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

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TÜV NORD GROUP

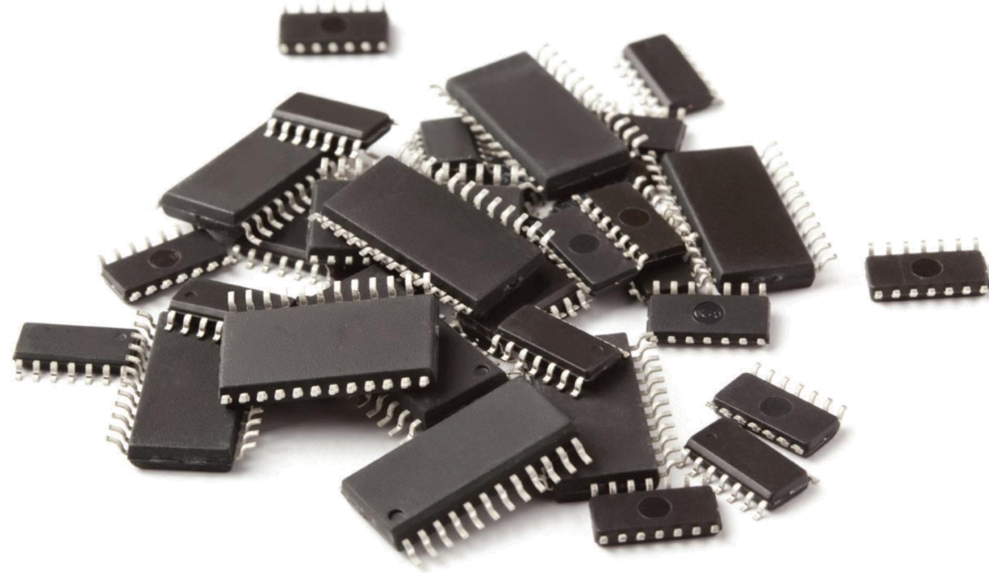
ALTER TECHNOLOGY

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

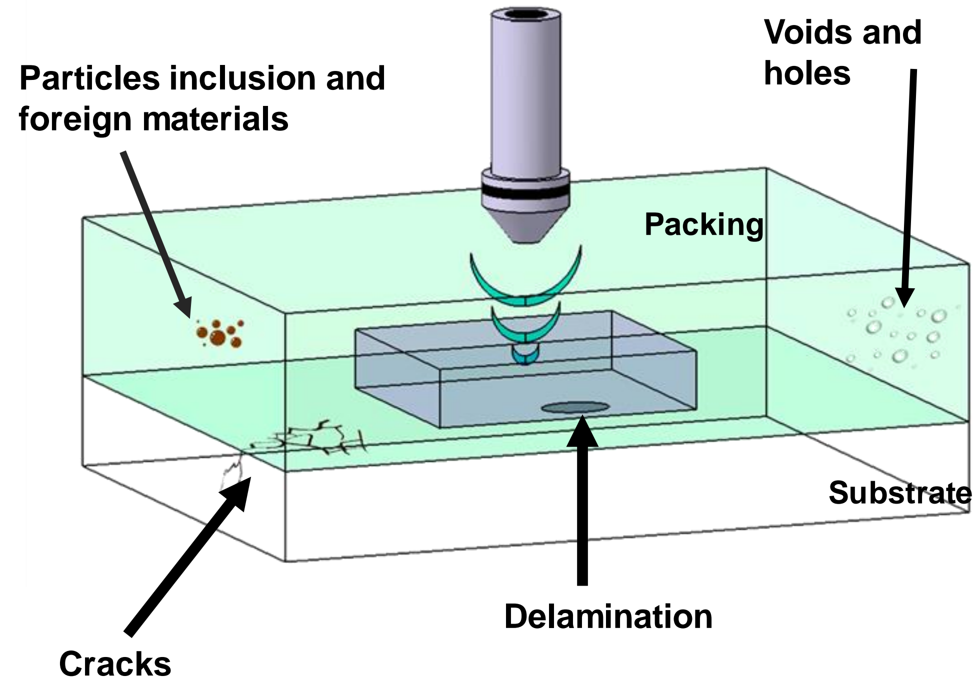
INTRODUCTION

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**

Metallic corrosion

Contamination and **moisture** ingress and accumulation

Lack of hermeticity

Popcorn cracking

Delamination on the **die surface**

Shear induced **damage** of the **die passivation**

Metal smearing (metallic tracks)

Cracks/void **intersecting a bond wire**

Bond wire degradation due to shear

CTE Mismatch

Lack of adhesion or voids in the **die attach**

Poor thermal dissipation

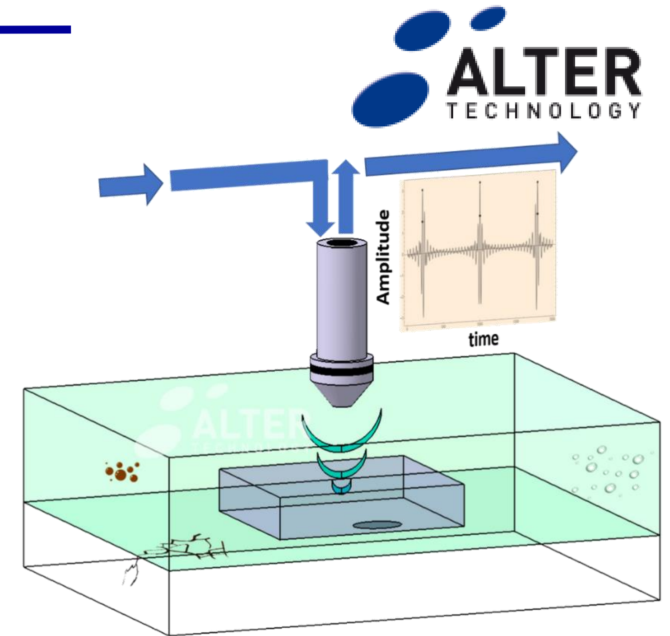
INTRODUCTION

Why Scanning acoustic Microscopy (SAM)?

