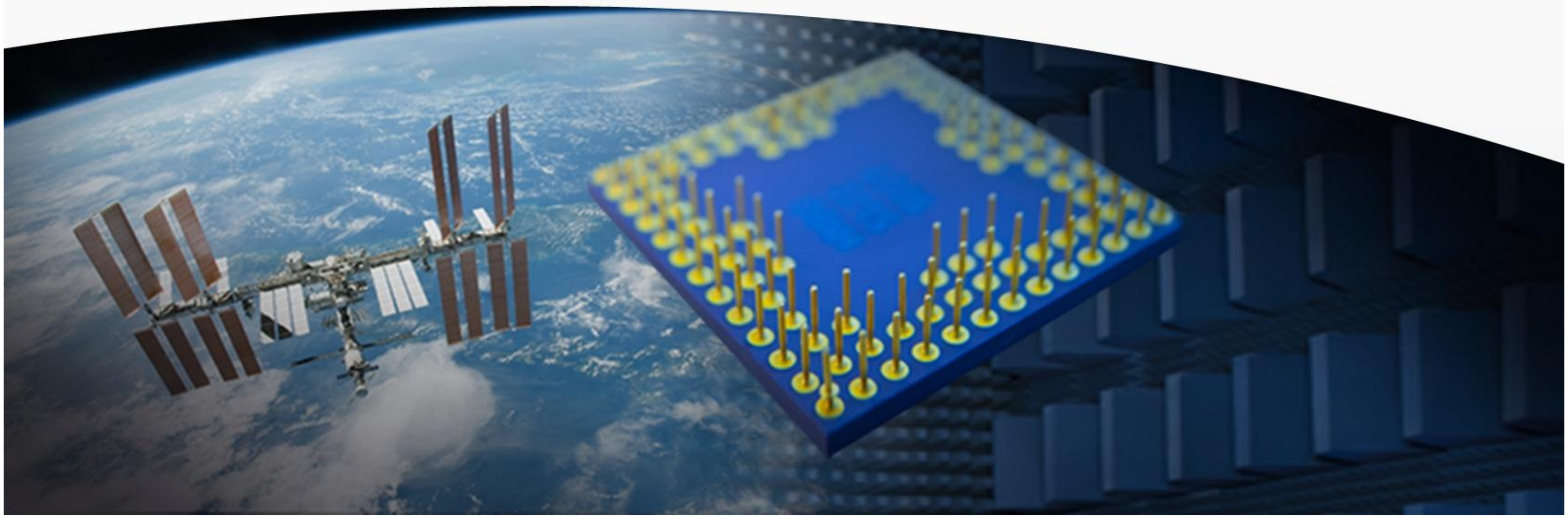
Workshop on Advances in Packaging and Components
APAC 2019 (14-15 March 2019)



"ANALYSIS OF INSPECTION AND DPA TEST REQUIREMENTS APPLIED TO FLIP CHIP TECHNOLOGIES".

(ESA CONTRACT 4000114087/14/NL/SW)

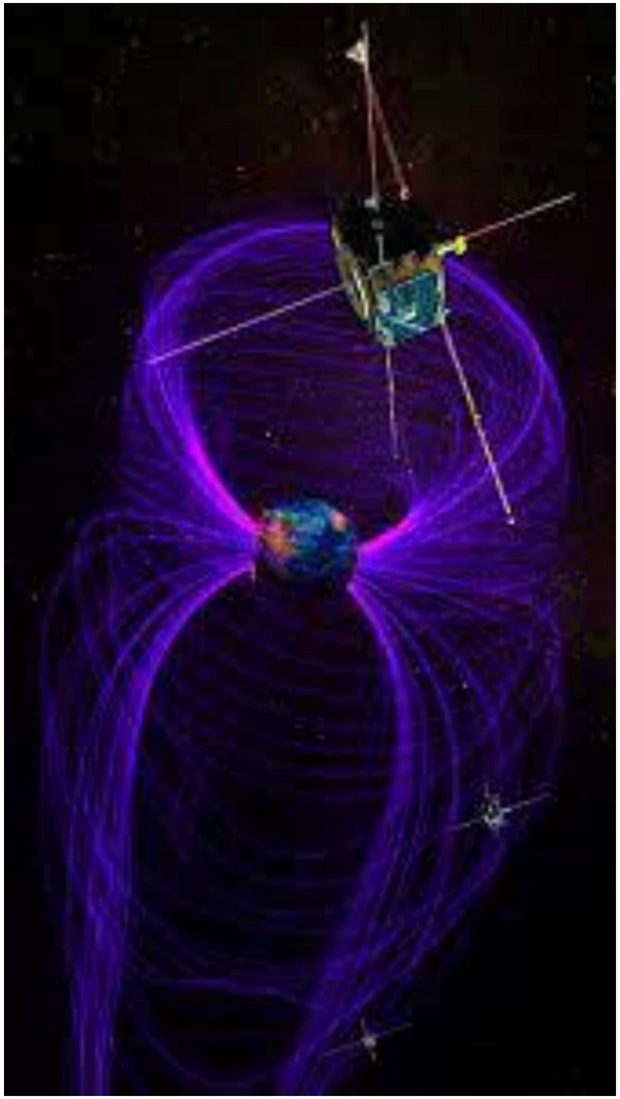
Gonzalo Fernández (Technical Advisor) Alter Technology Tüv Nord

