, additional defects can be caused by improper handling, such as the placement of the components with excessive force, or due to the thermal shock of the components during the mounting process. Figure 17 provides an example of surface mounted capacitors with delaminations and cracks.

Since the cost of passive components is usually minimal in comparison to the MCM assembly itself it is generally wise to "screen out" any defective components before mounting.

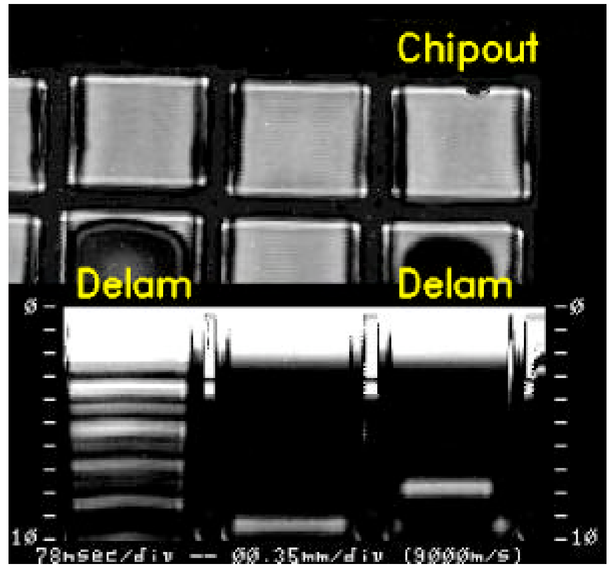


Figure 16: Unmounted ceramic chip capacitors with three (3) "good", one (1) chipout defect and two (2) delaminated components. The top half of the image is a C-Mode type of image and the bottom half is a Q-BAM™ type of image showing the depth of the delaminations within the components.

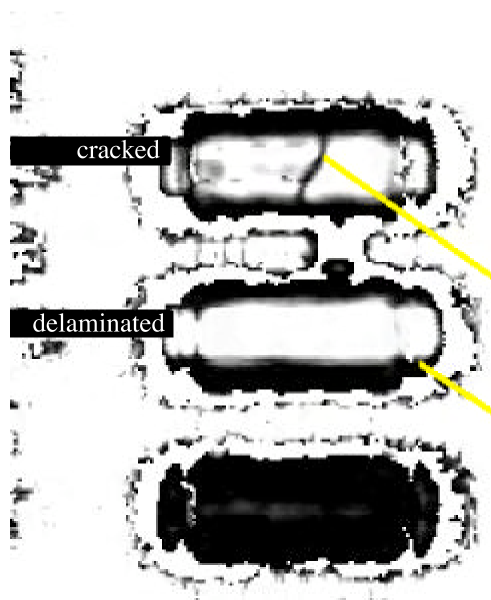


Figure 17: Three (3) surface mounted capacitors. A cracked, delaminated and good capacitor as indicated in the AM image.

Summary

The table in Figure 18 provides a summary of the recommended AMI techniques, frequencies and other additional comments for the various sub-assemblies and assemblies associated with MCMs. Since the development of MCMs is a continuing process the table includes information on the "state-of-the-art" as of today. As MCMs develop the technologies of AMI techniques will also.

References

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MCM Sub-Assembly	AMI Technique Recommended	Inspection Frequency Recommended (MHz)	Comments
Substrates Ceramic & Deposited Laminated	 SLAM or C-SAM SLAM or C-SAM	 50 to 200 5 to 50	Single layers and higher density materials allow higher frequency use.
Die Attach Eutectic, Solder, Epoxy or Silver/glass	 SLAM if open cavity C-SAM if open or not	 24 to 100 open 50 to 100 not open	Open cavities allow direct access to all die attach types at high frequencies.
Die Interconnections TAB ILBs TAB OLBs Flip Chip (C4 & BGA)	 SLAM SLAM(C or D), C-SAM all C-SAM	 100 to 200 50 to 100 50 to 100	Check ILBs before bonding to substrate when possible. Check pattern of observed Flip Chip bonds vs. design.
Seals Hermetic Encapsulation	 SLAM or C-SAM SLAM or C-SAM	 30 to 100 10 to 50	Best results obtained when focusing through the lid to the seal depth.
Passive Components (Chip Capacitors & Resistors) Unmounted Mounted	 SLAM or C-SAM C-SAM	 50 to 200 50 to 100	Screen all components before mounting to remove defective or damaged parts if at all possible.

Figure 18: Summary table for MCM sub-assembly QA analysis.