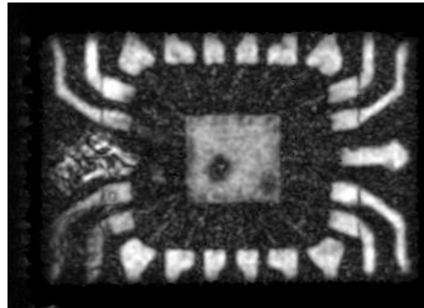
Ultrasound waves are extremely sensitive to density changes

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

Sequential confocal inspection

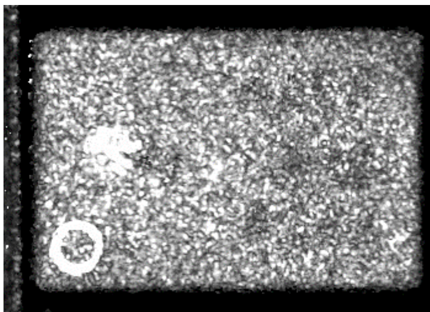


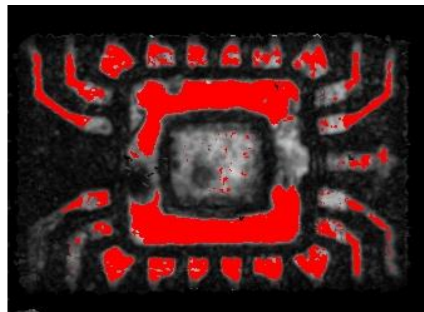
Surface Marking



Die Surface

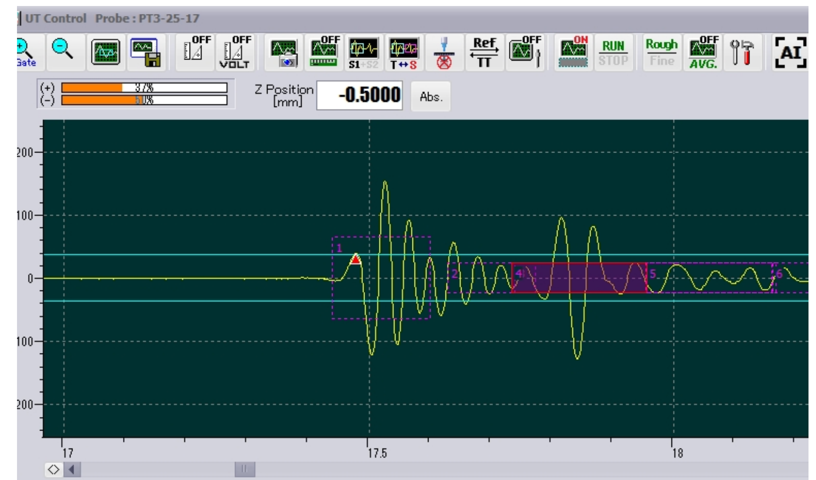
Moulding





Paddle Surface

Detailed phase inversion analyses provide additional delamination contrast



INTRODUCTION

Test methods

ESCC Basic Specification No. 25200

ESCC 25200 Application of Scanning Acoustic Microscopy to Plastic Encapsulated Devices

PEM-INST-001

Instructions for Plastic Encapsulated Microcircuit (PEM) Selection, Screening, and Qualification

PEM-INST-001 Instructions for Plastic Encapsulated Microcircuit (PEM) Selection, Screening, and Qualification

IPC/JEDEC J-STD-020E
December 2014

J-STD-020E Moisture/Reflow Sensitivity Classification for Nonhermetic Surface Mount Devices

DEPARTMENT OF DEFENSE
TEST METHOD STANDARD

MIL-STD-883
Test Method 2030
Ultrasonic Inspection of Die Attach

MIL-STD-1580
Paragraph 16.5.1.3
Acoustic Microscopy

INTRODUCTION

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

ESCC Basic Specification No. 25200

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.

IPC/JEDEC J-STD-020E
December 2014

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.

PEM-INST-001

Instructions for
Plastic Encapsulated Microcircuit (PEM)
Selection, Screening, and Qualification

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

+

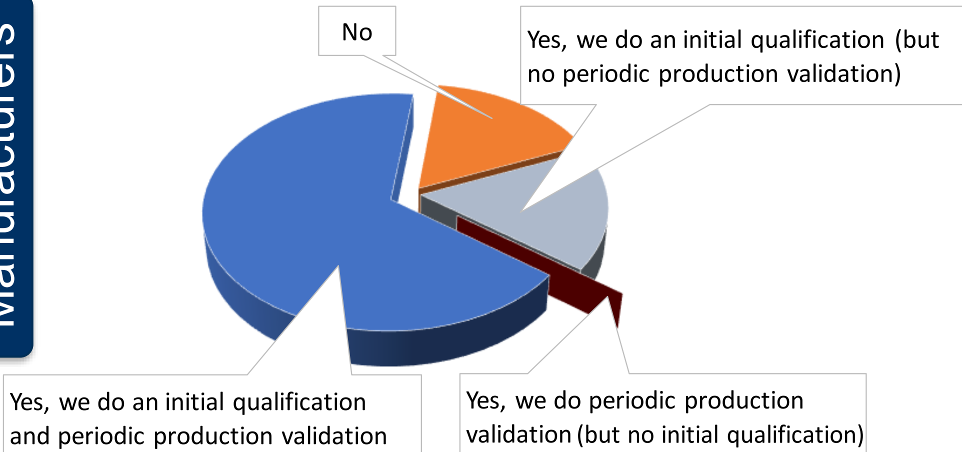
Detailed comparative **analysis of the different SAM inspection methods**

Development of an internal making decision flow by considering all the involved factors

SURVEY TO MANUFACTURERS AND USERS

Do you perform/consider initial qualification and/or periodic production validation with C-SAM (or other SAM tests)?

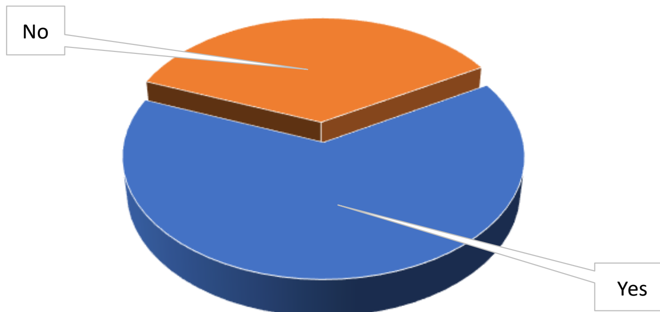
Manufacturers



A majority of manufacturers performs at least initial product validation by SAM

Do you perform/consider initial qualification and/or periodic production validation with C-SAM (or other SAM tests)?

