Evaluation of Soft Soldering on Aluminium Nitride (AlN)

ESTEC Contract No. 19220/05/NL/PA

CTB Hybrids WG – ESTEC-22nd May 2007

All the space you need

EADS astrium

Evaluation of Soft Soldering on AlN

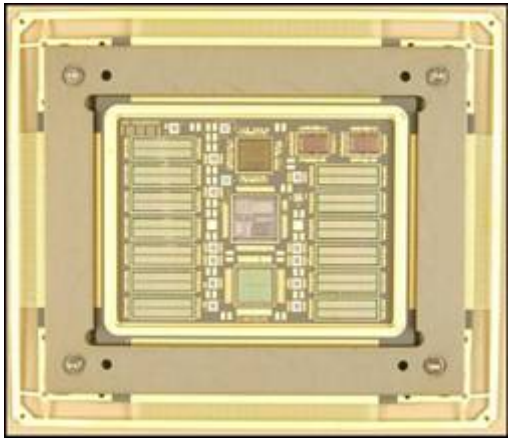
- Schedule
  - Project presentation
  - Feasibility study of tin/lead soldering on AlN
    - Specifications and definition of a test vehicle
    - Soldering processes and samples assembly
    - Reliability evaluation
  - Conclusion and future work

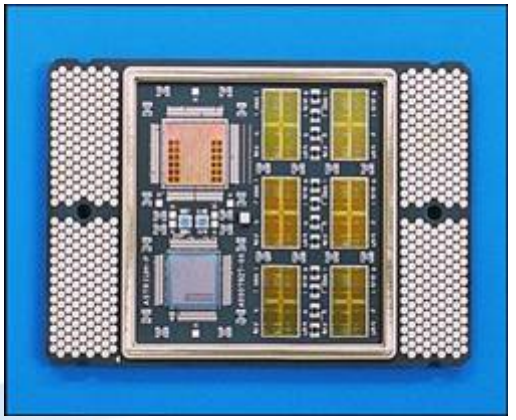
Project presentation

- Astrium knowledge on AlN packages :
  - Manufacturing of high performance MCM with HTCC (High Temperature Cofiring Ceramic) packages in AlN.
  - Single or dual hermetic cavity packages containing bare dice.

- Future needs :
  - Integration of new functions.
  - Lower costs.
  - Quick evolution of components/performances.

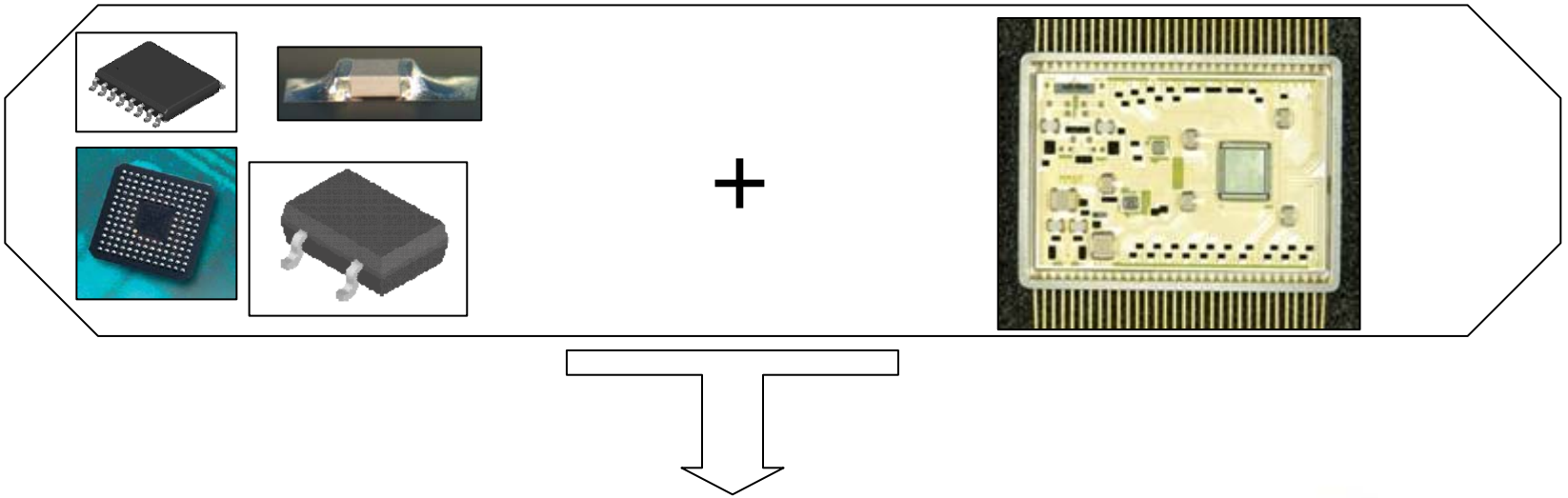
Not possible with only bare dice





Project presentation

- Objectives of the Soft Soldering project :
  - Develop a soldering process on AlN with eutectic SnPb (soft soldering)
  - Integrate on the same MCM an hermetic cavity and soldered components



New generation of MCM

Project presentation

- AlN HTCC strong points :
  - High thermal conductivity (150 W/m.K)
  - High interconnection density
  - High mechanical properties
- AlN HTCC weak points :
  - Price
  - Few manufacturers
  - Substrates size limited
- AlN HTCC presents a very low CTE (4-6ppm/K) :

Adapted to silicon dice

Critical for a lot of SMD components

Project presentation

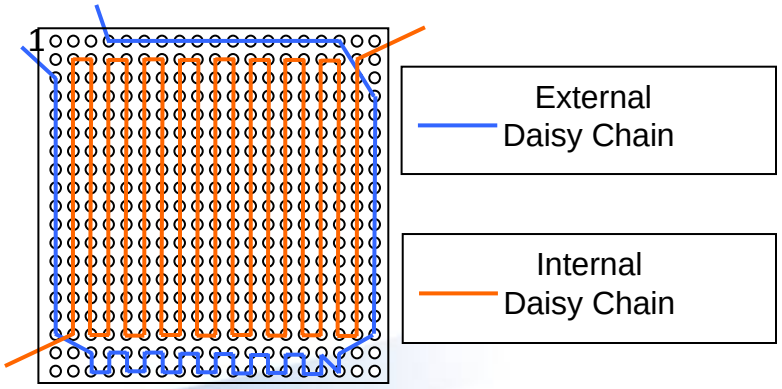
- Work packages and tasks description :

	Task	
Work Packages	N°	Description
WP 1 : Feasibility study of tin-lead soldering on AlN	1.1	State of the art
	1.2	Test vehicle definition with only soldered components
	1.3	SnPb assembly and evaluation of samples reliability
WP 2 : Compatibility study with hermetic hybrid process	2.1	Technological approach of products
	2.2	Definition of technological demonstrator (bare dice + soldered components)
	2.3	Assembly and evaluation of demonstrator

Feasibility study of soft soldering on AlN

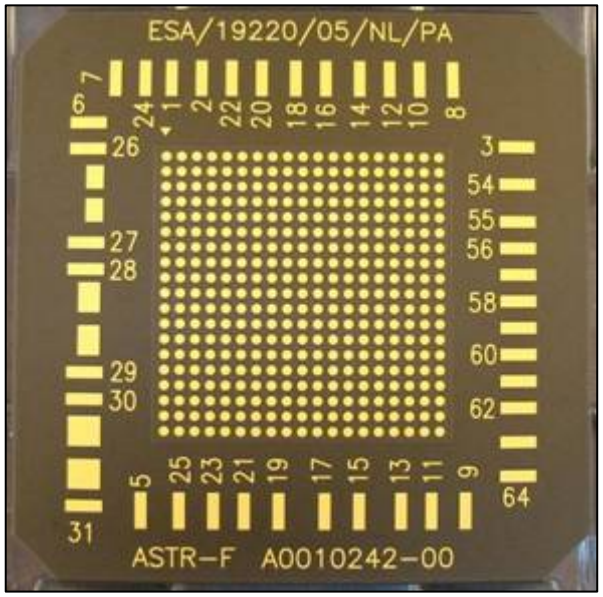
- Specifications of the test vehicle :
  - HTCC package in AlN
  - No hermetic cavity
  - Plating finish : NiAu (Au flash for tin-lead soldering)
  - Footprints for different SMD components : CBGA, ceramic capacitors (0805, 1206, 1210), SMD 0.5, SMD 1, copper wires.

