SCANNING ACOUSTIC MICROSCOPY: TEST FLOW AND PROCEDURES FOR THE ASSESSMENT OF DELAMINATION FLAWS

Francisco Javier Aparicio Rebollo, David Ramírez-Cruzado Monge; Jose Cándido Vázquez, Dimas Morilla Mairen, Manuel Domínguez Álvarez, Antonio Rodríguez Arenas
INTRODUCTION

Main Issues in Plastic Encapsulated Systems

Plastic Encapsulated COTS offers:

- Lower procurement cost
- Shorter procurement time
- More performance and functionality available
- Reduced size and weight

Inherent risk of PEMs are related to:

- Lack of hermeticity
- The mismatch with the thermomechanical properties of the inorganic internal part

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INTRODUCTION

Main Issues in Plastic Encapsulated Systems

Definitions

**Delamination:** Lack of adhesion at the interface between **different materials**; typically between the moulding compound and an internal inorganic part.

**Crack:** Fracture in the bulk or on the surface of a given material, either the moulding compound or internal inorganic parts (for instance the die surface).

**Void:** Lack of material within the bulk for instance within the die attach or in the moulding compound due to improper injection.
INTRODUCTION
Main Issues in Plastic Encapsulated Systems

- Delamination on a surface breaking part
- Delamination on the die/paddle surface
- Cracks/void from the external surface to an internal feature
- Popcorn cracking
- Delamination on the die surface
- Cracks/void intersecting a bond wire
- Lack of adhesion or voids in the die attach
- Metallic corrosion
- Contamination and moisture ingress and accumulation
- Shear induced damage of the die passivation
  - Metal smearing (metallic tracks)
  - Bond wire degradation due to shear
  - Poor thermal dissipation

Lack of hermeticity
CTE Mismatch

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INTRODUCTION

Why Scanning acoustic Microscopy (SAM)?

Ultrasound waves are extremely sensitive to density changes

The best non destructive approach for detection of air flaws in low density materials

Sequential confocal inspection

Detailed phase inversion analyses provide additional delamination contrast

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INTRODUCTION

Test methods

- **ESCC 25200** Application of Scanning Acoustic Microscopy to Plastic Encapsulated Devices
- **PEM-INST-001** Instructions for Plastic Encapsulated Microcircuit (PEM) Selection, Screening, and Qualification
- **J-STD-020E** Moisture/Reflow Sensitivity Classification for Nonhermetic Surface Mount Devices
- **MIL-STD-883** Test Method 2030 Ultrasonic Inspection of Die Attach
- **MIL-STD-1580** Paragraph 16.5.1.3 Acoustic Microscopy
Although powerful, SAM is a complex inspection technique **AND**

- The different used specifications apply **dissimilar rejection criteria**
- Due to the high sensitivity to air flaws, on occasions the impact of the observed deviations has to be assessed by **additional test/s**
- Verification procedures are **not well specified** in all the cases

**INTRODUCTION**

Delaminations found at the front side of the die, at the paddle area, at embedded films, or at the bonding area may have an impact on the reliability of the parts. If there is a significant relation to known failure mode (e.g. open circuit to delaminations in the bonding areas) the appearance of the delamination shall be observed as rejection criteria.

6.2 Criteria Requiring Further Evaluation  
Delamination is not necessarily a cause for rejection. To evaluate the impact of delamination on device reliability, the semiconductor manufacturer may either meet the delamination requirements shown in 6.2.1 or perform reliability assessment using JESD22-A113 and JESD47 or the semiconductor manufacturer’s in-house procedures. The reliability assessment may consist of stress testing, historical generic data analysis, etc. Annex A shows the logic flow diagram for the implementation of these criteria.

The following aspects shall be considered as reliability concerns and additional testing and screening of the lot might be necessary:

1. Delamination of more than half of the backside or top peripheral area of the interface between the paddle and molding compound.
2. Delamination of the top tie bar or lead area of more than 0.5 of its length.
3. Delamination at the top of the die paddle of more than 0.5 of the periphery area.
INTRODUCTION

In this context ALTER TECHNOLOGY has made an effort to clarify this scene and state a well-defined internal procedure to address SAM findings.