Manufacturers

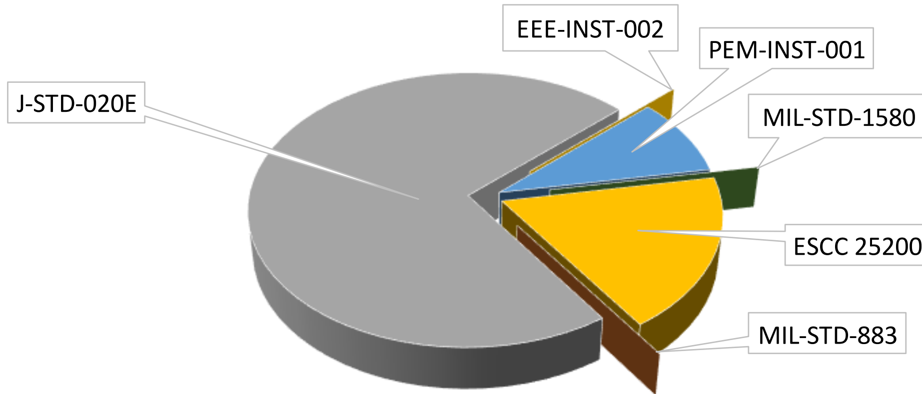


But a significant percentage does not perform SAM tests for production screening

SURVEY TO MANUFACTURERS AND USERS

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

Users

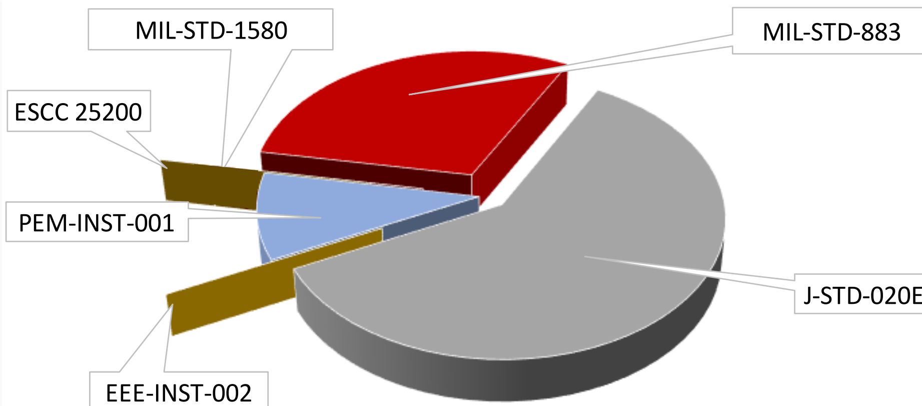


For manufactures and users the **preferred** specification is the **standard J-STD-020**

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)?

Manufacturers



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

SURVEY TO MANUFACTURERS AND USERS

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

Manufacturers

…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

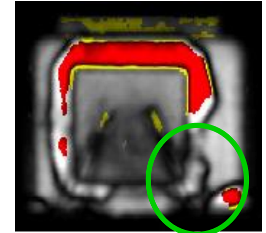
SAM TEST METHODS

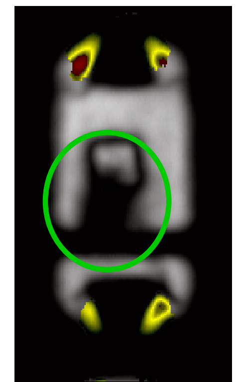
Rejection criteria comparison

Softer criterion | Stricter criterion

Deviation	Involved parts	Rejection threshold			
		J-STD-020	ESCC 25200	MIL-STD-1580	PEM-INST-001 (NASA)
Crack	Packing Surface	**> 2/3 the distance** from any **internal feature to the outside surface**		**Extending to the surface**	
Crack	Internal features	Extending **from any leadfinger to any other internal feature**		Extending **> 50 %** of the distance **from any leadfinger to any other internal feature**	
Crack	Bond wire and/or wire bond	Crack/void affecting a **bond wire or wire bond**			
Crack	Die surface	N/A	Any crack **out of the scribe line**	N/A	N/A

Crack extending from an internal features





Void affecting a bond wire

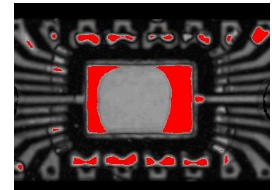
Additional testing: This deviation is considered as a reliability concern and additional tests must be conducted to check the system performance. From the point of view of the SAM inspection such deviations do not comply with the acceptance criterion

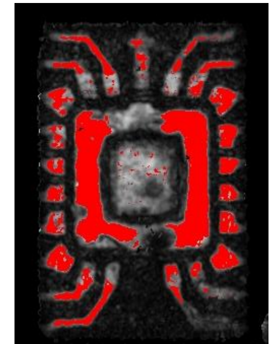
SAM TEST METHODS

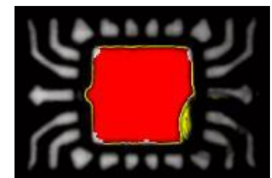
Rejection criteria comparison

Softer criterion | Stricter criterion

Deviation	Involved parts	Rejection threshold			
		J-STD-020	ESCC 25200	MIL-STD-1580	PEM-INST-001 (NASA)
Delamination	**Die surface**	**Any** (additional testing)	**Complete**	**Any**	
Delamination	**Surface breaking part**	**Complete** (additional testing)	**Complete**	**Lead finger 100 %** **Top tie bar > 50 %**	**Lead finger > 50 %** (additional testing) **Top tie bar > 50 %** (additional testing)
Delamination	**Wire bonding area**	**Any** (additional testing)	**Any**	**Any**	
Delamination	**Paddle**	N/A	**Complete**	**Bottom side > 50 %**	**Bottom side > 50 %** (additional testing) **Top side> 50 %** (additional testing)







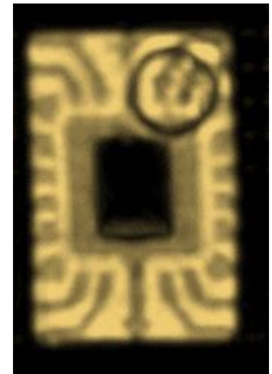
Additional testing: This deviation is considered as a reliability concern and additional tests must be conducted to check the system performance. From the point of view of the SAM inspection such deviations do not comply with the acceptance criterion

