ALTER

SiC Plastic High Temperature Diodes

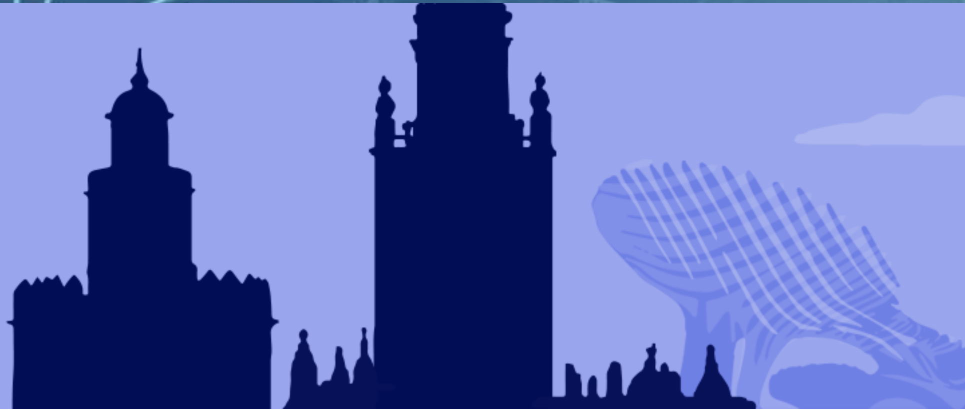
Juan Moreno | HRS Optoelectronics Laboratory | 27.03.2025

ALTER | esa

ACCEDE | ESCCON

2025 Seville - Spain

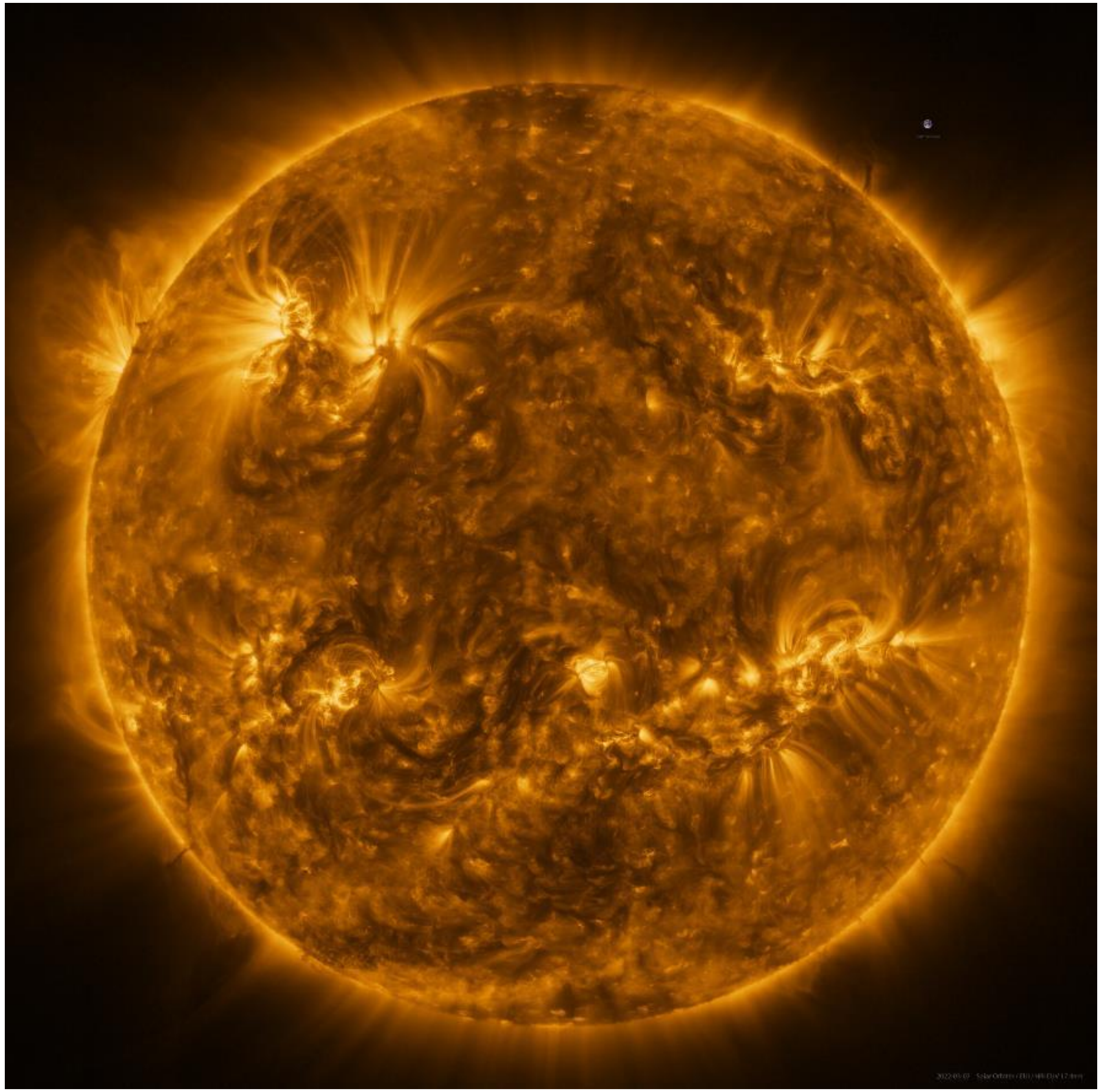
25 to 27th March



Outline

Presentation Contents

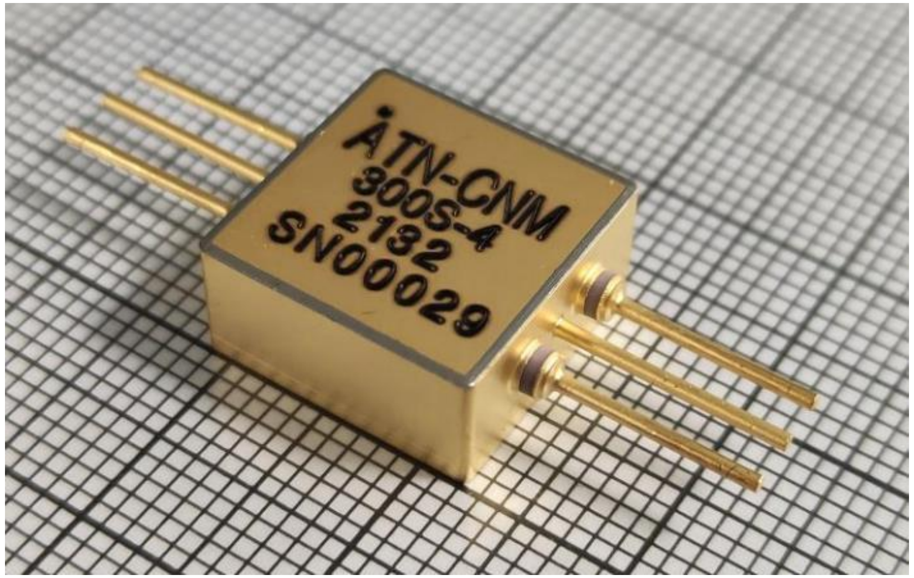
- Introduction: OSIP Project Objectives.
- Review of technical activities:
  - DUTs Design and Mold Compounds Selected
  - Devices manufactured
  - Test Plan, Results
- Conclusions



Credit: ESA & NASA/Solar Orbiter

Introduction

Project Objectives



Industry requirements for certain applications go beyond standard temperatures. SiC technology solves the semiconductor needs for many of them but packaging shall be in line with this requirements.

Package represents a substantial part of the budget of any hermetic device for high reliability applications, cheaper but still reliable solutions are needed.

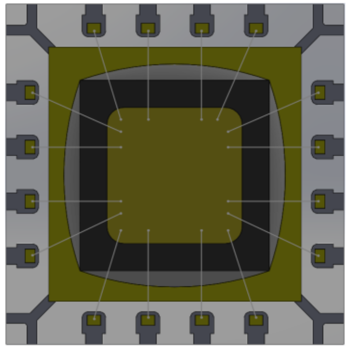
Plastic packaging solutions based on new mold materials is investigated in the frame of this project Target = operation at 250ºC