- Historical review of our **internal data accumulated for 30 years** with different manufacturers and packages
- **Survey to manufacturers and users** about the most extended SAM test methods and verification procedures
- Detailed comparative **analysis of the different SAM inspection methods**

Development of an internal making decision flow by considering all the involved factors.
A majority of manufacturers performs at least initial product validation by SAM

But a significant percentage does not perform SAM tests for production screening
SURVEY TO MANUFACTURERS AND USERS

What acceptance or reject criteria do you use for C-SAM (or other SAM tests)?

For manufactures and users the preferred specification is the standard J-STD-020

Within the space sector users also make use of ESCC and NASA standards

What acceptance or reject criteria do you use for C-SAM (or other SAM tests)?

A significant percentage the consulted manufacturers only employs the method MIL-STD-883K TM2030 that only addresses die attach inspection

ESCC 25200
MIL-STD-883
J-STD-020E
MIL-STD-1580
PEM-INST-001
EEE-INST-002

Manufacturers

Users

ESCC 25200
MIL-STD-883
J-STD-020E
MIL-STD-1580
PEM-INST-001
EEE-INST-002

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Survey to Manufacturers and Users

In case you find any issue in CSAM, do you directly...

- apply improvements in the manufacturing to mitigate C-SAM failures?
- no rejects at all?
- rejects the complete lot?
- classify the qualification and/or validation as failed?
- perform additional environmental and endurance tests?

Environmental and endurance tests are used to assess SAM findings.
**SAM TEST METHODS**

Rejection criteria comparison

<table>
<thead>
<tr>
<th>Deviation</th>
<th>Involved parts</th>
<th>Rejection threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crack</td>
<td>Packing Surface</td>
<td>&gt; 2/3 the distance from any internal feature to the outside surface</td>
</tr>
<tr>
<td>Crack</td>
<td>Internal features</td>
<td>Extending from any leadfinger to any other internal feature</td>
</tr>
<tr>
<td>Crack</td>
<td>Bond wire and/or wire bond</td>
<td>Crack/void affecting a bond wire or wire bond</td>
</tr>
<tr>
<td>Crack</td>
<td>Die surface</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**Additional testing:** This deviation is considered as a reliability concern and additional tests must be conducted to check the system performance. From the point of view of the SAM inspection such deviations do not comply with the acceptance criterion.

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### SAM TEST METHODS

#### Rejection criteria comparison

<table>
<thead>
<tr>
<th>Deviation</th>
<th>Involved parts</th>
<th>J-STD-020</th>
<th>ESCC 25200</th>
<th>MIL-STD-1580</th>
<th>PEM-INST-001 (NASA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delamination</td>
<td>Die surface</td>
<td>Any</td>
<td>Complete</td>
<td>Any</td>
<td></td>
</tr>
<tr>
<td>Delamination</td>
<td>Surface breaking part</td>
<td>Complete</td>
<td>Complete</td>
<td>Lead finger &gt; 50 % (additional testing)</td>
<td></td>
</tr>
<tr>
<td>Delamination</td>
<td>Wire bonding area</td>
<td>Any</td>
<td>Any</td>
<td>Bottom side &gt; 50 % (additional testing)</td>
<td></td>
</tr>
<tr>
<td>Delamination</td>
<td>Paddle</td>
<td>N/A</td>
<td>Complete</td>
<td>Bottom side &gt; 50 % (additional testing)</td>
<td></td>
</tr>
</tbody>
</table>

**Additional testing**: This deviation is considered as a reliability concern and additional tests must be conducted to check the system performance. From the point of view of the SAM inspection such deviations do not comply with the acceptance criterion.
# Rejection criteria comparison