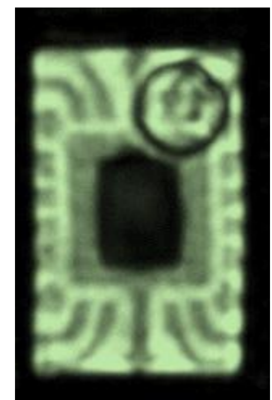
SAM TEST METHODS

Rejection criteria comparison

Softer criterion | Stricter criterion

Deviation	Involved parts	Rejection threshold	
		J-STD-020	ECSS 25200 / MIL-STD-1580 / PEM-INST-001 (NASA) MIL-STD-883 TM2030
Void / delamination	Die attach	**> 50 %** of the contact area if the electrical/thermal conductivity is a concern (additional testing)	**> 50 %** of the contact area
Void / delamination	Die attach	N/A	**> 70 % of quadrant contact area**
Void / delamination	Die attach	N/A	**Single feature > 15 %** of the contact area
Void / delamination	Die attach	N/A	**Single corner feature > 10 %** of the contact area



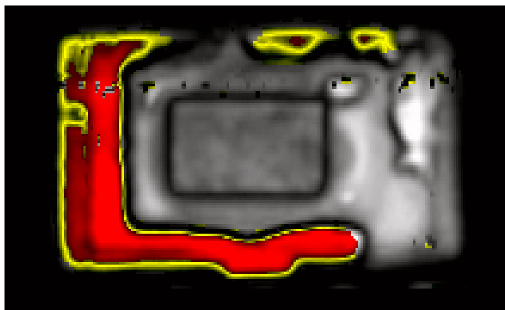


SAM TEST METHODS:

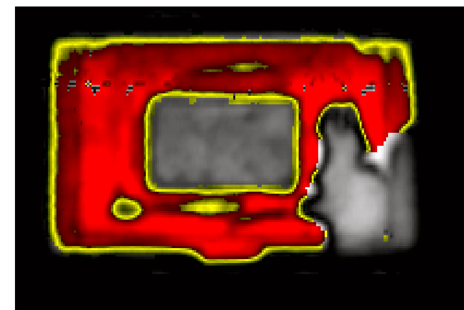
Rejection criteria comparison

Softer criterion | Stricter criterion

Deviation	Involved parts	Rejection threshold			
		J-STD-020	ESCC 25200	MIL-STD-1580	PEM-INST-001 (NASA)
Void / delamination	Underfill	**Any** (additional testing)	N/A	N/A	N/A
Delamination evolution		**> 10 %**	**> 10 %**	N/A	N/A



Temperature Cycling



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

SAM TEST METHODS

Deviations only considered in the ESCC 25200 specification

Deviation	Involved parts	Rejection threshold
		ESCC 25200
Foreign material	Moulding compound	Any foreign particle inclusion > 0.0254 mm, or sufficient to bridge non-connected conducting parts of the device
Foreign material	Moulding compound	Any foreign particle inclusion in contact with the die > 0.0254 mm
Foreign material	Moulding compound	Any foreign particle/inclusion that has deformed any of the bond wires or is closer than 0.05 mm to any bond wire
Wire deformation	Die attach	Any bond wire within 0.1 mm from the package surface
		Crossing of wire over a bond or crossing of wires
		Slack wire within 0.05 mm of another wire or leadframe structure
		Wire sweep > 15 5 of the length
Die tilt and shift	Die / Paddle	Lateral displacement of the die outside of the paddle area
		More than 10 degree tilt of the die
		Not located or oriented in accordance with the applicable assembly drawing

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

SAM TEST METHODS

Conclusions

The most frequently observed issues are addressed by all the analysed specifications. Nonetheless there are remarkable differences such as:

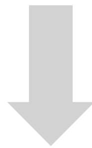
1) The rejection thresholds
2) Only in some methods additional tests and/or inspections are used to confirm suspected results and to further evaluate the actual impact on the systems performance, reliability and or durability

	Softer criterion	Stricter criterion
Straight rejection	ESCC European Space Components Coordination ESCC Basic Specification No. 25200	MIL-STD-1580 Destructive Physical Analysis For Electronic, Electromagnetic and Electromechanical Parts DEPARTMENT OF DEFENSE TEST METHOD STANDARD
Additional tests can be occasionally used	IPC JEDEC IPC/JEDEC J-STD-020E December 2014	NASA PEM-INST-001 Instructions for Plastic Encapsulated Microcircuit (PEM) Selection, Screening, and Qualification

ALTER TECHNOLOGY INTERNAL PROCEDURE

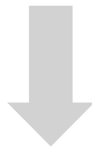
What if QPL parts are not available?

Some specific user requirements can not be fulfilled by QPL parts (scientific missions)



Plastic encapsulated COTSs are investigated in such situations

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



They comply with the applicable specification

ALTER TECHNOLOGY INTERNAL PROCEDURE

What if QPL parts are not available?

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

ALTER TECHNOLOGY internal criteria for the assessment of plastic encapsulated COTSs

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

ALTER TECHNOLOGY INTERNAL PROCEDURE

Other criteria | Our criterion

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

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

Other criteria | Our criterion

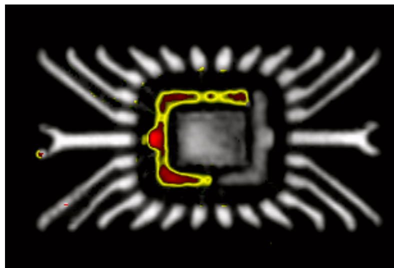
Deviation	Involved parts	Rejection threshold			
		J-STD-020	PEM-INST-001 (NASA)	**ALTER TECHNOLOGY Criteria**	**Min. Additional tests**
Delamination or crack	**Die surface**	**Any** (additional testing)	**Any**	**Complete** (straight rejection) **Any** (additional testing)	**SEM - IVI inspection** is conducted on the worst case samples to verify the glassivation and metallization integrity of at least the **affected parts**
Delamination	**Surface breaking part**	**Complete** (additional testing)	**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**	**> 10 %** (additional testing)	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

