Centre Français Fiabilité

NRTW 2026

National Reliability Technology Workshop

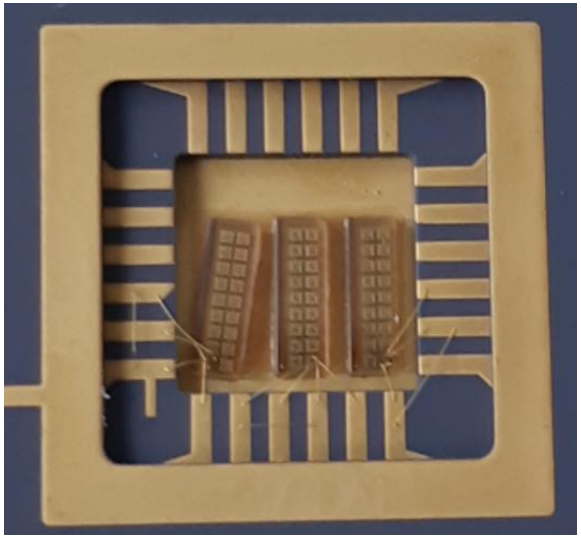
Mercredi 1er & jeudi 2 avril 2026| Grenoble

Evaluation de la protection des composants GaN contre la corrosion par dépôt de polymères

Giuseppe BELLOMONTE
Programme GaN RF
III-V Lab - Palaiseau

Organisé par :

Financé par :



III-V lab

Evaluation of the protection of GaN components against corrosion through polymer deposition

Centre Français de Fiabilité

Giuseppe BELLOMONTE

01/04/2026

NRTW 2026

Background

- Development of Fan-Out Wafer-Level Packaging (FOWLP) technology for System in Package (SiP)
- However considered as non-hermetic encapsulation
- Need to enhance protection against corrosion at chip level
- Evaluation of polymeric materials with good properties in a humid environment (breakdown voltage, induced mechanical stress, RF losses…)

Outlook

- ***Historical* background at III-V Lab**
- **Polymers**
- **HEMT**
- **Test bench**
- **Monitoring and observations**
  - Leakage currents monitoring
  - Optical observations
  - SEM observations
- **Conclusions**

THB tests at III-V Lab - I

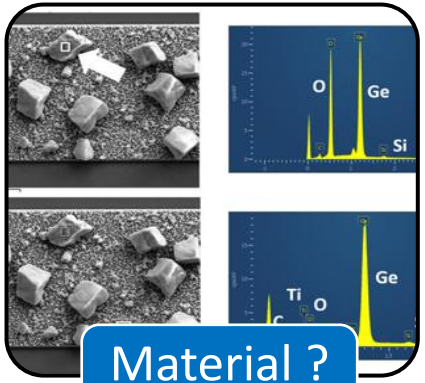
- **Looking for material sensible to humidity → Germanium (2021)**
  - Tested : Ge, Mo, Au, Al – TH tests
  - SEM / EDX Analysis
- **Ge Test Vehicles "Snakes" – TH, 1000 hours (2022)**
  - Polyimide and BCB
- **Ge Test Vehicles "Snakes" *new generation* – TH, 1000 hours (2022-23)**
  - Polymeric films by UCBL : Parylènes VT4 and HT, Polyimide and BCB
- **Ge Test Vehicles "Snakes" *new generation* – THB, 240 hours (2023)**
  - PCB UMS + Socket assembly and bondings by III-V

T - Temperature
H - Humidity
B - Bias

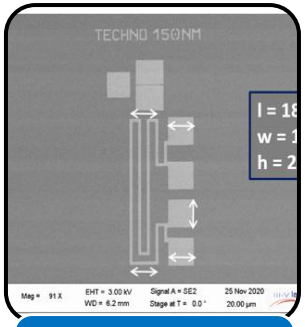
THB tests at III-V Lab - II

- **GaN HEMT – TH, 1000 hours (2023)**
  - Reliability, UCBL films : Parylènes VT4 and HT, Polyimide and BCB
- **Test Vehicles for Smart3 project – THB, 2000 hours (2024)**
  - Electrical monitoring
- **HEMT GaN (2025) – THB, 1000 hours**
  - PCB Support realized at III-V Lab
  - BCB and Polyimide films realized at III-V Lab
  - 1000 hours → 1369 hours overall

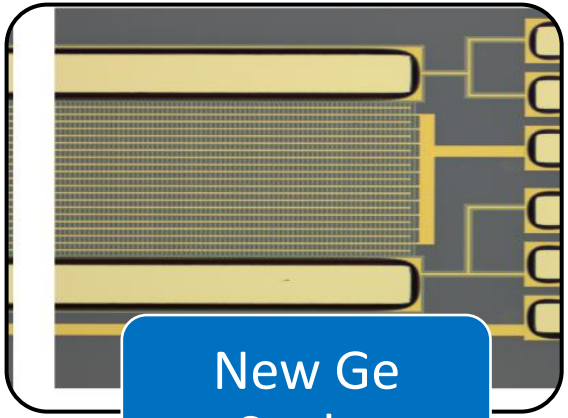
Historical background at III-V Lab



Material ?
→ Ge



Ge Snake
TH

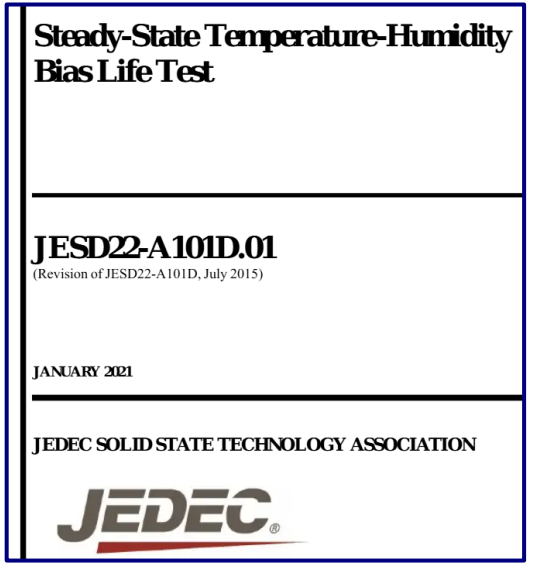


New Ge Snake
TH / THB

GaN HEMT
THB

Goal and method

- To protect GaN components against corrosion
- THB for evaluating polymer coatings against corrosion
- Protection by double passivation with polymeric films
- THB tests according to JEDEC-JESD22-A101D



Thales systems

Method

- **HEMT Transistors underwent *Temperature Humidity Biasing* « THB » test**
  - **85°C, 85% HR, 1000 hours (≈ 42 days)**
  - **→ 1369 hours**
- **HEMT protected by secondary passivation : BCB and Polyimide (PI)**
  - Thickness: **BCB ≈ 7 µm, PI ≈ 6 µm**
  - Comparison with REF HEMT – no protection
- **HEMT biased at OFF state Pinch-OFF (Transistors *normally ON*)**
  - **V_{GS} = -5 V / V_{DS} = 20 V**
- **Climate chamber 85°C - 85% HR**
  - Electric monitoring in situ – Leakage currents
  - Optical observations at t0 and t = 1369 hours
  - SEM observations at t = 1369 hours

HEMT technology

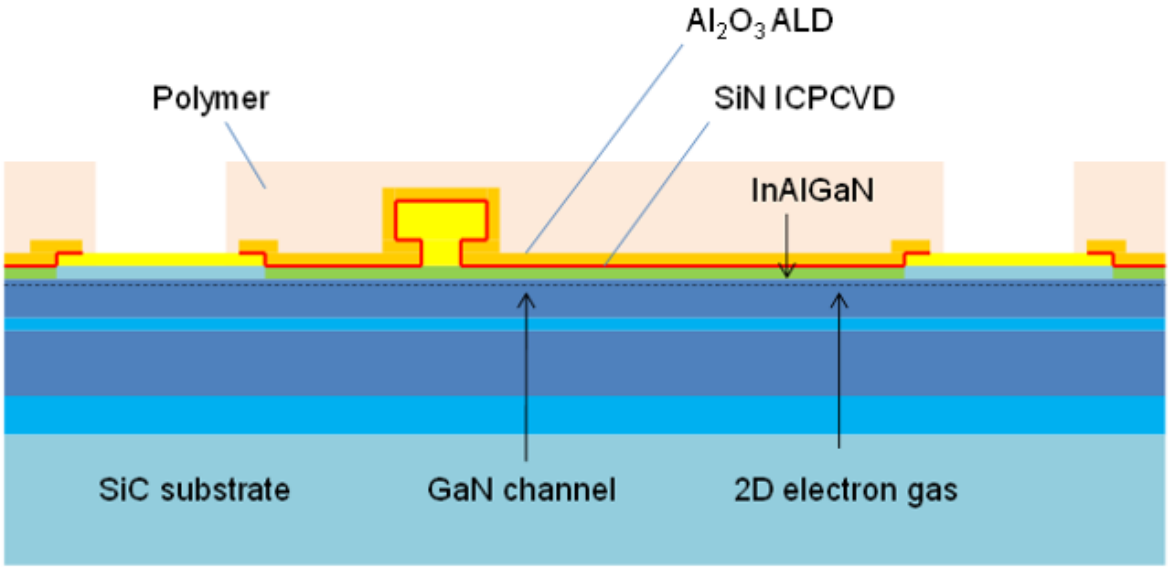
Polymer

Al2O3

SiN

InAlGaN

GaN

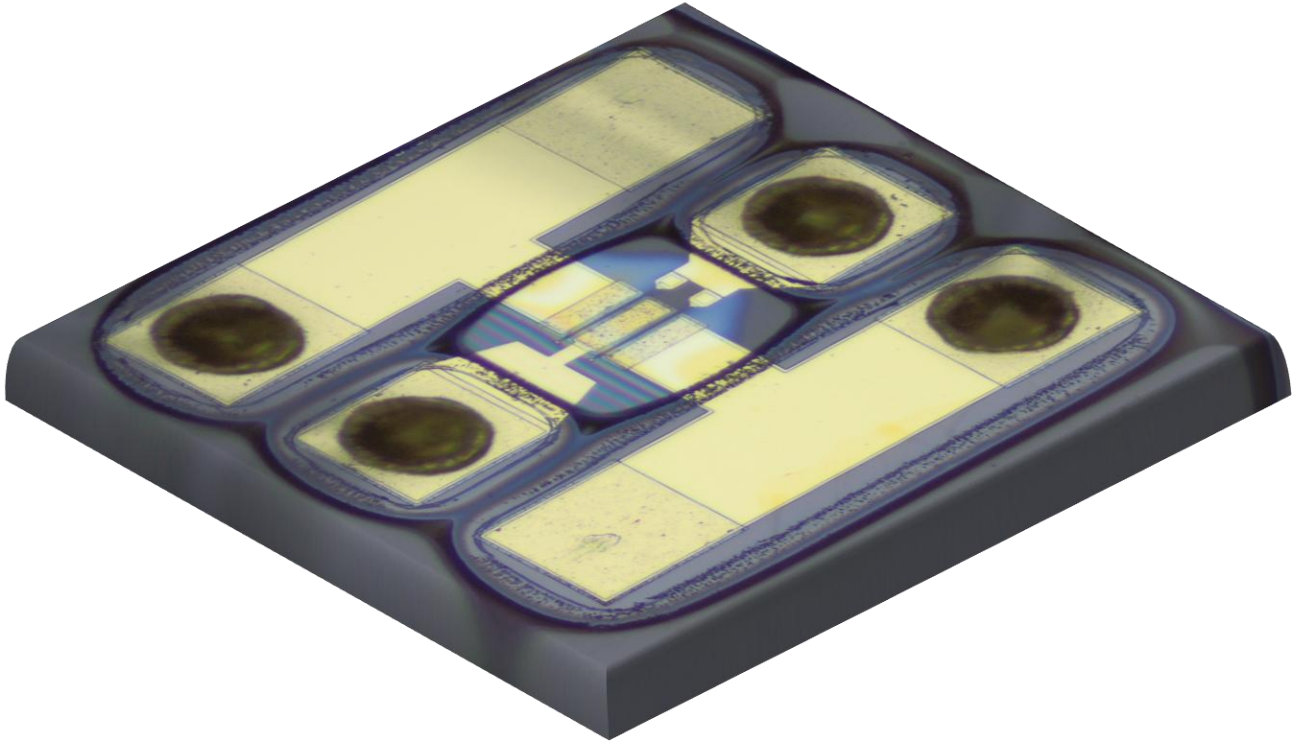


BCB ≈ 7 µm / PI ≈ 6 µm Polymer

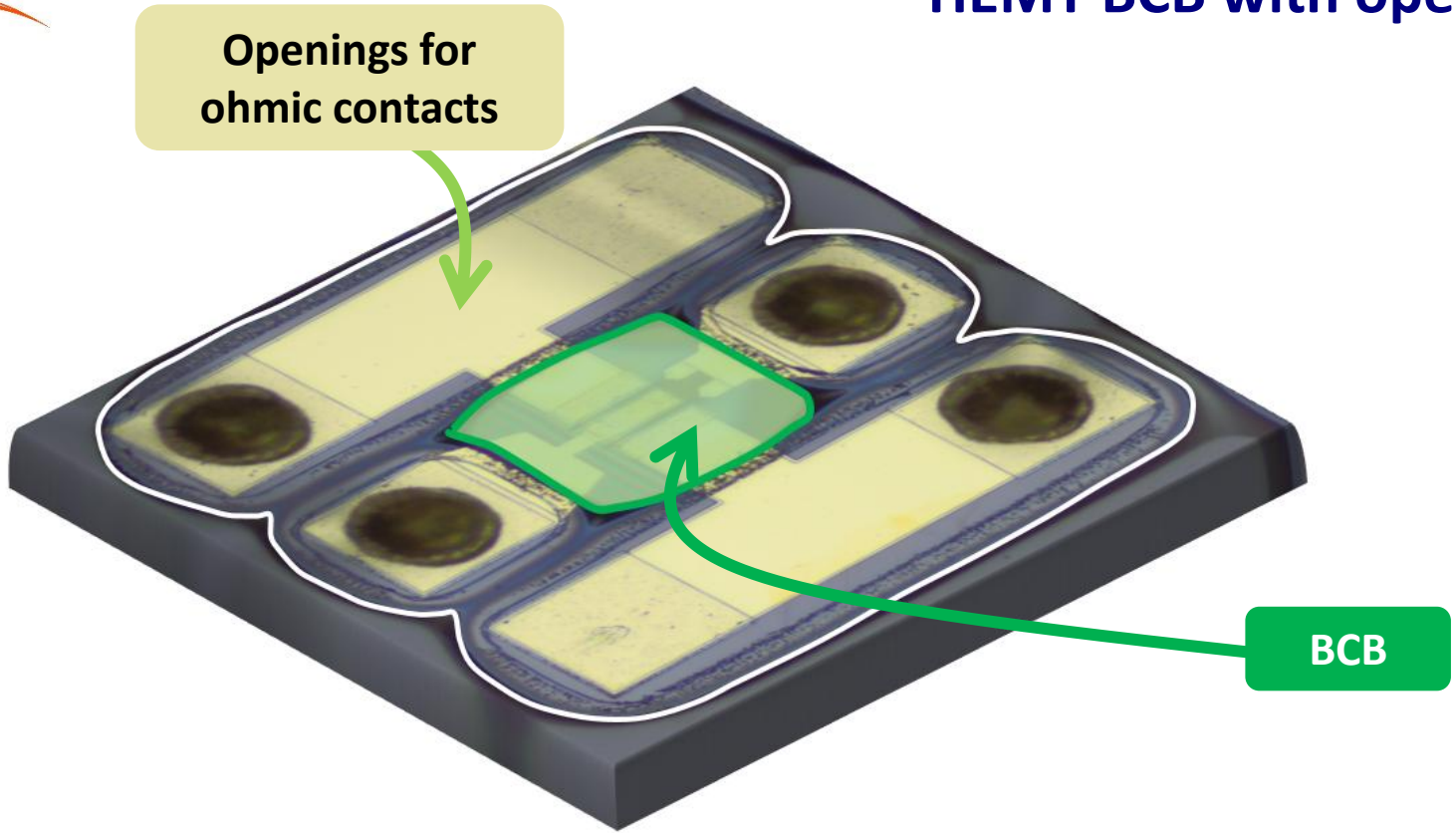
Al2O3 ALD - 100 nm Al2O3

SiN ICPCVD - 30 nm SiN

HEMT with BCB deposition

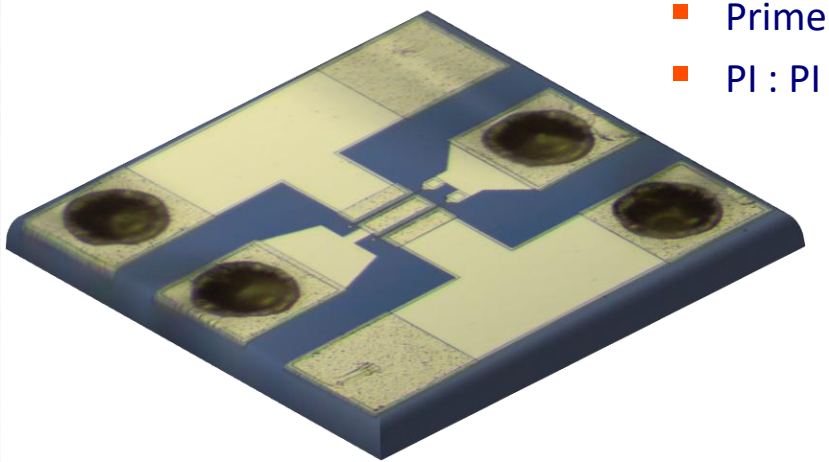


HEMT BCB with openings

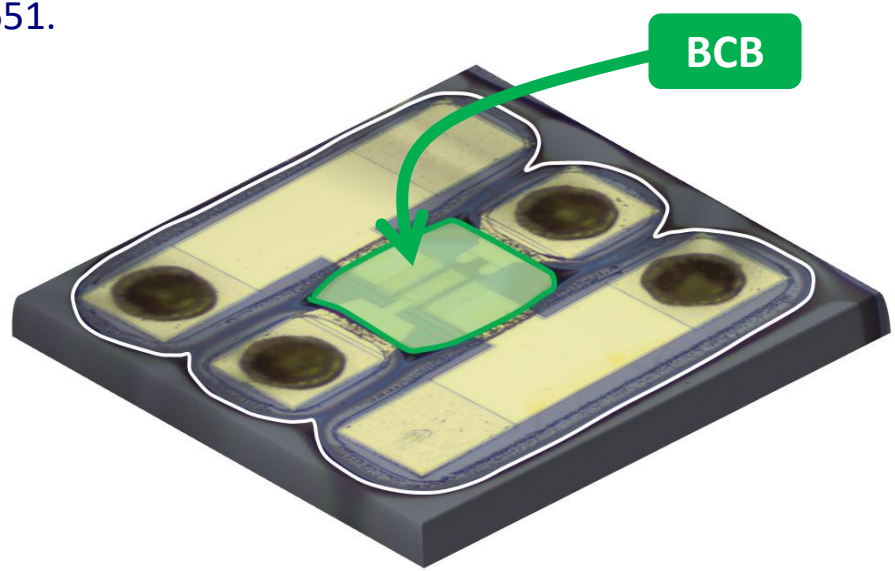


Polymers opening

- **BCB :**
  - Primer : AP3000
  - BCB : BCB 3022 57
- **PI :**
  - Primer : VM651.
  - PI : PI 2610