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<thead>
<tr>
<th>Deviation</th>
<th>Involved parts</th>
<th>Rejection threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Void / delamination</td>
<td>Die attach</td>
<td>&gt; 50 % of the contact area if the electrical/thermal conductivity is a concern (additional testing)</td>
</tr>
<tr>
<td>Void / delamination</td>
<td>Die attach</td>
<td>N/A</td>
</tr>
<tr>
<td>Void / delamination</td>
<td>Die attach</td>
<td>N/A</td>
</tr>
<tr>
<td>Void / delamination</td>
<td>Die attach</td>
<td>N/A</td>
</tr>
</tbody>
</table>
### SAM TEST METHODS:

## Rejection criteria comparison

<table>
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<tr>
<th>Deviation</th>
<th>Involved parts</th>
<th>Rejection threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Void / delamination</td>
<td>Underfill</td>
<td>Any (additional testing)</td>
</tr>
<tr>
<td>Delamination evolution</td>
<td>&gt; 10 %</td>
<td>&gt; 10 %</td>
</tr>
</tbody>
</table>

### Additional testing:

This deviation is considered as a reliability concern and additional tests must be conducted to check the system performance. From the point of view of the SAM inspection such deviations do not comply with the acceptance criterion.

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## SAM TEST METHODS

Deviations only considered in the ESCC 25200 specification

<table>
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<tr>
<th>Deviation</th>
<th>Involved parts</th>
<th>Rejection threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foreign material</td>
<td>Moulding compound</td>
<td>Any foreign particle inclusion &gt; 0.0254 mm, or sufficient to bridge non-connected conducting parts of the device</td>
</tr>
<tr>
<td>Foreign material</td>
<td>Moulding compound</td>
<td>Any foreign particle inclusion in contact with the die &gt; 0.0254 mm</td>
</tr>
<tr>
<td>Foreign material</td>
<td>Moulding compound</td>
<td>Any foreign particle/inclusion that has deformed any of the bond wires or is closer than 0.05 mm to any bond wire</td>
</tr>
<tr>
<td>Wire deformation</td>
<td>Die attach</td>
<td>Any bond wire within 0.1 mm from the package surface</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Crossing of wire over a bond or crossing of wires</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Slack wire within 0.05 mm of another wire or leadframe structure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wire sweep &gt; 15.5 of the length</td>
</tr>
<tr>
<td>Die tilt and shift</td>
<td>Die / Paddle</td>
<td>Lateral displacement of the die outside of the paddle area</td>
</tr>
<tr>
<td></td>
<td></td>
<td>More than 10 degree tilt of the die</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not located or oriented in accordance with the applicable assembly drawing</td>
</tr>
</tbody>
</table>

**Additional testing:** This deviation is considered as a reliability concerns and additional tests must be conducted to check the system performance. From the point of view of the SAM inspection such deviations do not comply with the acceptance criterion.
The most frequently observed issues are addressed by all the analysed specifications. Nonetheless there are remarkable differences such as:

1) The rejection thresholds
2) Only in some methods additional tests and/or inspections are used to confirm suspected results and to further evaluate the actual impact on the systems performance, reliability and or durability

Conclusions
Some specific user requirements cannot be fulfilled by QPL parts (scientific missions)

Plastic encapsulated COTSs are investigated in such situations

They comply with the applicable specification

The plastic encapsulated COTS with the required functionality does not meet the rejection criteria of conventional test methods
The plastic encapsulated COTS with the required functionality does not meet the rejection criteria of conventional test methods.

ALTER TECHNOLOGY and the final user agree a set of new rejection criteria for lot acceptance by considering the actual working conditions + additional validation test flow based on the expected use.

30 year of experience in the full assessment of EEE part for Hi-Rel applications and SAM inspections.