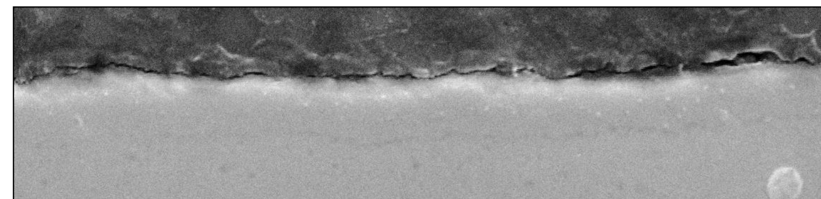
ALTER TECHNOLOGY INTERNAL PROCEDURE

Other criteria | Our criterion

Deviation	Involved parts	Rejection threshold			
		J-STD-020	PEM-INST-001 (NASA)	ALTER TECHNOLOGY Criteria	Min. Additional tests
Delamination	Wire bonding	**Any** (additional testing)	**Any**	**Any** (additional testing)	**Worst case** samples are selected for testing including **microsection verification and bond pull test after stress test**
Delamination	Paddle	**Complete** (additional testing)	**Bottom side > 50 %** (additional testing) **Top side > 50 top side** (additional testing)	**Complete** (straight rejection) > **50 %** of the inspected area (additional testing)	**Worst case** samples will be selected for additional testing



Cross-section verification

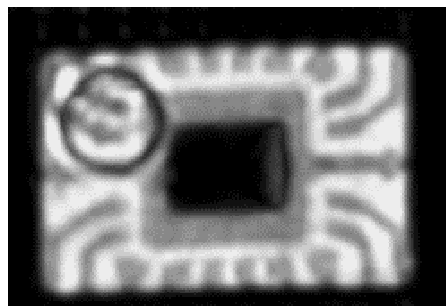


Additional testing: This deviation is considered as a reliability concern and additional tests must be conducted to check the system performance. From the point of view of the SAM inspection such deviations do not comply with the acceptance criterion

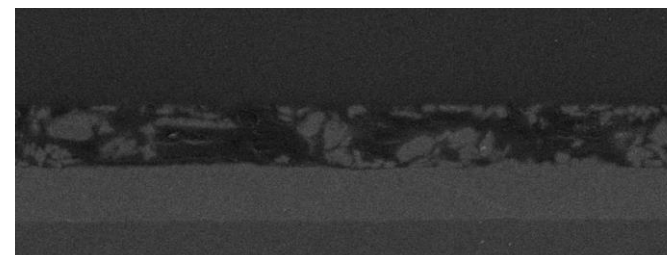
ALTER TECHNOLOGY INTERNAL PROCEDURE

Other criteria | Our criterion

Deviation	Involved parts	Rejection threshold		
		MIL-STD-883 TM2030	ALTER TECHNOLOGY Criteria	Min. Additional tests
Void / Delamination	Die attach	**> 50 %** of the contact area	**> 50 %** of the contact area	When the die paddle is used for thermal dissipation this is a straight rejection.
		Single feature > 15 % of the contact area	**Single feature > 15 % of the contact area**	
		> 70 % of quadrant contact area	**> 70 % of quadrant contact area**	
		Single corner feature > 10 % of the contact area	**Single corner feature > 10 % of the contact area**	



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

ALTER TECHNOLOGY INTERNAL PROCEDURE

Deviation	Involved parts	Rejection threshold	
		ALTER TECHNOLOGY criteria as per ESCC 25200	Min. Additional tests
Foreign material inclusion	Moulding compound	Any foreign particle inclusion > 0.0254 mm, or sufficient to bridge non-connected conducting parts of the device	**SEM - IVI inspection** is conducted on the worst case samples to verify the glassivation and metallization integrity of at least the **affected parts**
Foreign material inclusion	Moulding compound	Any foreign particle/inclusion in contact with the die > 0.0254 mm	**Worst case** samples are selected for testing **including temperate cycling**
Foreign material inclusion	Moulding compound	Any foreign particle/inclusion that has deformed any of the bond wires or is closer than 0.05 mm to any bond wire	**Worst case** samples are selected for additional testing
Wire deformation	Wire	Any bond wire within 0.1 mm from the package surface. Crossing of wire over a bond or crossing of wires Slack wire within 0.05 mm of another wire or leadframe structure Wire sweep > 15 5 of the length	**Worst case** samples are selected for additional testing (X-ray)
Die tilt and shift	Die / Paddle	Lateral displacement of the die outside of the paddle area More than 10 degree tilt of the die Not located or oriented in accordance with the applicable assembly drawing	**Worst case** samples are selected for additional testing (X-ray)

ALTER TECHNOLOGY INTERNAL PROCEDURE

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

No

Cross-sectioning (incl. SEM)

Any SAM Reject criteria?

Yes

No

Separation lines / gaps images

Comprehensive assessment

Life Test */ Extended Thermal Cycling */ HAST *

Xray Bond Pull / Die Shear / Internal Visual

Validated

Further guarantees

* EM = Electrical Measurement

Complete testing capabilites for the evaluation of plastic encapsulated IC

Stress test

Destructive and non-destructive **verification of SAM issues**

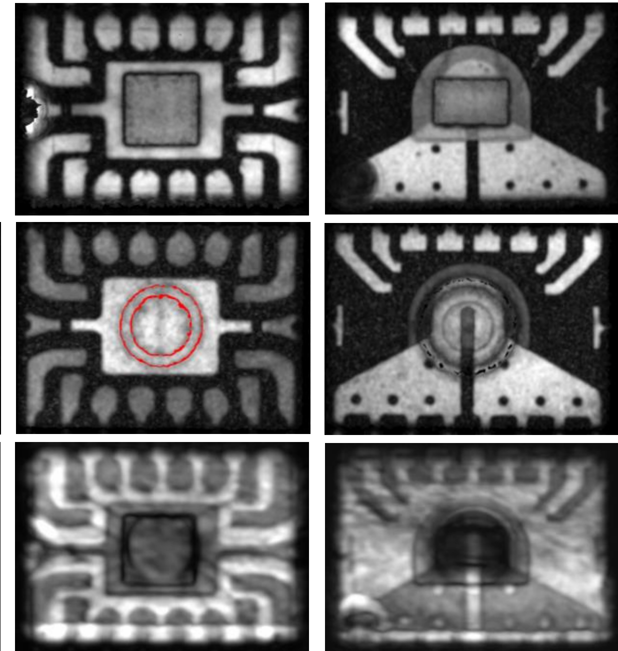
Impact evaluation DPA and Electrical functional test