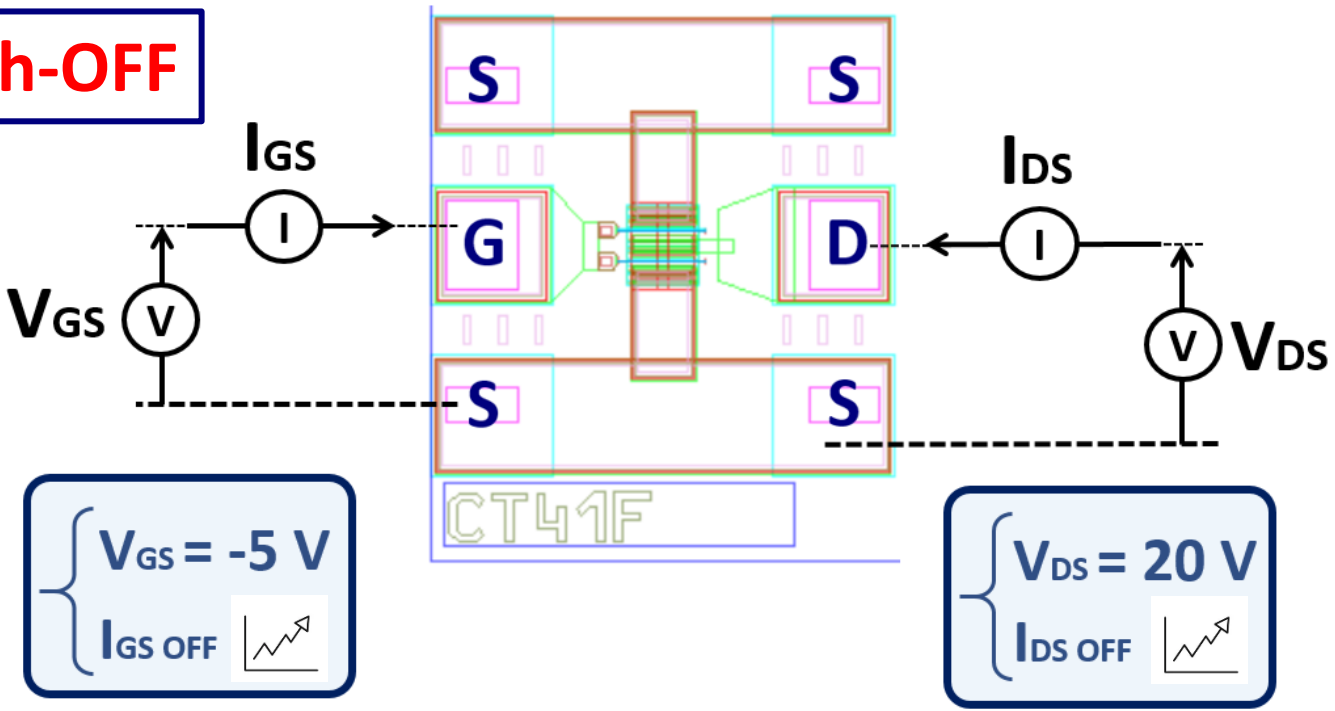


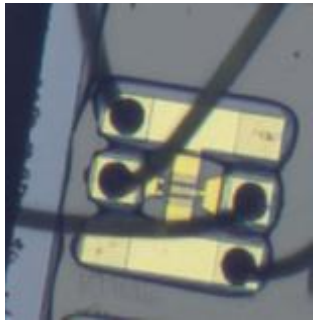
HEMT without deposition



HEMT transistor polarization

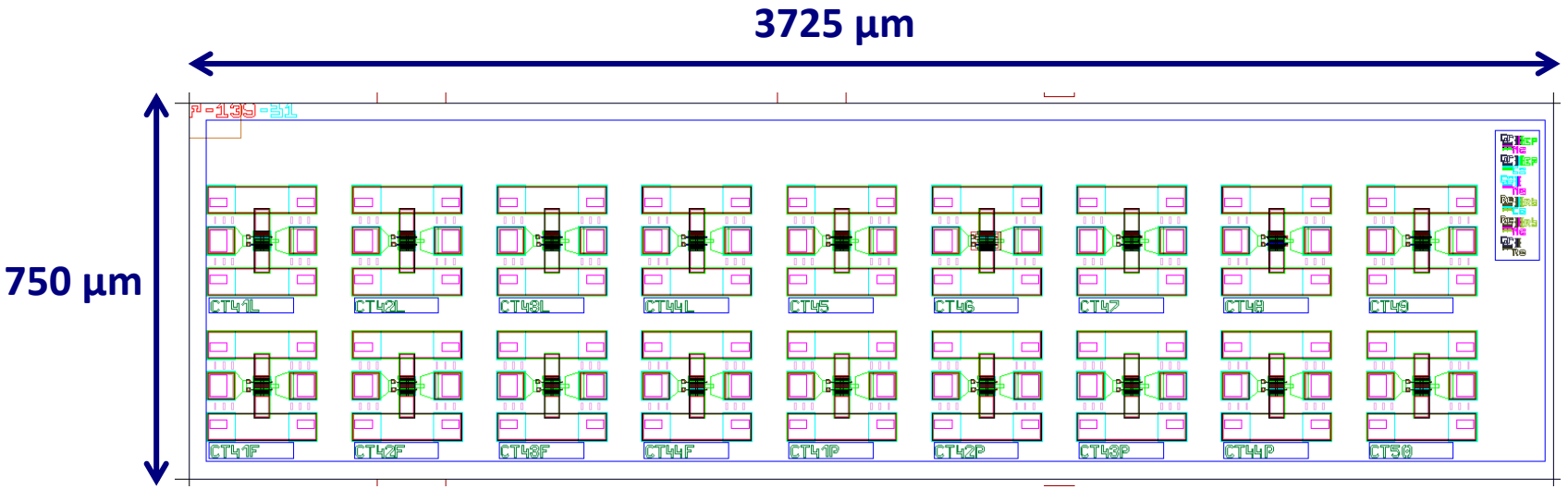
Pinch-OFF





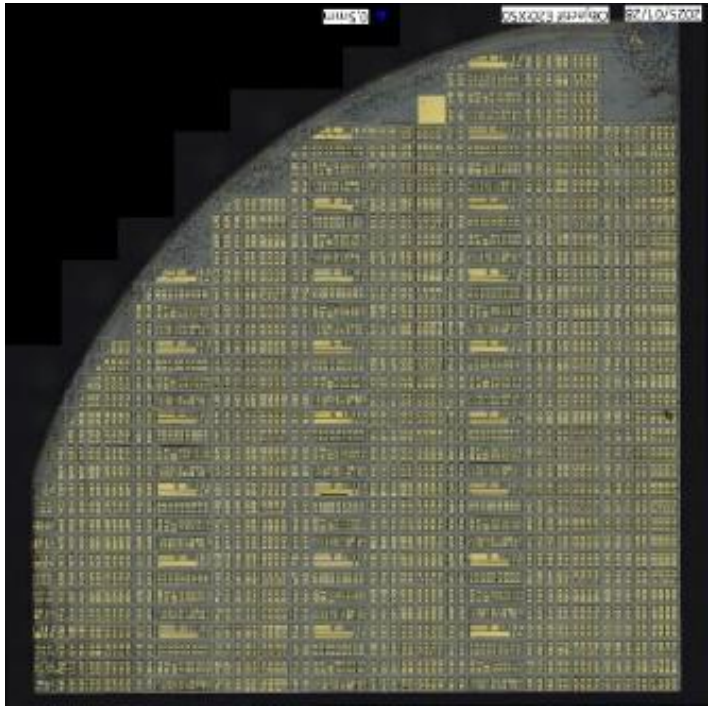
Leakage Currents monitoring

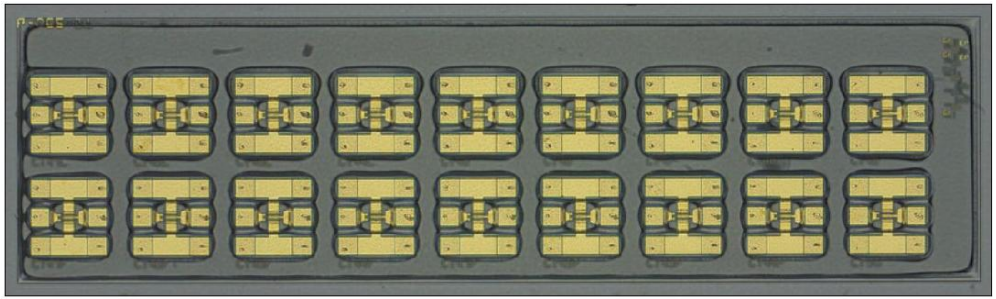
2x9 HEMT stripe

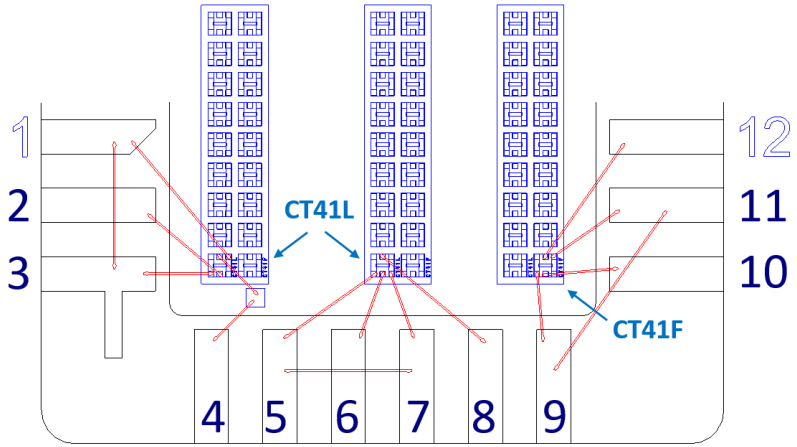


This coplanar topology corresponds to a transistor with 2 fingers of 50 µm development with a gate length of 100 nm.

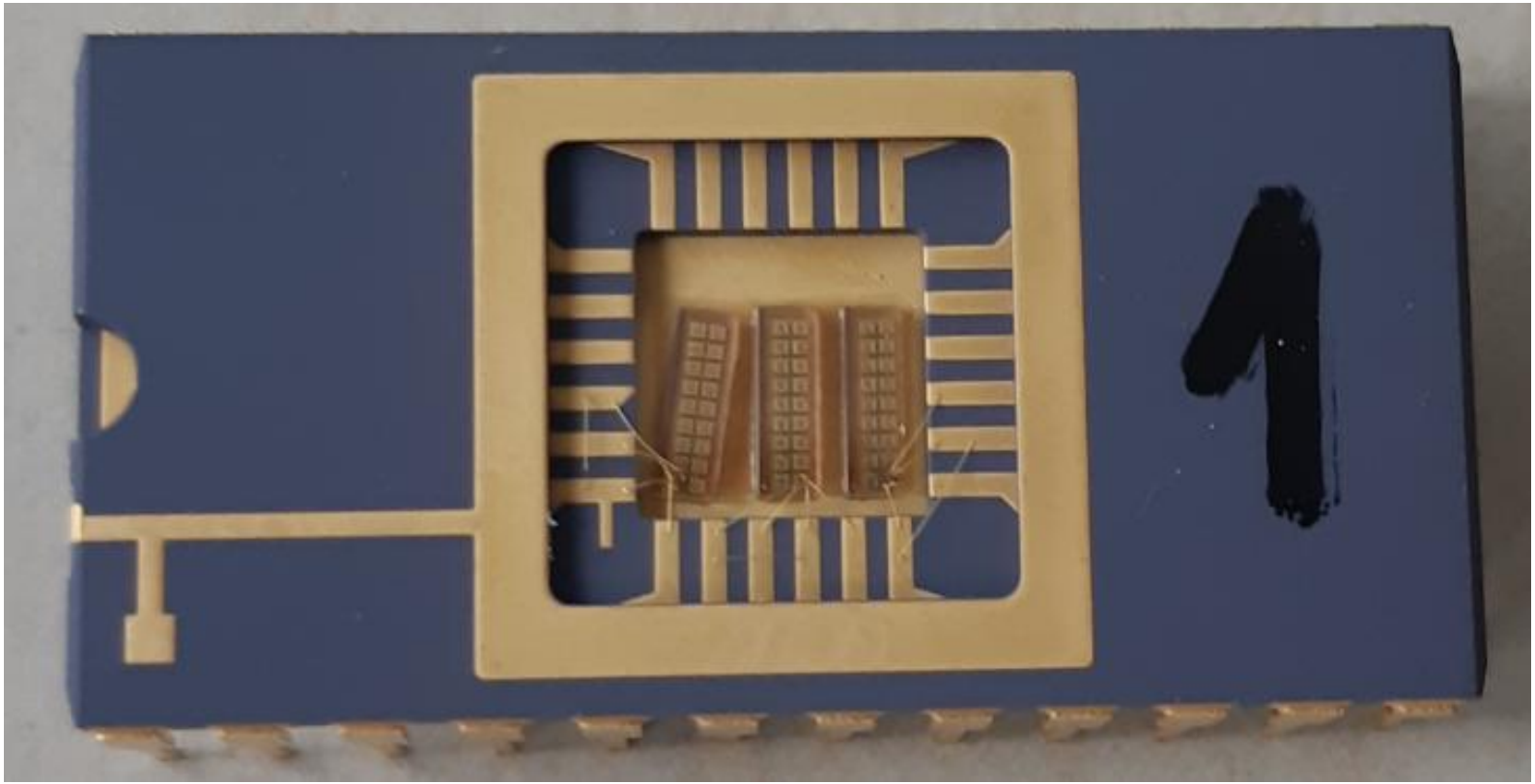
Wafer 4” and HEMT stripe bonding on socket







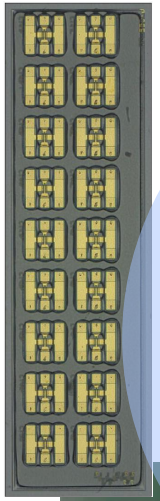
DIL24 Socket with Bondings

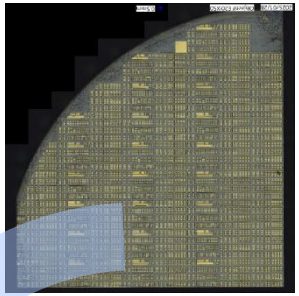


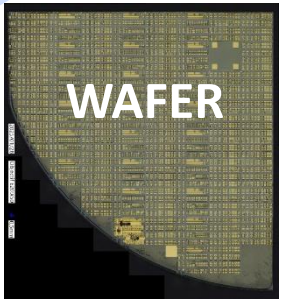
Tests “Temperature Humidity Biasing” - THB