ALTER TECHNOLOGY internal criteria for the assessment of plastic encapsulated COTSs.
## ALTER TECHNOLOGY INTERNAL PROCEDURE

<table>
<thead>
<tr>
<th>Deviation</th>
<th>Involved parts</th>
<th>J-STD-020</th>
<th>PEM-INST-001 (NASA)</th>
<th>ALTER TECHNOLOGY Criteria</th>
<th>Min. Additional tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crack</td>
<td>Packing Surface</td>
<td>&gt; 2/3 the distance from any internal feature to the outside surface</td>
<td>Extending to the surface</td>
<td>&gt; 2/3 the distance from any internal feature to the outside surface</td>
<td>Gross defect. Straight rejection without additional testing</td>
</tr>
<tr>
<td>Crack</td>
<td>Internal features</td>
<td>Extending from any leadfinger to any other internal feature</td>
<td>Extending &gt; 50% of the distance from any leadfinger to any other internal feature</td>
<td>Extending from any leadfinger to any other internal feature</td>
<td>Gross defect. Straight rejection without additional testing</td>
</tr>
<tr>
<td>Crack</td>
<td>Bond wire and/or wire bond</td>
<td>Crack/void affecting a bond wire or wire bond</td>
<td>Crack/void affecting a bond wire or wire bond</td>
<td>Crack/void affecting a bond wire or wire bond</td>
<td>After stress test microsection inspection is conducted to confirm the crack location and thickness in relation to wire characteristics</td>
</tr>
</tbody>
</table>

**Additional testing**: This deviation is considered as a reliability concern and additional tests must be conducted to check the system performance. From the point of view of the SAM inspection such deviations do not comply with the acceptance criterion.
## ALTER TECHNOLOGY INTERNAL PROCEDURE

### Deviation | Involved parts | Rejection threshold | Min. Additional tests
|---|---|---|---
| Delamination or crack | Die surface | J-STD-020: Any (additional testing); PEM-INST-001 (NASA): Any | Complete (straight rejection); Any (additional testing); SEM - IVI inspection is conducted on the worst case samples to verify the glassivation and metallization integrity of at least the affected parts |
| Delamination | Surface breaking part | J-STD-020: Complete (additional testing); PEM-INST-001 (NASA): Lead finger > 50 % (additional testing); Top tie bar > 50 % (additional testing) | Complete (straight rejection); > 50 % of the internal length or of the length from the external surface to the die, the shorter distance (additional testing); Worst case samples are selected for testing including temperate cycling |
| Delamination evolution | General | J-STD-020: > 10 % (additional testing); PEM-INST-001 (NASA): N/A | > 10 % (additional testing); Worst case samples are selected for additional testing |

**Additional testing:** This deviation is considered as a reliability concern and additional tests must be conducted to check the system performance. From the point of view of the SAM inspection such deviations do not comply with the acceptance criterion.
## ALTER TECHNOLOGY INTERNAL PROCEDURE

<table>
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<tr>
<th>Deviation</th>
<th>Involved parts</th>
<th>Rejection threshold</th>
<th>Min. Additional tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delamination</td>
<td>Wire bonding</td>
<td>J-STD-020: Any (additional testing)</td>
<td><strong>Worst case</strong> samples are selected for testing including <em>microsection verification</em> and bond pull test after stress test</td>
</tr>
<tr>
<td>Delamination</td>
<td>Paddle</td>
<td>PEM-INST-001 (NASA): Any (additional testing)</td>
<td><strong>Complete</strong> (straight rejection)</td>
</tr>
<tr>
<td>Delamination</td>
<td>Paddle</td>
<td>ALTER TECHNOLOGY Criteria: Complete (additional testing)</td>
<td>&gt; 50 % of the inspected area (additional testing)</td>
</tr>
</tbody>
</table>

### Cross-section verification

**Additional testing:** This deviation is considered as a reliability concern and additional tests must be conducted to check the system performance. From the point of view of the SAM inspection such deviations do not comply with the acceptance criterion.