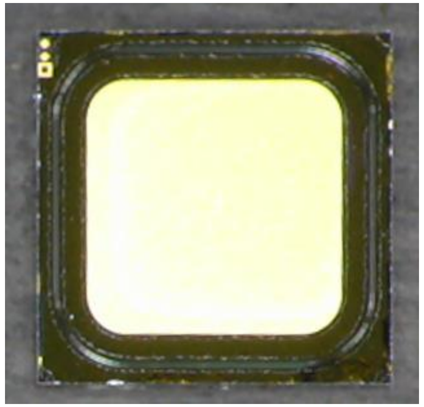
Review of Technical Activities

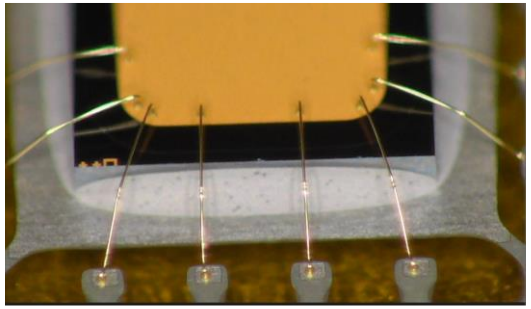
DUTs Design and Mold Compounds Selected

☐ Based on BepiColombo SolO Solar Array SiC Blocking diodes

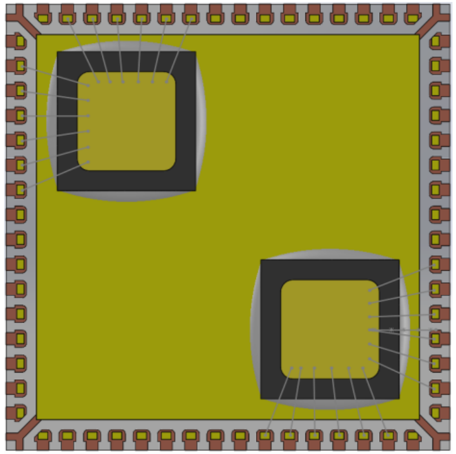
- Single die







- Two dies module, common cathode



Mold Type 1: Tg=120ºC

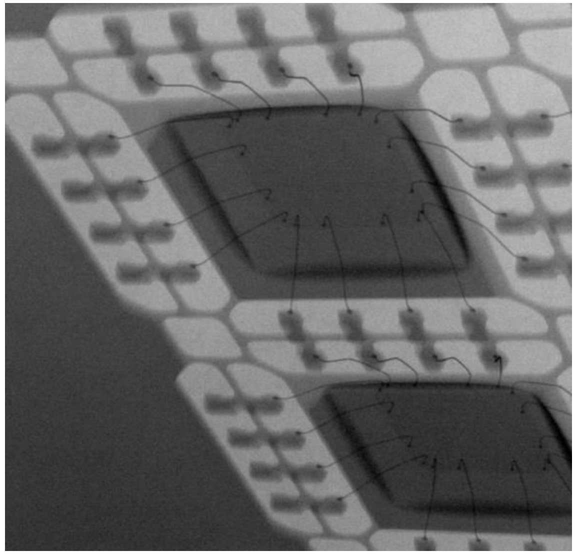
Mold Type 2: Tg=242ºC

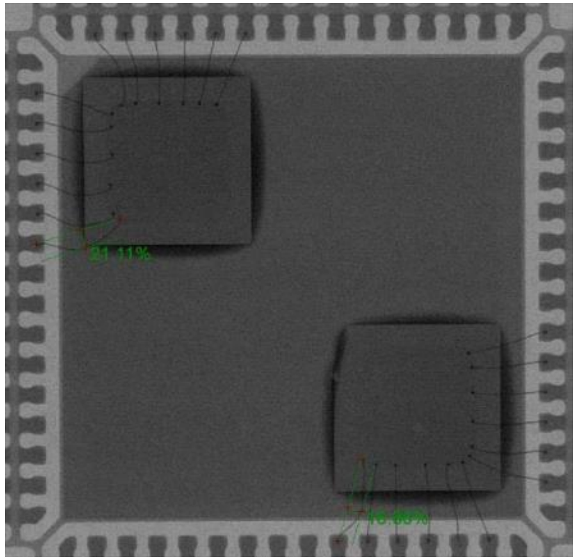
Mold Type 3: Tg=195ºC

Review of Technical Activities

Samples manufactured

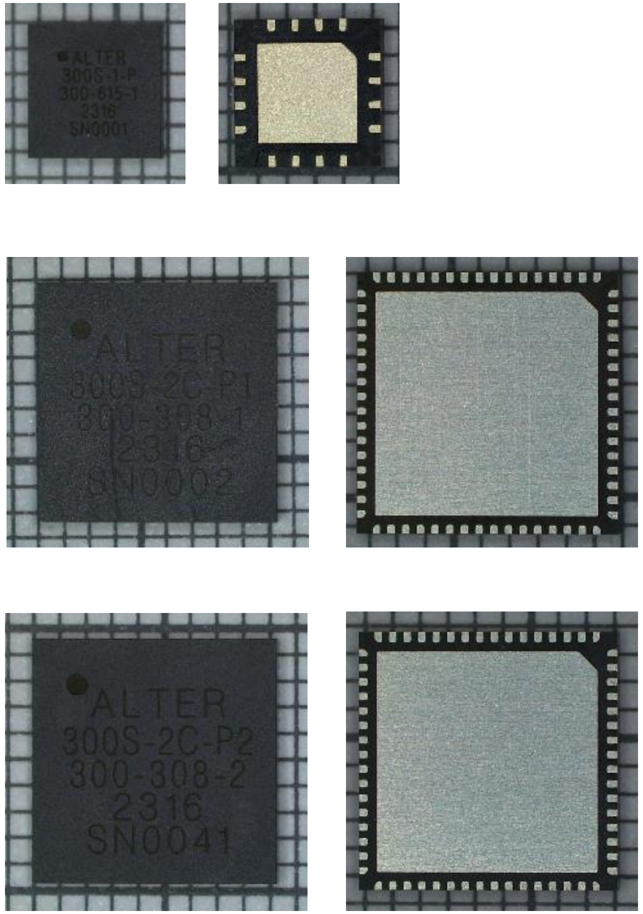
- Very good die attach strength
- Good, consistent bonding
- All mold compounds flowed with no issues
- Expected flowability of Type 1, similar for Type 3. <u>Low flowability for Type 2</u> leading to excessive wire sweep





Review of Technical Activities

Samples manufactured



Type	Die Type	Die Type	Die Config	Lead Frame Type	Die Attach Material	Wire Bond Material	EMC
1	SiC-300S-1-P	300S	Single Die	QFN32 5x5	Silver Sintering	33um Au	Type 1
2	SiC-300S-2C-P-1	300S	Twin Die	QFN64 9x9	Silver Sintering	33um Au	Type 2
3	SiC-300S-2C-P-2	300S	Twin Die	QFN64 9x9	Silver Sintering	33um Au	Type 3

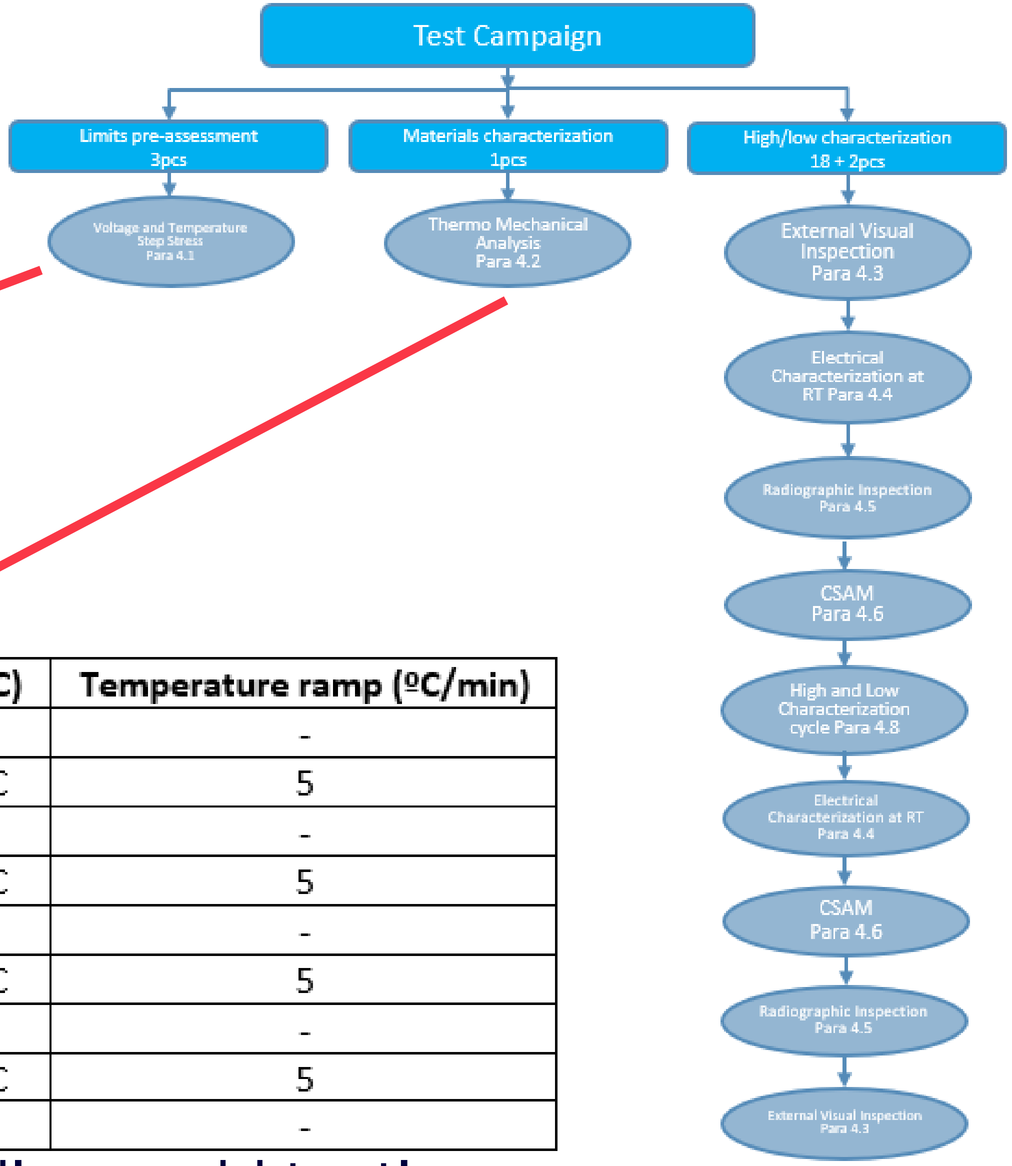
Electrical performances expected

Nº	SYMBOL	TEST	CONDITIONS (T$_A$=25ºC) (note 1)	LIMITS		UNIT
				MIN.	MAX.	
1	V_{Fwd}	Forward Voltage	I_{Fwd}=0.5, 1.5, 2.5A (note 2)	--	1.6	V
2	I_{Rev}	Reverse Current	V_{Rev}= Sweep from 0 to 250V In steps of 50V		10	uA

Targeted operation at 250°C

Review of Technical Activities

Test Sequence



Reduced amount of samples

Temperature (°C)	Reverse Bias (V)	Duration
125	100,150, 200, 250	1 minute dwell with each bias value applied
150	100,150, 200, 250	
175	100,150, 200, 250	
200	100,150, 200, 250	
225	100,150, 200, 250	
250	100,150, 200, 250	