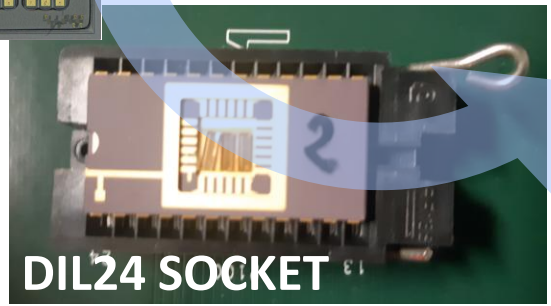
III-V lab

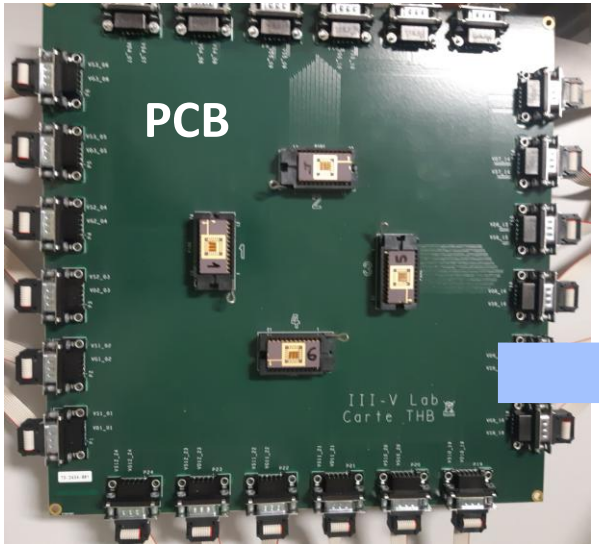
GaN HEMT











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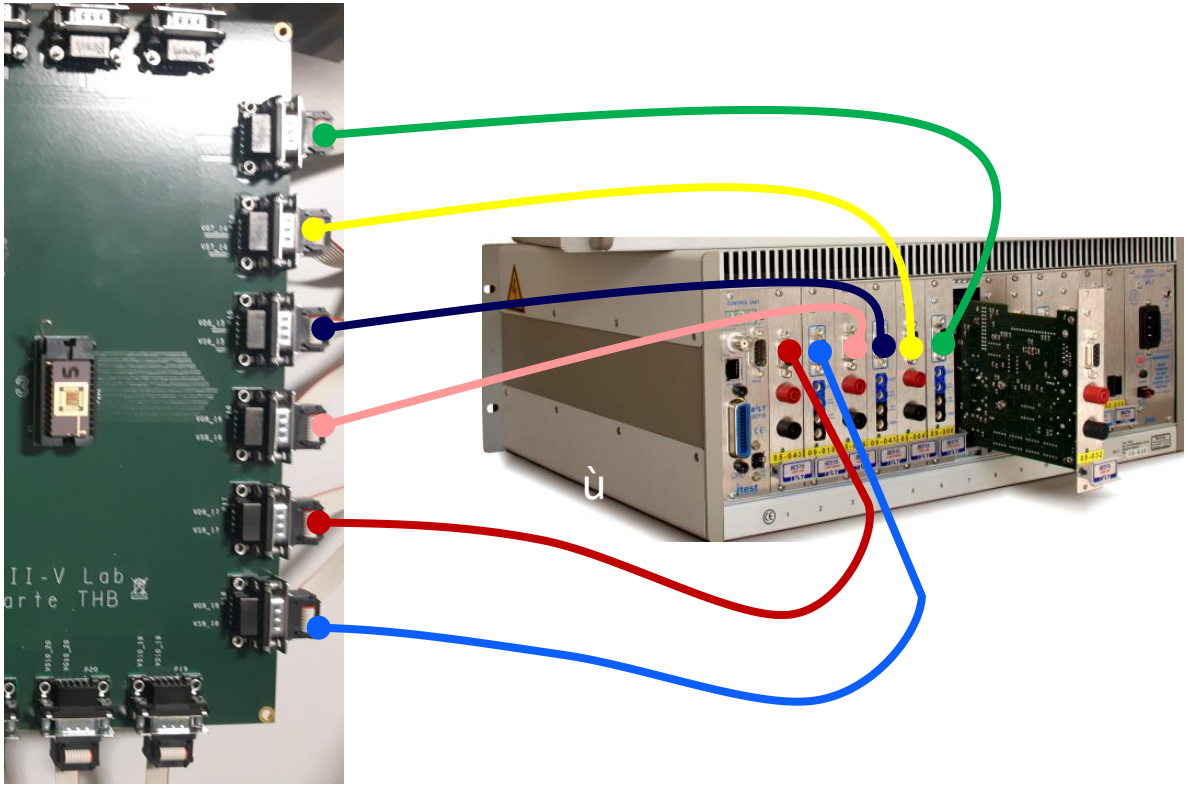
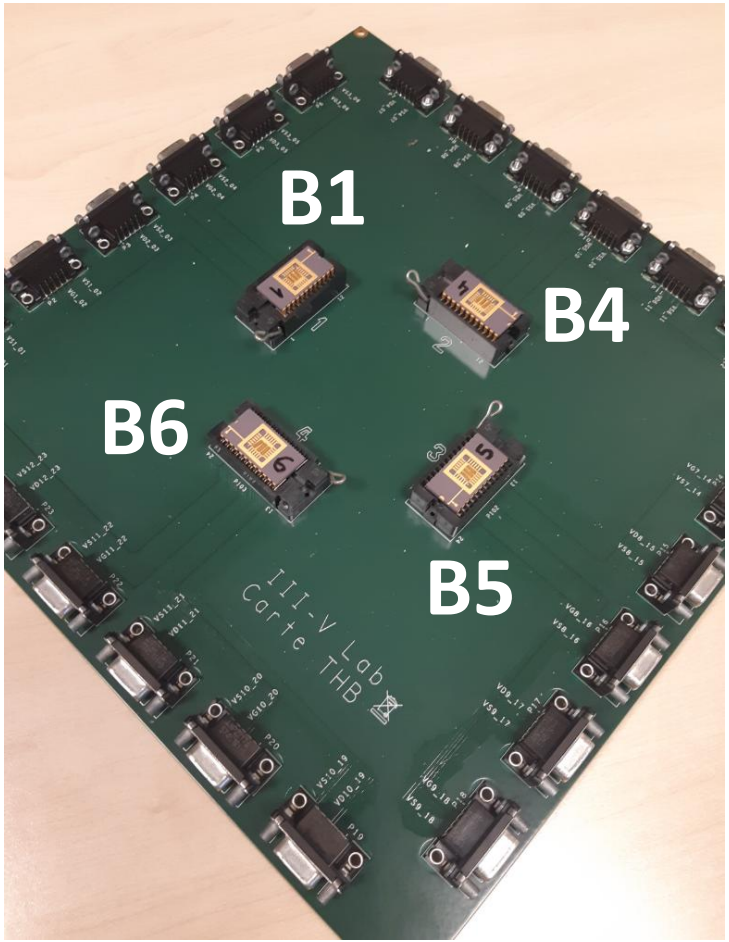
THALES Building a future we can all trust

Electrical connexions



4 Sockets – 12 HEMT

B1	B1-083-F-BCB
	B1-213-F-PI
	B1-166-L-REF
B4	B4-139-L-BCB
	B4-263-F-PI
	B4-067-L-BCB
B5	B5-186-L-REF
	B5-227-F-PI
	B5-141-L-BCB
B6	B6-202-L-REF
	B6-265-L-PI
	B6-155-L-BCB