Ana Collado (Hybrid and Packaging Components Engineer) ESA_ESTEC

TÜV NORD GROUP

Content and index:

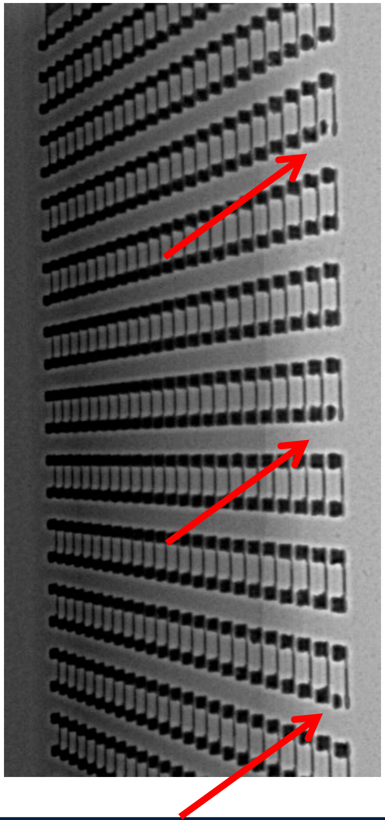
- Background and motivations.
- Study approach / Tasks.
- Flip Chip Technologies, Reliability and Failure Modes.
- Investigations on inspection and DPA requirements for Flip-chip technologies.
- Test vehicle design and manufacturing.
- Demonstration test performance and data assessment.
- Summary & Conclusions



Background and motivations

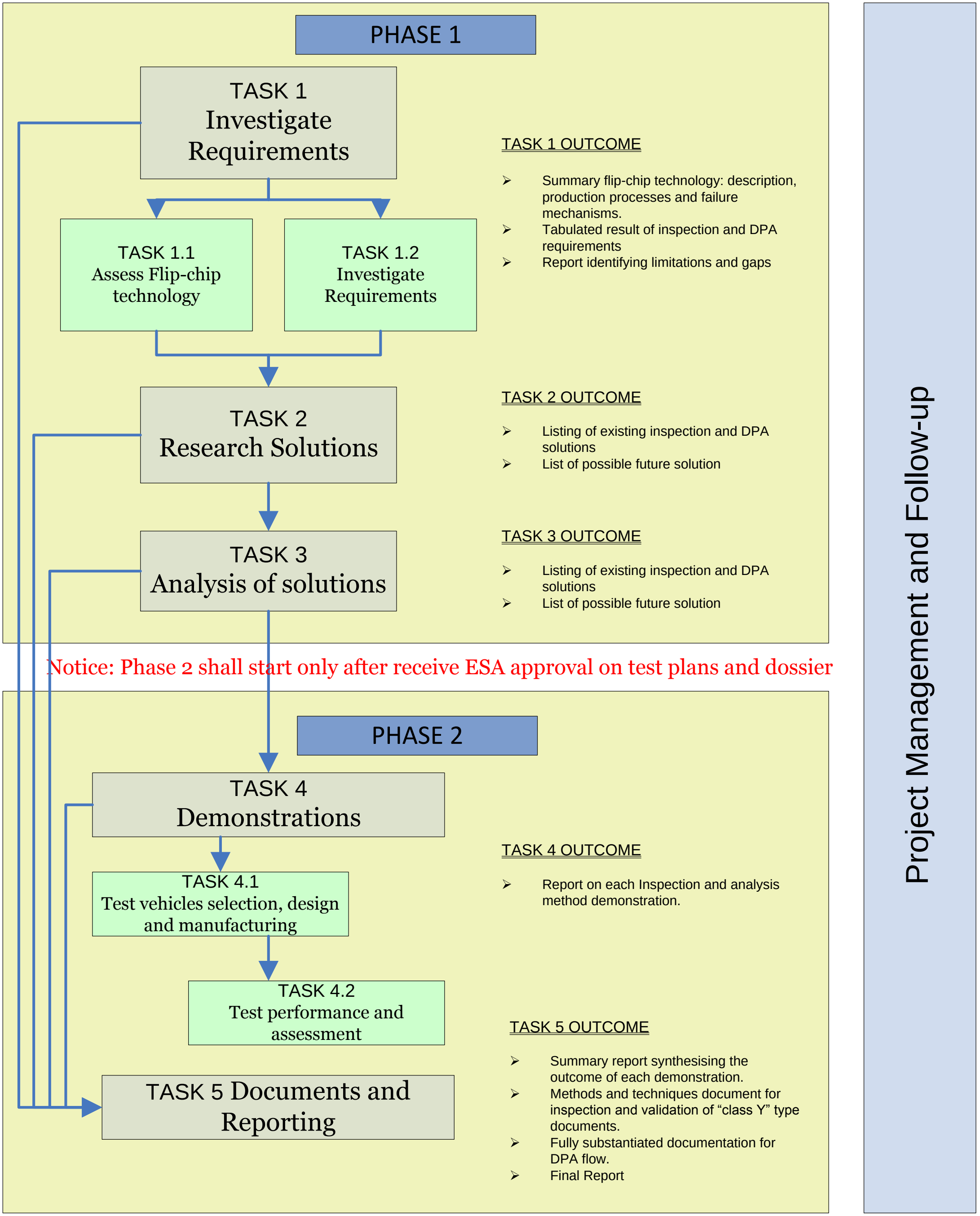
➢ Flip chip assembly techniques bring a wide range of benefits:

- Reduced parasitic interconnection between the semiconductor die and package.
- Provides a high final assembly integrity density.
- Minimize the interconnection length, providing better electrical performances, especially for high speed signals.
- Reduce the device size and weight,…, etc.