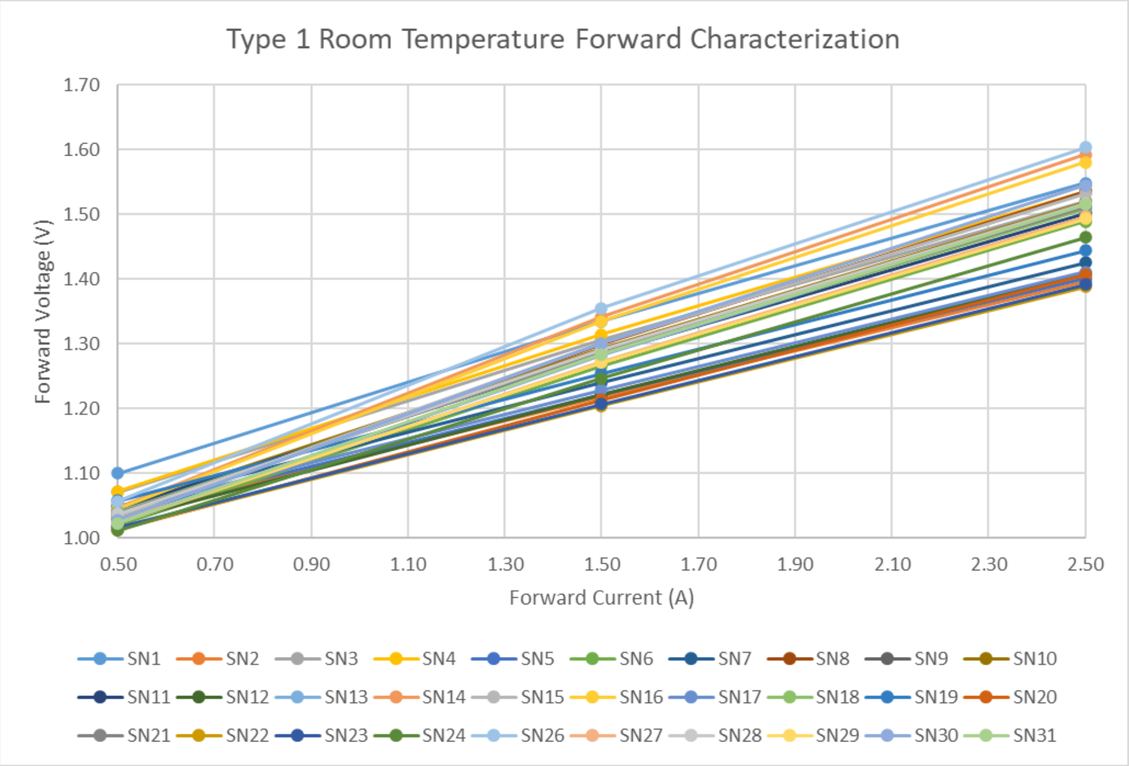
Tests	Conditions (ºC)	Temperature ramp (ºC/min)
SAM 1	-	-
TMA 1	-25 - + 150 ºC	5
SAM 2	-	-
TMA 2	-25 - + 200 ºC	5
SAM 3	-	-
TMA 3	-25 - + 250 ºC	5
SAM 4	-	-
TMA 4	-25 - + 300 ºC	5
SAM 5	-	-

Samples without die – mold testing

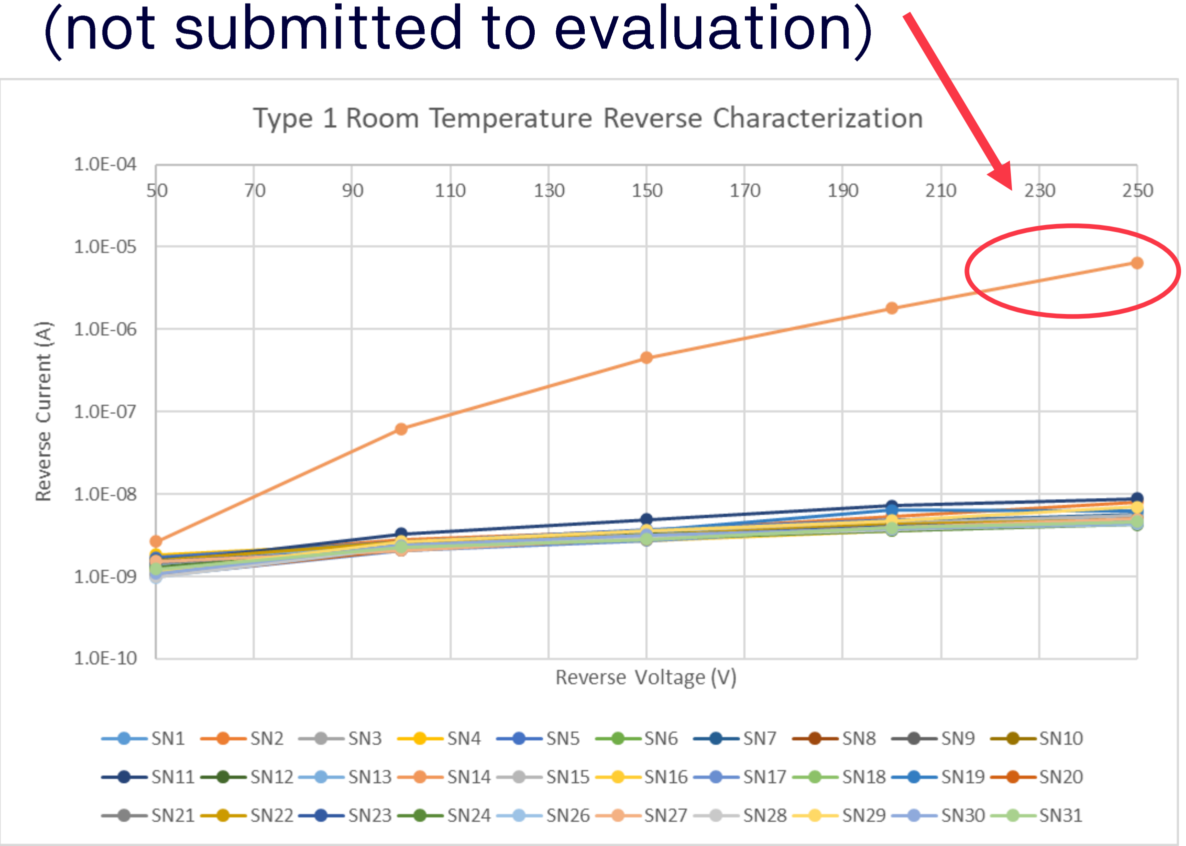
ALTER

Review of Technical Activities

Initial Electrical Characterization of the manufactured parts



In-specs but out-of-family behavior (not submitted to evaluation)



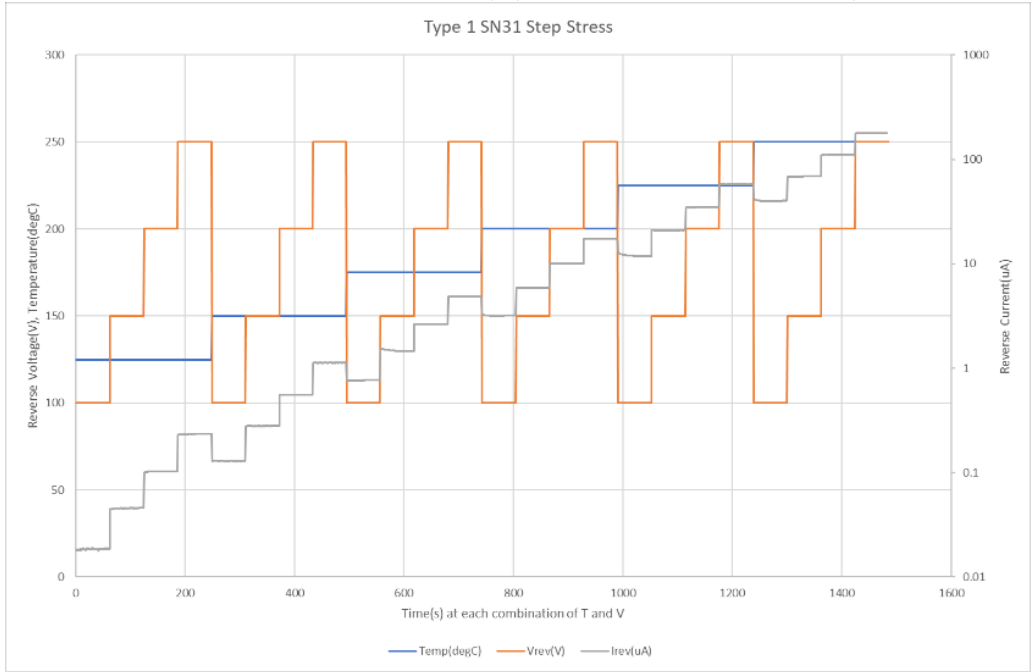
-> Enough parts for all the 3 types for the study