- CBGA specifications :
  - Dummy component (Topline)
  - Size : 29mm square
  - 361 Balls, Pb/Sn (90/10)
  - Two daisy chains

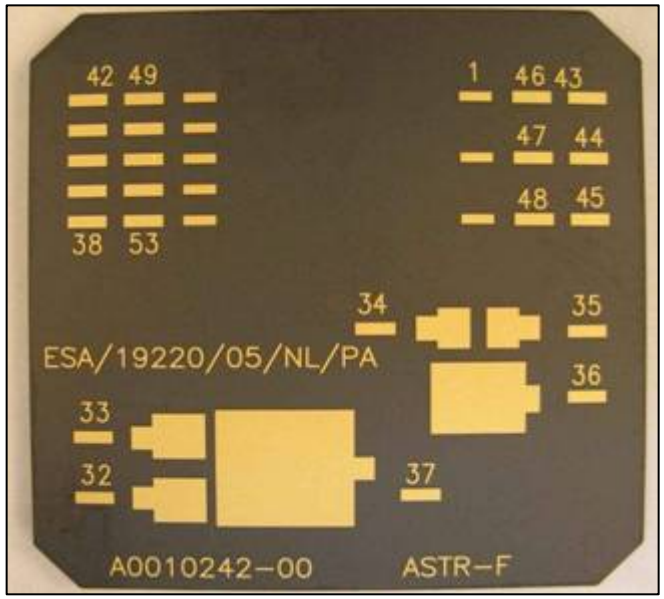


Feasibility study of SnPb Soldering on AlN

- Manufacturing of test vehicles : Kyocera



Top face

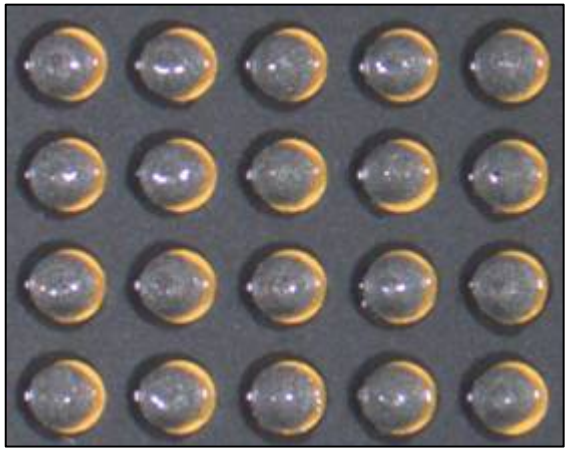


Bottom face

Size : 48.5mm square
Thickness : 2mm
6 layers

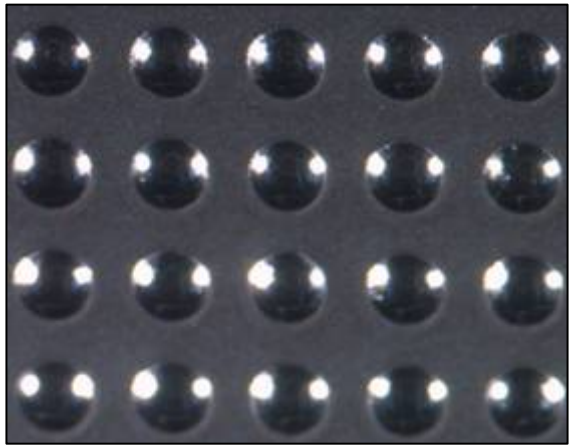
Assembly processes

- Soldering by vapour phase reflow : 3 steps
  - Solder paste deposition by screen printing.
  - Automatic Pick&Place of components.
  - Solder reflow by vapour phase.



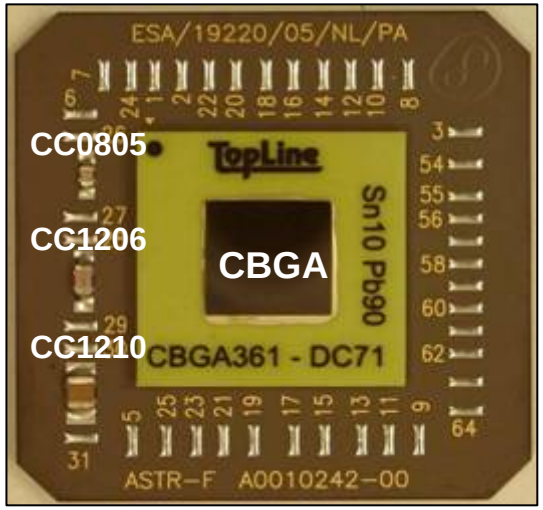
Vapour phase reflow

Good wettability
Shiny aspect of the solder

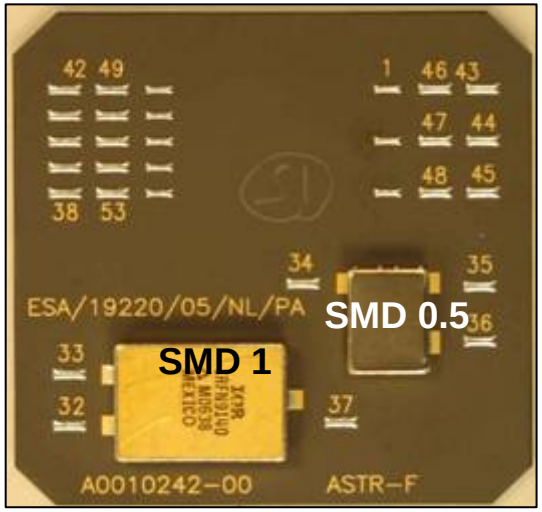


- Manual soldering : 2 steps
  - Tinning of NiAu pads
  - Manual soldering with iron solder.

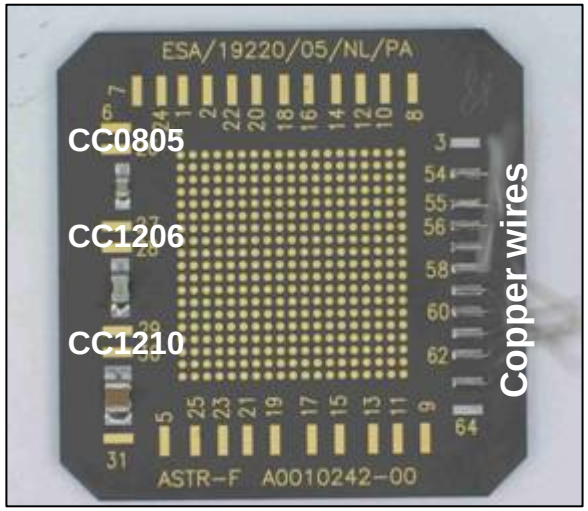
Evaluation of reliability : 25 samples assembled



12 samples assembled by vapour phase reflow with :
- 1 CBGA
- 3 ceramic capacitors (1210, 1206, 0805)

