



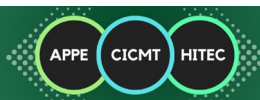
Aluminum oxynitride films for use in power electronics and advanced packaging.

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- Motivation
- Vision
- ALON Deposition
- Film properties
- Applicational tests
- Thermal modeling
- Next Steps





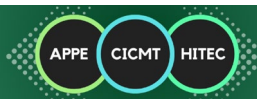
Motivation

For power electronics cooler is better



- **Strongly increasing importance of high power electronics**
 - Automotive
 - Energy conversion and transport
- **High power electronics requires efficient cooling**
 - Presently cooling limits maximum power and lifetime of the devices
- **Current cooling solutions (DBC, AMB) have strong limitations**
 - Limited thermal transport due to ceramic thickness
 - Limited stability in thermal cycling
 - Thermal stress, cracking etc.

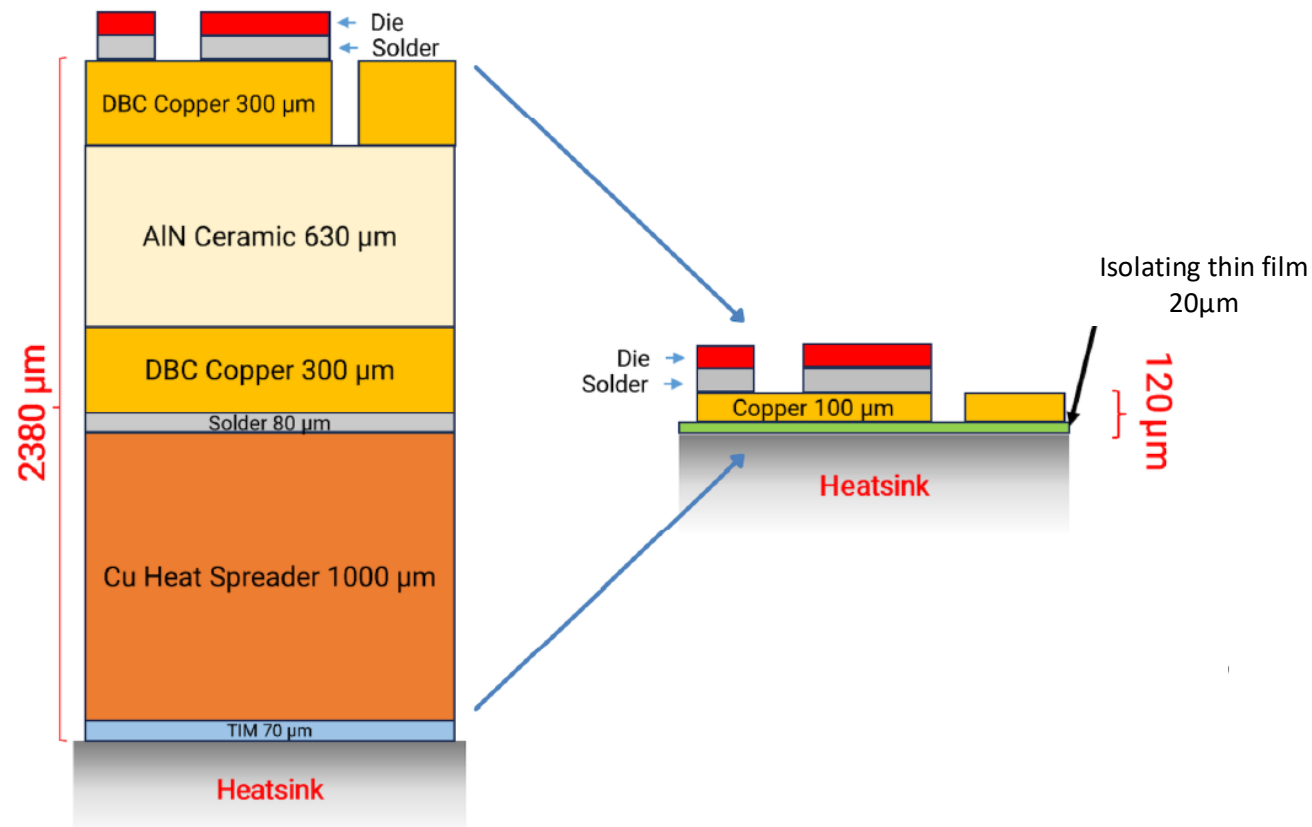
A New Solution Based on a Thin Film Approach





Vision

Eliminate unnecessary interfaces, direct die on heatsink



Conventional Ceramic technology:

- Can easily comprise >75% of the total thermal resistance of a power module.
- Eliminating interfaces can dramatically improve performances.