ALTER TECHNOLOGY TESTING CAPABILITES

Scanning Acoustic Microscopy Service

Recently upgraded capabilities

FineSatV
Hitachi



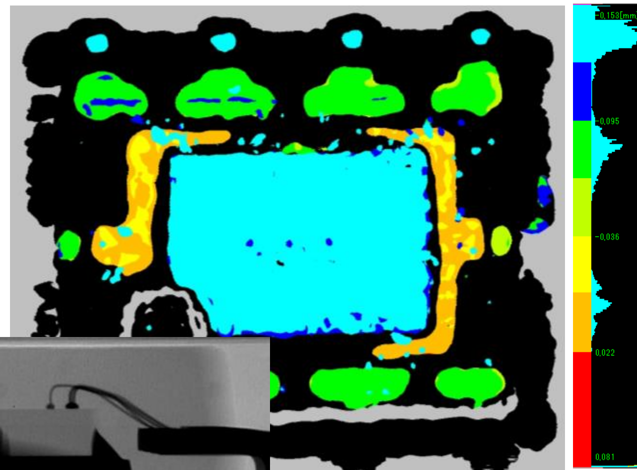
- A-scan, B-scan, C-scan and Through-scan
- Circuit, non-circuit and through-transmitted signal are systematically inspected at different focal depths
- Delamination (phase inversions) is confirmed by A-scan mode

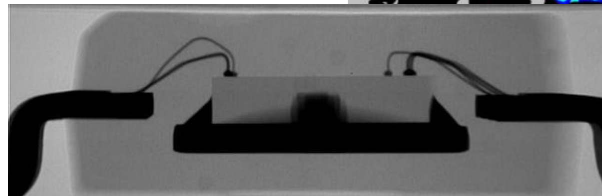
After analyses the inspected samples are subjected to gentle back-out process as per J-STD-033 to avoid water absorption issues

ALTER TECHNOLOGY TESTING CAPABILITES

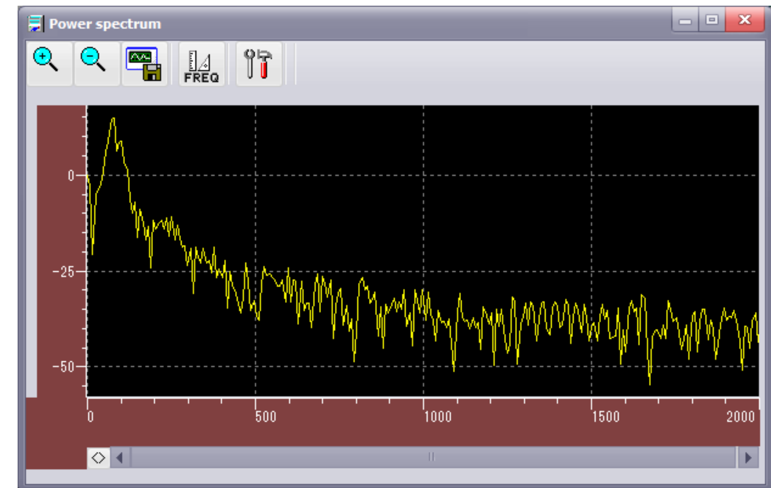
Scanning Acoustic Microscopy Service

Depth mapping

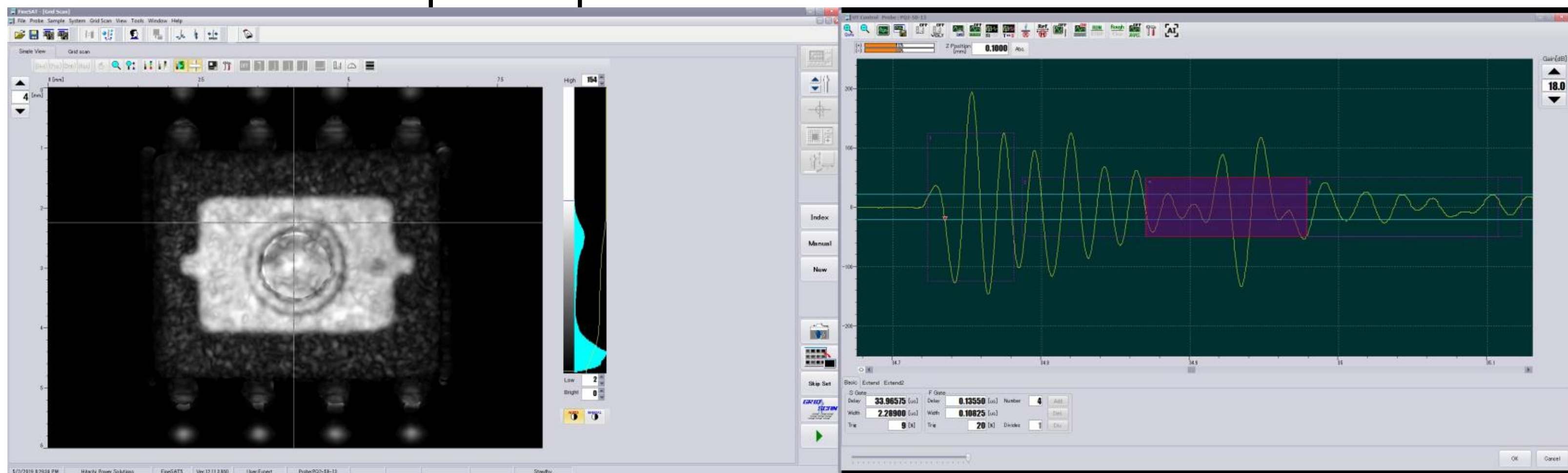




FT data treatment



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

INDUSTRIAL ETHERNET

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

No

Cross-sectioning (incl. SEM)

Separation lines / gaps images

Comprehensive assessment

Life Test */ Extended Thermal Cycling * / HAST *

Any SAM Reject criteria?