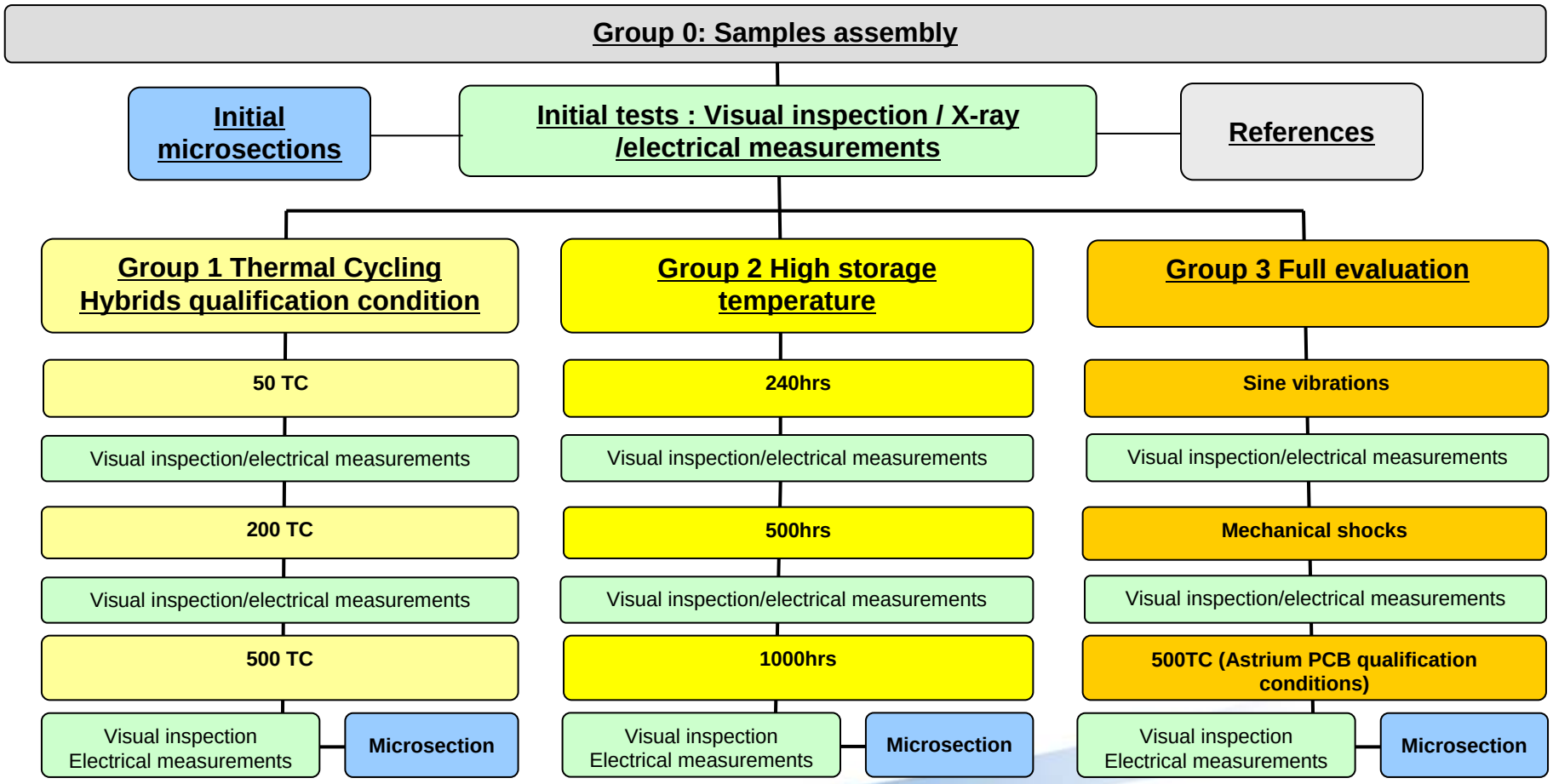


8 samples assembled by vapour phase reflow with :
- 1 SMD 1
- 1 SMD 0.5



5 samples assembled by manual soldering with :
- 3 ceramic capacitors (1210, 1206, 0805)
- 10 copper wires (Single strands, diameter 0.7mm) for peeling test.

Evaluation of reliability : Evaluation plan



Evaluation of reliability : Tests conditions

Tests performed	Tests conditions
Initial tests	- Visual Inspection. - X-Ray inspection.
High Temperature Storage	- T = +125°C. - Total duration of test : 1000 hours.
Sine Vibrations	- Frequency: 20 to 2000 Hz, with logarithmic variation. - Acceleration level: condition B (50g peak). - Number of cycles : 4 per axis (X, Y, Z). - Events detection (100ksamples/s) on CBGA daisy chains during test.
Shocks	- 1500g, 0.5ms, ½ sine. - 5 shocks along each axis (X, Y, Z). - Events detection (100ksamples/s) on CBGA daisy chains during test.
Thermal cycles (Astrium Hybrids qualification conditions)	- 500 cycles [-55°C ; 125°C]. - Dwell time of 20mn. - Two chamber oven with quick temperature ramps ⇨ **Thermal shocks!!** - Monitoring of CBGA daisy chains during test.
Thermal Cycles (Astrium PCB qualification conditions)	- 500 cycles [-55°C ; 100°C]. - Dwell time of 20min. - Temperature ramp controlled at 10°C/min (single chamber oven). - Monitoring of CBGA daisy chains during test.

Evaluation of reliability : Tests performed

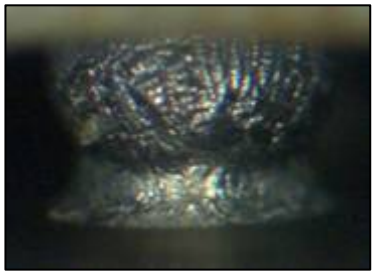
Samples Description	SN	Initial tests	Temperature storage at 125°C			Thermal cycles (Astrium Hybrids qualification conditions)		Vibrations + Shocks	Thermal cycles (Astrium PCB qualification conditions)		DPA
			240hrs	500hrs	1000hrs	200TC	500TC		200TC	500TC	
Capacitors + CBGA assembled by vapour phase reflow	1	X									
	2	X				X					X
	3	X				X	X				
	4	X				X	X				
	5	X	X	X	X						X
	6	X	X	X	X						
	7	X	X	X	X						
	8	X						X	In progress	In progress	
	9	X						X	In progress	In progress	
	10	X						X	In progress	In progress	
	11	X						X	In progress	In progress	
	12	X						X	In progress	In progress	
SMD 0.5 and SMD 1 assembled by vapour phase reflow	13	X				X	X				
	14	X						X	In progress	In progress	
	15	X									X
	16	X				X	X				X
	17	X				X					
	23	X							In progress	In progress	
	24	X							In progress	In progress	
	25	X							In progress	In progress	
Capacitors + copper wires assembled by manual soldering	18	X									
	19	X									X
	20	X				X	X				
	21	X				X	X				
	22	X				X	X				X