Review of Technical Activities

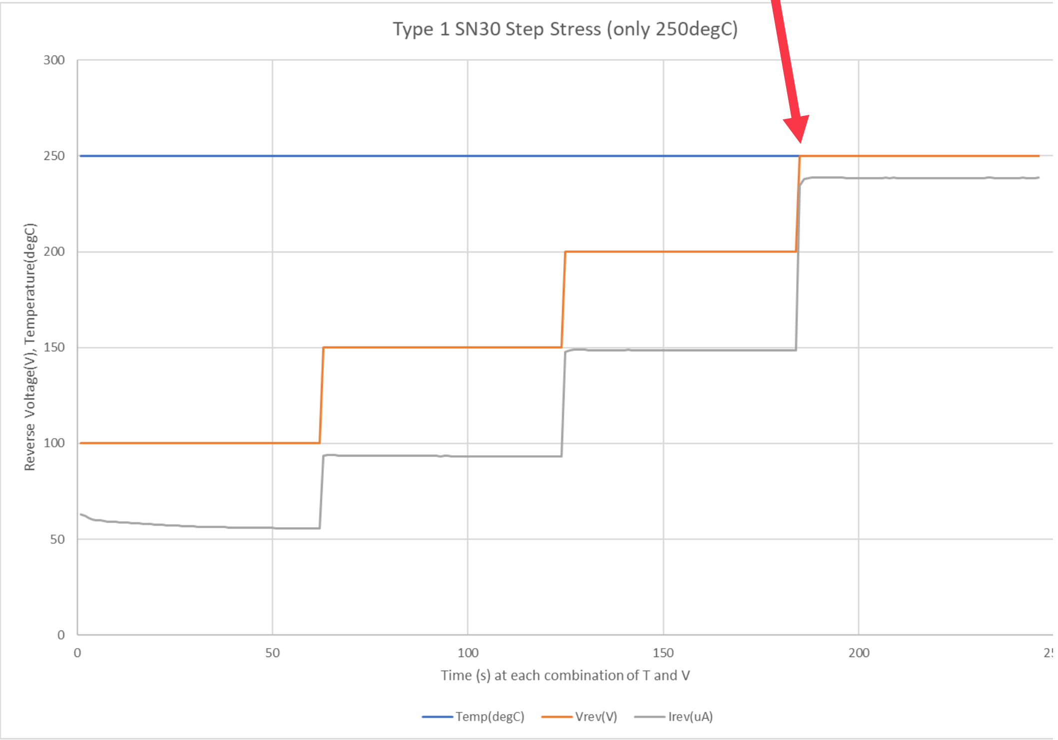
Temperature Step Stress

Electrical isolation capability tested at high temperature for a reduced set of samples

Good Results: Type 1 as example



Good stability of the leakage at 250°C and 250V

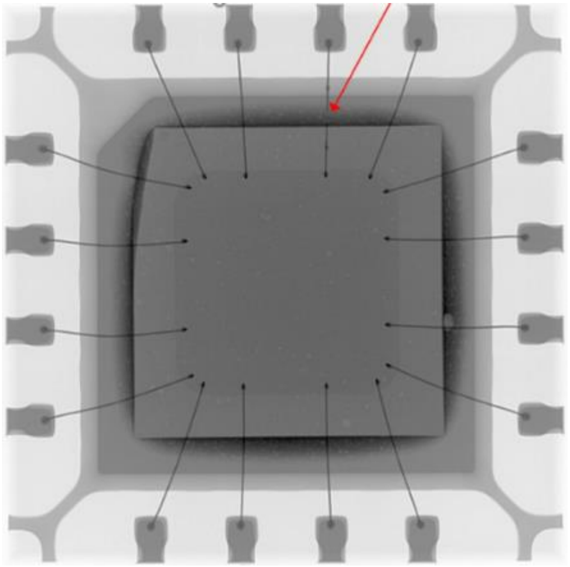


Same Results for Type 2 and Type 3

Review of Technical Activities

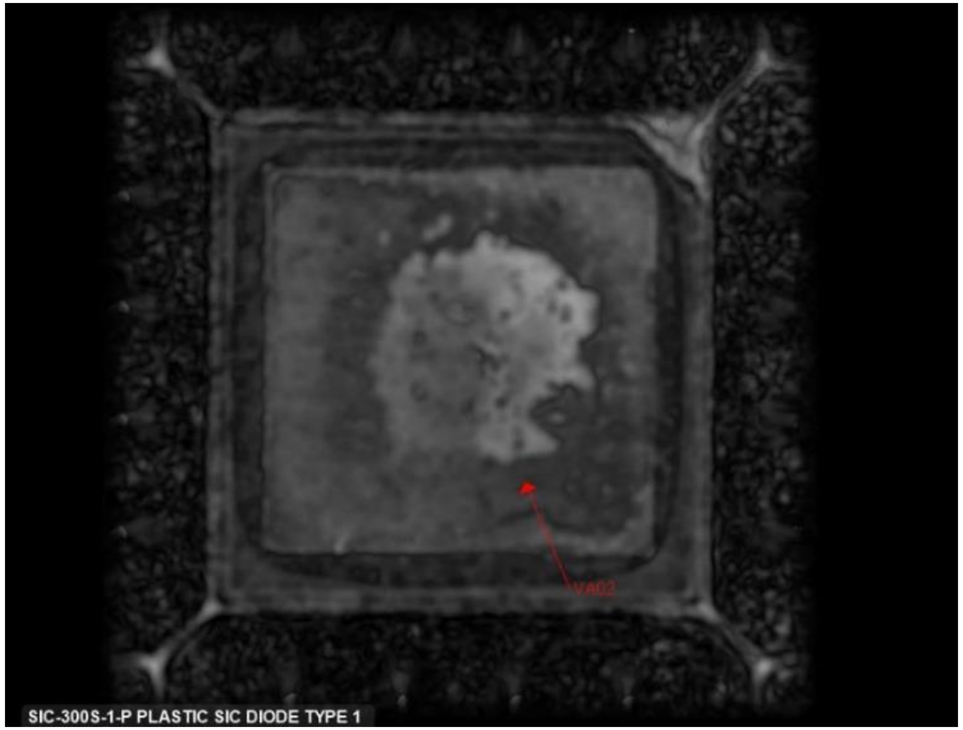
Initial Radiographic and CSAM Inspection

Minor issues:
Example melt wire



Carefully investigate bias conditions

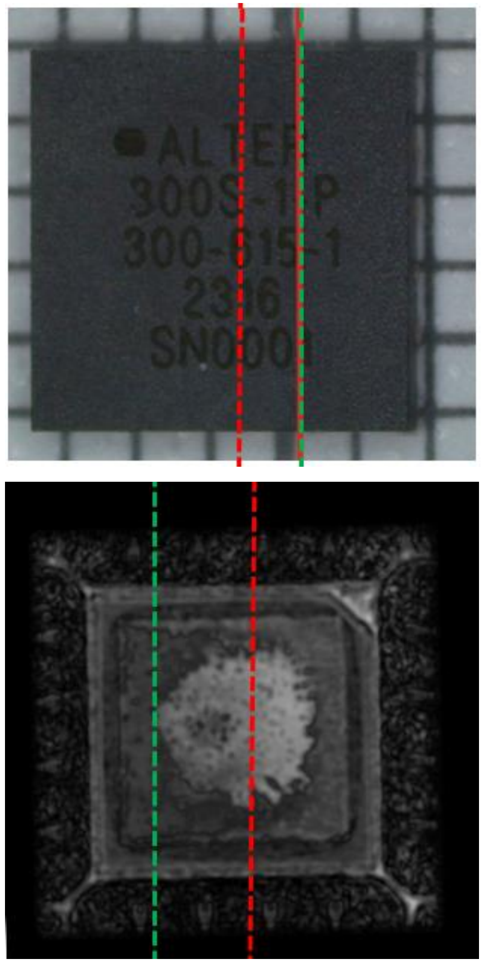
<u>Major issues: </u>8 out of 18 devices rejected during CSAM inspection for type 1. Single void within the die attach larger than 15 % of the contact area. (ESCC 25200 Issue 2 §7.3.b)



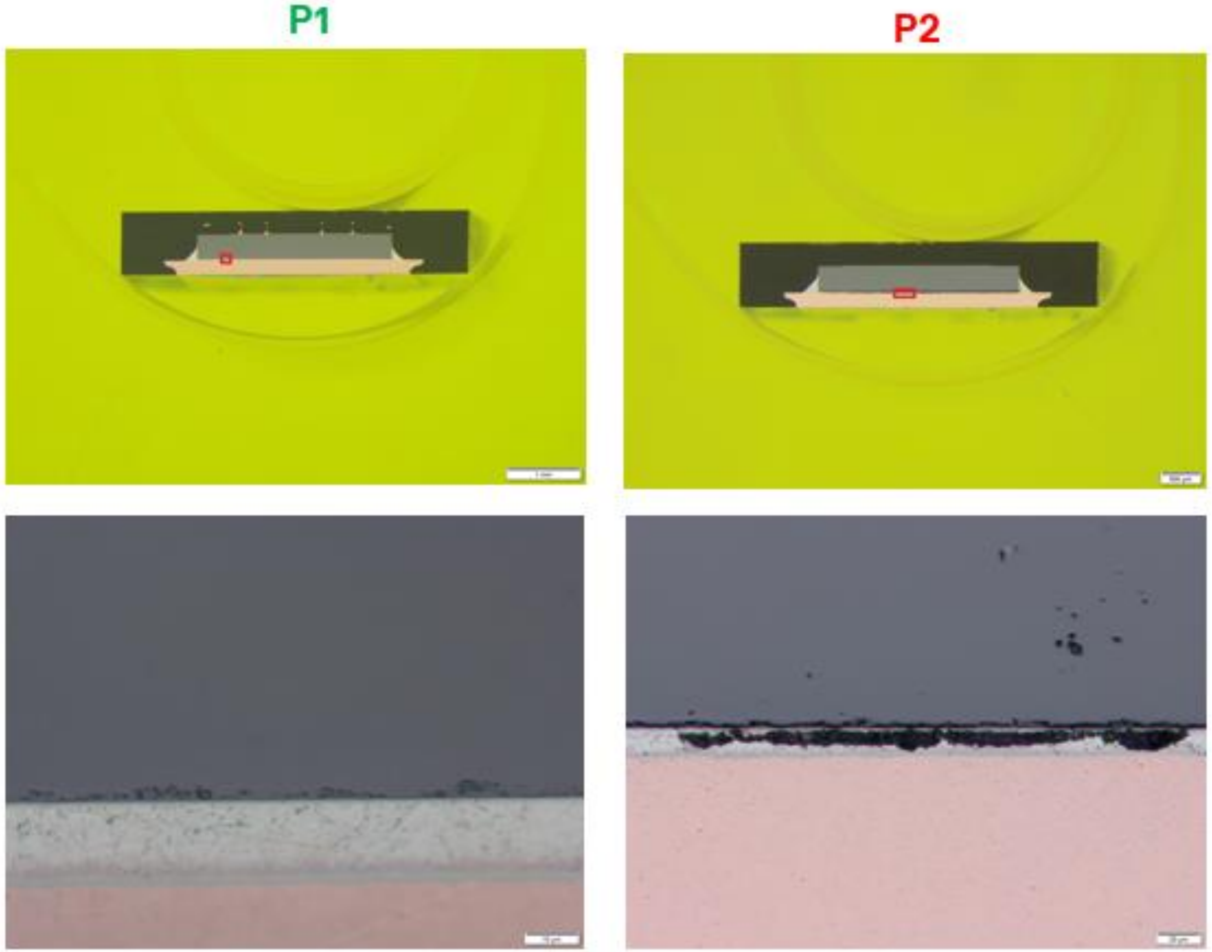
100% rejected for types 2 & 3 when cross section confirmed delamination

