Detecting Die Surface Delamination

The defects unique to PEMs can create problems in high-reliability applications, and die surface delamination is one of the most serious. AMI is one of the tools that can assure the user that the PEMs being used are free from such defects.

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In the recent push to use commercial electronics in high-reliability applications, one of the most important considerations has been the applicability of plastic encapsulated microcircuits (PEMs). Reduced weight and cost, higher pin counts,and newer technology integrated circuits (which depend on high pin counts) have combined to make PEMs a desirable commodity in the military and spaceflight worlds.

PEMs, however, have their own set of reliability issues and these have been well documented. Many of these issues are moisture or contamination related, and many are related to delamination within the package. “Delamination” in this case usually refers to a lack of adhesion, or an adhesion failure, between the epoxy molding compound (EMC) and the internal circuit elements. It can also refer to failure of the die attach, the epoxy connecting the silicon die to the leadframe assembly.

Delamination inside the PEM varies in its impact on reliability, depending on the location of the delamination and the final application for the PEM. For example, delamination of a surface-breaking feature might increase the moisture sensitivity of the part; on the other hand, a fully enclosed delamination may not be a concern at all.

Of these delamination issues, a critically important one is delamination of the EMC along the silicon die surface. This interface is critical for two reasons. Delamination allows movement of the die and EMC relative to each other, placing shear stresses on the die surface and on the wirebonds. This can result in mechanical damage to the die surface and wirebonds. It also allows moisture to collect at the die surface, and the resulting bond pad corrosion can cause open circuit failures.

Specification	Relevant paragraph
J-STD-020A Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices	8.2.1(a) No measurable delamination change on the top surface of the die
MIL-STD-1580B Destructive Physical Analysis for Electronic, Electromagnetic, and Electromechanical parts (in working group as of this writing)	16.5.1.3.2(e) Any measurable amount of delamination between plastic and die
Plastic Encapsulated Microcircuit (PEM) Guidelines for Screening and Qualification for Space Applications (NASA Draft, 1997)	7.3.2(5) Any measurable amount of delamination between plastic and die

Table 1

Specifications and their approaches to classifying die surface delamination.

How Die Surface Delamination Causes Failures

When the EMC/die surface interface is delaminated, differences in the thermal coefficient of expansion (TCE) allow movement of the EMC and die relative to each other. The resulting shear stresses can deform metalization traces, and crack polysilicon traces and underlying oxides. The shear stresses are particularly strong at the corners and the die periphery, where the wirebonds are located. This can cause lifted bonds (Figure 1) and can even crack the silicon under the bonds (Figure 2). The latter effect is often mistakenly attributed to a bonder setup problem.

These conditions can manifest themselves as extremely intermittent electrical failures. They can be temperature-sensitive, or even sensitive to touch. Furthermore, they generally become more pronounced with more temperature excursions. These factors combine to make the problem difficult to detect electrically, and often this type of problem

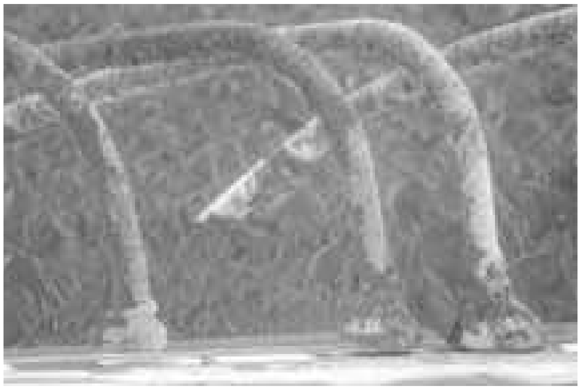

Figure 1

Scanning electron micrograph, showing lifted ball bonds as a result of die surface delamination.

first manifests itself in the field.

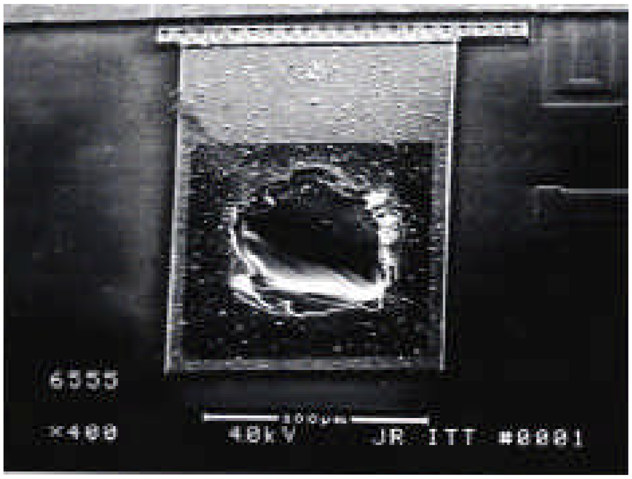

Figure 2

Scanning electron micrograph, showing silicon chipout ("crater") caused by delamination, where the ball bond was formerly located. Such damage is also caused by wire bonder setup problems, so acoustic micro imaging (AMI) becomes very important in distinguishing between the two.