But there is no dedicated inspection requirements nor DPA standard which address all the necessary aspects associated to this construction type or only cover partially the topics to be inspected.

Study approach / Tasks.



Task 1 – Investigate Requirements.

Task 2 – Research Solutions.

Task 3 – Analysis of Solutions.

Task 4 – Demonstrations.

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Flip Chip Technologies, Reliability and Failure Modes.

Process	Failure Mode	Failure Mechanism
Solder ball attach	Missing bumps	Poor process set up
		Physical Damage
	Fractured bumps	Poor process set up
	Poor wetting	Poor process set up
	Bump Height	Poor process set up
	Bump Alignment	Mask design / Poor process set up
Alignment/placement of die by flip chip bonder	Cracked Die	Uneven bump height
		Contamination
		Variation in material strength
	Stressed Die	Uneven bump height
		Poor process set up
	Poor electrical connection	Uneven bump height
		Missing Bumps
		Contamination
		Variation in substrate
	Shorts / misaligned	Operator error
		Machine set up
		Fudicial clarity on substrate

Underfill Process	Voiding	Poor degassing
		Variation in die/substrate clearance
		Contaminated substrate
	Delamination	Contaminated substrate
		Incomplete Cure
		Poor substrate metalisation
Reliability Issues	Cracked Die	Stress Failure
	Delamination	Underfill, UBM, or Bump Failure
	Underfill Failure	Radiation degradation
	Electrical Failure	All the above and Radiation Degradation

Flip Chip Technologies, Requirements investigations.

MIL

MIL-STD-883 J , MIL-STD-1580 B, MIL-PRF-38535 K, EPS on Flip-Chip underfill test requirements

ESCC

- 20400 , 20500, 20900
- 21400, 25300, 25500

JEDEC

- JESD22-B1XX
- JEP 154 ,170,…

IPC

IPC-7094 on Design and assembly process implementation for Flip-chip , MIL-STD-1580 B,
IPC-TM-650 Test Method Manual
…

IPC/JEDEC

- J-STD-029. “Test Methods for Flip Chip or Chip Scale Products”.
- J-STD-030. “Guideline for Selection and Application of Underfill Material for Flip Chip and Other Micropackages”, …

Others

- AEC - Q100-010. “Attach. 10 Rev. A. Solder Ball Shear”.
- IEC-PAS 62084. “Implementation of Flip Chip and Chip Scale”.
- Direct consultation to companies involved on Flip-chip: service providers, researcg intitutions and test equipment suppliers….

A wide range of test methods, standars and , technical documents were investigated, gathering information on available flip-chip requirements and inspection test techniques.

Investigations on inspection and DPA requirements for Flip-chip technologies.

	Flip Chip Applicability	Applicable MIL Test Method	Flip-chip coverage	Comments
External visual	Y	MIL-STD-883 T.M. 2009	N	Test method acceptable but recomendable additional requirements in terms of underfill lateral side inspection, heat spreader and related interface.
Physical Dimension Check	Y	MIL-STD-883 T.M. 2016 DETAIL SPECIFICATION	Y *	Test method valid, missing some recomendations on numbr of measurements related to leads.
Lead Finish Verification	Y	MIL-STD-883 T.M. 2037 MIL-STD-1580B. Req. 9	Y	Flip chip is not referenced, general requirement can be applied, but furhter development would be wished.
Hermeticity	N	MIL-STD-883 T.M. 1014 (FINE & GROSS LEAK)	N	Test not applicable
PIND	N	MIL-STD-883 T.M. 2020	N	Test not applicable
CSAM	Y	MIL-STD-883 T.M. 2030 JEDEC J-STD-035	N	Detailed reject criteria and inspectioon conditions are not defined
X-Ray (2D & 3D)	Y	MIL-STD-883 T.M. 2012 ESCC 2099000	N	Detailed reject criteria and inspectioon conditions are not defined
Solderability	Y	MIL-STD-883 T.M. 2003	Y	Test condition for generic leads / contacts styles, includiong those used for flip chip.
Resistance to Solvents	Y	MIL-STD-883 T.M. 2015	Y	Flip chip is not referenced, general requirement can be applied.
Terminal Strength	Y	MIL-STD-883 T.M. 2004 MIL-STD-883 T.M. 2038 JESD22-B117	Y	Test conditions referenced for all terminal / contacts types, including those used for Flip chip technologues
RGA / IVA	N	MIL-STD-883 T.M. 1018	N	Test not applicable
Lid Shear / Torque	Y	MIL-STD-883 T.M. 2024	N	Lid torque test MIL-STD-883 Test Method 2024 when a lid/heat sink is attached on the back side of a flip chip die.
Decapsulation	Y	-	N	Methodology not standarized for flip chip construction which need to be defined
Internal Visual	Y	MIL-STD-883 T.M. 2010 MIL-STD-883 T.M. 2017	Y	Detail paragraphs are included in the inspection test methods to cope with flip chip assembly types: MIL-STD-883 T.M. 2010 Par. 3.2.1.6. & 3.1.3.i. Good coverage but some addemdum to consider.
SEM	Y	MIL-STD-883 T.M. 2018	Y	Flip chip is not referenced, general requirement can be applied, but furhter development would be wished.
Bond-Strength / Flip-Chip Pull	Y	MIL-STD-883 T.M. 2011 MIL-STD-883 T.M. 2031	Y*	Test methods applicable and usable. Neccesary to specify secuence, ans sample fixing procedures for DPA.
Die-Shear / Substrate Attach	Y	MIL-STD-883 T.M. 2019	Y*	Test methods applicable and usable. Neccesary to specify secuence, ans sample fixing procedures for DPA.
Cross-section	Y	MIL-STD-1580 Req. 16 MIL-STD-883 T.M. 2018	N	Flip chip is not referenced, general requirement can be applied, but requirements are needed.