Review of Technical Activities

Microsection



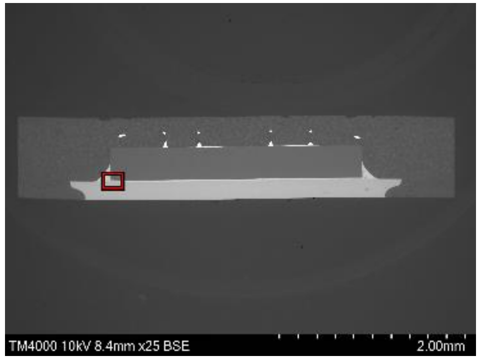
Delamination confirmed SN8

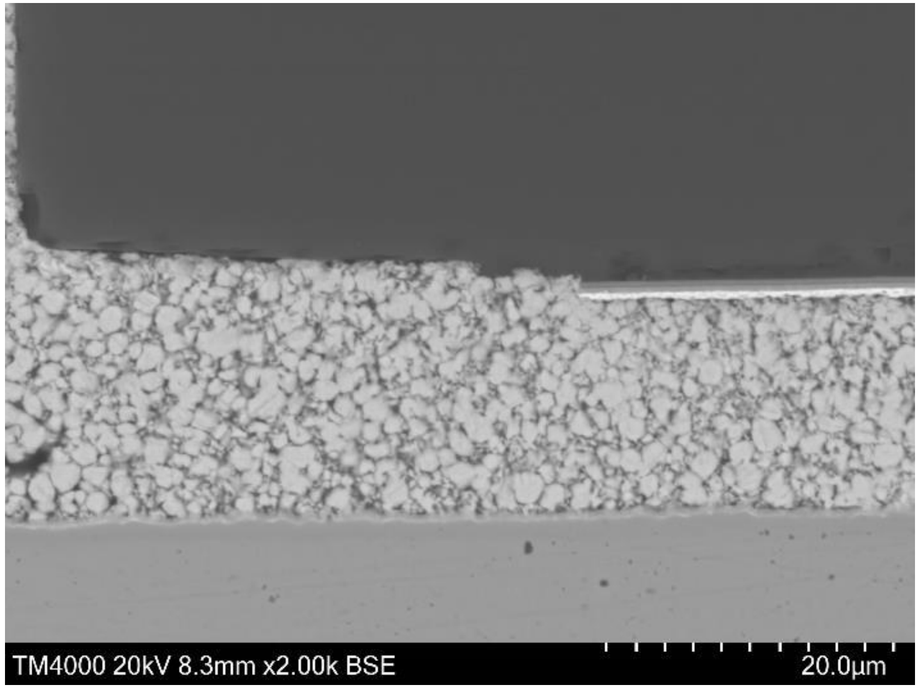


Review of Technical Activities

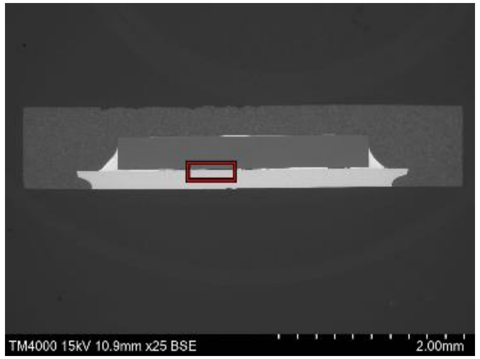
SEM Inspection

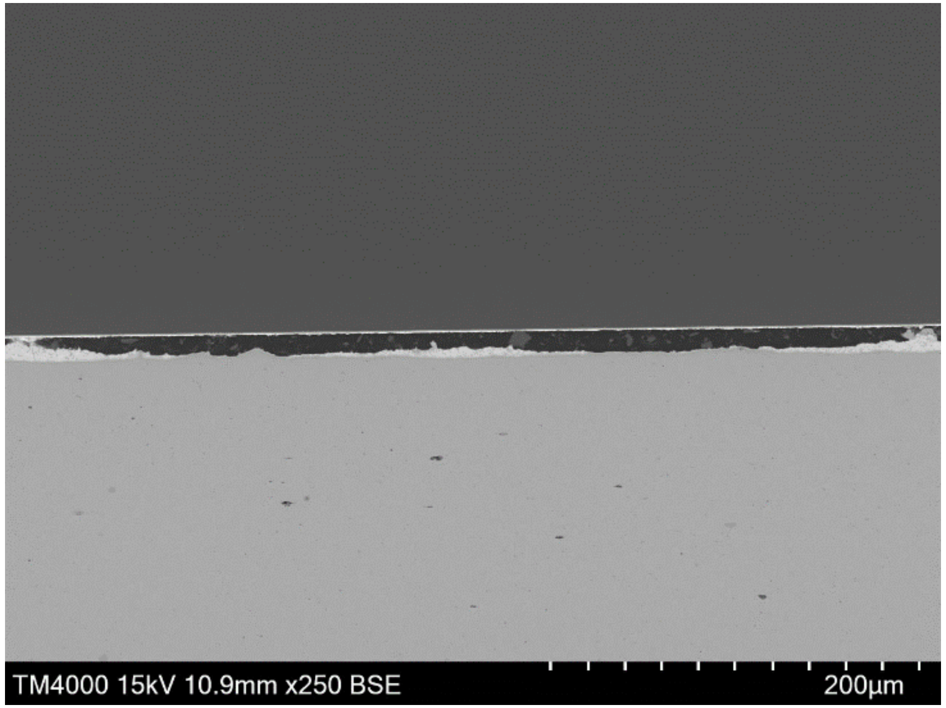
P1





P2

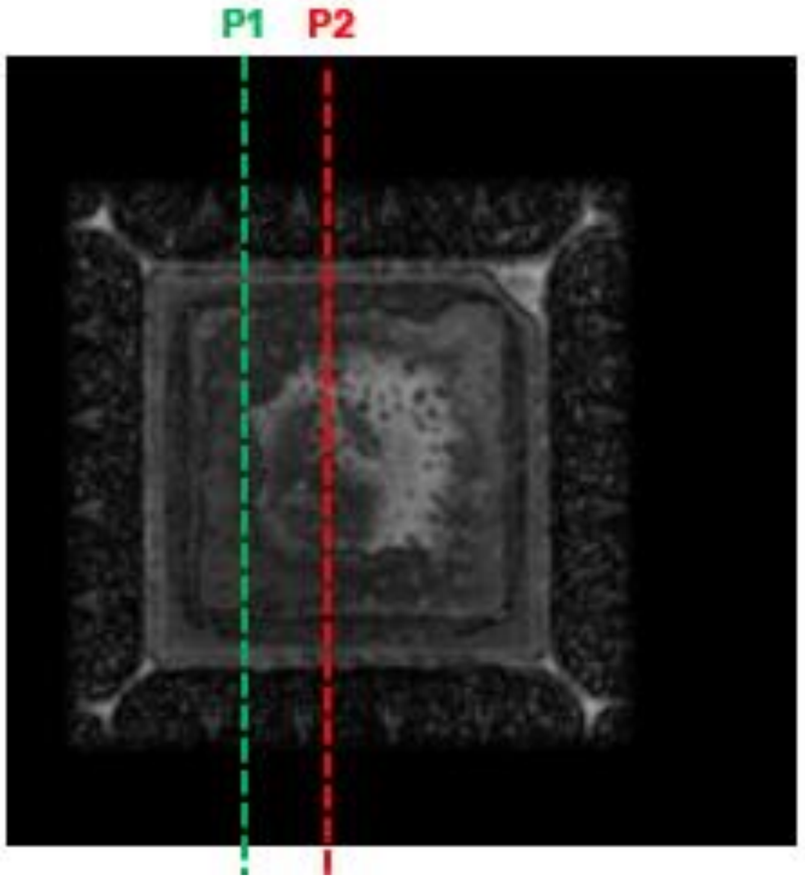




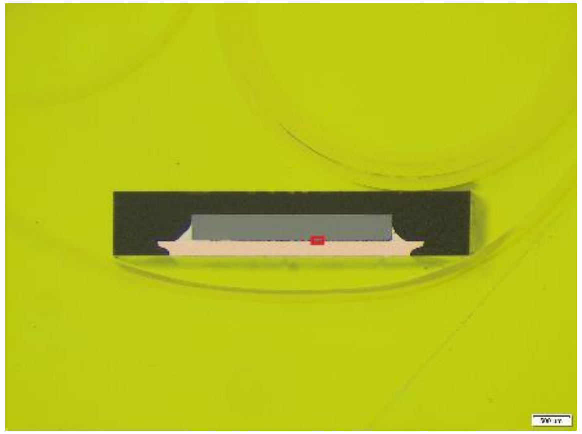