Potential Causes of Die Surface Delamination

There are a number of potential factors influencing die surface delamination.

- Moisture ingress into the bulk EMC can cause delamination. In extreme cases, soldering moisture-laden packages can cause catastrophic failure by cracking the package ("popcorning").
- Surface cleanliness is also a factor. It has been reported that even fractions of a monolayer of adsorbed contamination can interfere with die surface adhesion. Recent studies have pointed to silicone contamination on the die surface as a cause of delamination. One source for this is the adhesive tape used to hold the wafer during backside grinding. Any organic contamination can prevent the adhesion promoters within the EMC from properly bonding to the die surface.
- Poor material selection can cause adhesion problems. For example, a given die passivation and EMC combination may be incompatible with good EMC/die adhesion.

Industry Views on Die Surface Delamination

The concern over this defect has been reflected both in specifications and in current literature (Table 1). Consider IPC/JEDEC J-STD-020, which deals with moisture sensitivity classifications for PEMs. Any change in die surface adhesion results in the part failing that classification level. The military specification for destructive physical analysis, MIL-STD-1580, is in the process of being revised (at this writing, a meeting is scheduled to discuss Revision B). In that revision, delamination on the die surface is cause for rejection of the part.

Another draft document is NASA's "Plastic Encapsulated Microcircuit (PEM) Guidelines for Screening and Qualification for Space Applications". This specification also rejects for any die surface delamination.

The risks associated with delamination make it important to be able to detect it.

Concern over this issue has also been reflected in the current literature. A recent paper by an industry leader stated that even the smallest delamination, tens of Angstroms, can cause problems, and that "intimate adhesion" at this interface is essential.

Detecting Die Surface Delamination With AMI

The risks associated with delamination make it important to be able to detect it. One way to detect it, of course, is through electrical failures. This is not very desirable, especially since many times the failures occur in the field—the most expensive place for a failure to occur. In cases of gross package cracking or "popcorning" (Figure 3), high resolution x-ray imaging can sometimes detect the delamination when the failure is so severe that a large gap exists between the molding compound and the die.

The only way to reliably and nondestructively detect delamination in PEMs is by acoustic micro imaging, or AMI. AMI works by alternately producing and receiving pulses of ultrasonic energy, typically from 10 to 200 MHz. Since ultrasound will not transmit through air, the energy is carried to the sample by a coupling medium, usually deionized

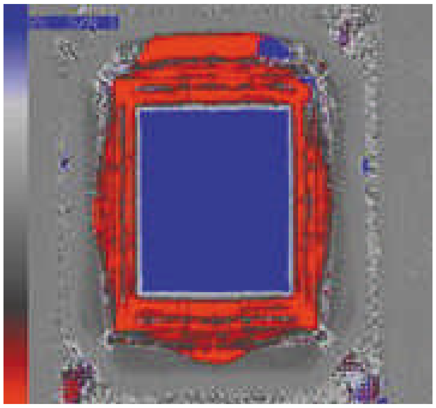

Figure 3

Acoustic image of a ball grid array with "popcorn" damage. The red area is massive cracking and delamination of the plastic due to the explosive release of moisture during soldering.

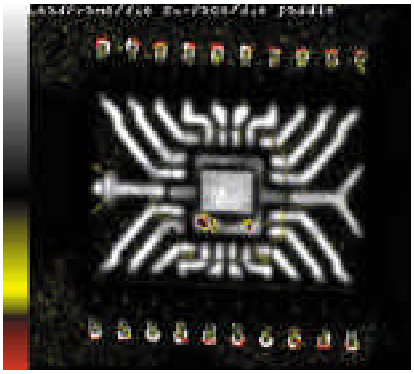

Figure 4

Acoustic image of a typical microcircuit. Note the die in the center, the die paddle, and leadframe elements. Red on the die paddle indicates small delaminations. Die surface is well-bonded.

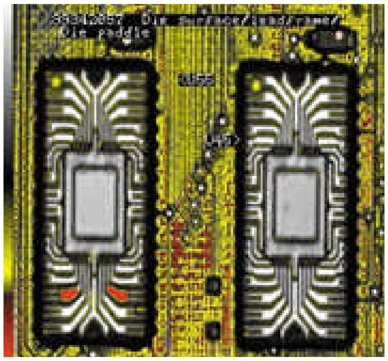

Figure 5

Acoustic image of microcircuits still on a circuit board. Red on the leadframe indicates delamination. Die surfaces are good.

water. A focused spot of ultrasound is generated by an acoustic lens and can be focused at subsurface levels within the sample.