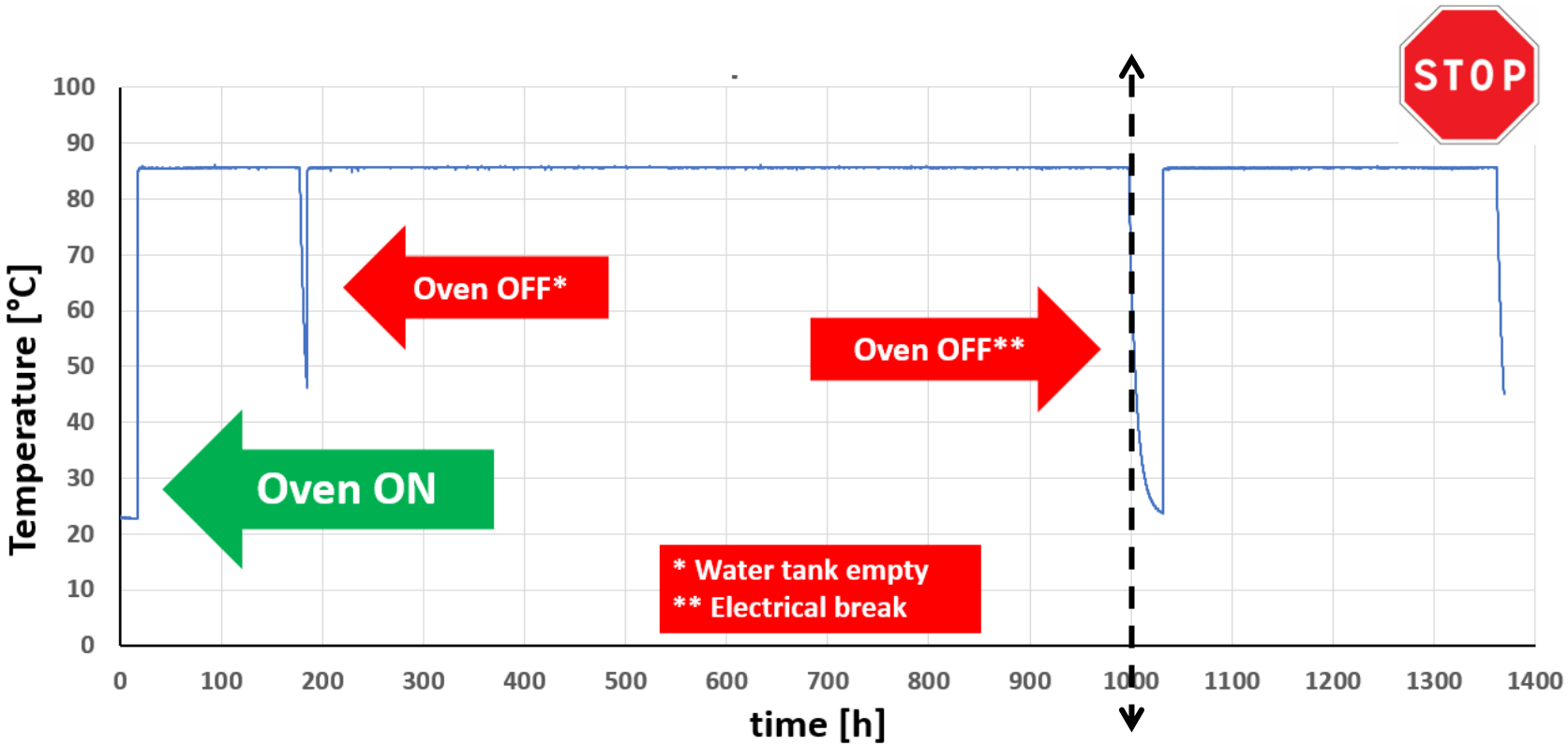


5 x BCB

4 x PI

3 x REF

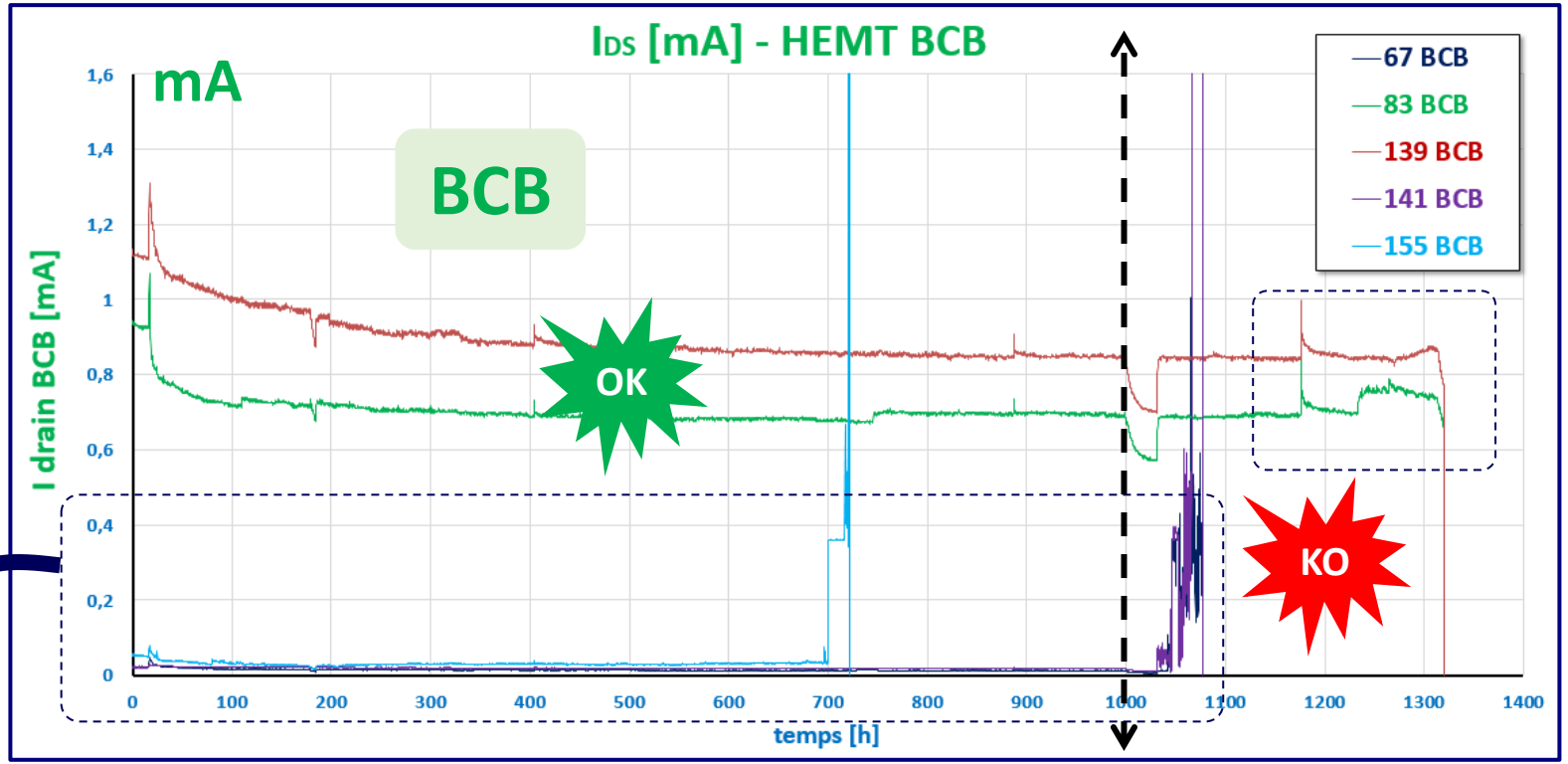
Temperature timeline



Drain leakage current monitoring

BCB – Drain Leakage current

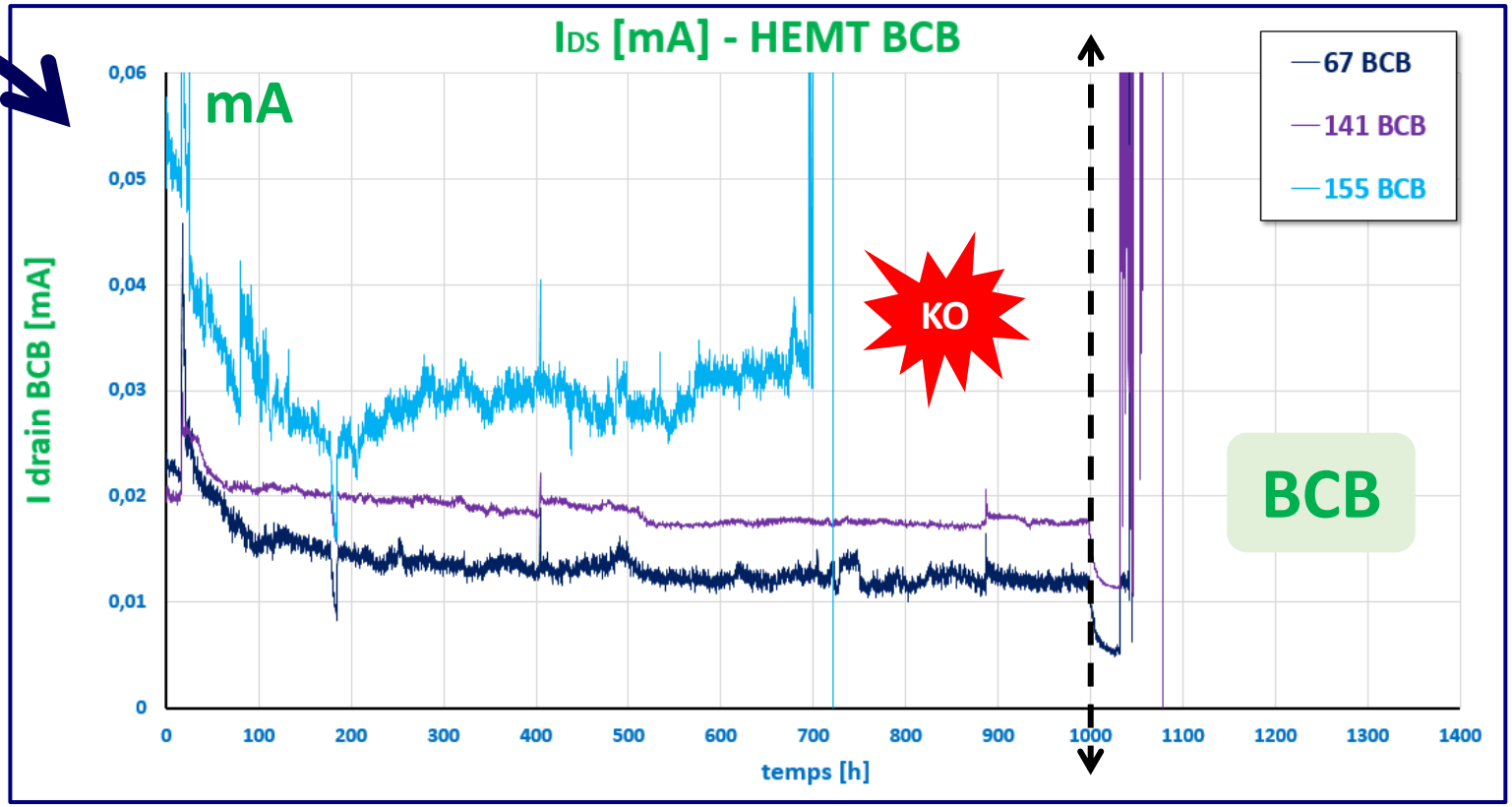
x10 mA/mm



Next page

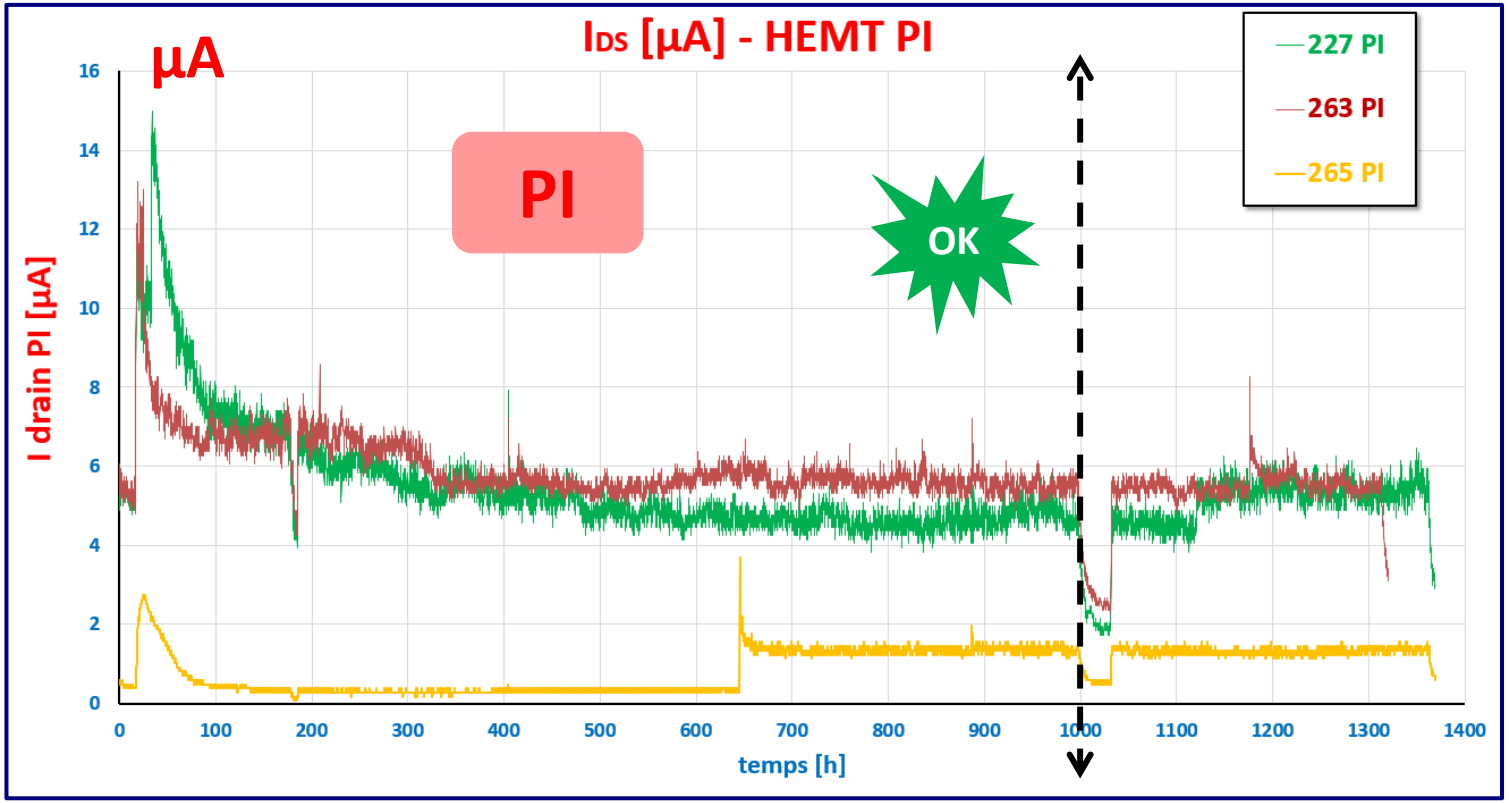
BCB – Drain Leakage current

x10 mA/mm



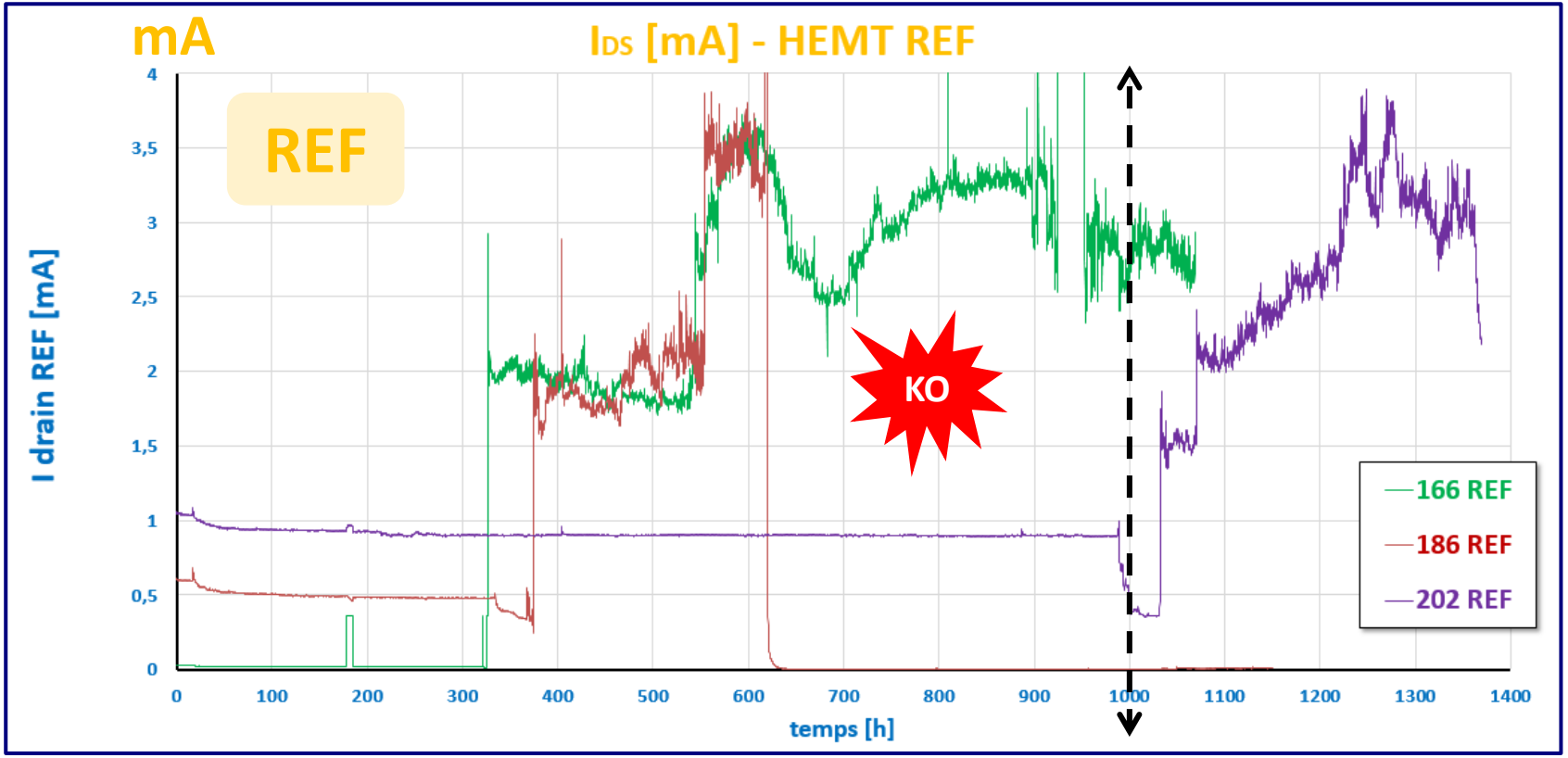
PI – Drain Leakage current

x10 µA/mm

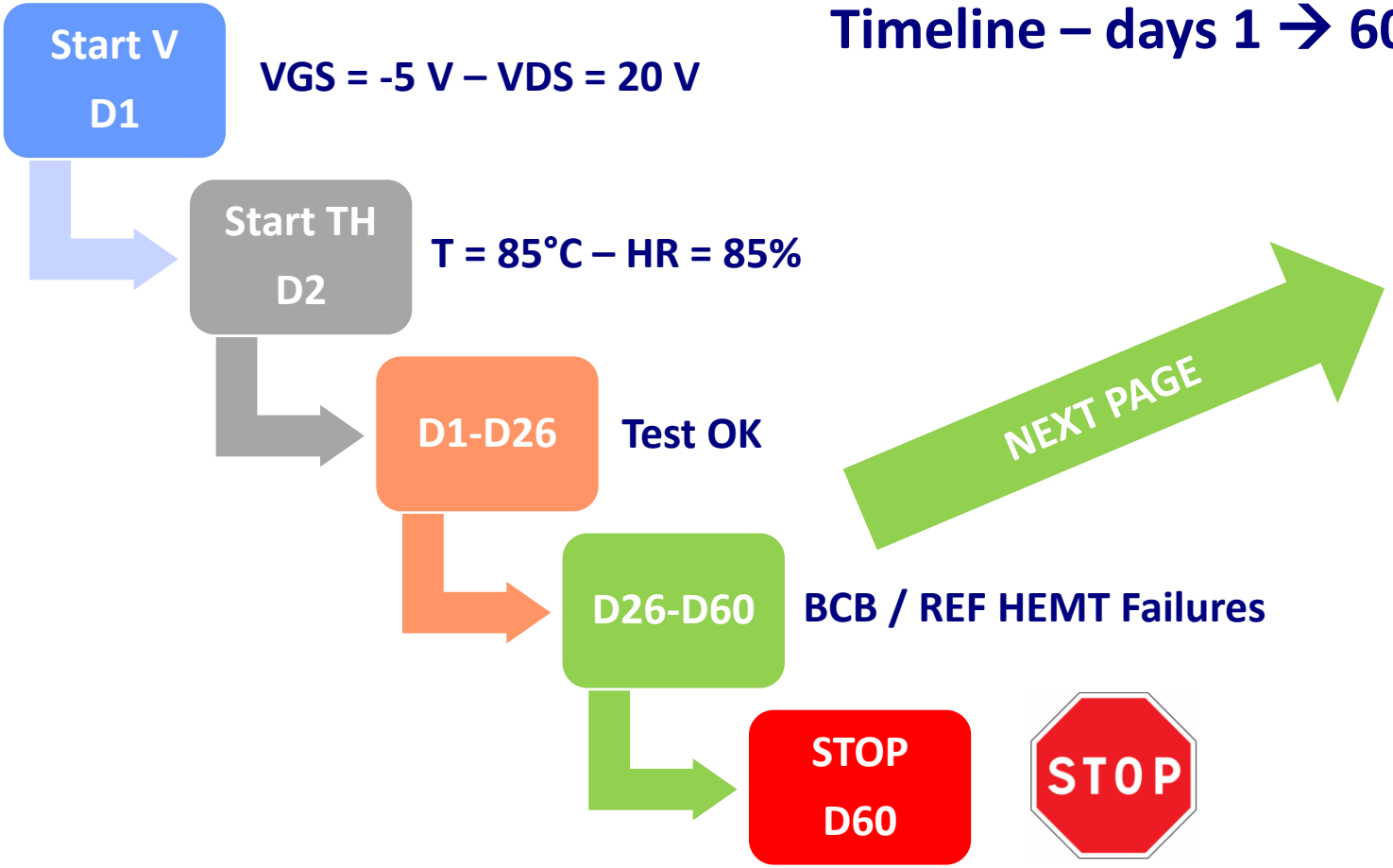


REF – Drain Leakage current

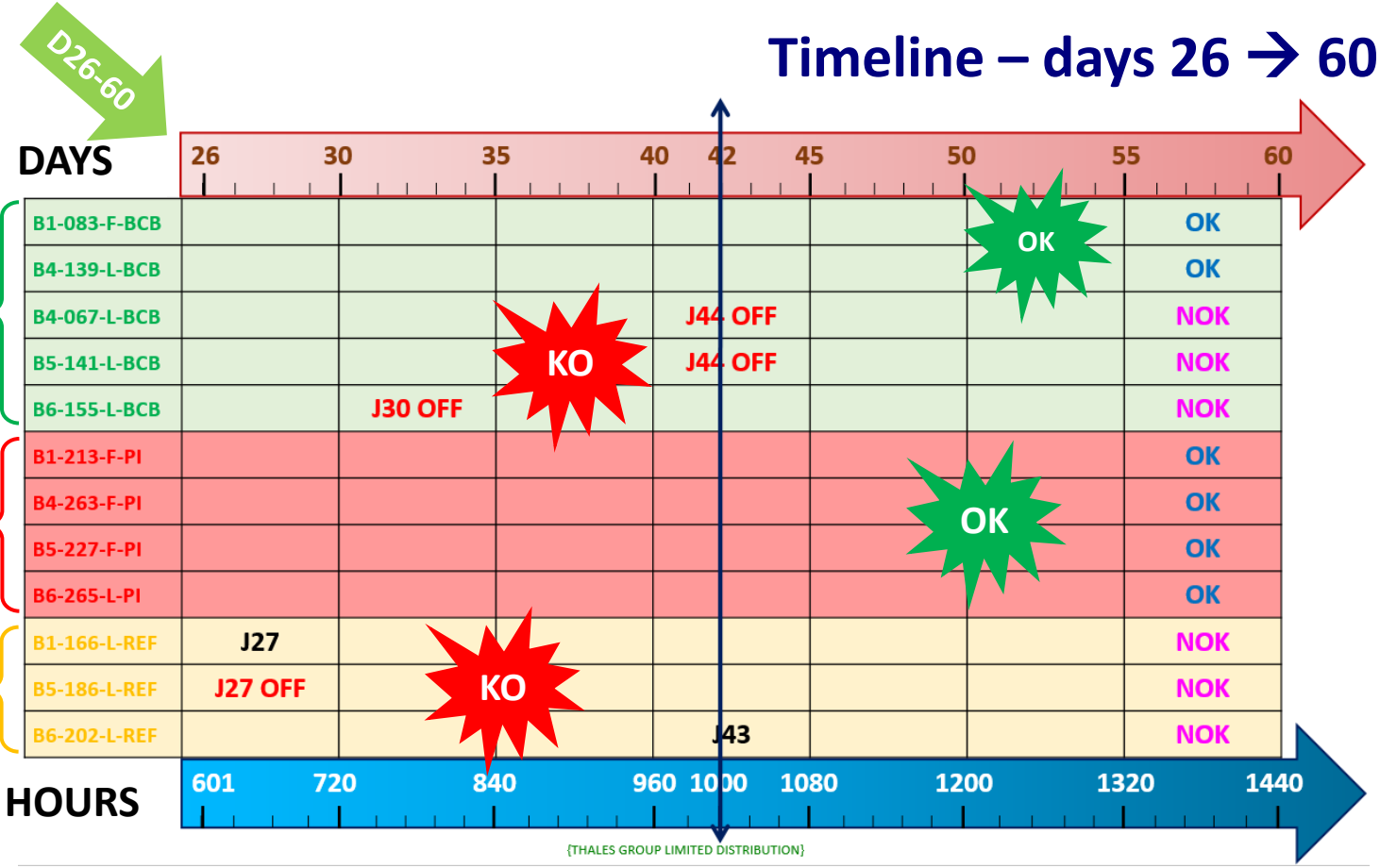
x10 mA/mm



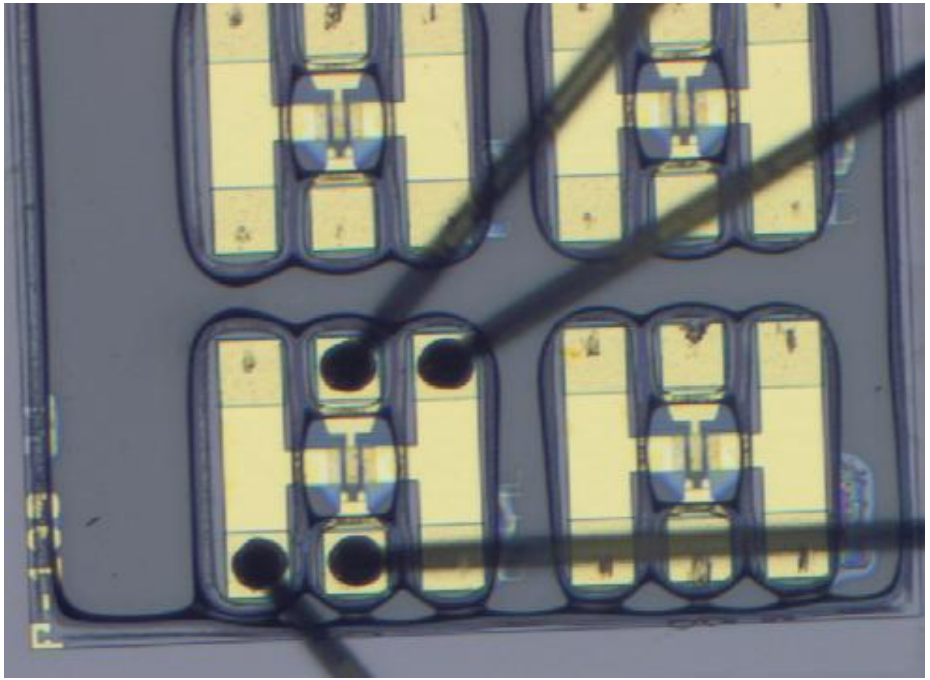
Timeline – days 1 → 60



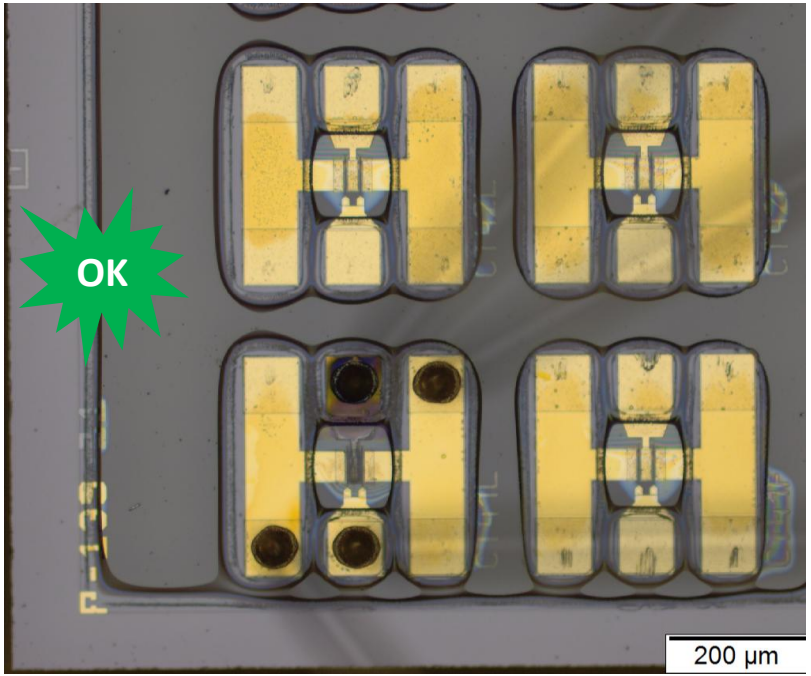
Timeline – days 26 → 60



BCB 139 / HEMT OK

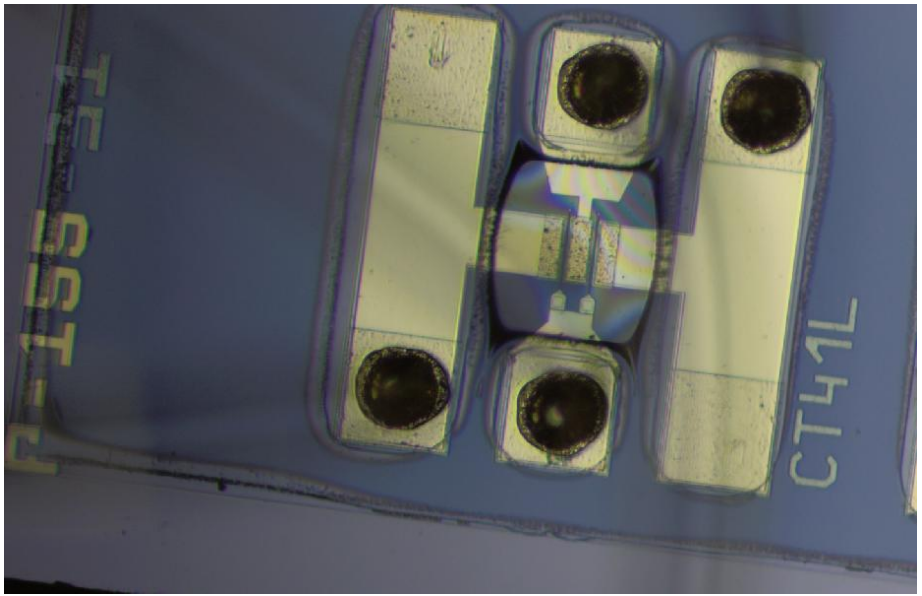