A solution would need a good Isolating thin film:

- Isolating thin film with good electrical isolation and high thermal conductivity to replaces bulk ceramic and eliminate unnecessary interfaces

Eliminate Thermal Infaces / Eliminate Ceramic DBC

Overview priorities of ALON



Here is what is important and why

- **Fast and cost-effective method of production**
- **Strong Breakdown (V_{bd})**
- **Fully dense coating (Density)**
- **Adhesion and durability**
- **Can we use standard process used in the packaging industry**

AlON Deposition

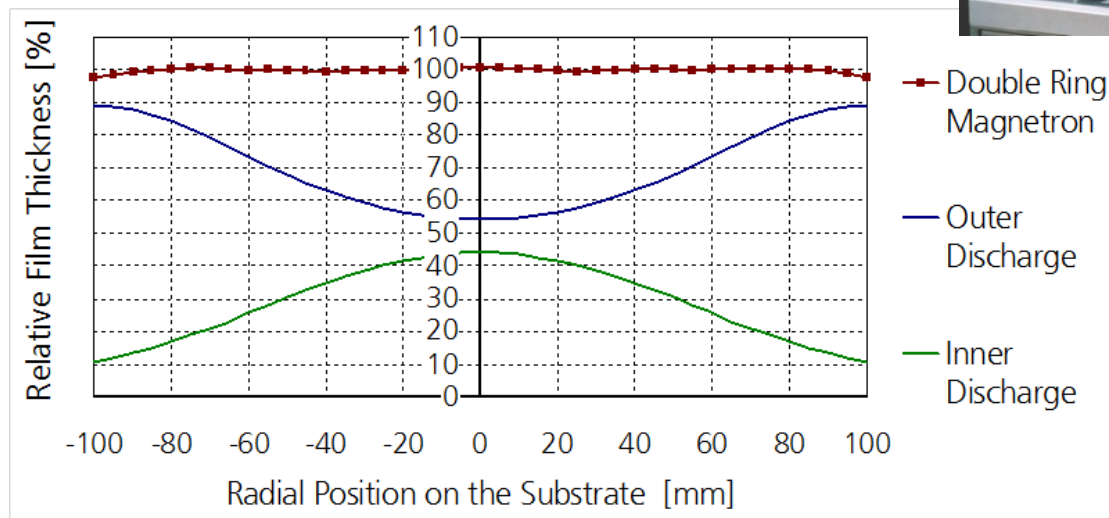
Reactive pulse magnetron sputtering using DRM 400

Film thickness uniformity:
up to $\pm 0.5\%$ on 8" substrate
($\phi 200\text{mm}$)

Deposition rate of AlON
> 120 nm/min

Achievable film thickness
up to 50 μm (AlON)