The ultrasound interacts within the solid, and the echoes reflected can be analyzed for information about the sample. Each interface within the PEM will generally reflect some ultrasound and transmit some ultrasound. By studying the echoes produced as the transducer is scanned over the sample, an image can be produced (Figure 4).

Since air does not transmit ultrasound, any voids, cracks, delaminations, or other "air-filled" disbonds will show extremely high contrast, because the air reflects all of the energy (Figure 5). As a result, AMI excels at detecting this type of defect, which is generally invisible to other nondestructive imaging techniques. With the ability to focus at specific levels, information about the depth and size of the defect can be obtained.

Applying AMI to Die Surface Delamination

Figure 6 shows a typical case of die surface delamination. If this part were, for example, the same date code as parts used in fielded material, then a number of questions present themselves. Is the problem confined to one date code? Where in the process is the delamination occurring, or are parts delaminated as-received? What is the risk to the fielded material? Will the delamination "grow" as the part is exercised or subjected to thermal cycles? What is the likelihood of a delaminated part actually failing electrically? Can the problem be eliminated with better handling (keeping parts dry)?

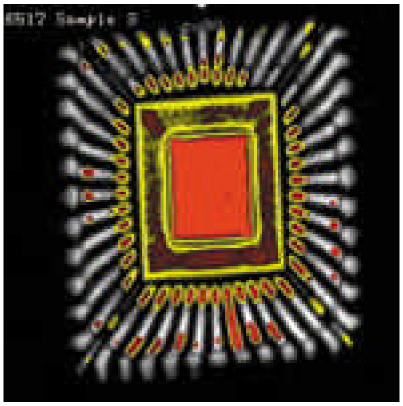

Figure 6

Acoustic image of a plastic quad flat pack (PQFP). Numerous areas are delaminated (red), but note especially the die surface is completely delaminated (red square in center).

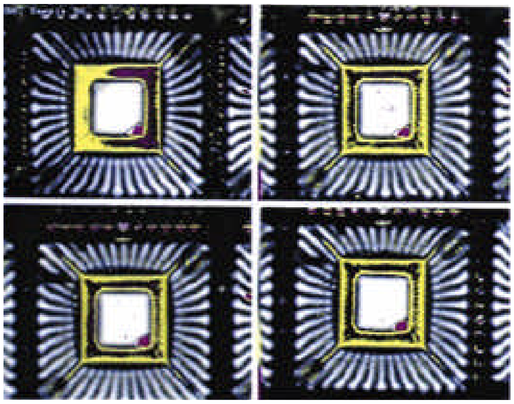

Figure 7

Acoustic image of a plastic leaded chip carrier (PLCC), scanned at four different points in the process. Note the small delamination at the lower right hand corner of the die surface, which remains unchanged during the various process steps.

Because AMI is a nondestructive test, it is ideally suited to answering such questions. For example, Figure 7 shows a part imaged—initially with AMI and then after several environmental tests—to determine if the die surface delamination was stable (its stability will depend on the actual root cause of the delamination). In addition, a large number of parts can be evaluated quickly, so the percentage of parts affected can be determined and extrapolated to those in the field. Furthermore, parts that have been imaged can continue to be stressed and tested to evaluate what the probability of electrical failure is for a given test profile.

The part in Figure 7 represents a large experiment in which AMI played a notable part. As an example,the following conclusions were gleaned from that experiment:

- The die surface delamination was date code related.
- The delamination occurred at the supplier.
- In many cases,the initial delamination would grow dramatically during solder reflow, then remain stable until the units were fielded. Others were stable even during reflow.
- AMI of a part any time after reflow would give a good indication of its appearance in the field.

Another key role that AMI plays is in failure analysis. For example, if the analyst uncovers a condition as shown in Figure 1, immediate questions arise because of the difficulty of "opening" PEMs (which is accomplished by chemical or plasma means). Was this an artifact of the chemical process? Was it due to contamination on the die that was washed away by the opening process?

In such a case the AMI data is essential. For example,if AMI determined that the die surface was delaminated before the failure analysis was performed, the analyst can use that data along with the electrical data and be assured that this condition is directly failure-related and not an artifact. In the case of poor ball bond quality, die surface delamination would give a clear picture that widespread die contamination was interfering with the bond formation. In the case of chipouts under the ball bonds (refer back to Figure 2), die surface delamination detected by AMI proves it was not a bonder setup issue. This type of information is lost if the failure analysis proceeds without AMI.

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