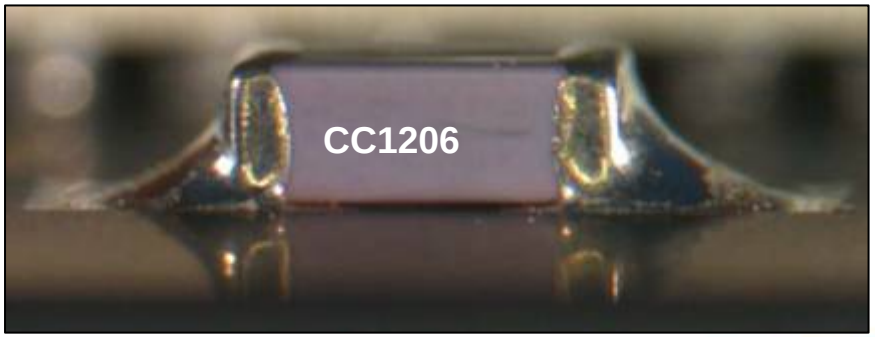
Evaluation results : Initial tests

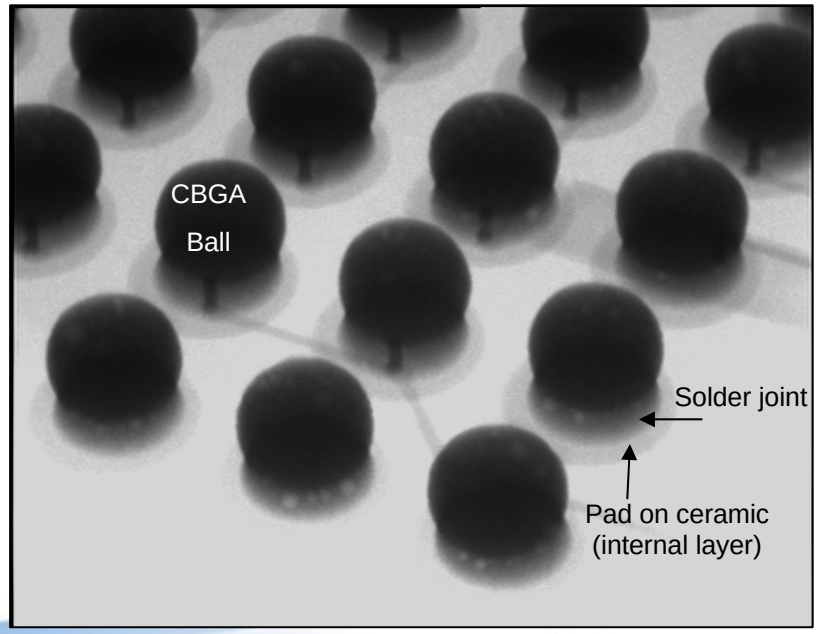
- CBGA 361 + ceramic capacitors (Vapour phase soldering):

Initial tests : Pass

Solder joints shape conform
CBGA alignment conform
X-Ray conform (voids below 20%, no shortcuts, no microballs)





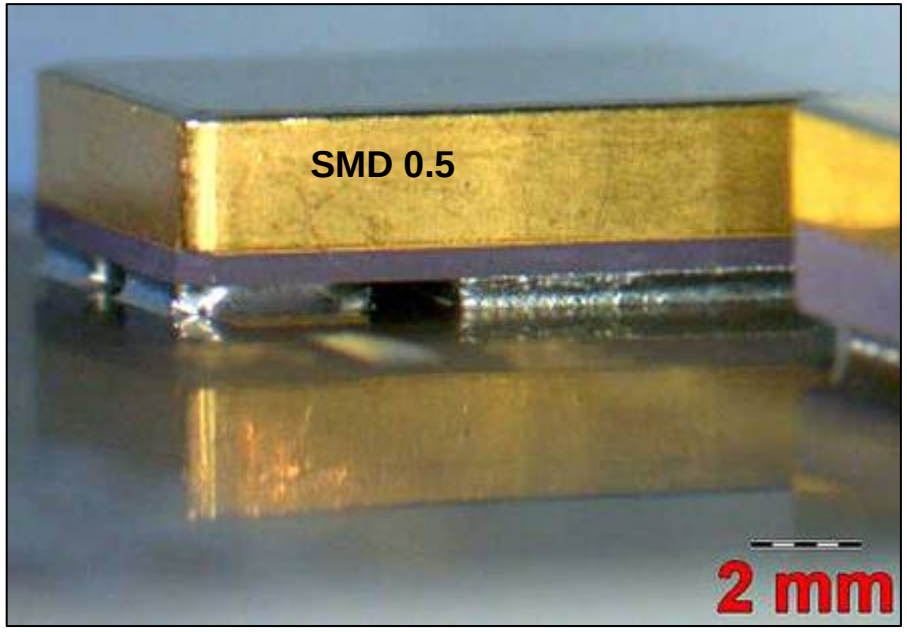


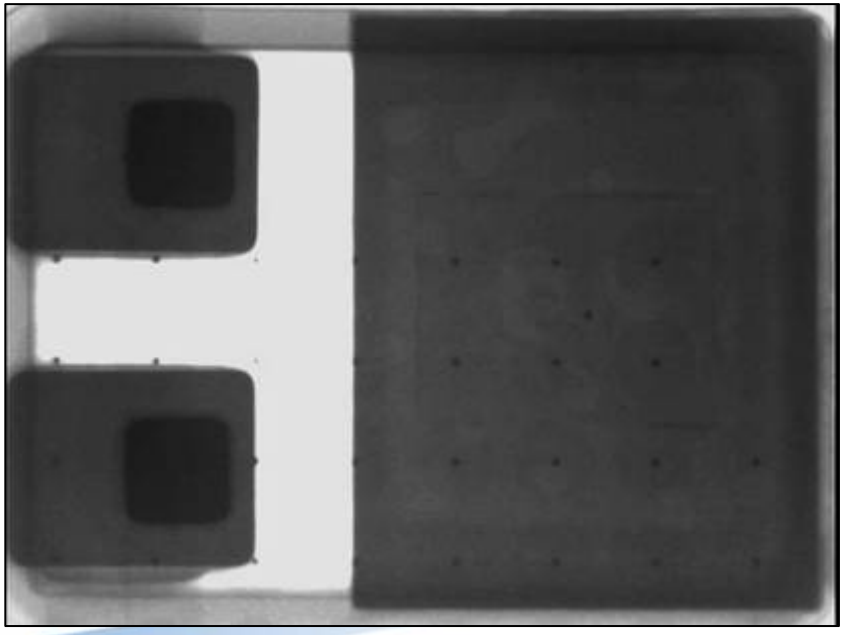
Evaluation results : Initial tests

- SMD 0.5 and SMD 1 (Vapour phase soldering):

Initial tests : Pass

Shiny solder joints
X-Ray conform (voids below 20%, no shortcuts, no microballs)



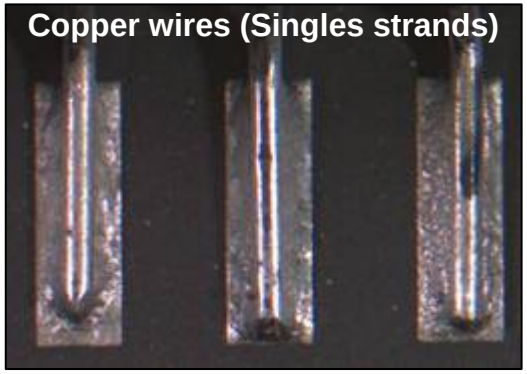


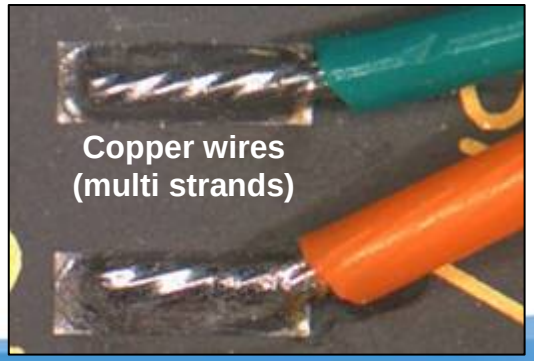
Evaluation results : Initial tests

- Ceramic capacitors and copper wires assembled by manual soldering :

Initial tests : Pass

Ceramic capacitors : Shiny solder joints/solder shape conform
Single strands wires : Bad wetting for several wires, probably due to the wires as multi strands wires used for CBGA monitoring present a good wetting.