t0

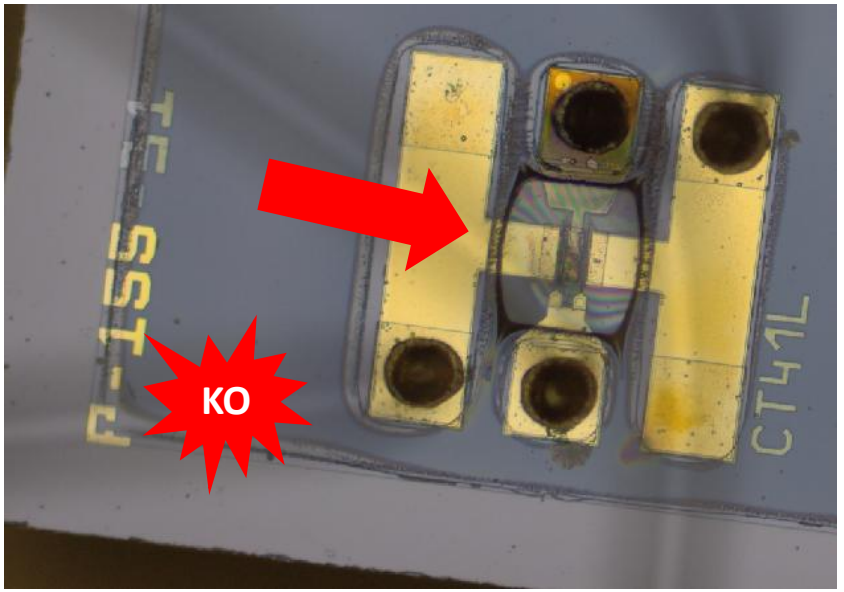


1369 hours

BCB 155 / HEMT KO



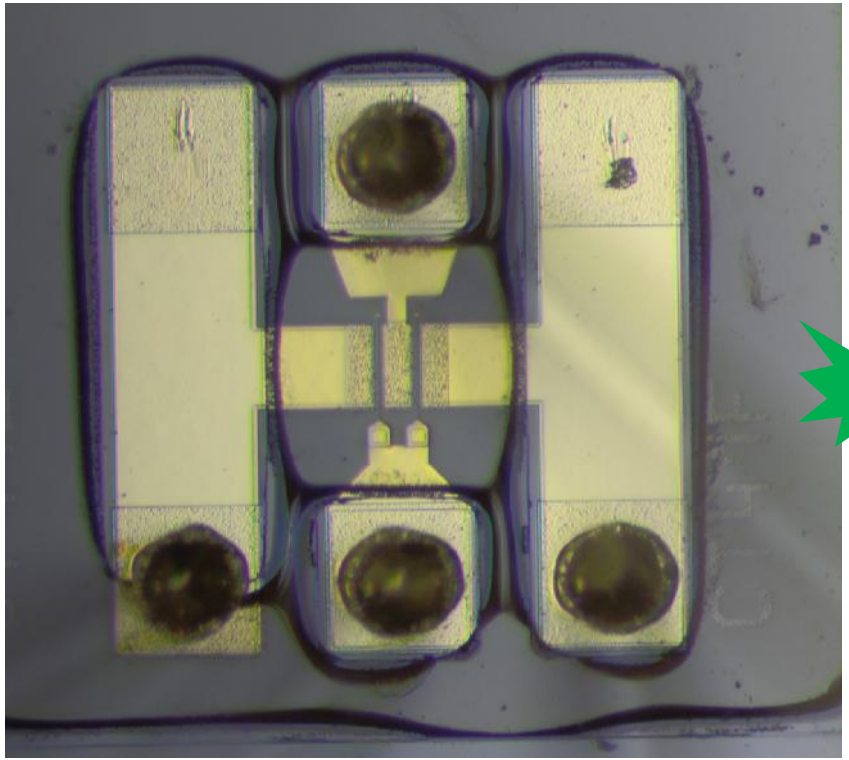
t0



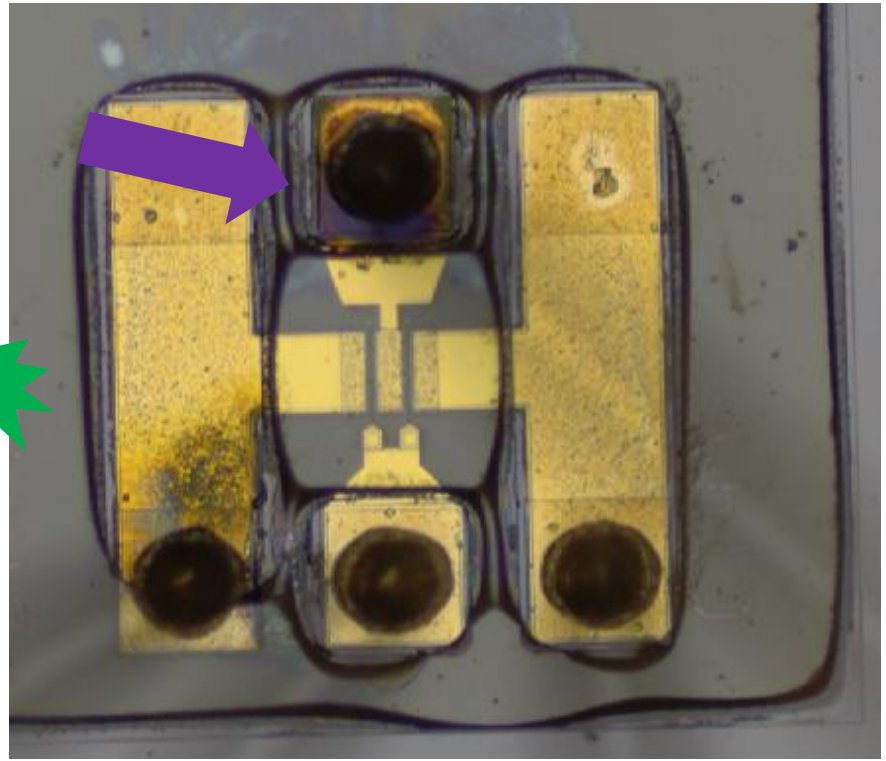
1369 hours

PI

PI 227 / HEMT OK



OK

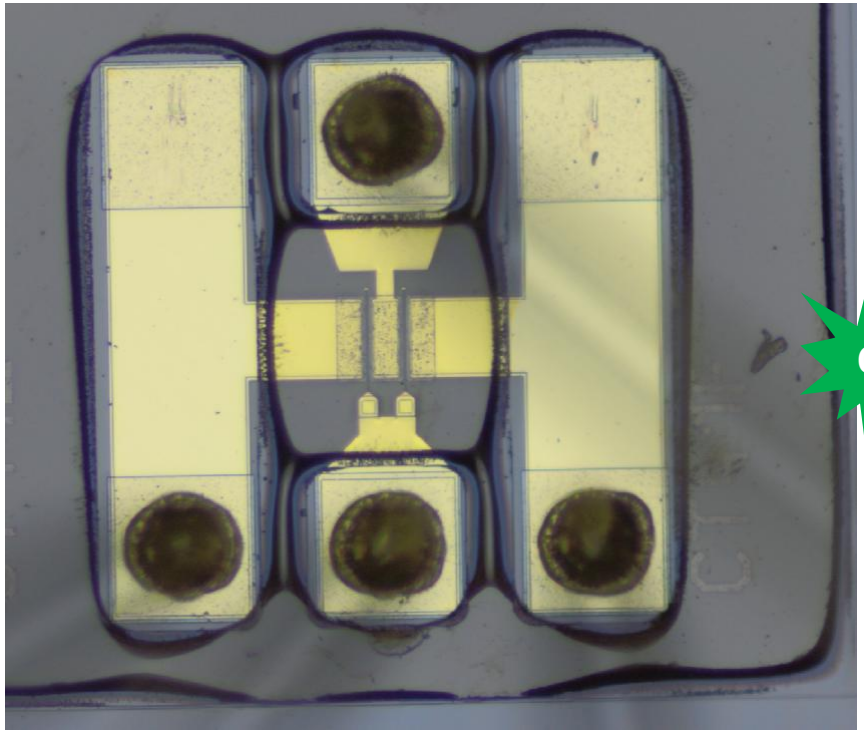


t0

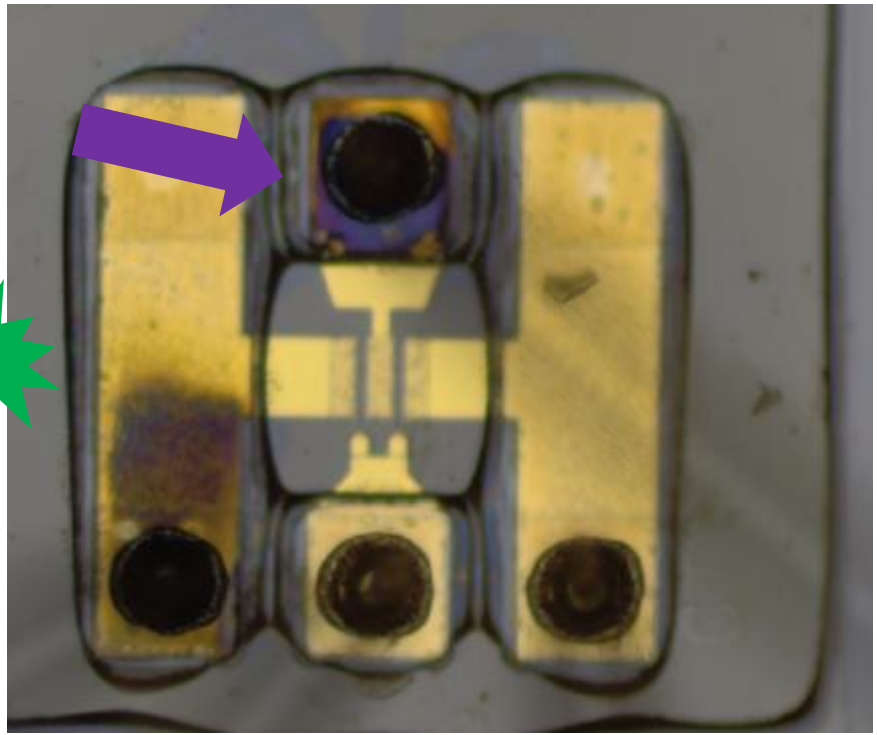
1369 hours

PI

PI 263 / HEMT OK



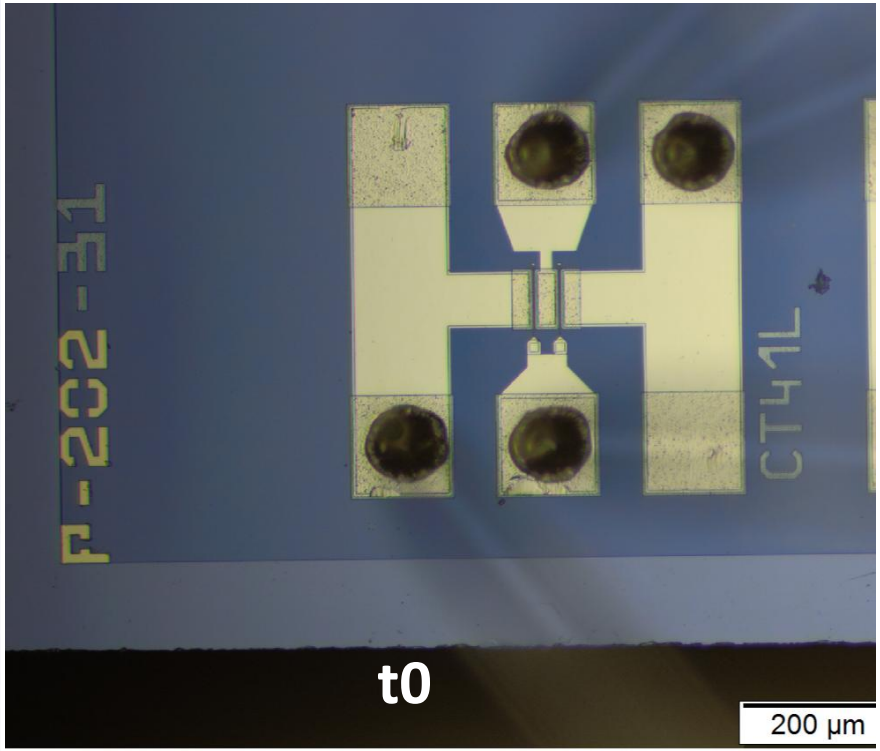
OK

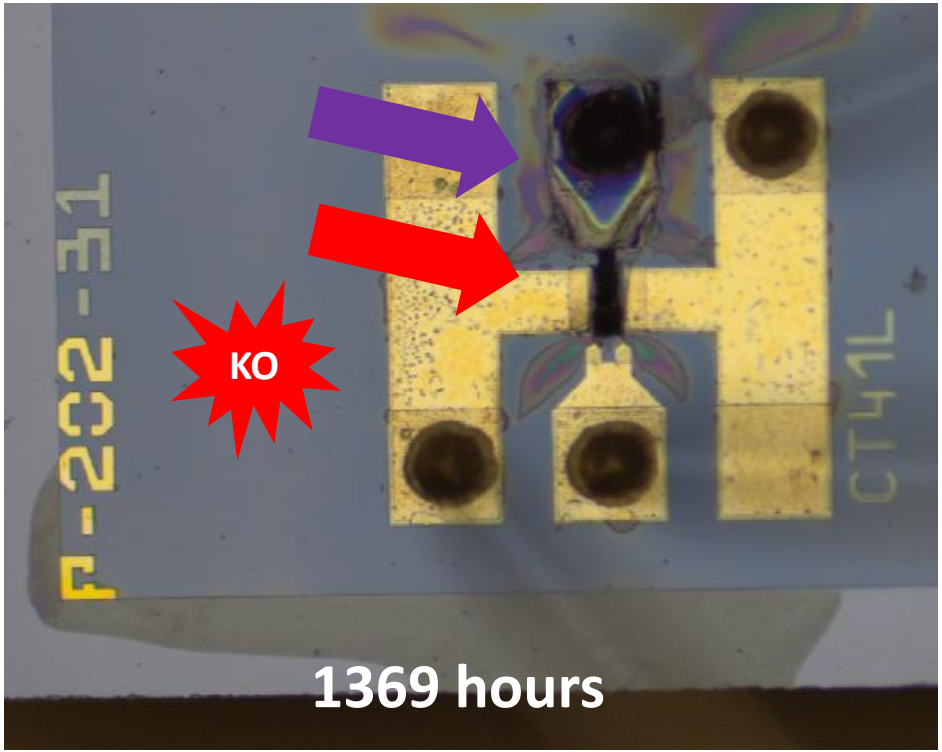


t0

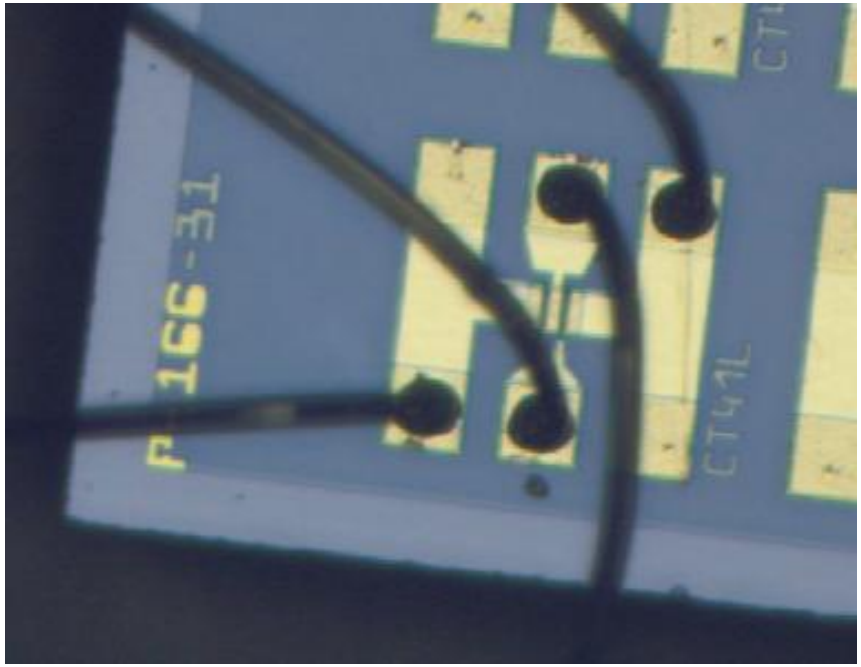
1369 hours

HEMT REF 202 / HEMT KO

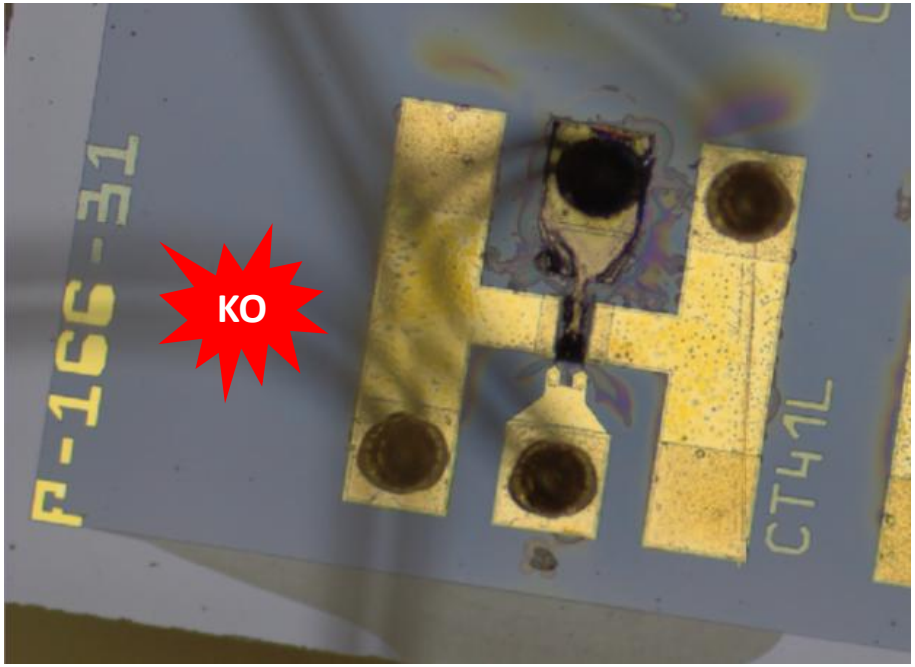




HEMT REF 166 / HEMT KO



t0



1369 hours

SEM Images

Boitier 3		
N.	HEMT	Type
065	L	BCB
247	F	PI
184	L	REF

0 h

NO THB

Boitier 1		
N.	HEMT	Type
166	L	REF
213	F	PI
083	F	BCB

1369 h