Investigations on inspection and DPA requirements for Flip-chip technologies.

Other techniques were also assessed:

- CT X-Ray Inspection. Valid and interesting technique but time consuming process and quite often difficult to assess when dealing with high complexity structures, requiring additional X-ray inspections. Only recommendable on case by case basis.

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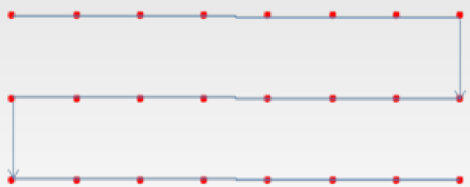
Investigations on inspection and DPA requirements for Flip-chip technologies.

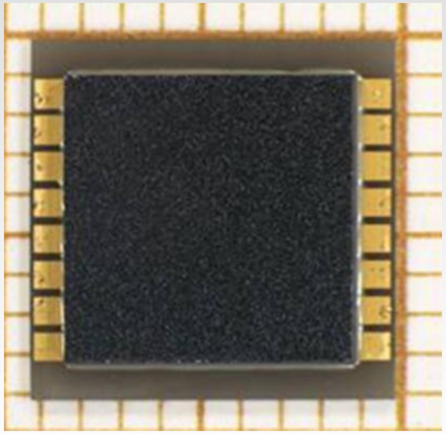
Other techniques were also assessed:

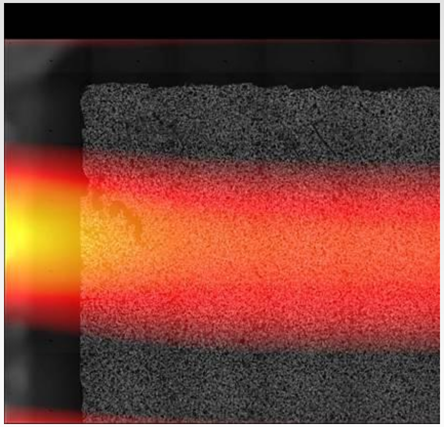
- Magnetic microscopy. Good as a failure analysis but not as a standard DPA step.
- FIB, known technique but not especially necessary for flip-chip, recommended for certain IC device complexity in the same manner as for an IC DPA.
- SLAM. Promising technique currently growing and in use in other industrial sectors, but not well developed to be applied on electronic devices.
- Infrared – emission microscopy. Classic FA tool but not specially necessary for a flip-chip DPA.

Demonstration test flow and performance

A sample with an open circuit in a pre-defined daisy chain was selected (the other daisy chains have good electrical continuity). In order to proceed with the magnetic inspection the heatsink was removed, exposing the substrate pads and the device was biased and inspected with a magnetic microprobe. (Each device has have 8 daisy chain tracks , track 1 at the top of the test part, and 8 at the bottom. The bump array has 24X24 bumps, so each daisy chain corresponds with three bumps lines).







The technique is promising but, it seems very dependant on the kind of available materials in the sample, and the distance, being in our case difficult to obtain useful information.

The activity could be performed thanks to Fulvio Infante / Nicolas Courjault INTRASPEC TECHNOLOGY

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Test vehicle design and manufacturing.

Test Vehicle Ref:		Qty
TV 001	Solder Ball Process, Missing Bumps	3
	Fractured Solder Bumps	3
	Control Sample	1
TV 002	Poor Solder Ball Wetting	3
	Uneven bump height	3
	Control Sample	1
TV 003	Die Placement (Poor Alignment with bumps - rotation)	3
	Die Placement (Poor alignment with bumps - lateral)	3
	Control Sample	1
TV 004	Underfill Voiding	3
	Underfill Delamination	3
	Control Sample	1
TV 005	Heatsink Attach Delamination	3
	Ceramic Substrate Cracked	3
	Control Sample	1
TV 006	Samples with PCB substrate	2
	Control Sample	2

Optocap built 37 samples as Test Vehicles inducing key flip-chip failures modes to assess if the selected test flow was able to properly detect the problems.