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### Deviation

**Involved parts**

<table>
<thead>
<tr>
<th>Deviation</th>
<th>Involved parts</th>
<th>Rejection threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Void / Delamination</td>
<td>Die attach</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>MIL-STD-883 TM2030</strong> <strong>ALTER TECHNOLOGY Criteria</strong> <strong>Min. Additional tests</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 50 % of the contact area</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Single feature &gt; 15 % of the contact area</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 70 % of quadrant contact area</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Single corner feature &gt; 10 % of the contact area</td>
</tr>
</tbody>
</table>

**Additional testing:** This deviation is considered as a reliability concern and additional tests must be conducted to check the system performance. From the point of view of the SAM inspection such deviations do not comply with the acceptance criterion.

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**Cross-section verification**

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**Additional tests:**

- **MAG:** 1500 x
- **HV:** 20,0 kV
- **WD:** 15,0 mm

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## ALTER TECHNOLOGY INTERNAL PROCEDURE

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<th>Min. Additional tests</th>
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<tbody>
<tr>
<td>Foreign material inclusion</td>
<td>Moulding compound</td>
<td>Any foreign particle inclusion &gt; 0.0254 mm, or sufficient to bridge non-connected conducting parts of the device</td>
<td>SEM - IVI inspection is conducted on the worst case samples to verify the glassivation and metallization integrity of at least the affected parts</td>
</tr>
<tr>
<td>Foreign material inclusion</td>
<td>Moulding compound</td>
<td>Any foreign particle/inclusion in contact with the die &gt; 0.0254 mm</td>
<td>Worst case samples are selected for testing including temperate cycling</td>
</tr>
<tr>
<td>Foreign material inclusion</td>
<td>Moulding compound</td>
<td>Any foreign particle/inclusion that has deformed any of the bond wires or is closer than 0.05 mm to any bond wire</td>
<td>Worst case samples are selected for additional testing</td>
</tr>
<tr>
<td>Wire deformation</td>
<td>Wire</td>
<td>Any bond wire within 0.1 mm from the package surface.</td>
<td>Worst case samples are selected for additional testing (X-ray)</td>
</tr>
<tr>
<td>Die tilt and shift</td>
<td>Die / Paddle</td>
<td>Lateral displacement of the die outside of the paddle area</td>
<td>Worst case samples are selected for additional testing (X-ray)</td>
</tr>
</tbody>
</table>

### Notes:
- SEM - IVI inspection is conducted on the worst case samples to verify the glassivation and metallization integrity of at least the affected parts.
- Worst case samples are selected for testing including temperate cycling.
- Worst case samples are selected for additional testing.
Complete testing capabilities for the evaluation of plastic encapsulated IC

Stress test

Destructive and non-destructive verification of SAM issues

Impact evaluation DPA and Electrical functional test

Further guarantees

Validated

Screening

SAM 1
- Initial EM
- Thermal Cycling
- Post TC EM

SAM 2
- Delamination evolution?
- Cross-sectioning (incl. SEM)
- Separation lines / gaps images

DPA
- Any SAM Reject criteria?
- Comprehensive assessment

Life Test / Extended Thermal Cycling /
HAST

 ALTER TECHNOLOGY INTERNAL PROCEDURE

Default test flow where SAM microscopy is routinely used

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A-scan, B-scan, C-scan and Through-scan

Circuit, non-circuit and through-transmitted signal are systematically inspected at different focal depths

Delamination (phase inversions) is confirmed by A-scan mode

Recently upgraded capabilities

FineSatV Hitachi

After analyses the inspected samples are subjected to gentle back-out process as per J-STD-033 to avoid water absorption issues
Scanning Acoustic Microscopy Service

**Depth mapping**

**FT data treatment**

Full area A-scan records upon request
ALTER TECHNOLOGY TESTING CAPABILITES

Scanning Acoustic Microscopy Service

Virtual Lab.
Our Lab and knowledge at your fingertips
Instant data access and additional features

AGILITY
Help and expertise are available in an instant

Introduction  Survey to manufacturers and users  Test-method comparison  Our criteria  Additional tests
ALTER TECHNOLOGY SERVICES