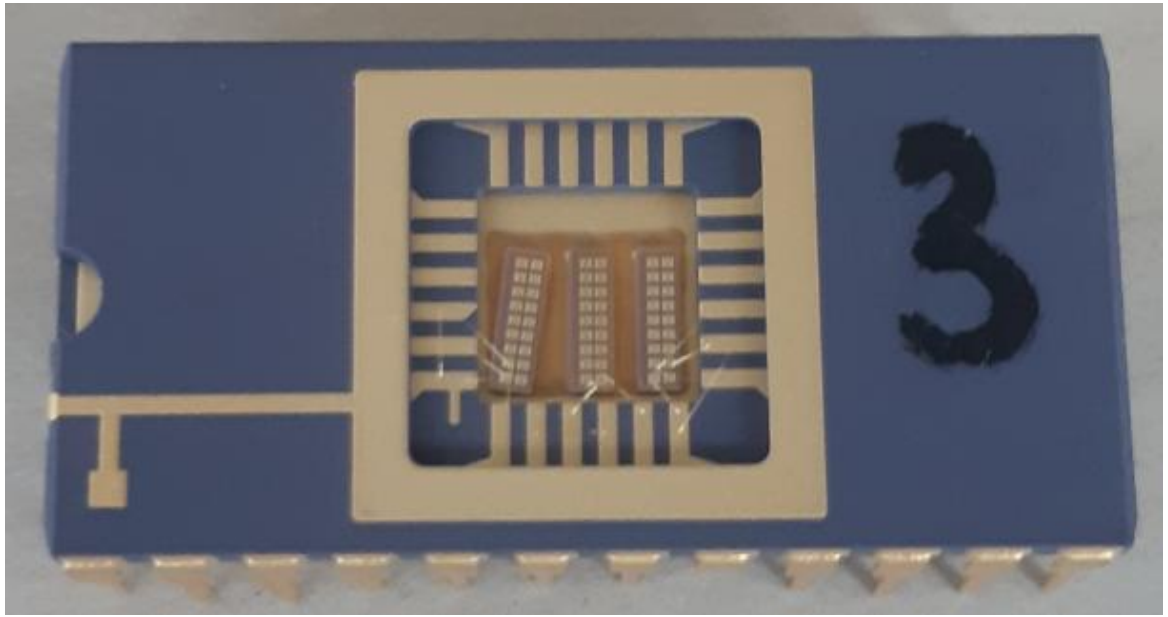
Boitier 4		
N.	HEMT	Type
067	L	BCB
263	F	PI
139	L	BCB

1369 h

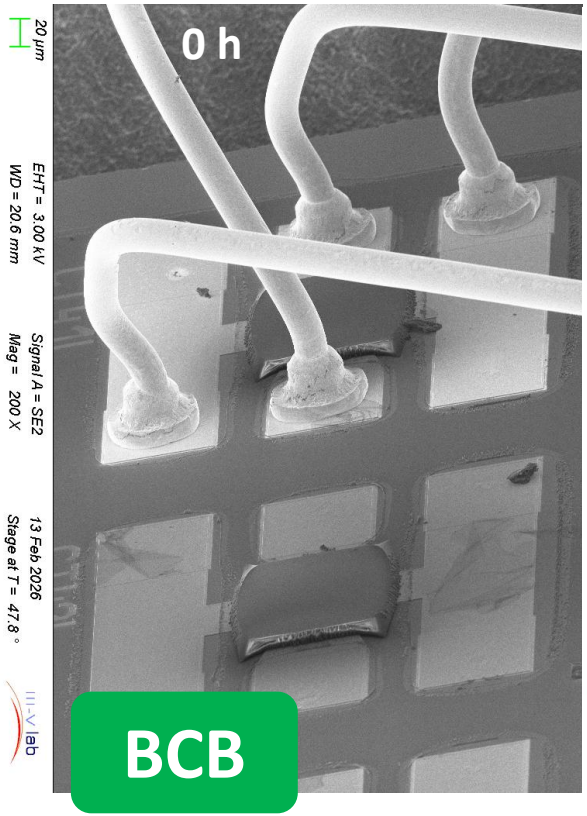
SEM Images

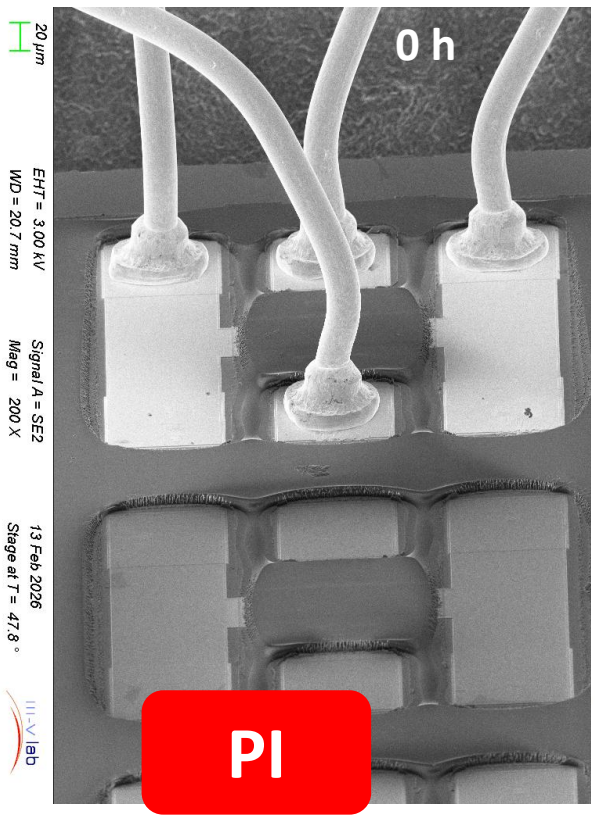
Boitier 3		
N.	HEMT	Type
065	L	BCB
247	F	PI
184	L	REF

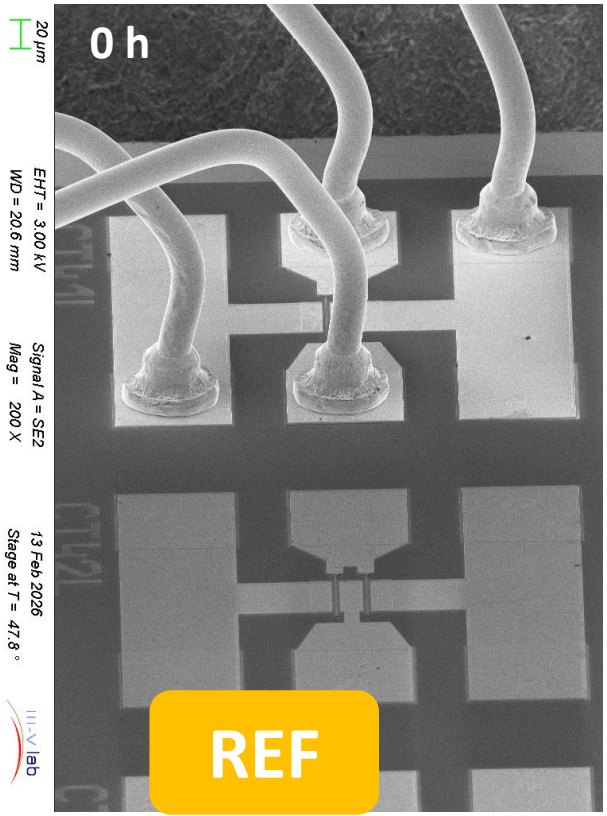
0 h



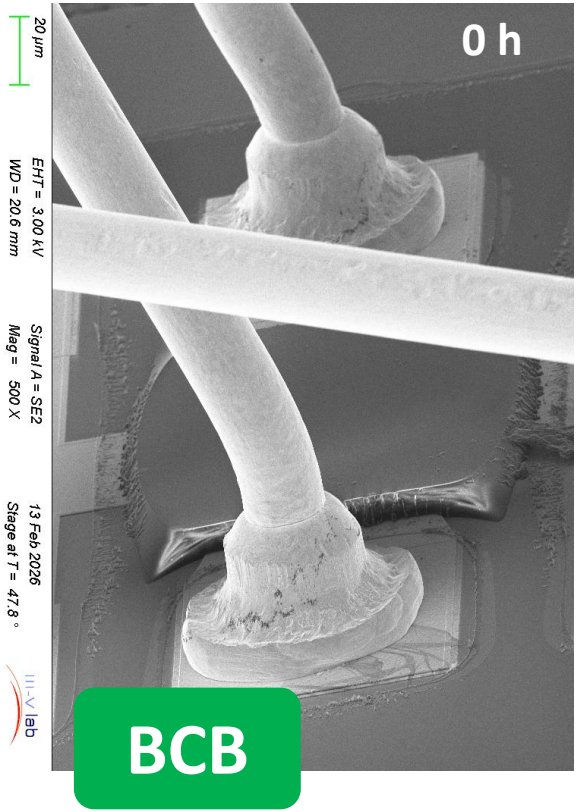
SEM – B3-065-L-BCB – B3-247-F-PI – B3-184-L-REF



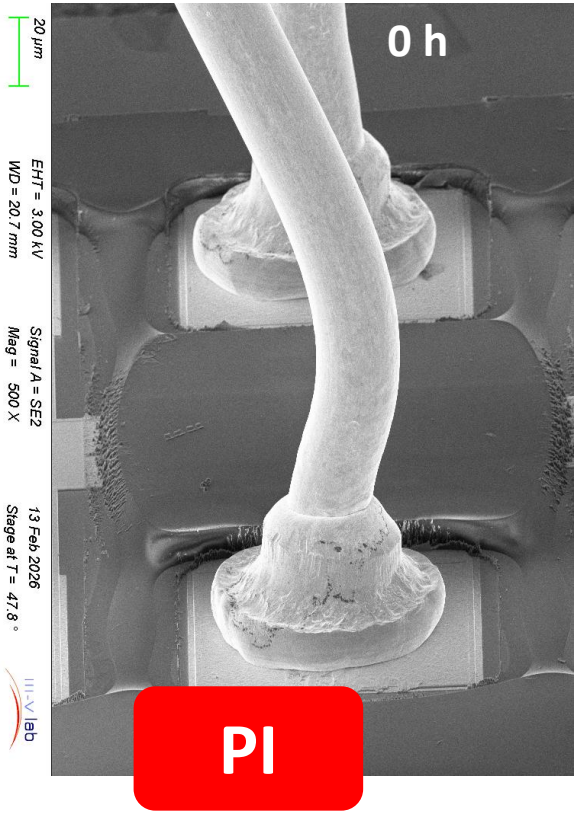




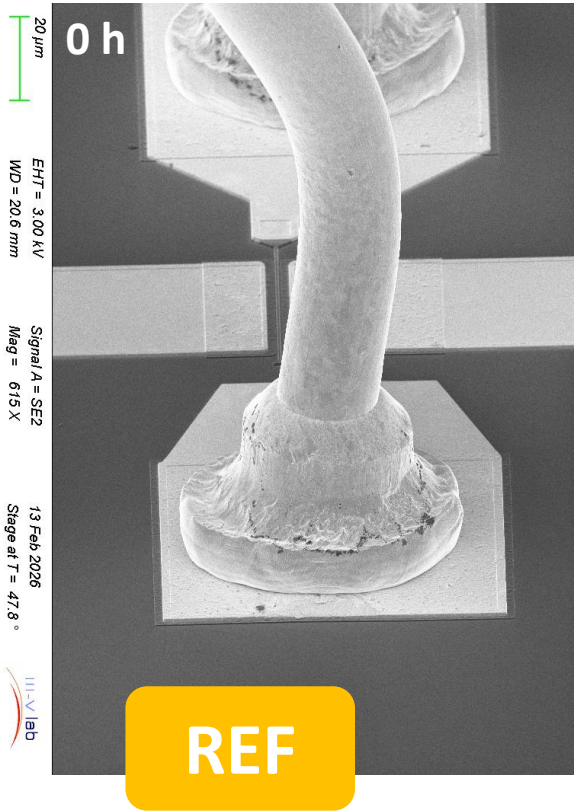
SEM – B3-065-L-BCB – B3-247-F-PI – B3-184-L-REF



BCB



PI

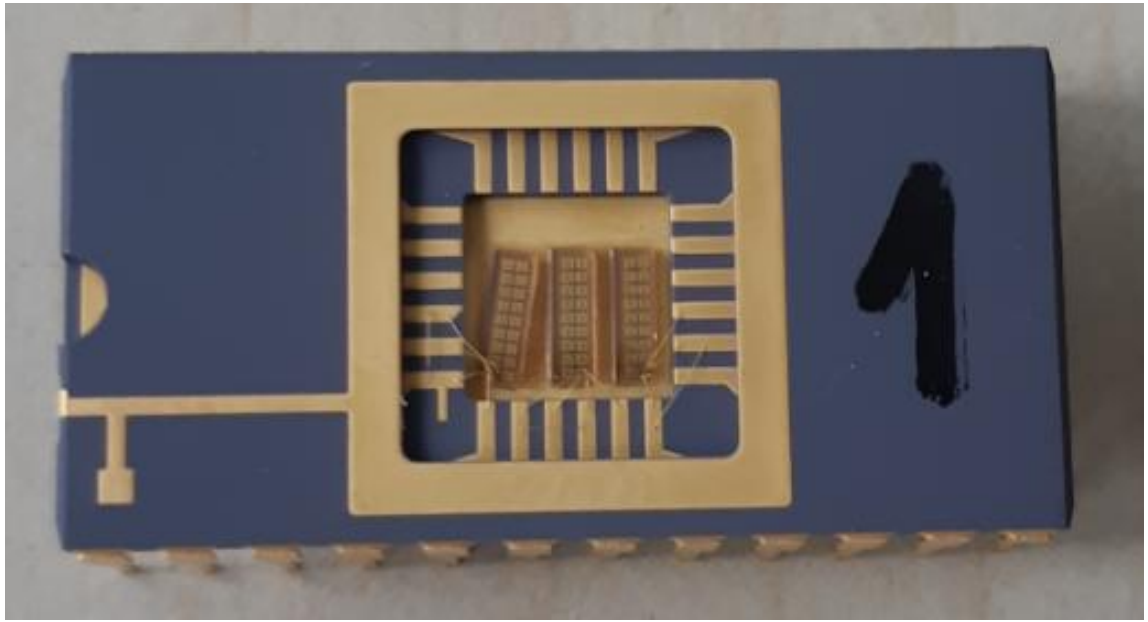


REF

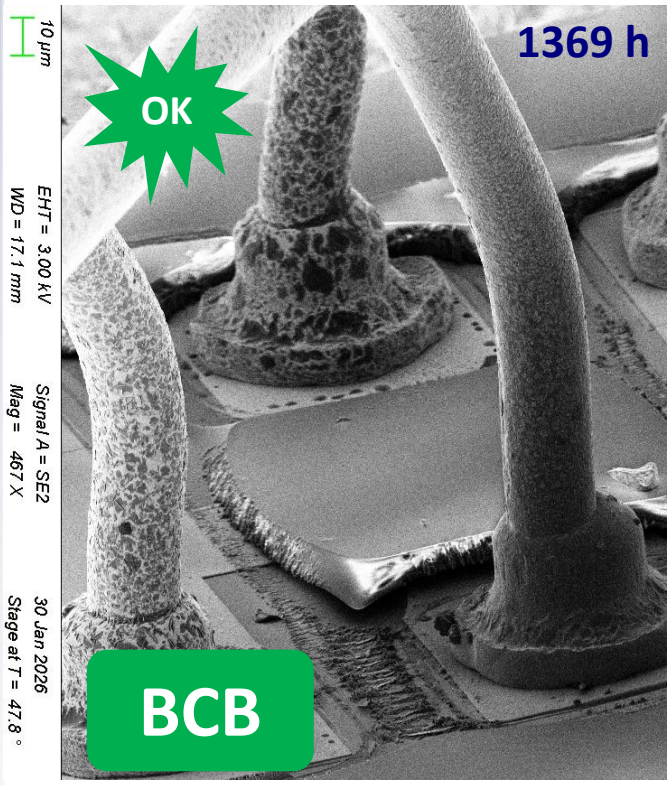
SEM Images

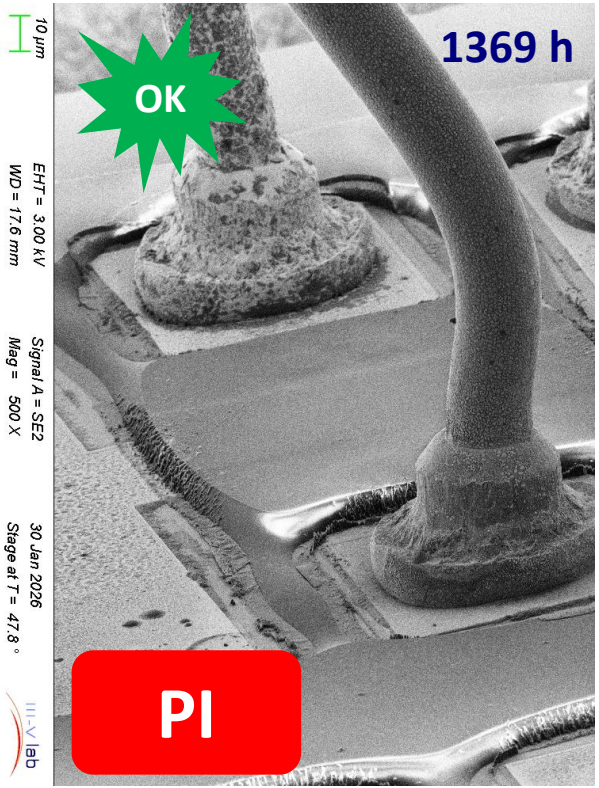
Boitier 1		
N.	HEMT	Type
166	L	REF
213	F	PI
083	F	BCB