Temperature of substrate is about
100 - 300°C



Double ring magnetron good uniformity, fast process, thick coating

Vbr Testing

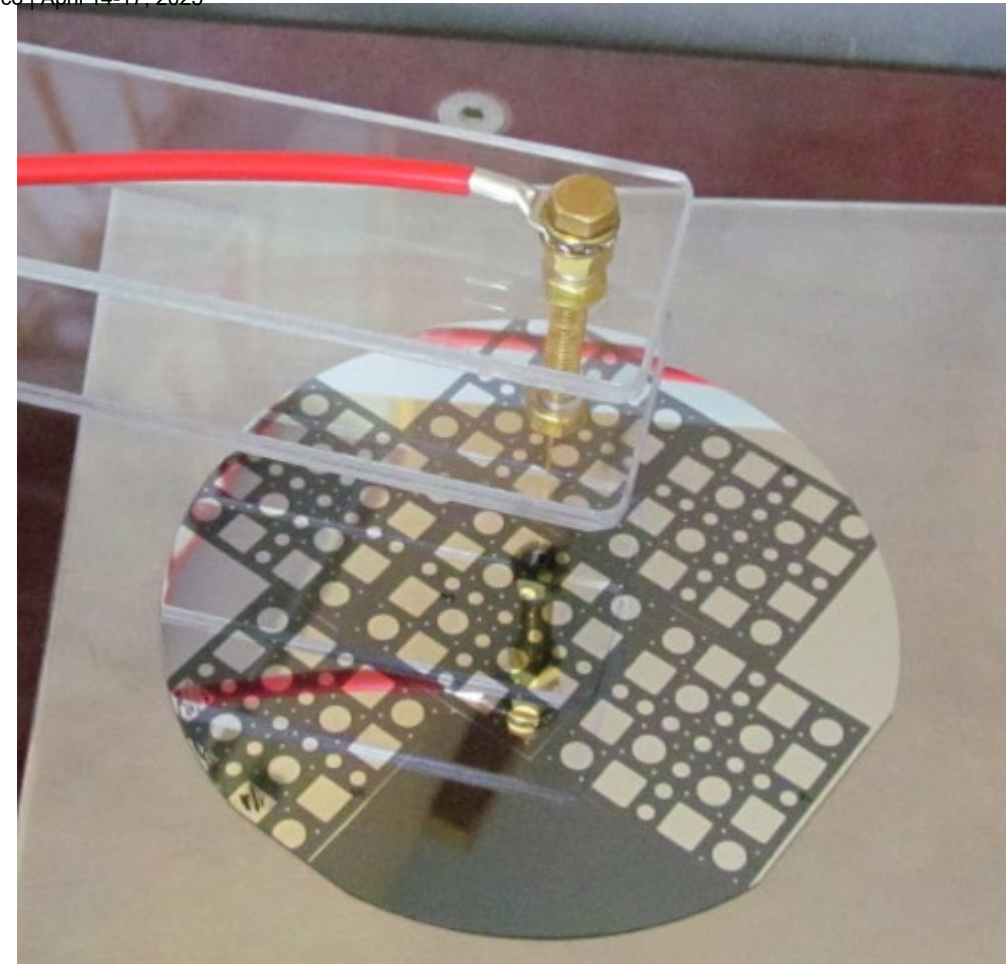
Cu or Al pad structure by shadow mask deposition,
electrode size 1...25mm²

In-house developed measurement set-up for isolation

Measurement in air at max. 6kV

Measurement in oil at max. 6kV

Current exceeding 1μA/cm² is evaluated as breakthrough

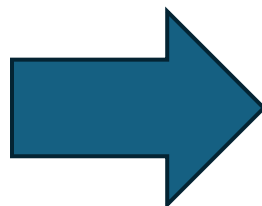




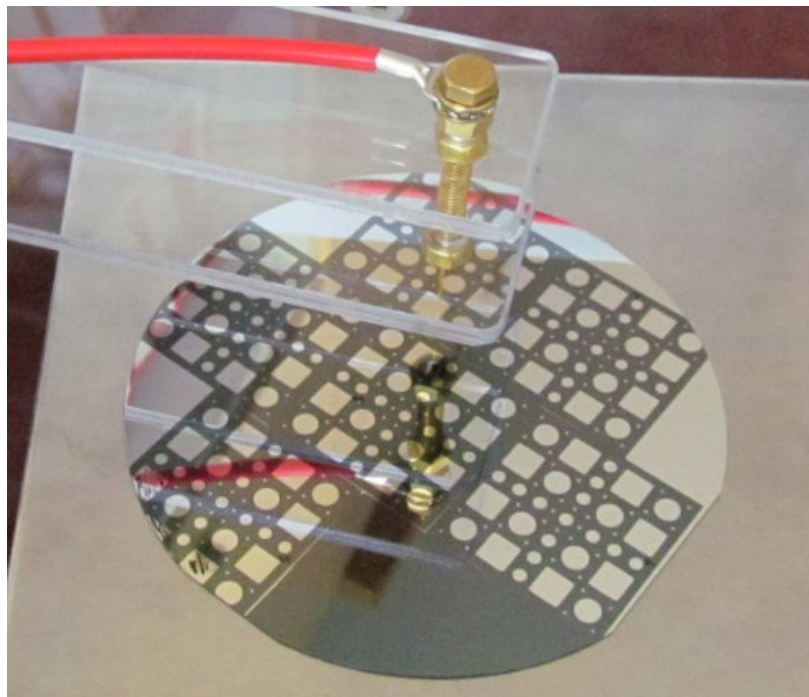
Measurement on Si



- **Measurement in air**
- **At 3 μm film thickness:**
Maximum breakdown voltage (DC): 2.0 kV
i.e. 6.4 MV/cm