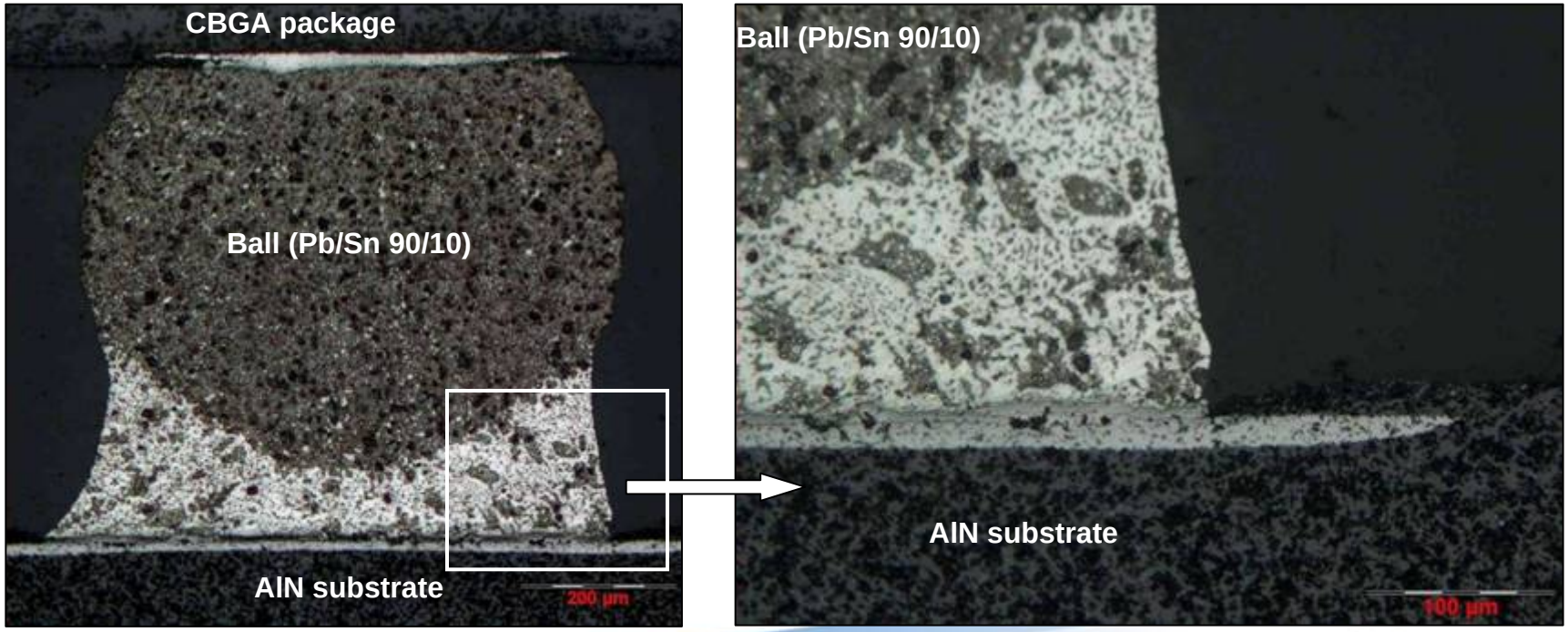


Evaluation results : Thermal Cycles (Hybrids qualification)

- CBGA 361 (Vapour phase soldering):

200TC : Pass

No evolution of CBGA daisy chains resistances
No failure observed on microsections



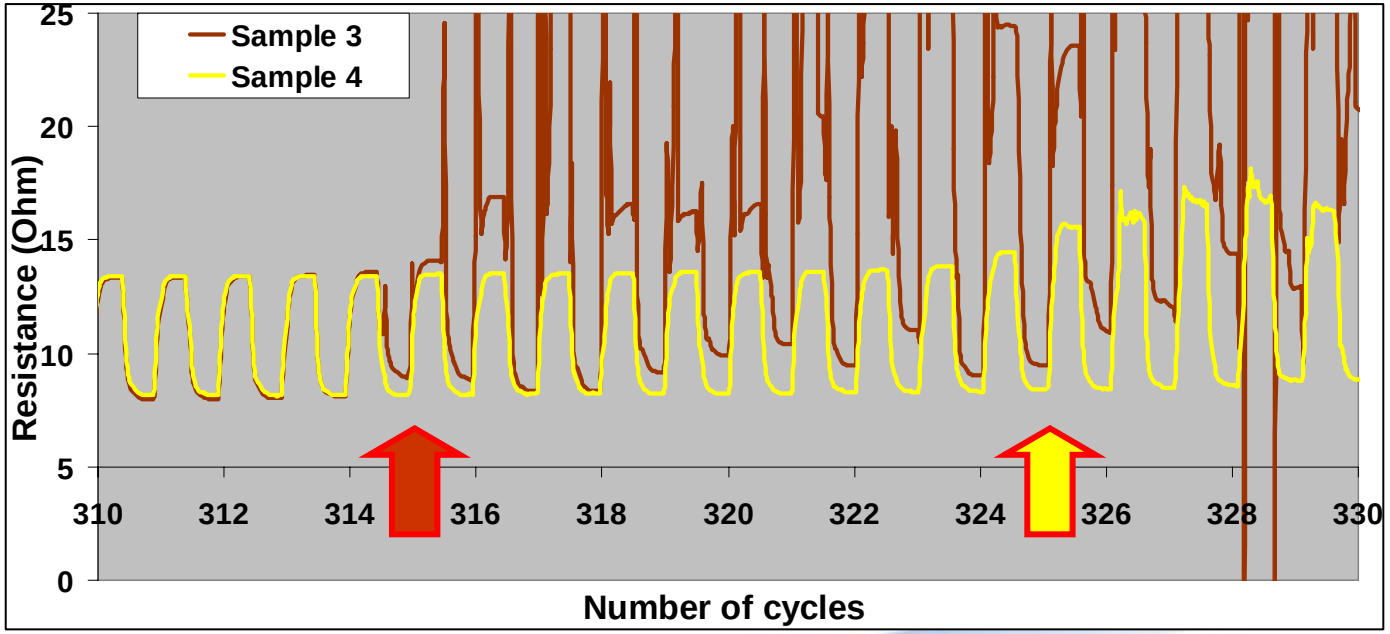
Evaluation results : Thermal Cycles (Hybrids qualification)

- CBGA 361 (Vapour phase soldering):

500 TC : Fail

Electrical failure of CBGA daisy chains before 500TC.

- External daisy chains failed at 314TC (Sample 3) and 323TC (Sample 4).
- Internal daisy chains failed at 350TC (Sample 3) and 403TC (Sample 4).



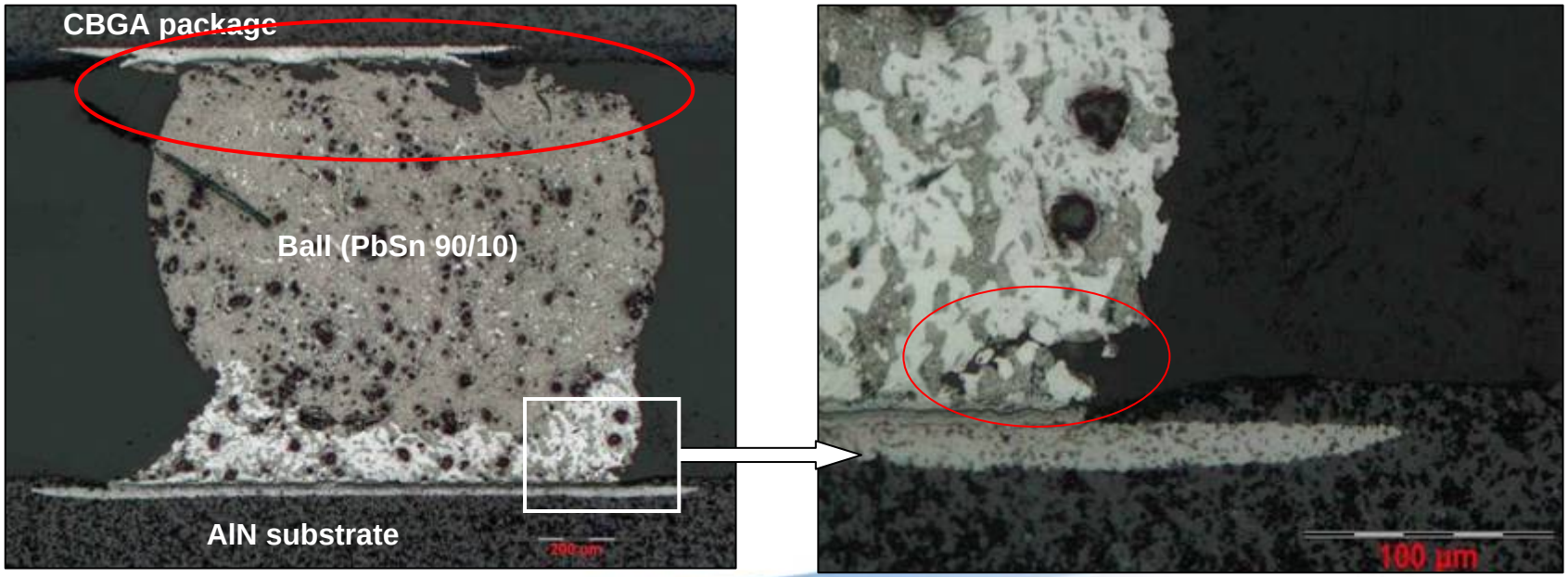
View of electrical failures during monitoring (external daisy chains)

Evaluation results : Thermal Cycles (Hybrids qualification)

- CBGA 361 (Vapour phase soldering):

500 TC : Fail

Microsection on an external row :
- Failure at the interface between balls and CBGA package (for entire row).
- Only small cracks in the solder joint itself.