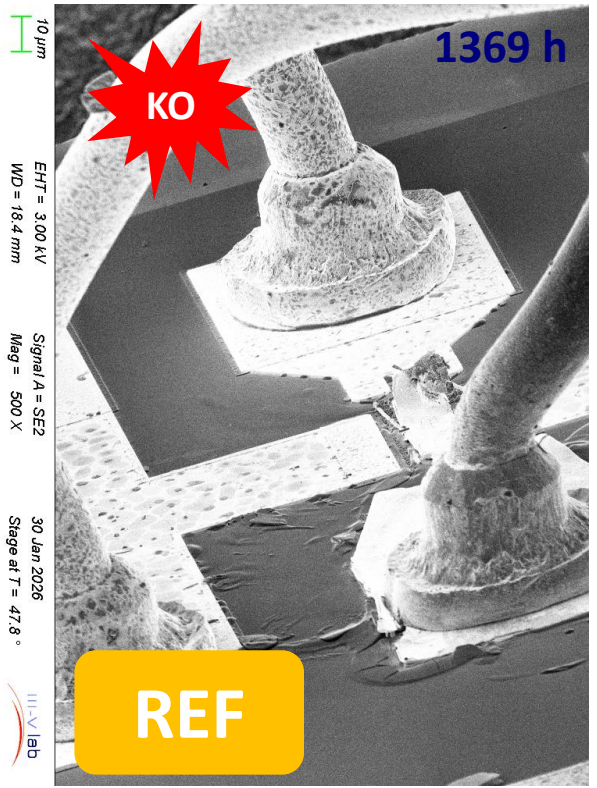
1369 h



SEM – B1-083-F-BCB - B1-213-F-PI - B1-166-L-REF



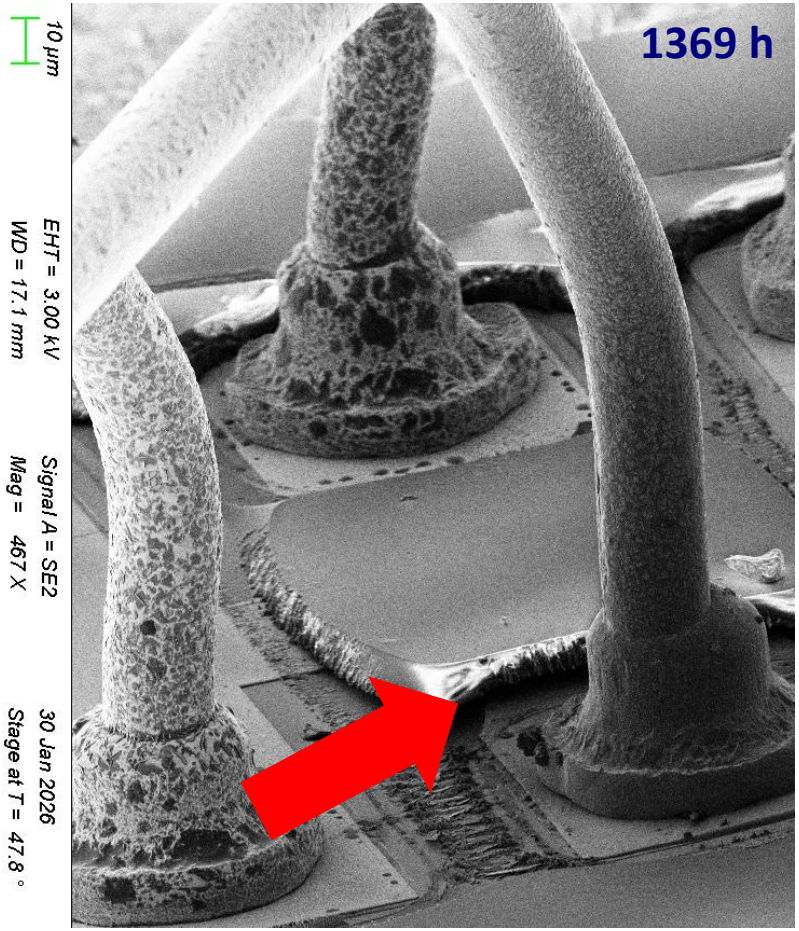




SEM – B1-083-F-BCB

OK

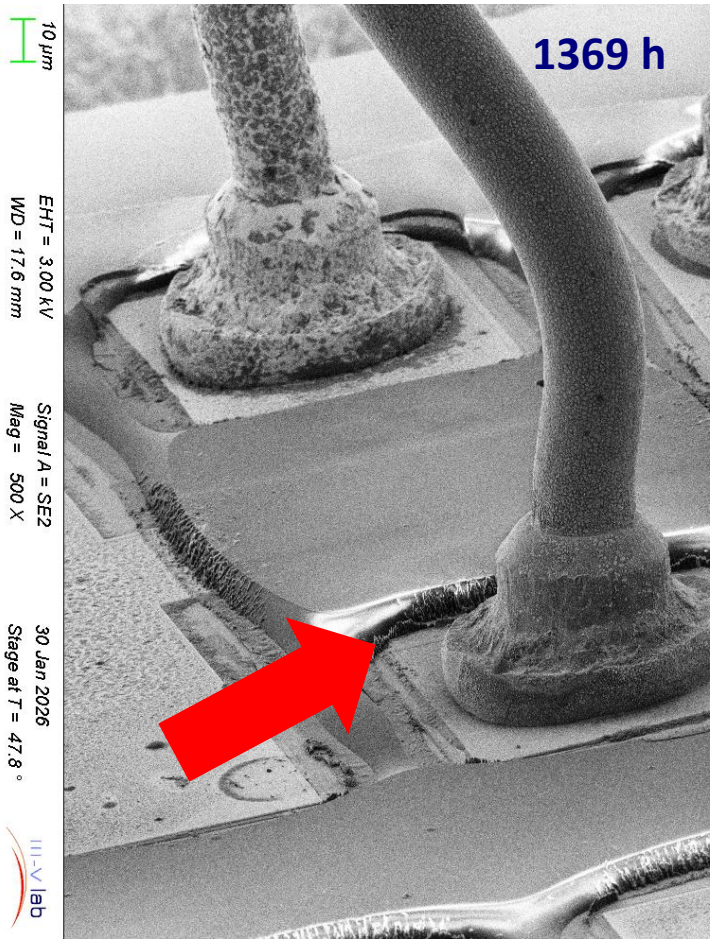
BCB



SEM – B1-213-F-PI

OK

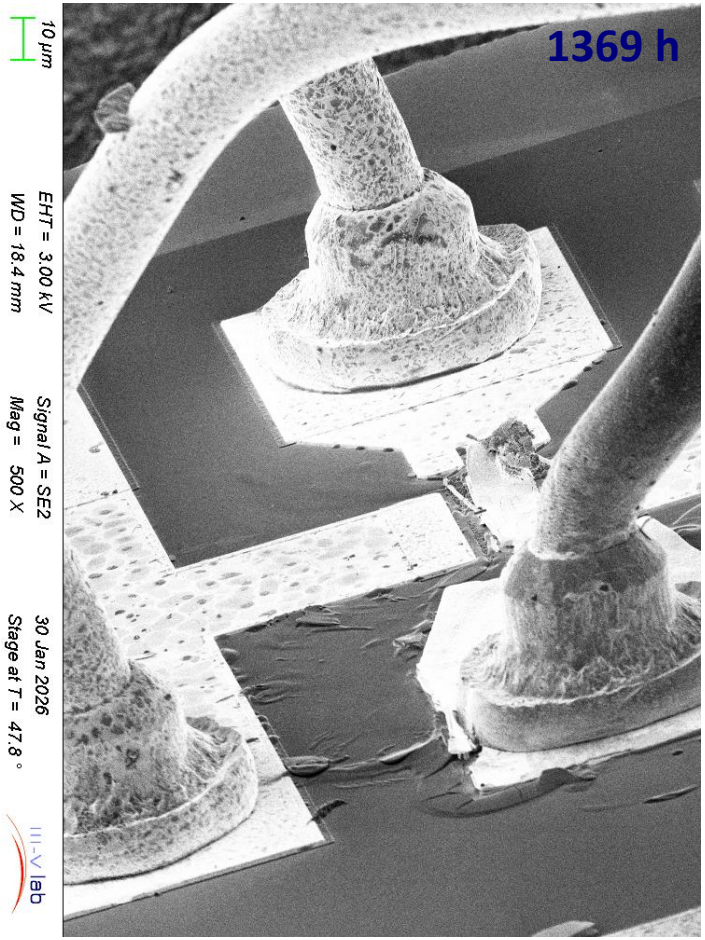
PI

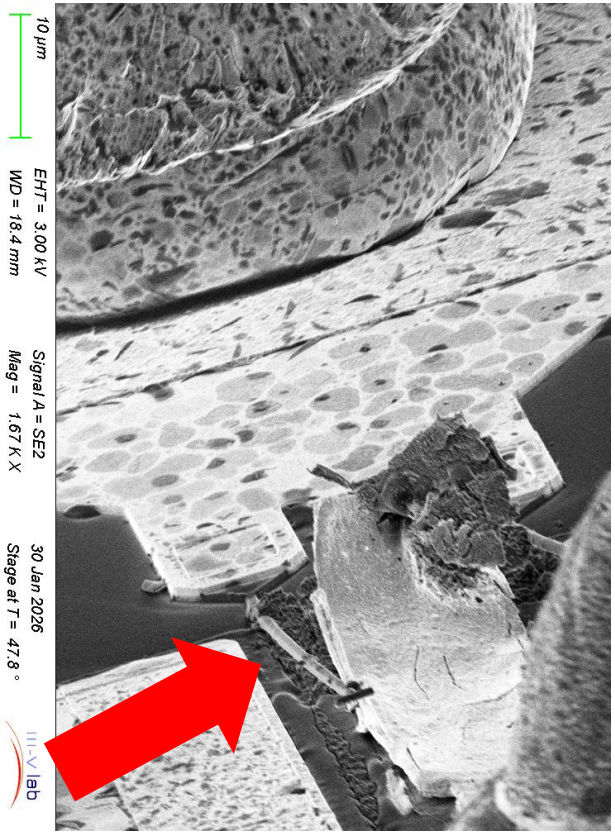


SEM – B1-166-L-REF

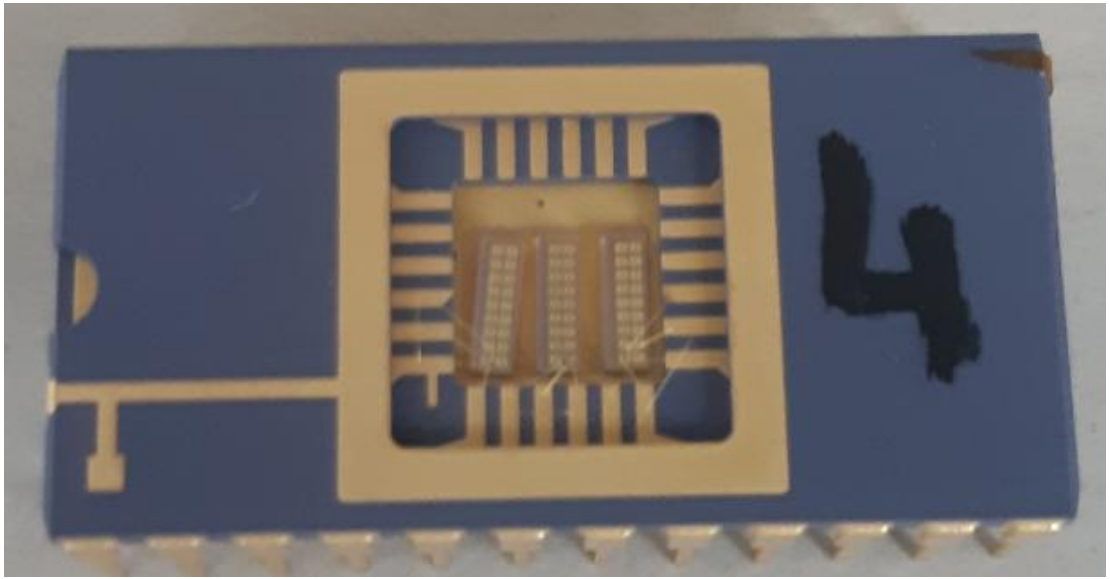
KO

REF





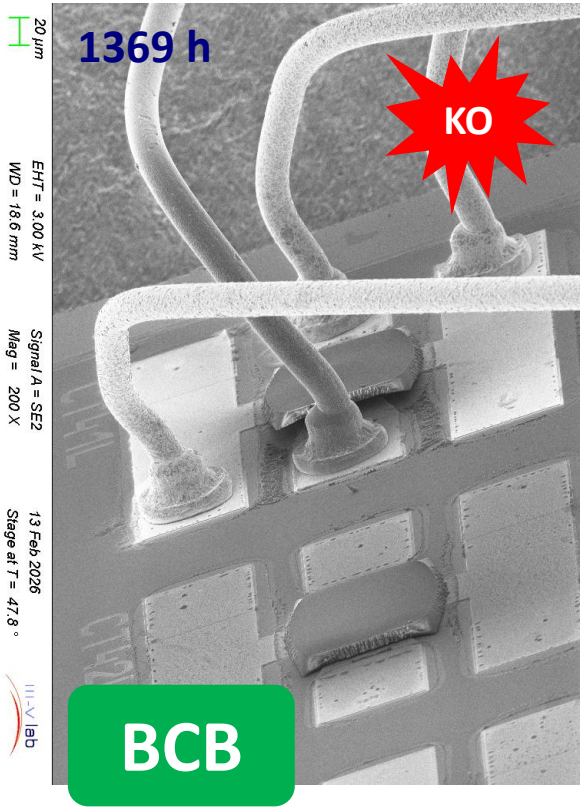
SEM Images

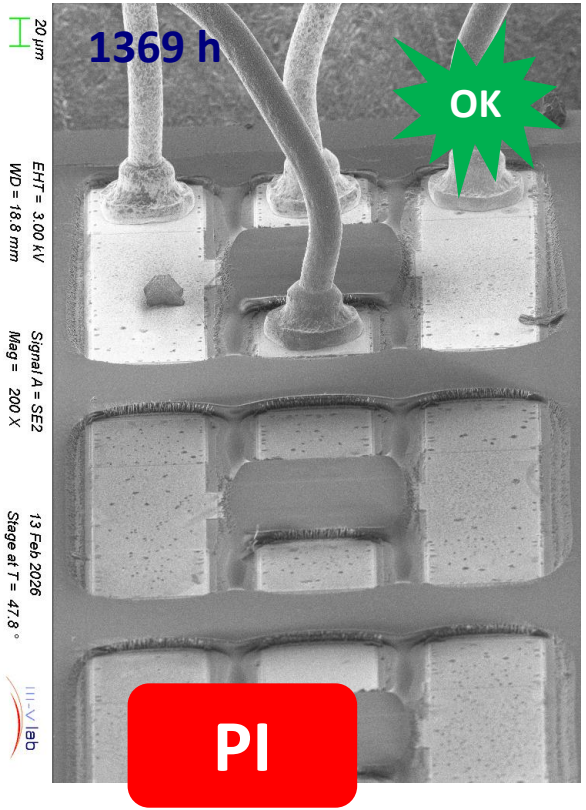


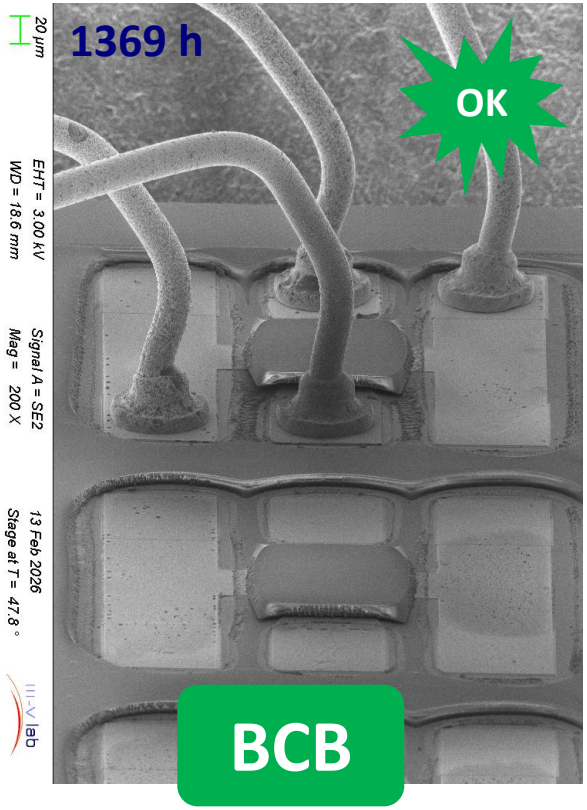
Boitier 4		
N.	HEMT	Type
067	L	BCB
263	F	PI
139	L	BCB