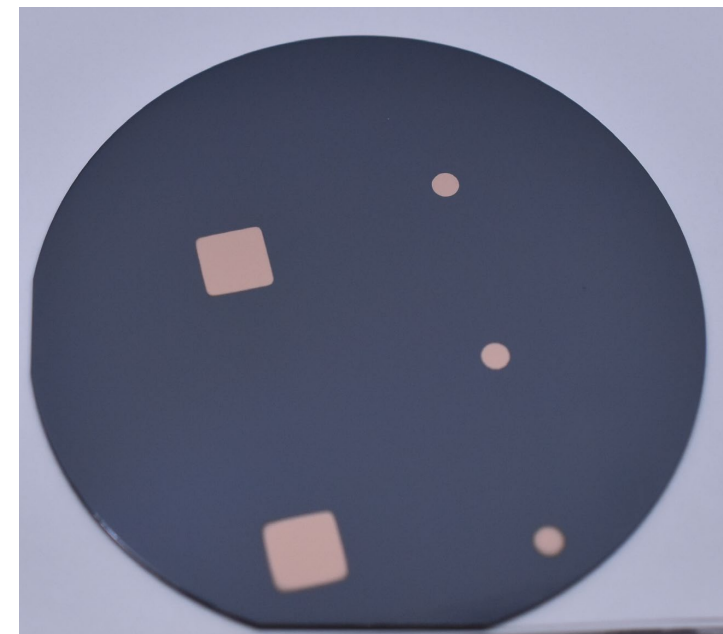


- **Measurement in oil (FC-770)**
- **At 15 μm film thickness:**
Maximum breakdown voltage (DC): 8.3 kV
i.e. 5.8 MV/cm



Elektrode comparison - 3 μm AlON on 4" Si-Wafer

Elektrode	Working	Pad area	U Break	E Break
Material	Point	[mm ²]	[V]	[MV/cm]
Al	350V	3,1	1709	5,5
		25	1677	5,4
	360V	3,1	1853	6,0
		25	1758	5,7
Cu	350V	3,1	1950	6,2
		25	1642	5,2
	360V	3,1	1956	6,3
		25	1339	4,3



Typical break down field strength on Si: 5...6 MV/cm.