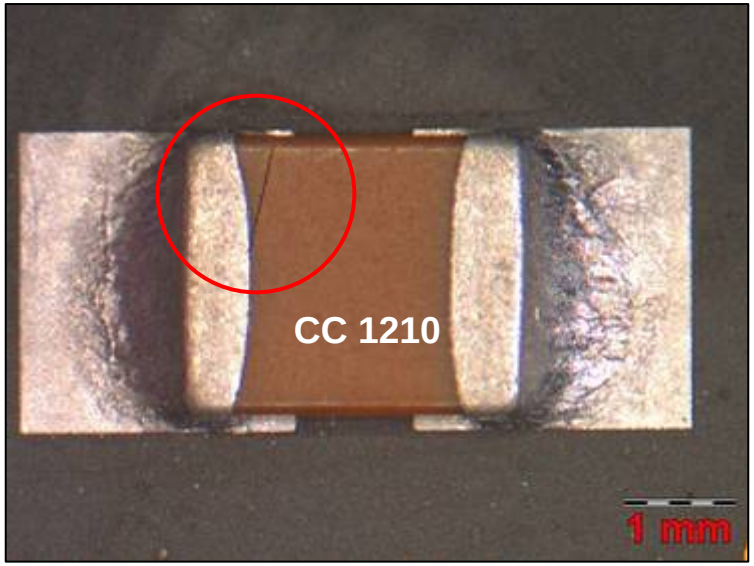


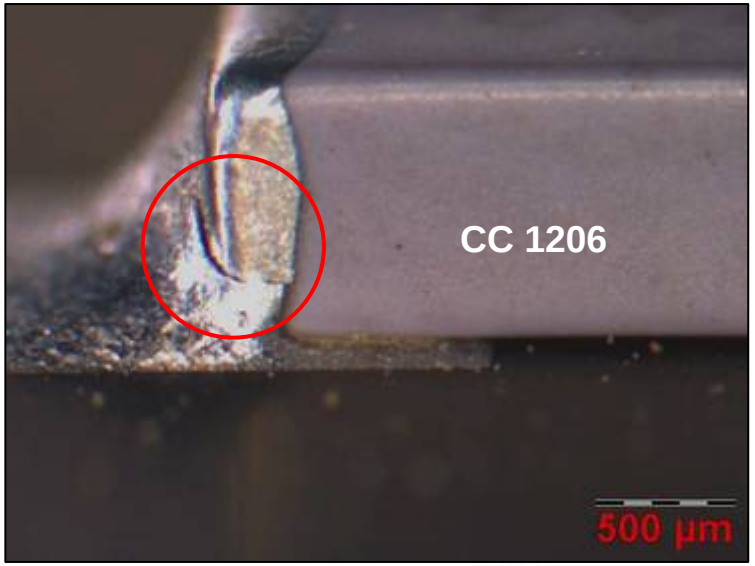
Evaluation results : Thermal Cycles (Hybrids qualification)

- Ceramic capacitors 1210 and 1206 (Vapour phase or manual soldering):

200 TC : Fail

Cracks in capacitors 1210 (capacitors bodies)
Cracks in capacitors 1206 (capacitors terminations)

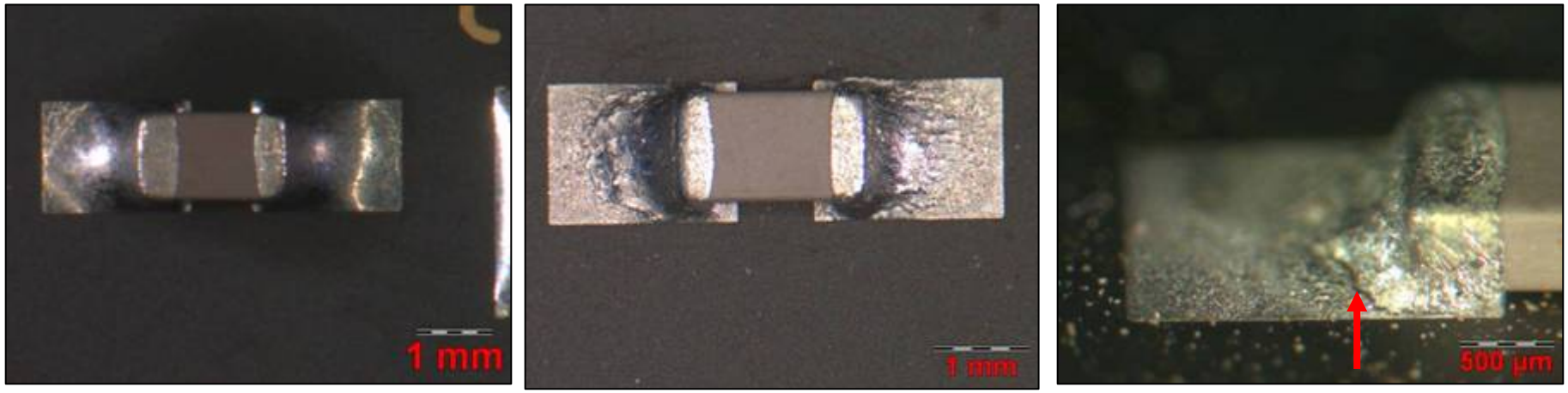




Evaluation results : Thermal Cycles (Hybrids qualification)

- Ceramic capacitors 0805 (Vapour phase or manual soldering):