Optocap Assembly design and manufacturing.

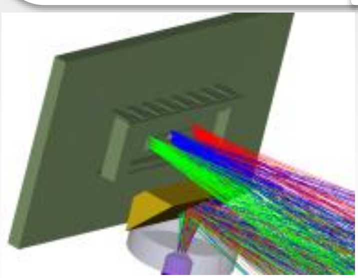
Optical modelling

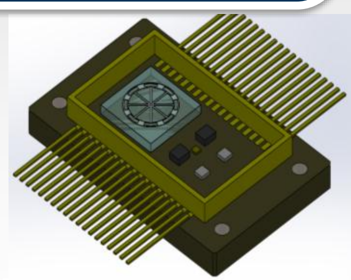
Package design

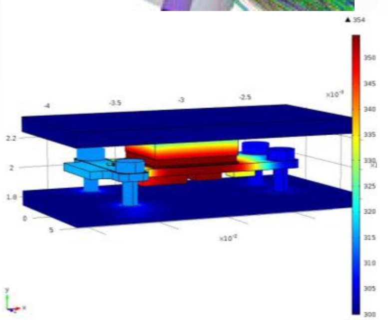
New Product Introduction

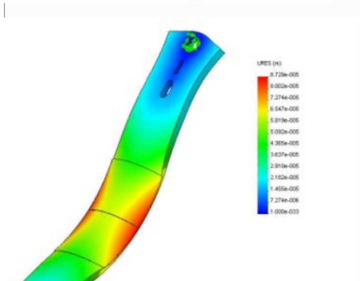
Thermal modelling

Mechanical stress modelling









European Production

- Automated pick & place
- Wafer post process.
- Wire bond
- Flip chip
- Ceramic & plastic package
- Hermetic sealing
- Optical alignment

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Test vehicle and test sample assignment.

		TV 001			TV 002			TV 003			TV 004			TV 005		TV 006	
	Test Vehicle Def	Missing Bumps (Note 1)	Fractured Solder Bumps	Cont Sample (Note 0)	Poor Solder Ball Wetting	Uneven bump height	Cont Sample (Note 0)	Die Placement (bumps - rotation)	Die Placement (bumps - lateral)	Cont Sample (Note 0)	Underfill Voiding	Underfill Delam.	Cont Sample (Note 0)	Heat sink Attach Delamin	Cont Sample (Note 0)	Samples with PCB substrate	Cont Sample (Note 0)
Test step	Qty	3	3	1	3	3	1	3	3	1	3	3	1	3	1	2	2
1	External Visual Inspection	3 - ALL	3 - ALL		3 - ALL	3 - ALL		3 - ALL	3 - ALL		3 - ALL	3 - ALL		3 - ALL			
2	Physical Dimension Check	3 - ALL	3 - ALL		3 - ALL	3 - ALL		3 - ALL	3 - ALL		3 - ALL	3 - ALL		3 - ALL			
3	Lead Finish Verification	3 - ALL	3 - ALL		3 - ALL	3 - ALL		3 - ALL	3 - ALL		3 - ALL	3 - ALL		3 - ALL			
4	CSAM	3 - ALL	3 - ALL		3 - ALL	3 - ALL		3 - ALL	3 - ALL		3 - ALL	3 - ALL		3 - ALL		2 - ALL	
5	X-Ray (2D & 3D)	3 - ALL	3 - ALL		3 - ALL	3 - ALL		3 - ALL	3 - ALL		3 - ALL	3 - ALL		3 - ALL		2 - ALL	
6	Lid - heat sink Shear / Torque													1			
7	Flip-Chip Pull																
8	Die-Shear / Sub Attach	1(Note 2)	1(Note 2)		1(Note 2)	1(Note 2)		1(Note 2)	1(Note 2)		1(Note 2)	1(Note 2)		1(Note 2)			
9	Dye Penetrant	3 - ALL	3 - ALL		3 - ALL	3 - ALL		3 - ALL	3 - ALL		3 - ALL	3 - ALL		3 - ALL			
10	Device Sec: A) Parallel sec.	TV1-1A	TV1-2A		TV2-1A	TV2-2C		TV3-1A	TV3-2A		TV4-1A	TV4-2A		TV5-1A			
11	Device Sec: B) Cross Section	TV1-1B	Note 5		TV2-1B	TV2-2A		TV3-1B	TV3-2B		TV4-1B	TV4-2B		TV5-1B		TV6-1 / TV6-2	
12	Decap (Note 4)	TV1-1C	TV1-2C		TV2-1C	TV2-2B		TV3-1C	TV3-2C		TV4-1C	TV4-2C		TV5-1C			
13	Internal Visual	TV1-1C	TV1-2C		TV2-1C	TV2-2B		TV3-1C	TV3-2C		TV4-1C	TV4-2C		TV5-1C			
14	SEM	TV1-1C	TV1-2C		TV2-1C	TV2-2B		TV3-1C	TV3-2C		TV4-1C	TV4-2C		TV5-1C			
15	Bump Shear (Note 3)	TV1-1A	TV1-2A		TV2-1A	TV2-2C		TV3-1A	TV3-2A		TV4-1A	TV4-2A		TV5-1A			

Minimum DPA flow for Flip-chip construction.