Yes

No

Xray Bond Pull / Die Shear / Internal Visual

Further guarantees

Validated

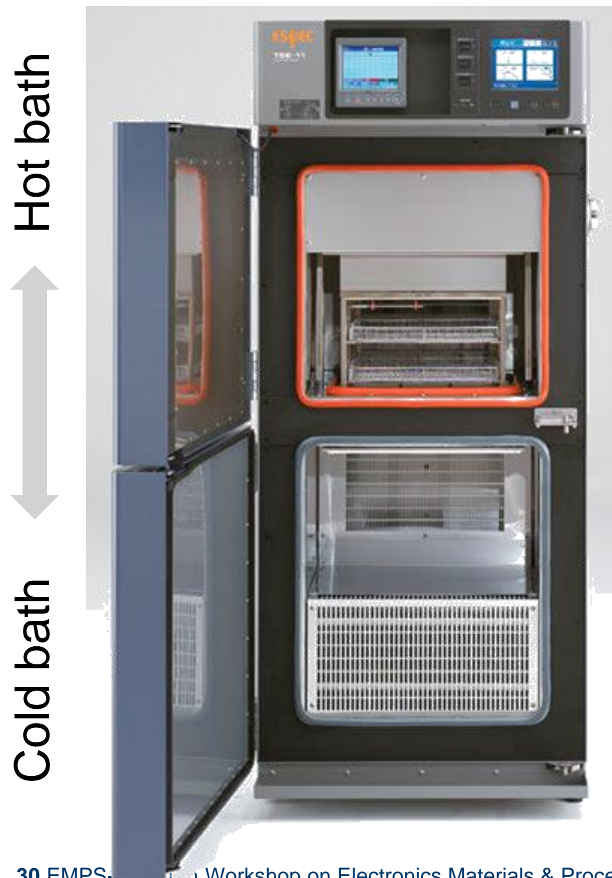
* EM = Electrical Measurement

ALTER TECHNOLOGY TESTING CAPABILITES

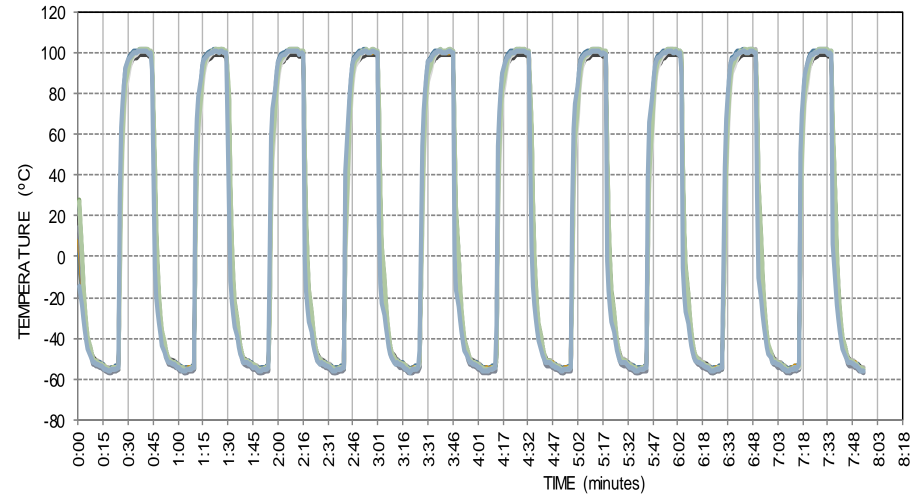
Different temperature cycling capabilities

In-house temperature cycling capabilities

Hot bath



Cold bath



Software control and verification

TEMPERATURE CYCLING VERYFICATION				
Completed Cycles	125	Remaing cycles	125	
Parameter	Maximum value	Minimum value	Criterion	Nº Devirations
Dwell time at low temperature / s	660	600	> 600	0
Dwell time at high temperature / s	660	600	> 600	0
Maximum temperature per cycle	101	N/A	< 110	0
Minimum temperature per cycle	-55	N/A	> -65	0
Stabilization time heating	480	540	< 900	0
Stabilization time cooling	420	480	< 900	0

ALTER TECHNOLOGY TESTING CAPABILITES

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ALTER TECHNOLOGY TESTING CAPABILITES

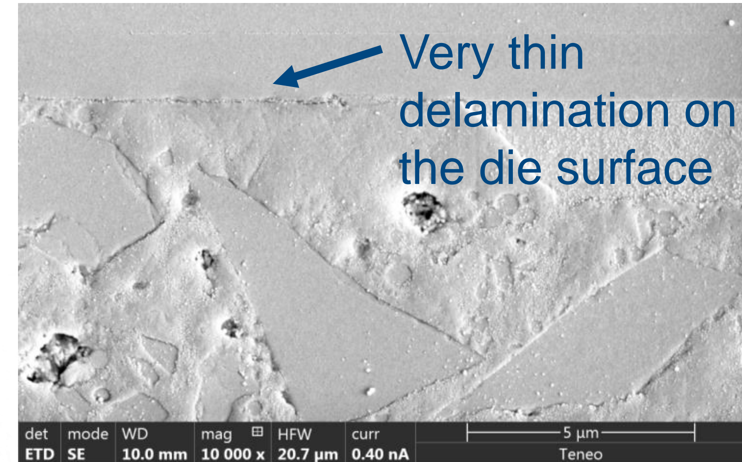
Complementary internal inspection techniques

ESA recommended microsection facility

MEMO

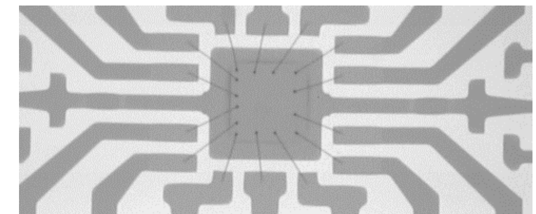
ESA-TECMSP-MO-013165

Ultra High resolution FE-SEM verification



X-ray inspection

Ideal to confirm wire-deformation findings



ALTER TECHNOLOGY TESTING CAPABILITES

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Further guarantees

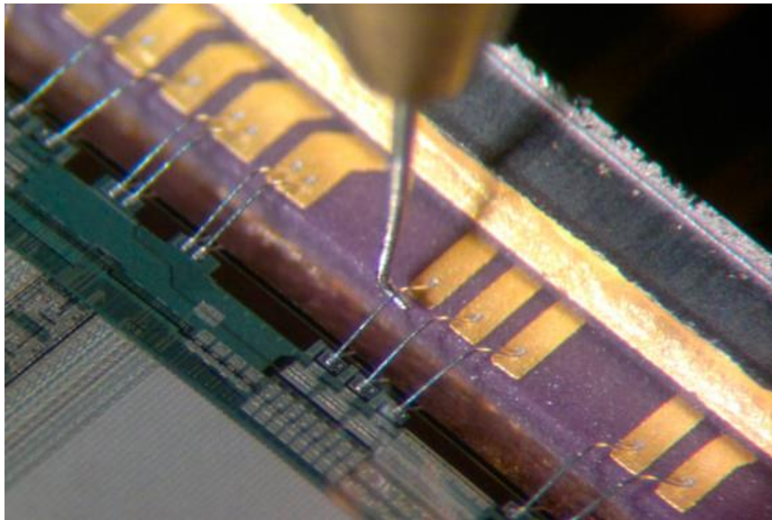
ALTER TECHNOLOGY TESTING CAPABILITES

Destructive Physical Analyses to evaluate SAM deviations

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

SEM internal detection of issues ascribed to crack and delamination

- Glassivation and metallization integrity
- Corrosion sings
- Contamination residues