  Important ageing of solder joints during TC, cracks in solder joints after 500TC



Initial assembly: Pass

After 200TC
Ageing of solder joint
No cracks observed

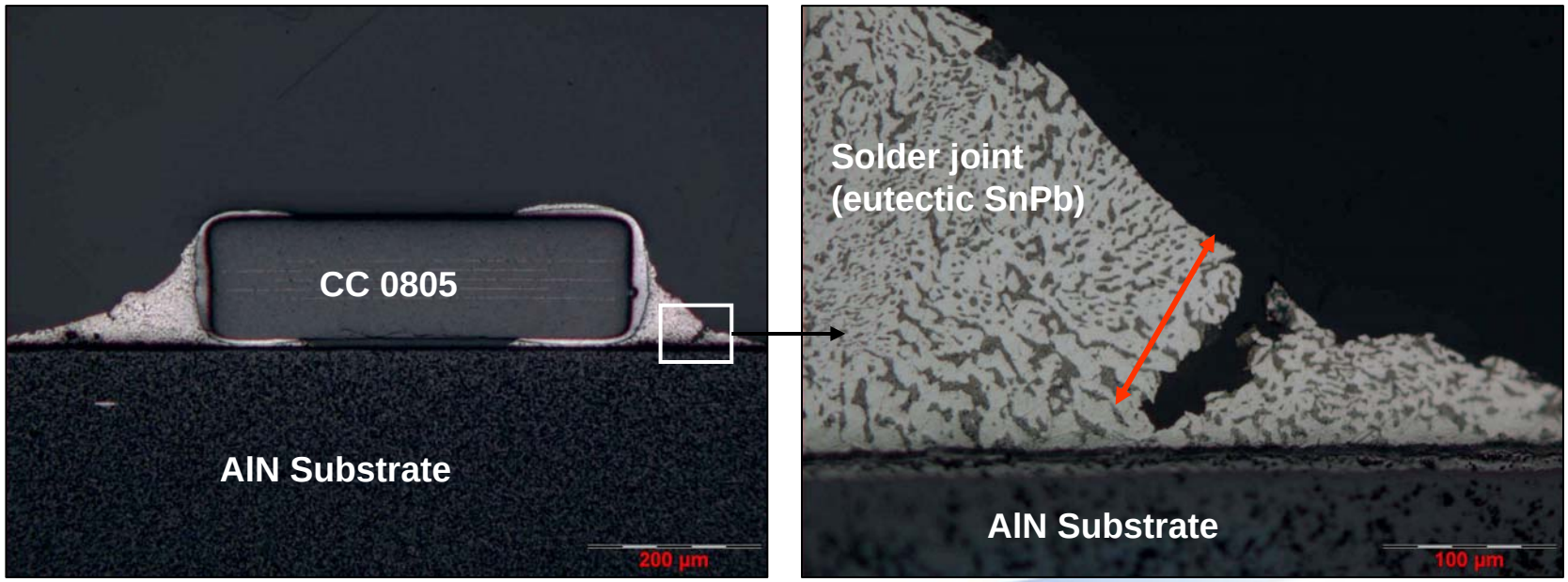
After 500TC
Cracks in solder joints

Evaluation results : Thermal Cycles (Hybrids qualification)

- Ceramic capacitors 0805 (Vapour phase or manual soldering):

500 TC : Pass

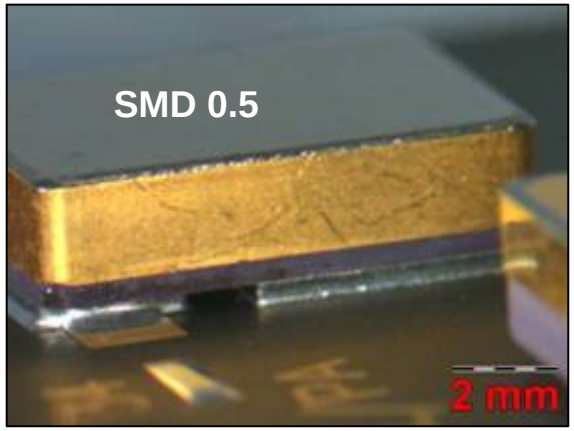
Microsections on CC0805 after 500TC
- Cracks do not propagate

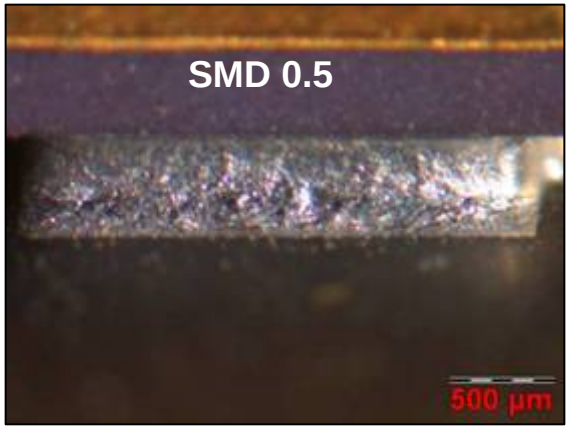


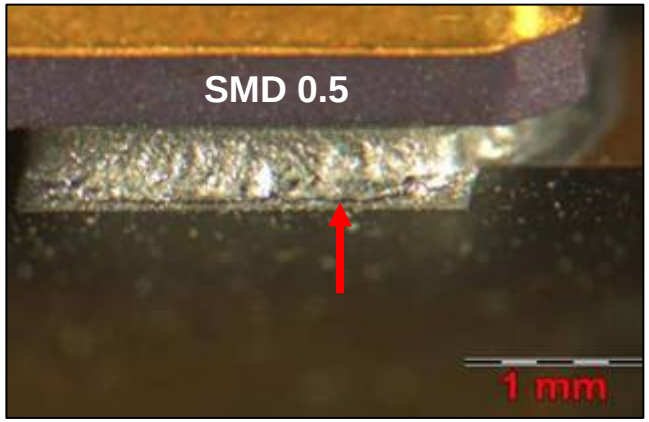
Evaluation results : Thermal Cycles (Hybrids qualification)

- SMD 0.5 or SMD 1 (Vapour phase soldering) :

  After 500TC, observation of cracks in solder joints (external pads)







Initial assembly : Pass

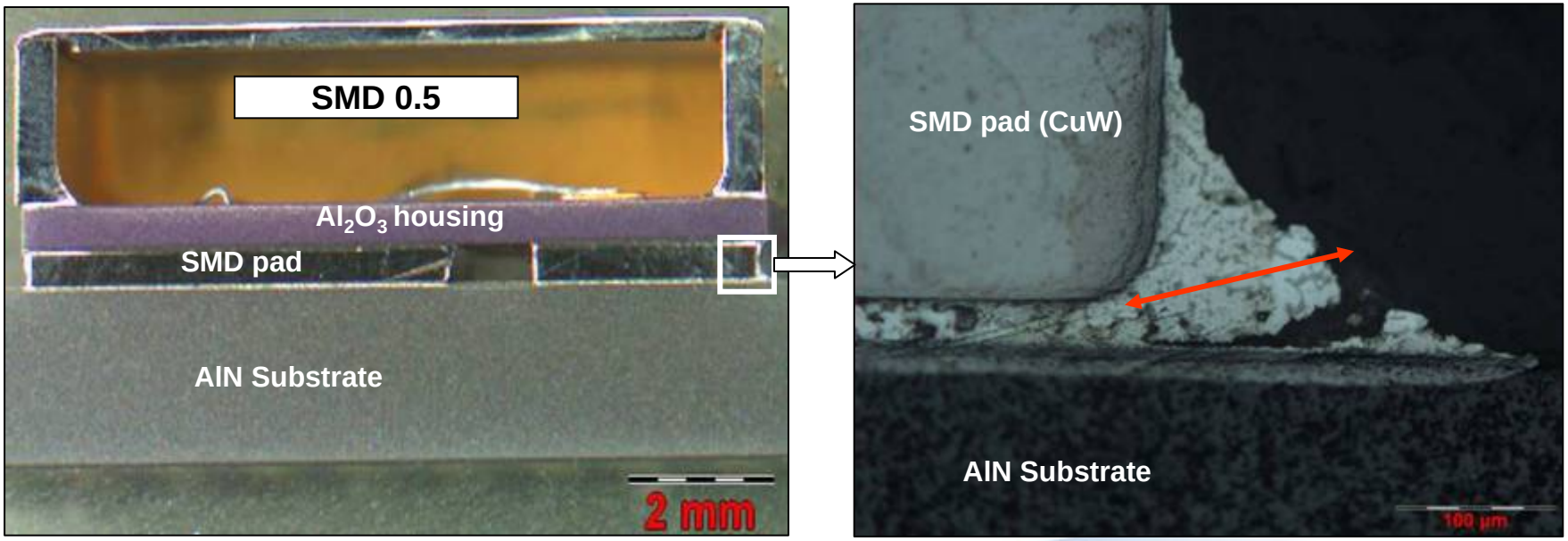
After 200TC
Ageing of solder joint
Slight cracks observed

After 500TC
Increasing of cracks

Evaluation results : Thermal Cycles (Hybrids qualification)

- SMD 0.5 or SMD 1 (Vapour phase soldering) :

500 TC : Pass → Microsections on SMD 0.5 and SMD 1
- Cracks do not propagate under the components



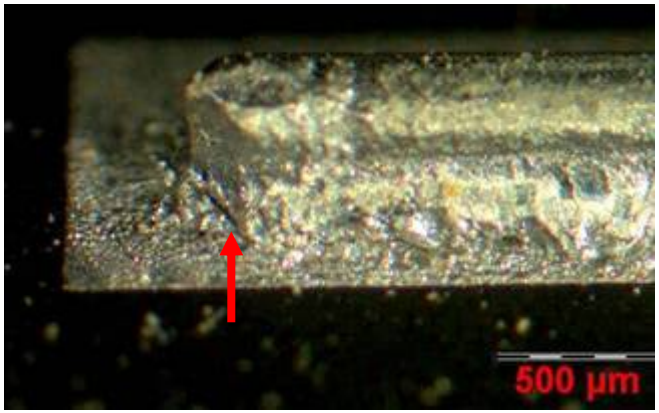
Evaluation results : Thermal Cycles (Hybrids qualification)

- Copper wires by manual soldering :

500 TC : Pass

Slight cracks at the solder joints extremities.
Peeling strength decreases slightly after thermal cycles.