MINIMUM DPA FLOW REQUIREMENTS FOR MICROCIRCUITS WITH FLIP-CHIP CONSTRUCTION

Test Sequence	Test Description	Test Method	Sample Allocation
1	External Visual Inspection	ESCC Basic Spec. No. 20500 MIL-STD-883 TM2009 (Note 1)	3 Parts
2	Photographic Record	Appendix AX.X (Note 2)	1 Part
3	Verification of Lead Material Finish	ESCC 25500 (Note 3)	1 Part
4	Scanning Acoustic Microscopy	ESCC Basic Specification No. 25200	3 Parts
5	Radiographic Inspection	ESCC Basic Specification No. 25200 (Note 4)	3 Parts
6	Seal Test (Note 5)	MIL-STD-883 TM1014	3* Parts
7	PIND (Note 6)	MIL-STD-883 TM2020 Cond A	3 Parts
8	Residual Gas Analysis (Note 7)	MIL-STD-883 TM 1018	3 Parts
9	Solderability Test	MIL-STD-883 Method 2003. (Note 8)	3 Parts
10	Marking Permanence Test	ESCC Basic Specification No 24800	3 Parts
11	Lead Integrity / Terminal Strength Test	Detail Specification (Note 9)	3 Parts
12	Lid / Heat Sink Torque	MIL-STD-883 TM 2024 (Note 10)	1 Part
13	Flip-Chip Pull-off / Bond Strength (Note 11)	MIL-STD-883 TM 2031 / MIL-STD-883 TM 2011	1 Part
14	Die-Shear / Substrate Attach (Note 12)	MIL-STD-883 TM 2019 / MIL-STD-883 TM 2027	1 Part
15	Dye Penetrant	MIL-STD-883 TM 1034 (Note 13)	3 Parts
16	Device Sectioning	(Note 14)	2 Parts
17	De-capsulation	(Note 15)	1 Part
18	Internal Visual Inspection (Note 16)	ESCC Basic Specification No. 20400 / 2049000	1 Part
19	SEM Inspection. (Notes 17)	ESCC Basic Specification No. 21400 / 2149000	1 Part
20	Photographic Record	Appendix AX.X	1 Part
21	DPA Report	Para. 6.3	3 Parts

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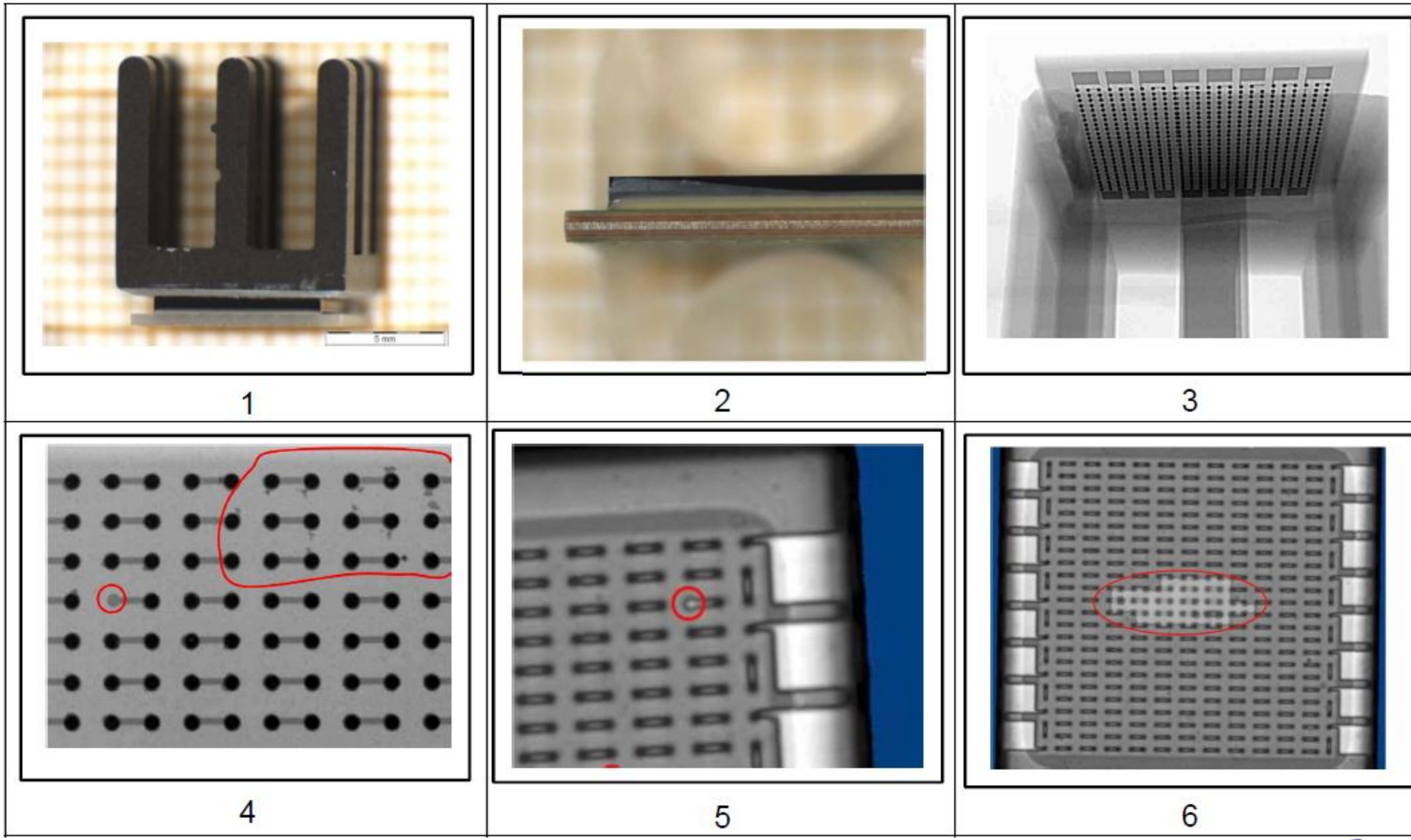
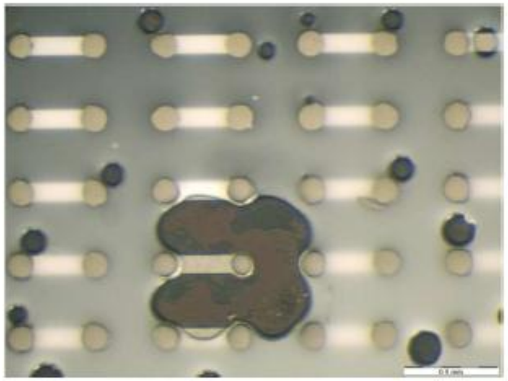
Typical DPA pictures.