Review of Technical Activities

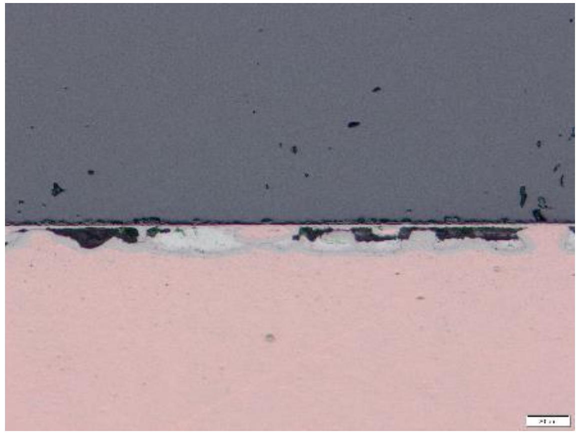
Microsection and SEM

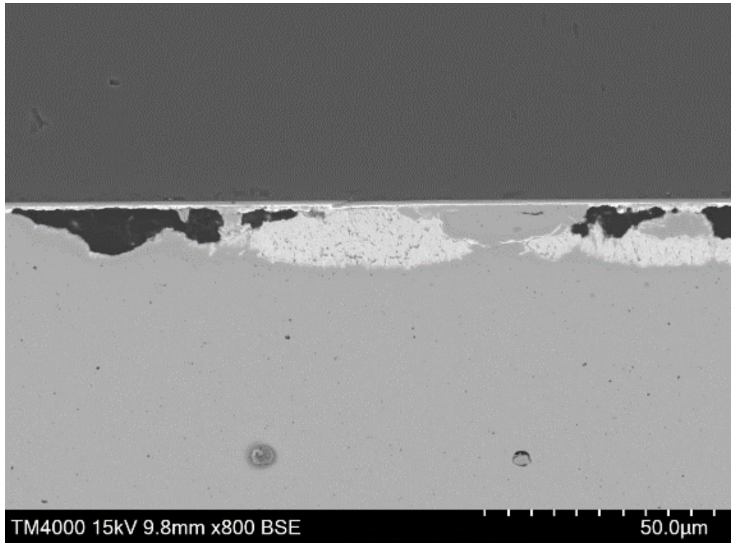
Additional device (SN9)



P2





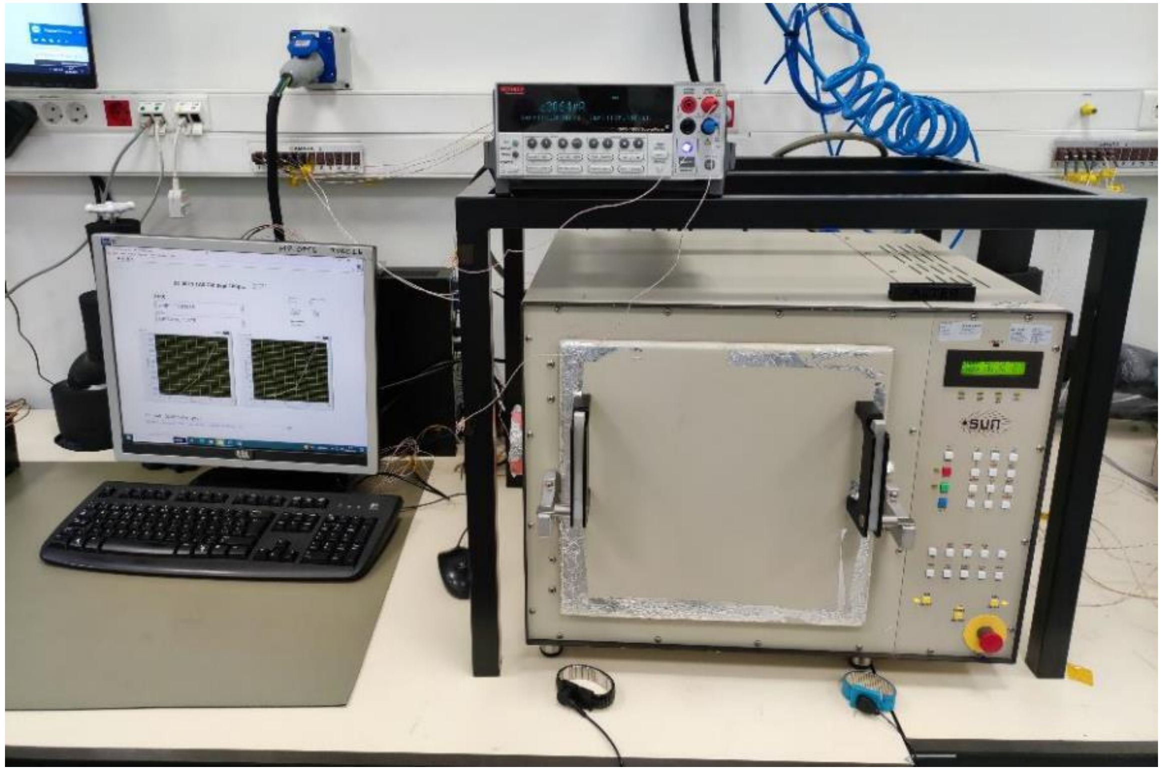


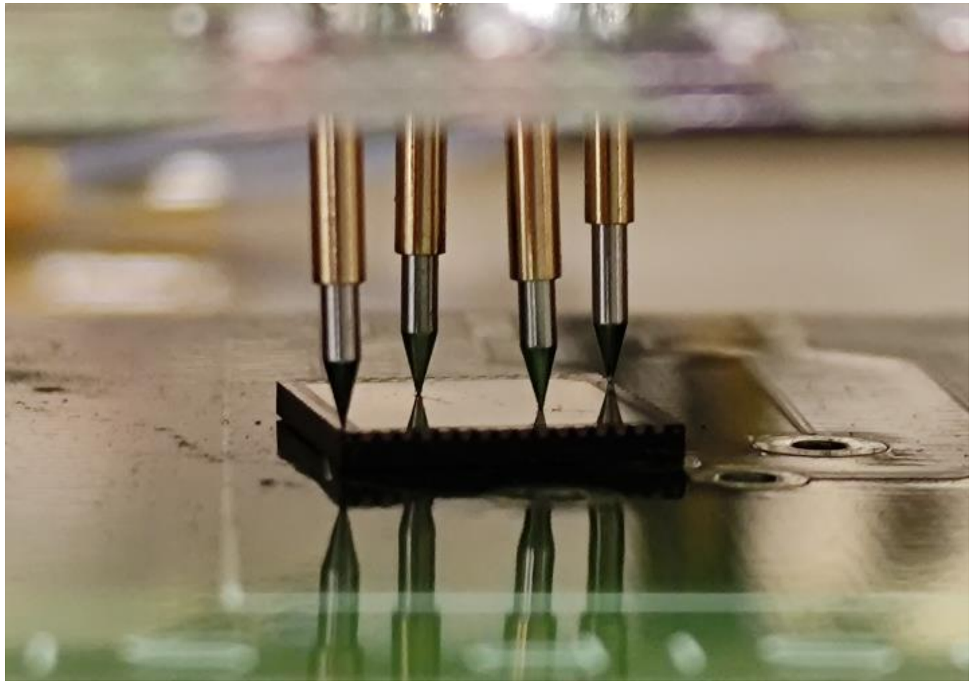
CTE mismatch

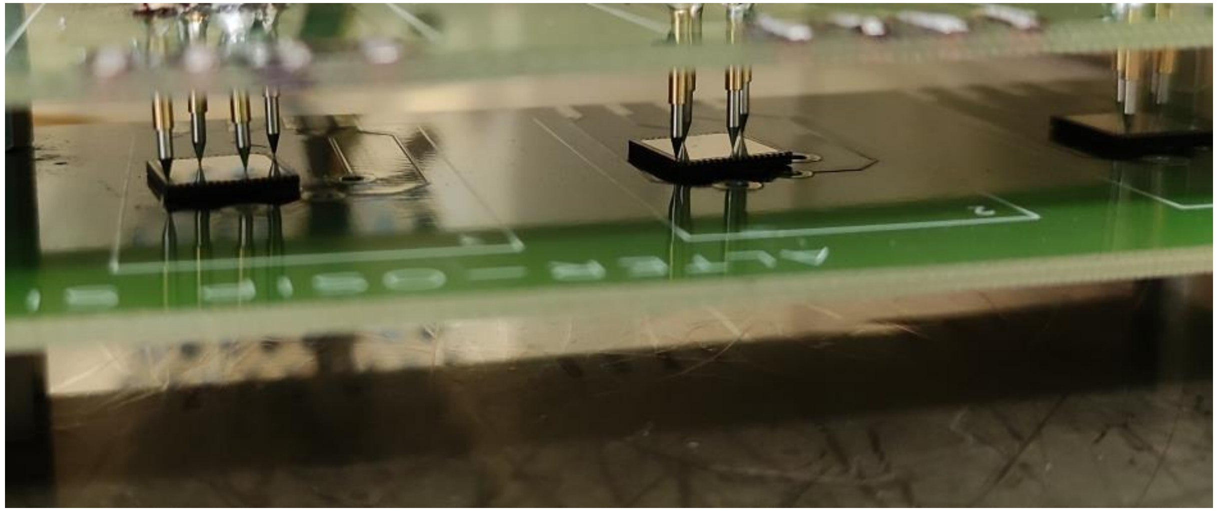
Review of Technical Activities

Thermal Characterization sequence.