Mechanical test

Bond pull, wire and bond strength

Ball shear

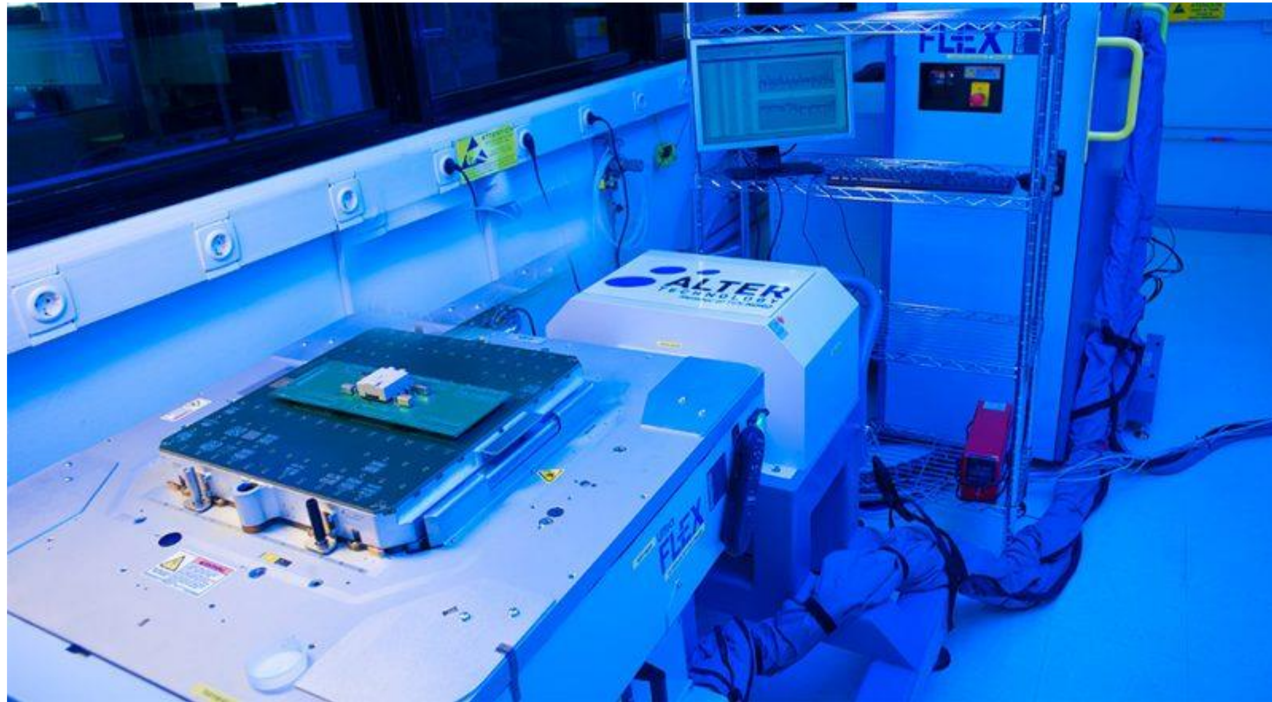
Die shear

ALTER TECHNOLOGY TESTING CAPABILITES

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



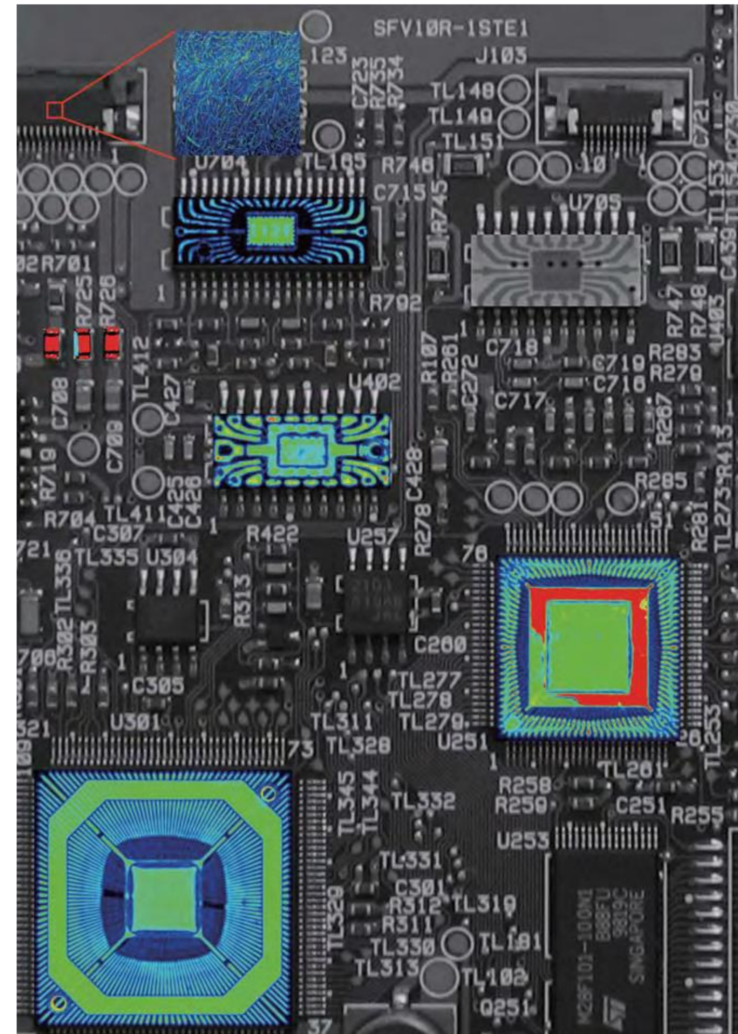
SUMMARY:

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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https://wpo-altertechnology.com/scanning-acoustic-microscopy-csam/