Typical DPA pictures.



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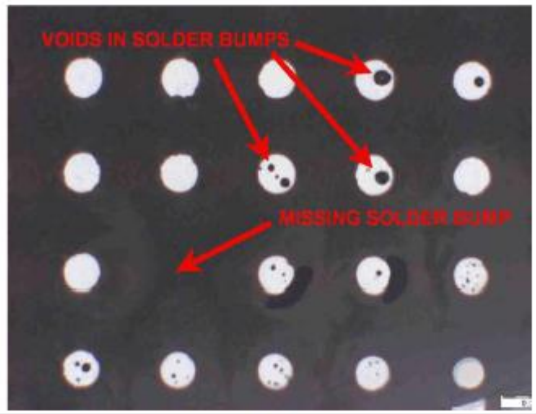

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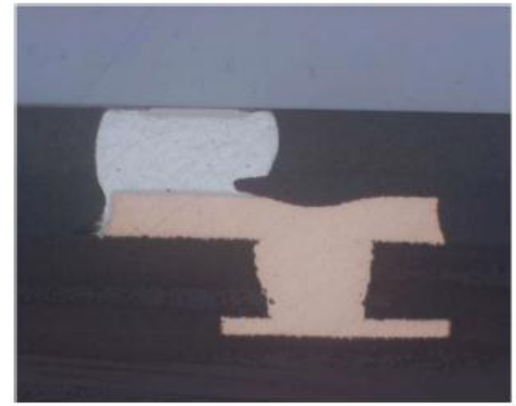

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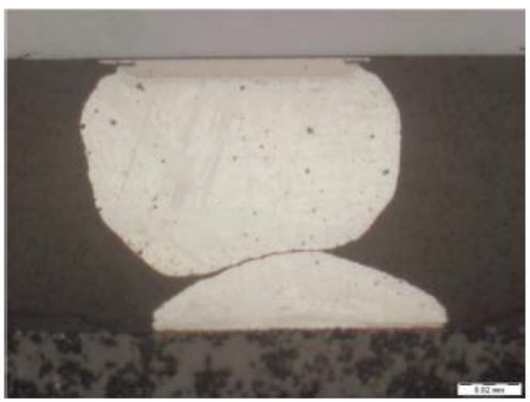

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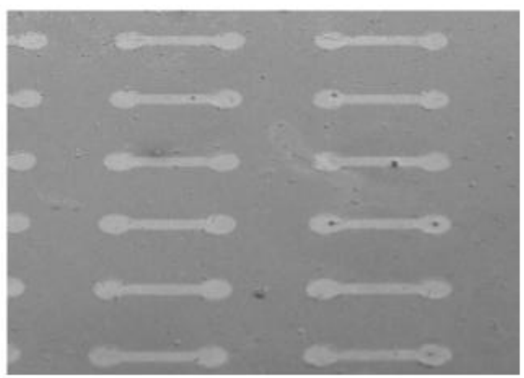

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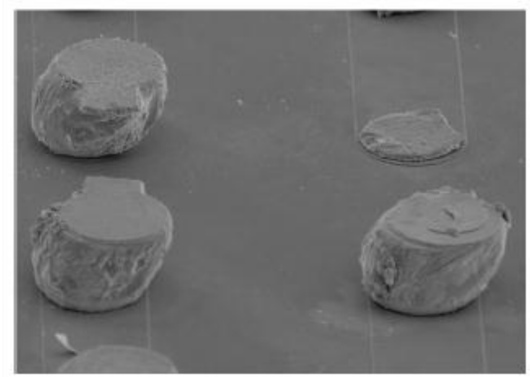

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Summary and some Conclusions.