- Package to be tested with probes (soldering not allowed)





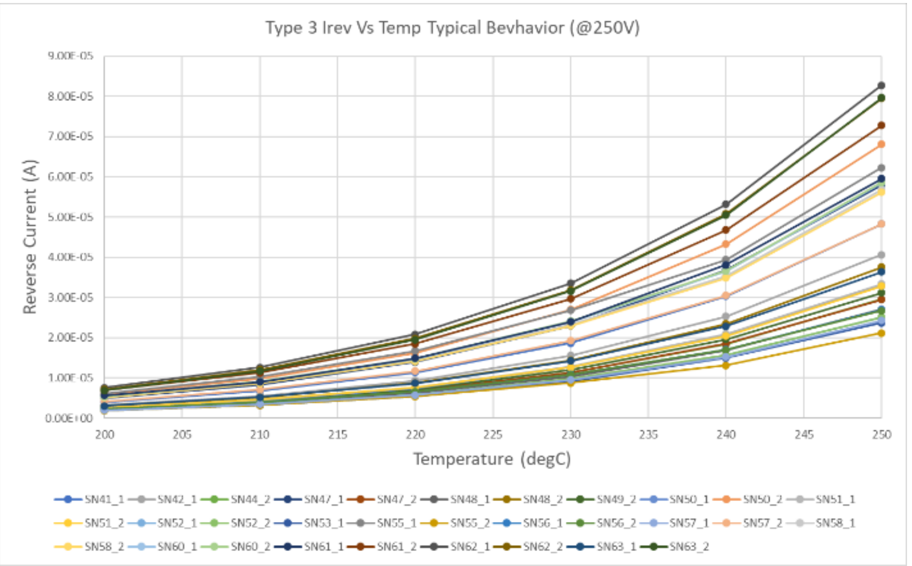


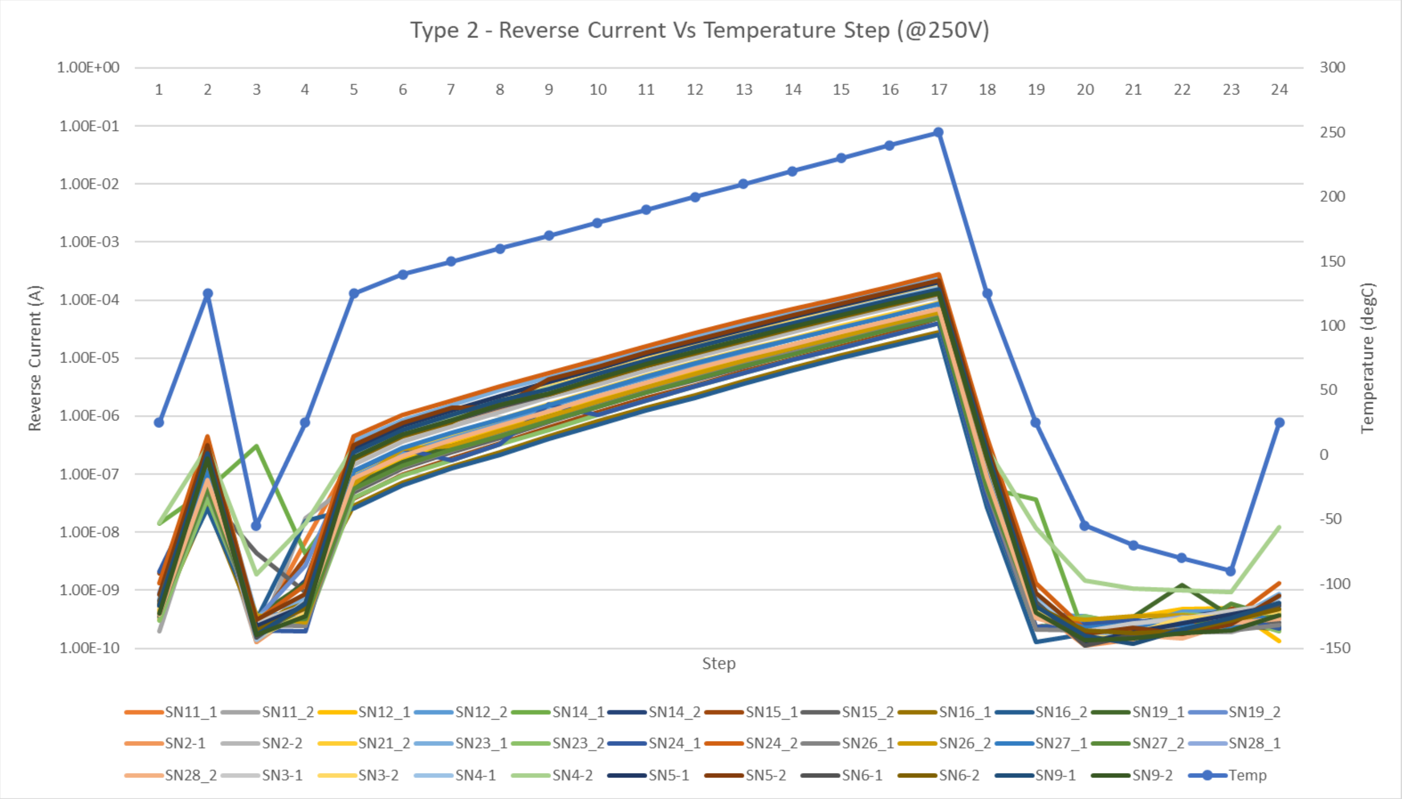
Review of Technical Activities

Thermal Characterization sequence (High/Low temperature)

Big amount of data gathered:

- Electrical behavior as expected
- Same behavior for the 3 mold



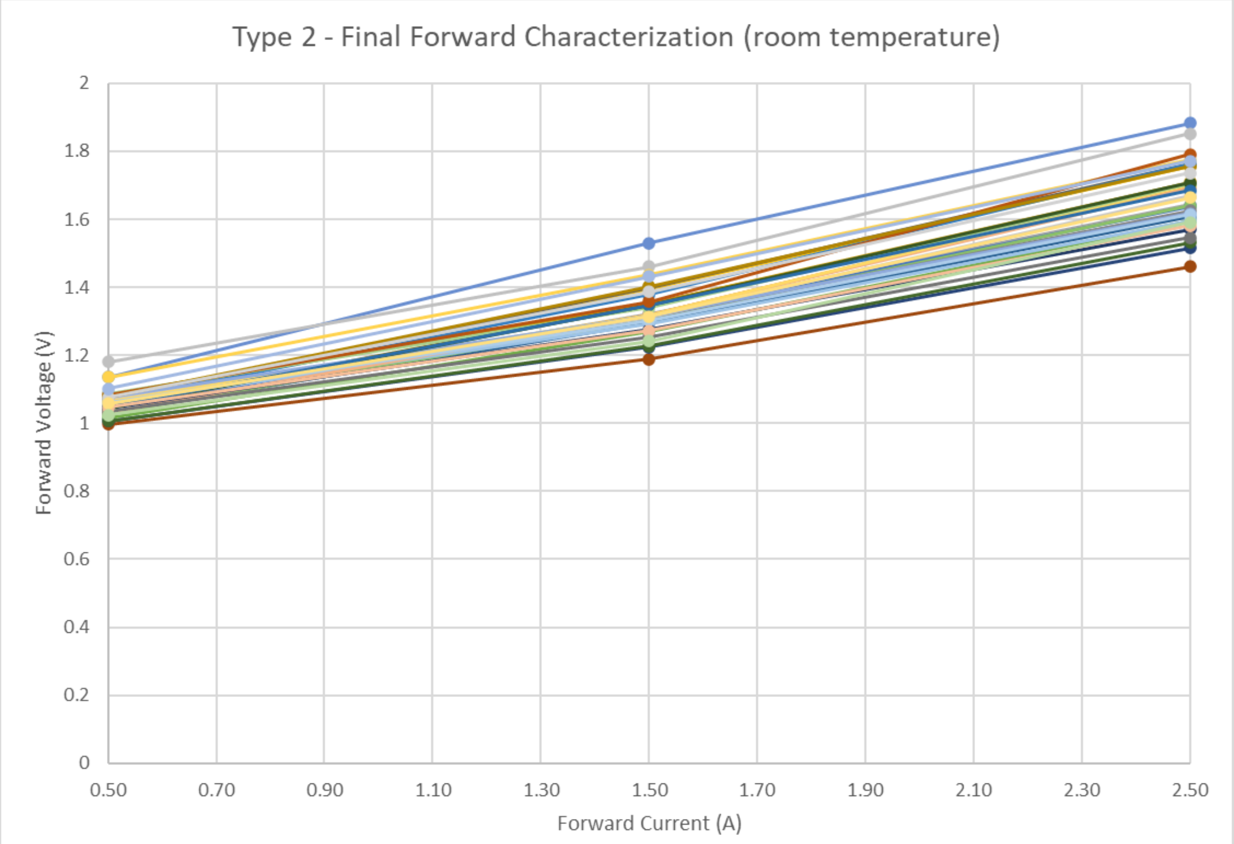


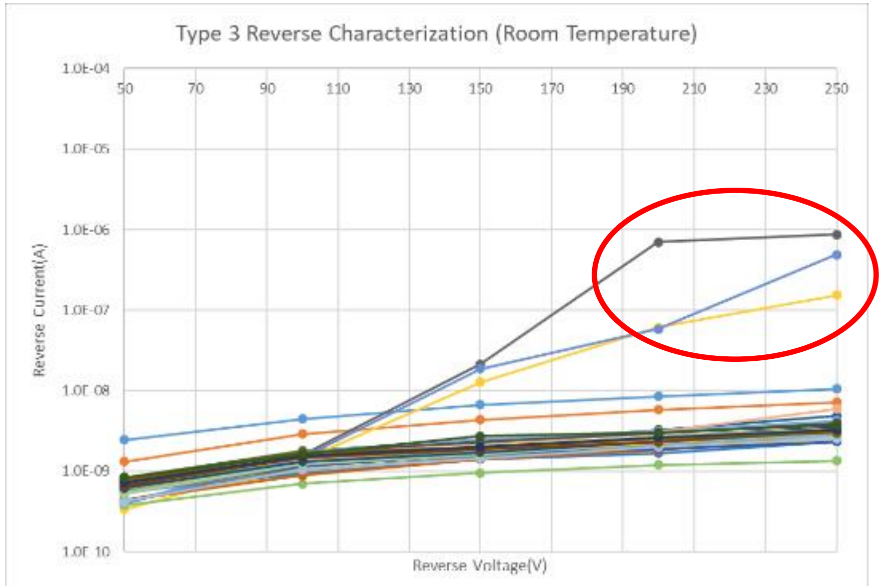
ALTER

Review of Technical Activities

Final Room Temperature Characterization after Thermal Sequence

- ❑ Reverse currents OK, few abnormally higher (instable dies)
- ❑ Slight drift in forward voltages for types 2 & 3.