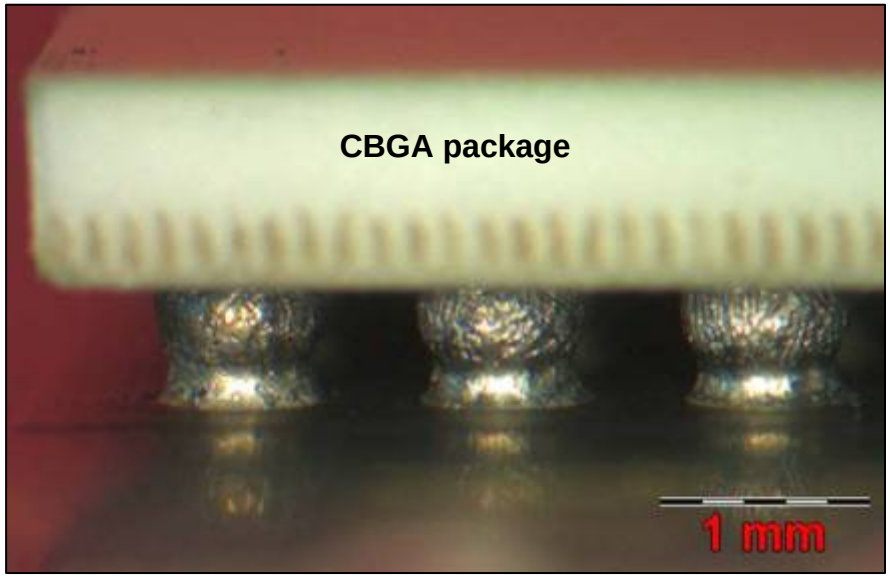
Tests	Peel test results on 5 copper wires (Strength in Newton)			
	Mean	Maximum	Minimum	Standard Deviation
Initial	7.4	7.9	7.1	0.4
After 200TC	7.2	8.0	5.5	1.0
After 500TC	6.5	7.6	5.9	0.6

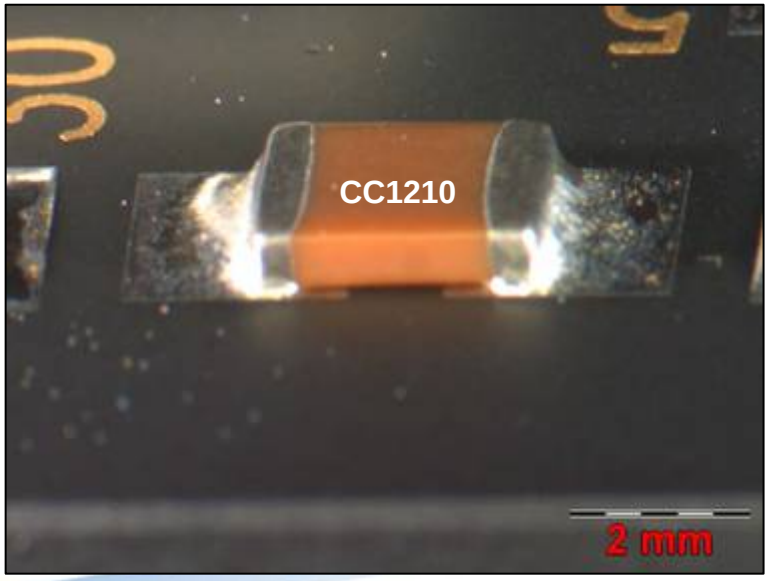


Evaluation results : Storage at 125°C

- Test only performed on CBGA and capacitors assembled by vapour phase reflow.

1000hrs : Pass → No evolution of the daisy chains resistances
Solder joints keep a shiny aspect





Evaluation results : Sine vibrations + shocks

- CBGA/ceramic capacitors/SMD 0.5/SMD 1 (vapour phase soldering).

Vibrations : Pass → No microcuts detected for CBGA daisy chains (resolution = 10µs)
No cracks observed in solder joints after test.

Shocks : Pass → No microcuts detected for CBGA daisy chains (resolution = 10µs)
No cracks observed in solder joints after test

Sine Vibrations : - Frequency: 20 to 2000 Hz, with logarithmic variation.
- Acceleration level: condition B (50g peak.).
- Number of cycles : 4 per axis (X, Y, Z).

Sine Vibrations : -1500g, 0.5ms, ½ sine.
- 5 shocks along each axis (X, Y, Z).

Evaluation results : Summary

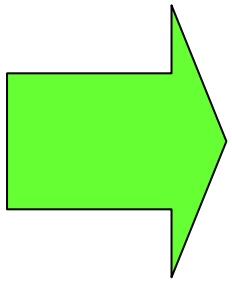
- Assembly reliability for the different test files

Component	Thermal cycles (Astrium hybrids qualification conditions) *		Temperature storage at 125°C	Sine vibrations + Shocks	Thermal cycles (Astrium PCB qualification conditions) **	
	200 TC	500TC			200TC	500TC
CBGA 361	Pass	Fail (Topline component ?)	Pass	Pass	In progress	In progress
CC 1210	Fail	/	Pass	Pass	In progress	In progress
CC 1206	Fail	/	Pass	Pass	In progress	In progress
CC 0805	Pass	Cracks in solder joints	Pass	Pass	In progress	In progress
SMD 0.5	Pass	Pass	Not tested	Pass	In progress	In progress
SMD 1	Pass	Pass	Not tested	Pass	In progress	In progress
Copper wires	Pass	Pass	Not tested	Not tested	Not tested	Not tested

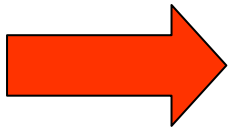
* **Astrium hybrids qualification conditions :** [-55°C ; 125°C]
Dwell time of 20mn
Quick temperature ramp (two chamber oven)

** **Astrium PCB qualification conditions :** [-55°C ; 100°C]
Dwell time of 20mn
Temperature ramp of 10°c/min (single chamber oven)

Conclusion for the feasibility study



- Feasibility of Soft Soldering assembly on AlN packages.
- Either vapour phase or manual soldering are possible.
- Good reliability during temperature storage/vibrations and shocks.
- Good reliability of SMD 0.5 and SMD 1 packages.



- Failures during TC (hybrids conditions) for cc1210, cc1206 and CBGA.

Comparatively to organic PCB, AlN has a very low CTE and a high stiffness. So standard components dedicated to PCB are submitted to important stresses during thermal cycles.

The type and the size of components will be limited by the qualification levels.

Soft Soldering : Future work

- Reliability evaluation of assembled component during thermal cycles with Astrium PCB qualification conditions (trials in progress).
- Manufacturing of a MCM with soldered SMD components next to an hermetic cavity containing bare dice.
- Evaluation of the reliability of the MCM integrating soldered components and bare dice.