1. During the test performance and after the data assessment it appear that CSAM, X-Ray and metallurgical sections are the key test steps to evaluate the flip-chip device construction.
2. The available test method have not a complete technical coverage for flip-chip constructions, being recommended to stablish:
   - External visual failure criteria for underfill and heat sink assembly.
   - Criteria to measure and accept flip-chip co-planarity.
   - Quantitative criteria for CSAM inspection regarding delaminations, voiding,...
   - Update the current X-Ray test methods considering the requirements already defined within the internal visual inspection but adapted to this technique.
   - …etc.
3. The information has been presented in ESCC format for easier adoption in future ESCC basic specification 21001 update.

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ASSESSMENT OF COMMERCIAL COMPONENTS ENABLIG DISRUPTIVE SPACE ELECTRONICS

ACCEDE
COTS2019
SEVILLE – SPAIN 2-4 OCTOBER

Focusing on all aspects related to the usage of Commercial of the Shelf (COTS) Electrical, Electronic and electro-mechanical (EEE) parts in space applications. Although the main goal is to address specific needs of "New Space" programs such as constellations and /or nano & small satellites, the workshop will cover also classical space missions.

Those interested in particular topics and wishing to provide a presentation / talk are encouraged to make contact with the organizing committee.

e-mail: accede@altertechnology.com
Web page: http://wpo-altertechnology.com/accede

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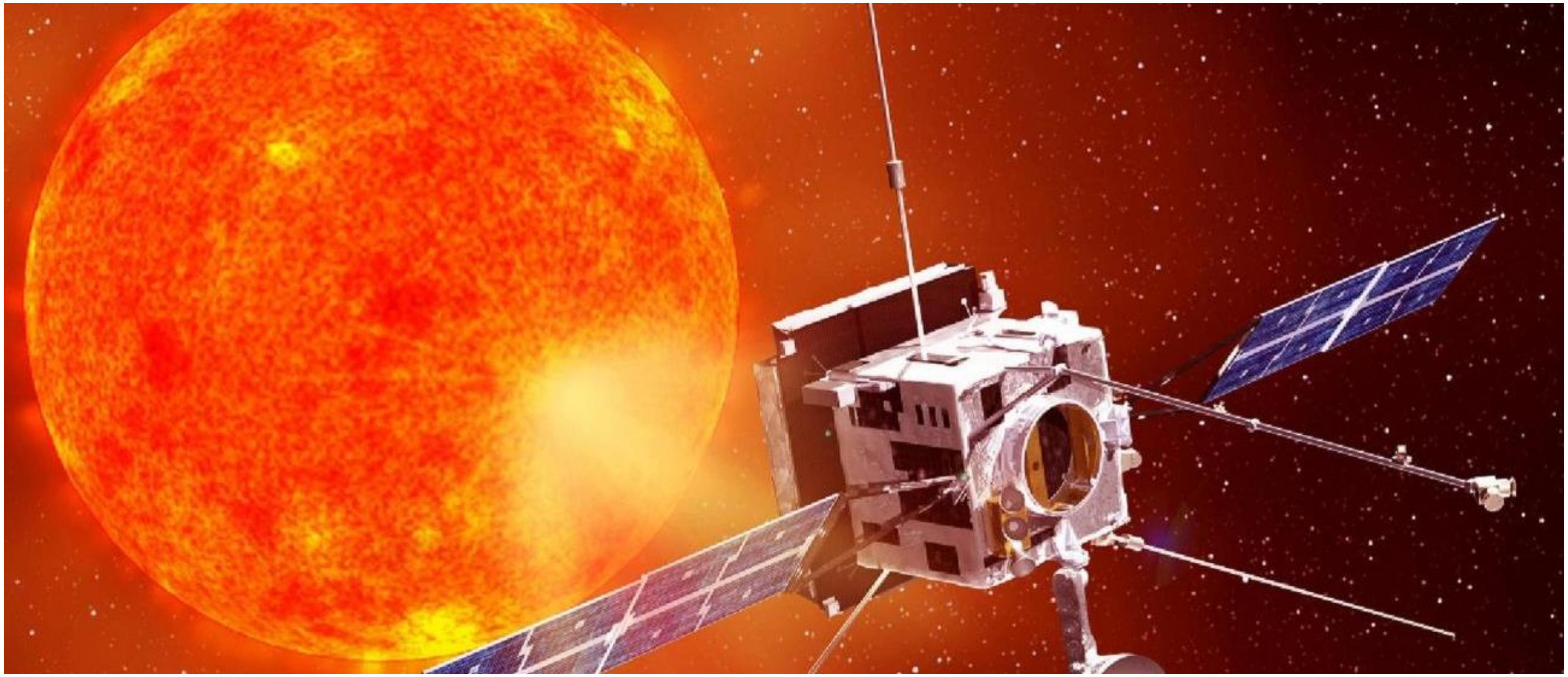

THANK YOU FOR YOUR ATTENTION

Gonzalo Fernández

C/ Tomás Alba Édison, 4
41092 Sevilla
Spain
Phone + 34 95 446 70 50
Email: gonzalo.fernandez@altertechnology.com
www.altertechnology.com

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