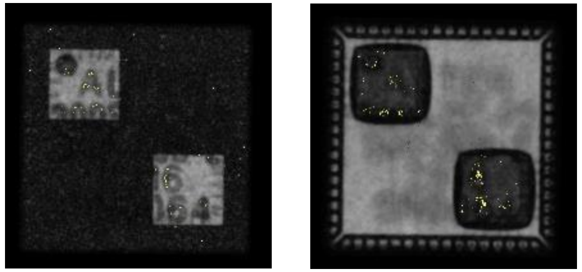


Vfwd(@2.5A) drift (die attach

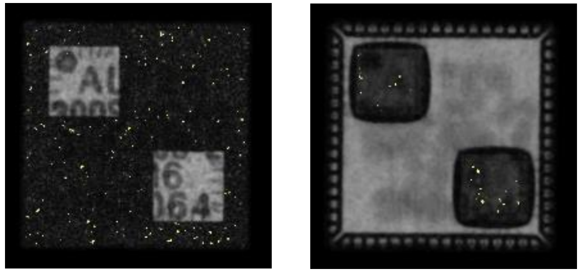
- Type 1: No drift
- Type 2: 9% average increase
- Type 3: 8% average increase

Review of Technical Activities

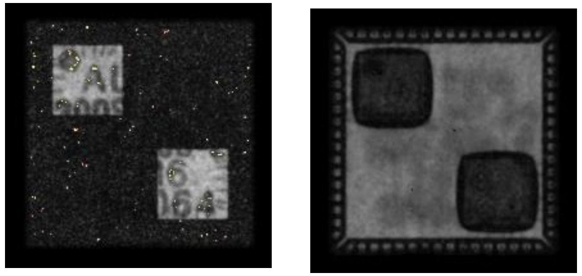
TMA + CSAM Results (only intermediate CSAM shown)



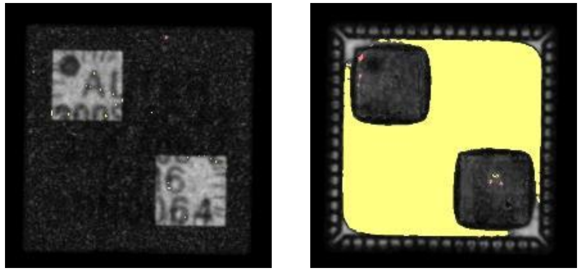
SAM 01
Initial die attach
delamination



SAM 02
(After 150ºC)
No evolution

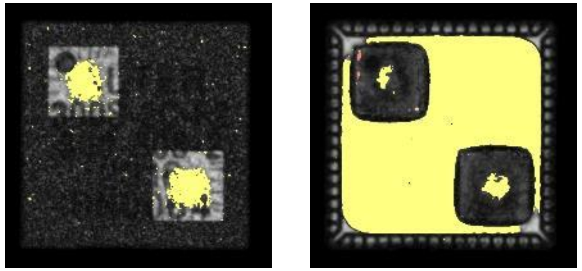


SAM 03
(After 200ºC)
No evolution



SAM 04
(After 250 ºC)
Die attach del. evol.
Paddle del. evol.

The expansion caused by the delamination was detected in TMA



SAM 05
(After TMA at 300 ºC)
Evol. MC/Die interface

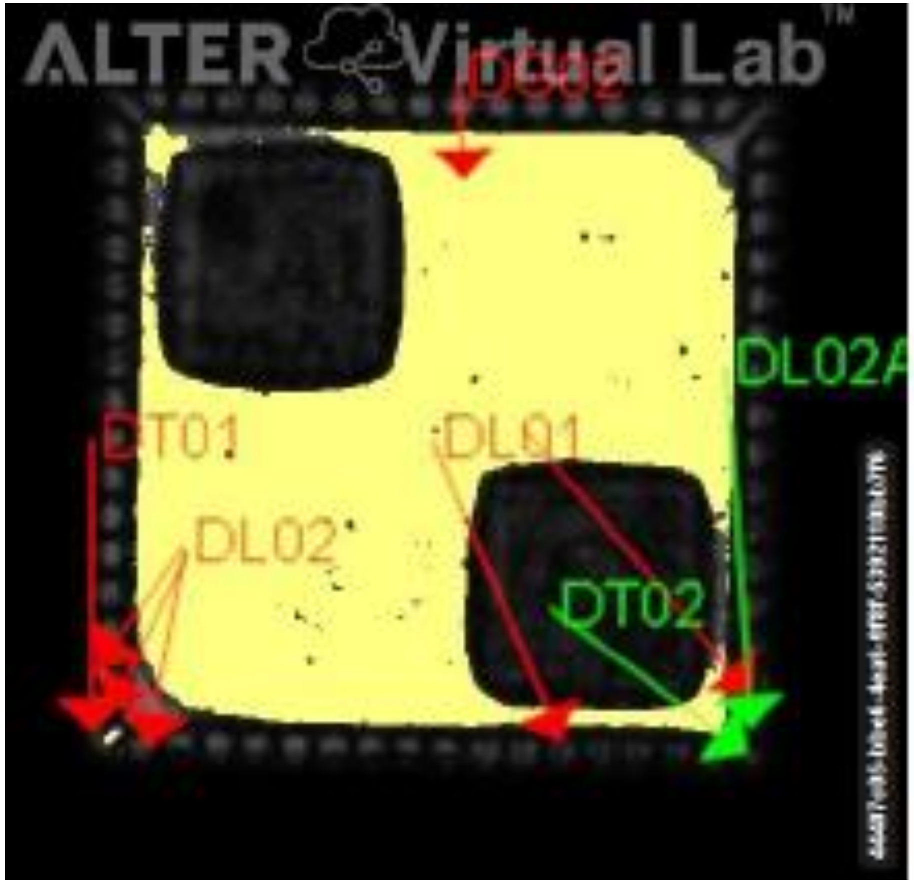
Tests	Conditions (ºC)	Temperature ramp (ºC/min)
SAM 1	-	-
TMA 1	-25 - + 150 ºC	5
SAM 2	-	-
TMA 2	-25 - + 200 ºC	5
SAM 3	-	-
TMA 3	-25 - + 250 ºC	5
SAM 4	-	-
TMA 4	-25 - + 300 ºC	5
SAM 5	-	-

- Die attach and MC/paddle interfaces are the most sensitive
- Similar results observed for the 3 types

All non-chip side views

Review of Technical Activities

CSAM after thermal characterization



TYPE 3 WORST CASE PART (FINAL SAM)

Circuit Side – Phase Inversion:

❑ DG02: Delamination change >10 % of the affected interface.

❑ DL01: Delamination on a bonding area of the lead frame.

❑ DL02: Delamination of a surface-breaking part (lead finger) across its entire length.

❑ DT01: Delamination of a surface-breaking part (tie bar) over its entire length.

Conclusions

Project Conclusions

Three SiC plastic configurations were tested up to 250ºC

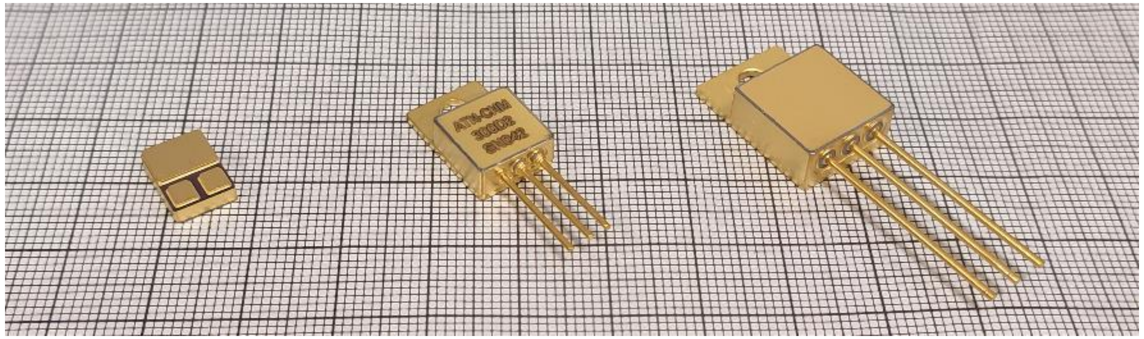
- ❑ Mold type 1 demonstrated suitability for applications up to 200ºC, delaminations observed in the silver sintering used for die attach.
- ❑ Good electrical isolation was observed for the 3 mold at extreme temperature.
- ❑ Electrical characterization revealed significant Vfwd drift for types 2 and 3.
- ❑ Thermomechanical stresses produced severe delamination's.
  - ❑ Not acceptable for high power operation. Need to improve.
  - ❑ CSAM testing is paramount for validation.

Further studies needed: Changing construction materials i.e. of plating of the leadframes to improve adhesion. Silver sintering attach material to closer match CTE mismatch…

Special Thanks

D+T Microelectrónica, A.I.E.

esa



D+T people
Our UK colleagues
Ana Collado (ESA)