1369 h

SEM – B4-067-L-BCB – B4-263-F-PI – B4-139-L-BCB



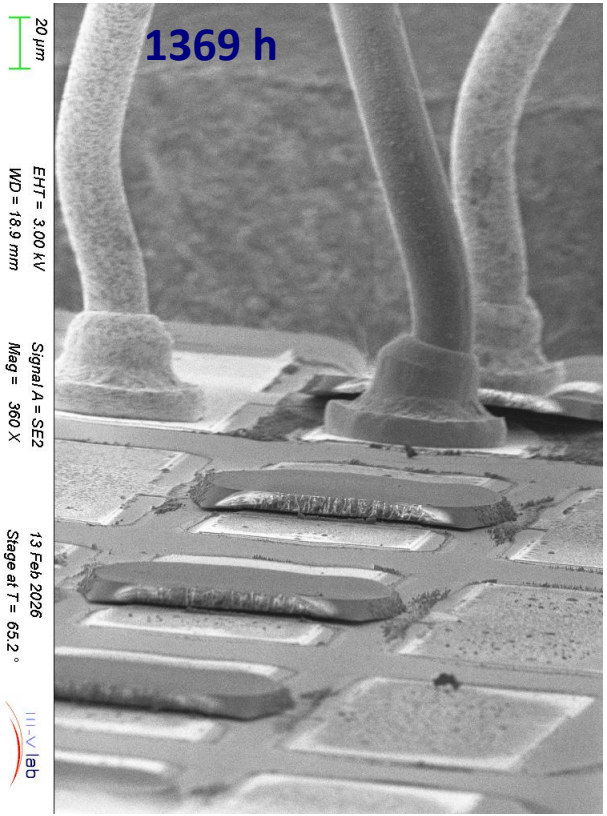


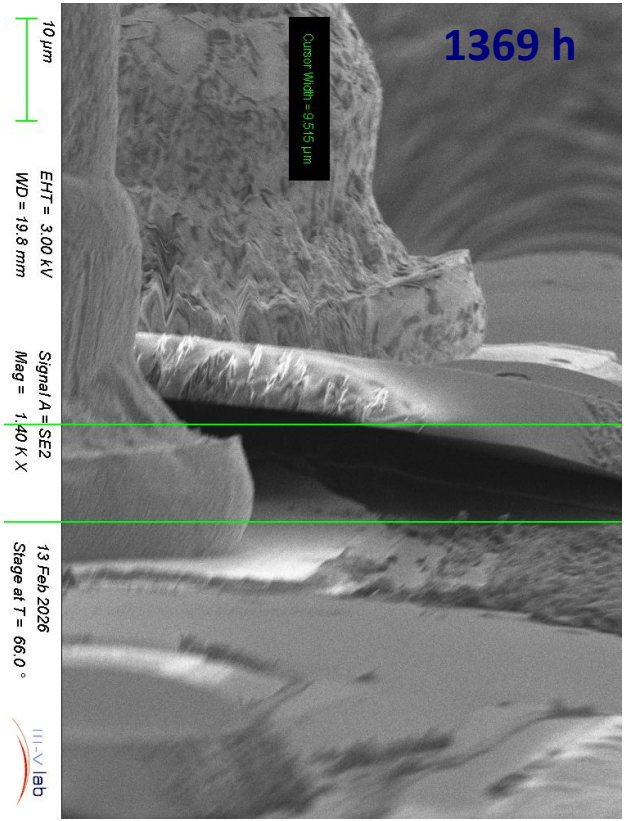


SEM – B4-067-L-BCB

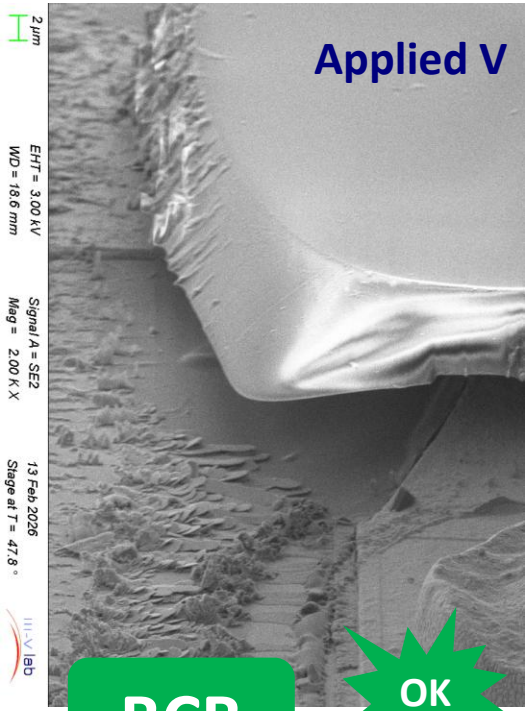
KO

BCB





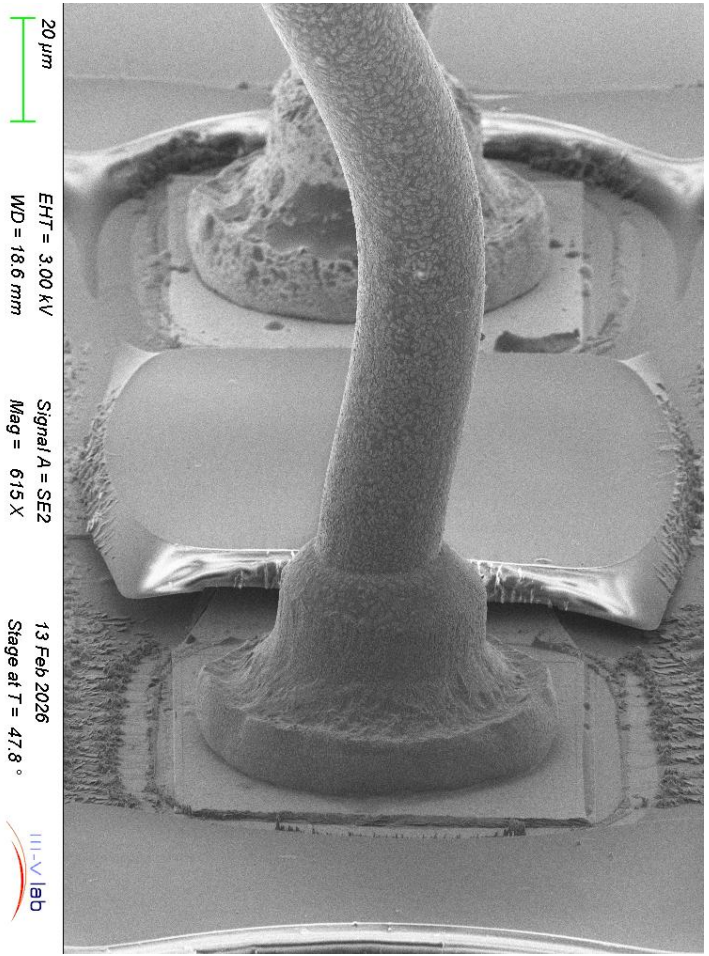
SEM – B4-139-L-BCB

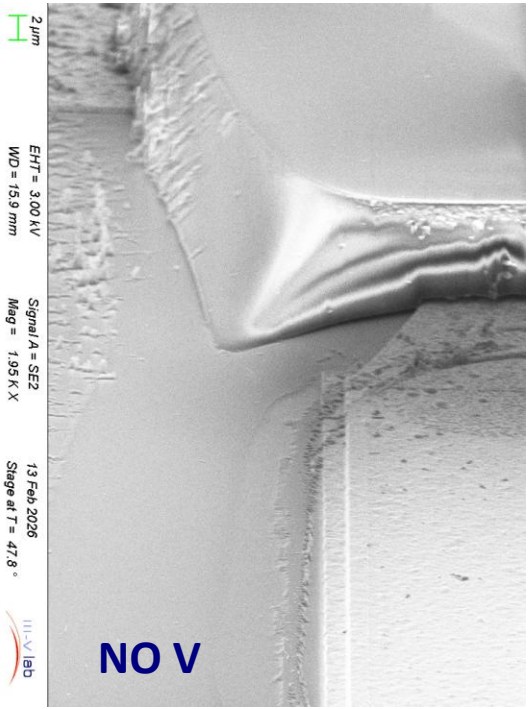


Applied V

BCB

OK



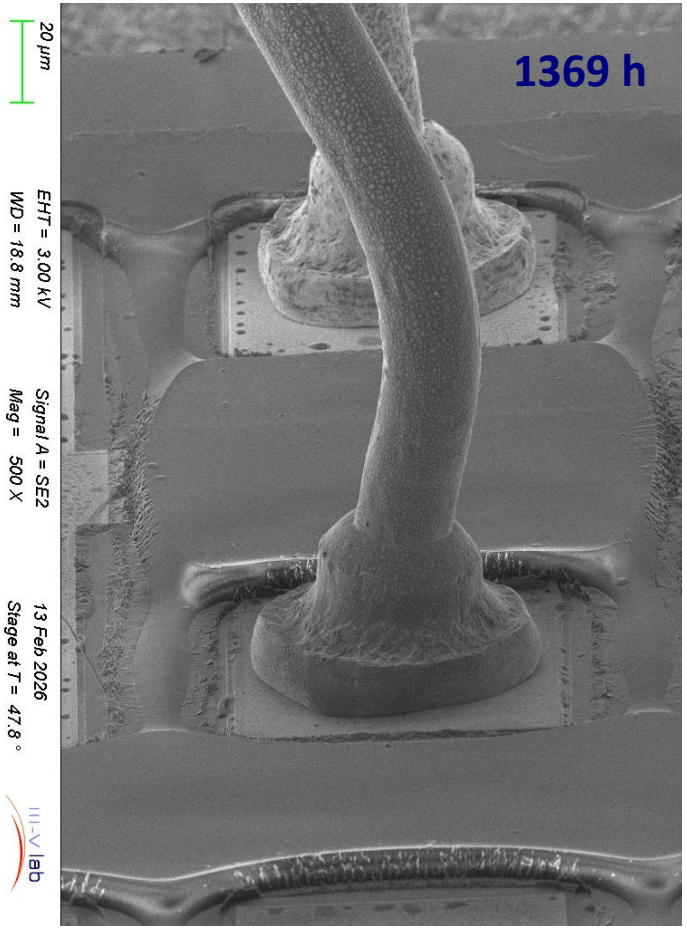


NO V

SEM – B4-263-F-PI

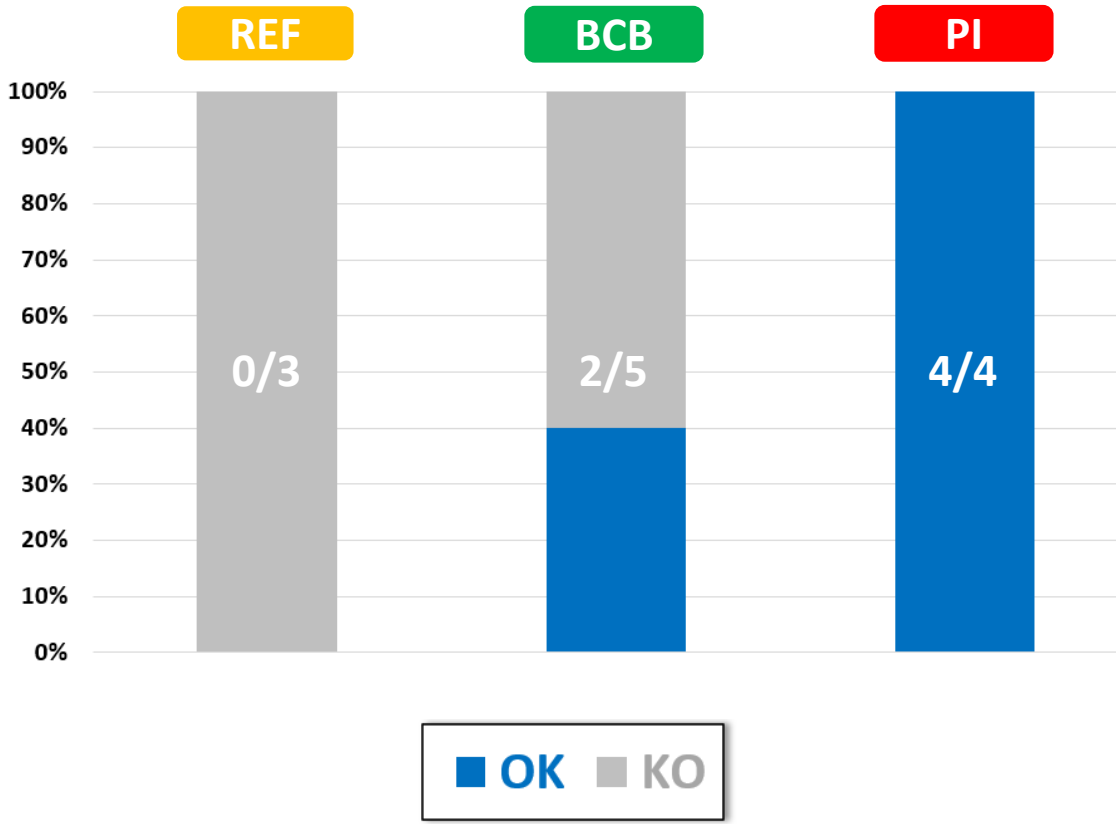
OK

PI



Conclusions

HEMT without failure



0/3 x REF

2/5 x BCB

4/4 x PI

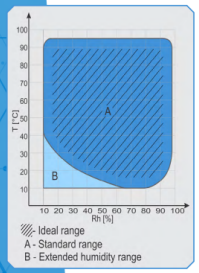
Results after 1369 hours and next…

- **REF HEMT : 100% failure**
  - Leakage currents divergence sharply after 27 days
  - Optical microscope images confirm damages onto HEMT active zone
- **BCB HEMT : 2/5 without failure**
- **PI HEMT : 4/4 without failure**
- **Next investigations**
  - continue THB tests with PI under several biasing conditions (voltage & current)
  - evaluate life time, activation energies…
  - develop simulation models of humidity penetration

New III-V Lab oven

RETOUR ACCUEIL

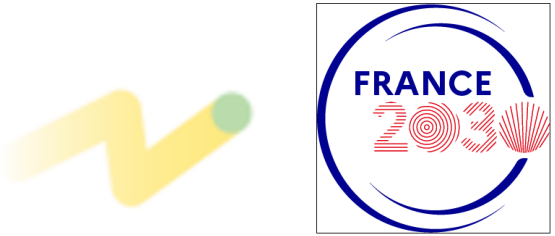
Enceinte climatique +5°C à +180°C
Enceinte climatique -40°C à +180°C



- Toutes nos enceintes sont certifiées CE et équipées de groupe froid chargé en gaz Opteon™ XP40 (R-449A) conforme aux dernières directives européennes.
- Nos enceintes climatique gèrent l'humidité sur une plage de 10 à 98% de RH entre 10°C et 95°C, en utilisant le principe physique du point de rosée.
- Toutes nos enceintes proposent un système de programmation simple et efficaces, un logiciel d'enregistramant des données, ainsi qu'une porte équipée d'une fenêtre d'observation.

Plage de température	+5°C à +180°C / -40°C à +180°C				
Dimensions Externes (L×H×P)	650 x 1223 x 796 mm	835 x 1661 x 951 mm	835 x 1881 x 1126 mm	1035 x 1880 x 1381 mm	1235 x 1928 x 1579 mm
Dimensions Internes (L×H×P)	410 x 475 x 350 mm	600 x 615 x 510 mm	600 x 835 x 685 mm	800 x 835 x 800 mm	1000 x 1035 x 1000 mm
Volume	68 Litres	190 Litres	340 Litres	500 Litres	1 000 Litres
Rampe de chauffe	4,0°C/min	2,0°C/min	1,5°C/min	3,0°C/min	3,0°C/min
Rampe de refroidissement	3,0°C/min - 2,5°C/min	3,0°C/min - 2,5°C/min	3,0°C/min - 2,5°C/min	2,0°C/min - 2,5°C/min	2,0°C/min - 2,5°C/min
Stabilité de la température	±0,2°C à -40°C ±0,05°C à 50°C 50% RH ±0,05°C à 90°C 90% RH ±0,1 °C à 180 °C	±0,2°C à -40°C ±0,05 °C à 50 °C 50% RH ±0,05 °C à 90 °C 90% RH ±0,15 °C à 180 °C	±0,2°C à -40°C ±0,05 °C à 50 °C 50% RH ±0,05 °C à 90 °C 90% RH ±0,15 °C à 180 °C	±0,2°C à -40°C ±0,05°C à 50°C 50% RH ±0,05°C à 90°C 90% RH ±0,2°C à 180°C	±0,2°C à -40 °C ±0,05°C à 50°C 50% RH ±0,05°C à 90°C 90% RH ±0,2°C à 180°C
Uniformité de la température	±1,0°C à -40 °C ±0,3°C à 50°C 50% RH ±0,3°C à 90°C 90% RH ±2,5°C à 180 °C	±0,5°C à -40°C ±0,3°C à 50°C 50% RH ±0,3°C à 90°C 90% RH ±1,5°C à 180°C	±0,5 °C à -40 °C ±0,3°C à 50 °C 50% RH ±0,3°C à 90 °C 90% RH ±1,0°C à 180 °C	±0,5°C à -40°C ±0,3°C à 50°C 50% RH ±0,3°C à 90°C 90% RH ±1,5°C à 180°C	±0,5°C à -40°C ±0,3°C à 50°C 50% RH ±0,3°C à 90°C 90% RH ±1,5°C à 180°C
Stabilité de l'humidité relative	±0,3% à 50°C 50% RH ±0,3% à 90°C 90% RH			±0,5% à 50°C 50% RH - ±0,3% à 50°C 50% RH ±0,5% à 90°C 90% RH - ±0,3% à 90°C 90% RH	
Résolution de l'affcheur	0,1°C - 0,1% RH				
Précision de réglage	0,1°C - 1% RH				
Compensation thermique	±1 500 W à +20°C	±3 000 W à +20°C	±3 000 W à +20°C	±3 000 W à +20°C	±5 000 W à +20°C
Étagères	1 (Max 6)	1 (Max 8)	1 (Max 8)	1 (Max 8)	1 (Max 8)
Capacité étagères	25 Kg	35 Kg	35 Kg	50 Kg	50 Kg
Capacité max. de l'enceinte	40 Kg	80 Kg	100 Kg	150 Kg	200 Kg
Contrôle	Contrôleur PID - Programmable : 50 programmes avec 50 étapes par programme				
Alarme	Alarme visuel et sonore				
Interface et Passage de câble	USB et Ethernet - Ø50 mm à gauche en standard (Ø50, Ø90 mm à droite en option)				
Puissance	3 500 W	3 600 W	3 600 W	9 000 W	12 000 W
Alimentation électrique	230V - 50/60Hz			3×400V – 50/60Hz	
Poids	195 kg	278 kg	324 kg	435 kg	604 kg
Bruit à 1 mètre de distance	Environ 60 dBA				
Annexes	VOIR LES OPTIONS				

Thanks to : CAPTIVANT2



The Consortium Members of CAPTIVANT2 are

NANOE THALES III-V lab CISTEME

UNIVERSITÉ CÔTE D'AZUR asYGN cnrs UMS United Monolithic Semiconductors

Centre Français Fiabilité

NRTW 2026

National Reliability Technology Workshop

Mercredi 1er & jeudi 2 avril 2026| Grenoble

merci pour votre écoute !

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