Default test flow where SAM microscopy is routinely used

**Screening**

**DPA**

**SAM 1**
- Initial EM
  - Thermal Cycling
- Post TC EM

**SAM 2**
- Delamination evolution? Yes
- Cross-sectioning (incl. SEM)
  - Separation lines / gaps images
    - Comprehensive assessment
      - Life Test / Extended Thermal Cycling
  - Any SAM Reject criteria? No
    - Post TC EM

**X-ray Bond Pull / Die Shear / Internal Visual**

**Validated**

*EM = Electrical Measurement*
**ALTER TECHNOLOGY TESTING CAPABILITIES**

Different temperature cycling capabilities

**In-house temperature cycling capabilities**

![Temperature Cycling Machine]

**Software control and verification**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Completed Cycles</th>
<th>Remaining cycles</th>
<th>TEMPERATURE CYCLING VERIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dwell time at low temperature / s</td>
<td>660</td>
<td>600</td>
<td>&gt; 600</td>
</tr>
<tr>
<td>Dwell time at high temperature / s</td>
<td>660</td>
<td>600</td>
<td>&gt; 600</td>
</tr>
<tr>
<td>Maximum temperature per cycle</td>
<td>101</td>
<td>N/A</td>
<td>&lt; 110</td>
</tr>
<tr>
<td>Minimum temperature per cycle</td>
<td>-55</td>
<td>N/A</td>
<td>&gt; -65</td>
</tr>
<tr>
<td>Stabilization time heating</td>
<td>480</td>
<td>540</td>
<td>&lt; 900</td>
</tr>
<tr>
<td>Stabilization time cooling</td>
<td>420</td>
<td>480</td>
<td>&lt; 900</td>
</tr>
</tbody>
</table>
ALTER TECHNOLOGY TESTING CAPABILITIES
Default test flow where SAM microscopy is routinely used

**Screening**

**SAM 1**
- Initial EM*
- Thermal Cycling
- Post TC EM

**SAM 2**
- Delamination evolution?
  - No
  - Any SAM Reject criteria?
    - No
    - Yes

**Cross-sectioning (incl. SEM)**
- Separation lines / gaps images
- Comprehensive assessment

**DPA**

**Life Test / Extended Thermal Cycling / HAST**

**Validation**

* EM = Electrical Measurement

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Ultra High resolution FE-SEM verification

Very thin delamination on the die surface

ESA recommended microsection facility

X-ray inspection

Ideal to confirm wire-deformation findings
ALTER TECHNOLOGY TESTING CAPABILITIES

Default test flow where SAM microscopy is routinely used

[Flowchart of test procedures including screening, SAM 1, SAM 2, Delamination evolution?, Cross-sectioning (incl. SEM), Separation lines / gaps images, Comprehensive assessment, Life Test / Extended Thermal Cycling, X-ray, Bond Pull / Die Shear / Internal Visual, Validated, Further guarantees, and additional testing options.]

* EM = Electrical Measurement

Additional tests

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After stress test our **specialized DPA lab** assesses the impact of the SAM detected issues by destructive physical test.

**SEM internal detection** of issues ascribed to crack and delamination:

- Glassivation and metallization integrity
- Corrosion signs
- Contamination residues

**Mechanical test**

- Bond pull, wire and bond strength
- Ball shear
- Die shear
ALTER TECHNOLOGY TESTING CAPABILITIES

Specialized lab in Electrical testing

In-house capability and expertise to perform **electrical screening of any type of electronic component technology**

Active devices testing: discrete (diodes and TRT) through standard linear and digital components to VLSI
SUMMARY:

Internal making decision flow based on:

- The **30 years of experience on EEE and SAM inspections** and complementary tests
- A survey about the most commonly accepted rejection and acceptance criteria
- A comparative study of **current industrial and space agencies test methods**

The adopted criteria combines

- **Strict rejection criteria for gross defects**
- **An adapted test flow** conceived to assess the **actual impact** of minor issues on the performance and durability

THANK YOU!

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