Measurement on Cu in Oil

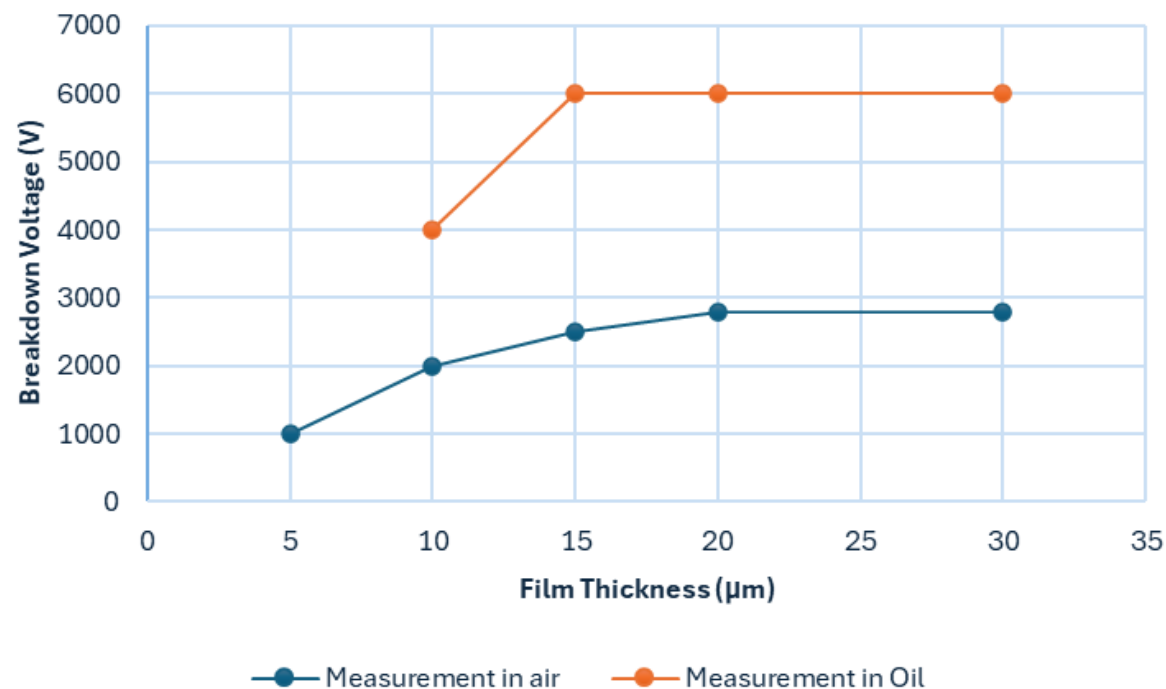


Dependency on film thickness (air):

- Average breakdown voltage increases with film thickness
- Average breakdown voltage is limited by max. test voltage 2.8 kV
- At 30 μm and at max. test voltage: yield 100%

Measurement in oil:

- At 15 μm film thickness already max. test voltage of 6kV is reached (breakdown field strength 4 MV/cm)



Breakdown field strength and yield are generally lower on Cu compared to Si substrates due to surface imperfections and roughness



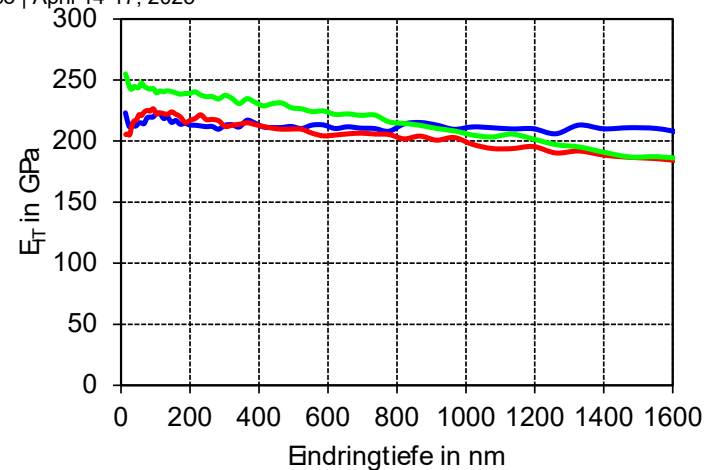
Mechanical properties

Nanoindentation: Hardness and Youngs modulus

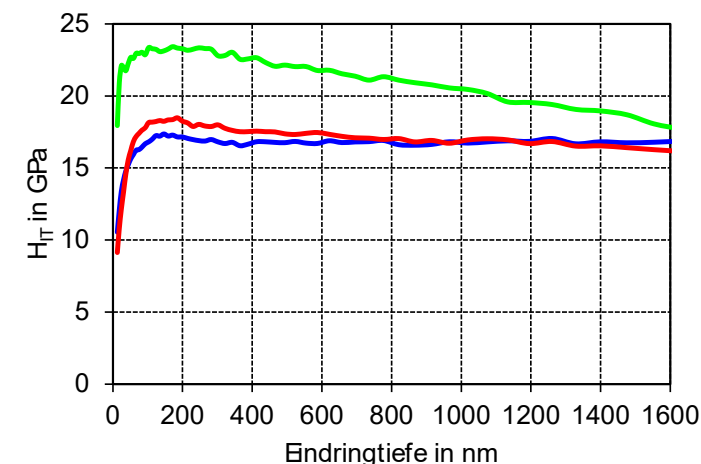
Comparison of AlON with previous values of pure Al_2O_3 (amorphous) and AlN (pure wurtzite crystalline structure)

Deposition	Hardness in GPa	Youngs modulus in GPa
AlN (previous)	24	265
Al_2O_3 (previous)	12	190
AlON	23.2 ± 1.4	238 ± 9

AlON has a substantial hardness close to pure AlN



— 03-A-1 — 03-4-2 — 03-4-8
Youngs Modulus



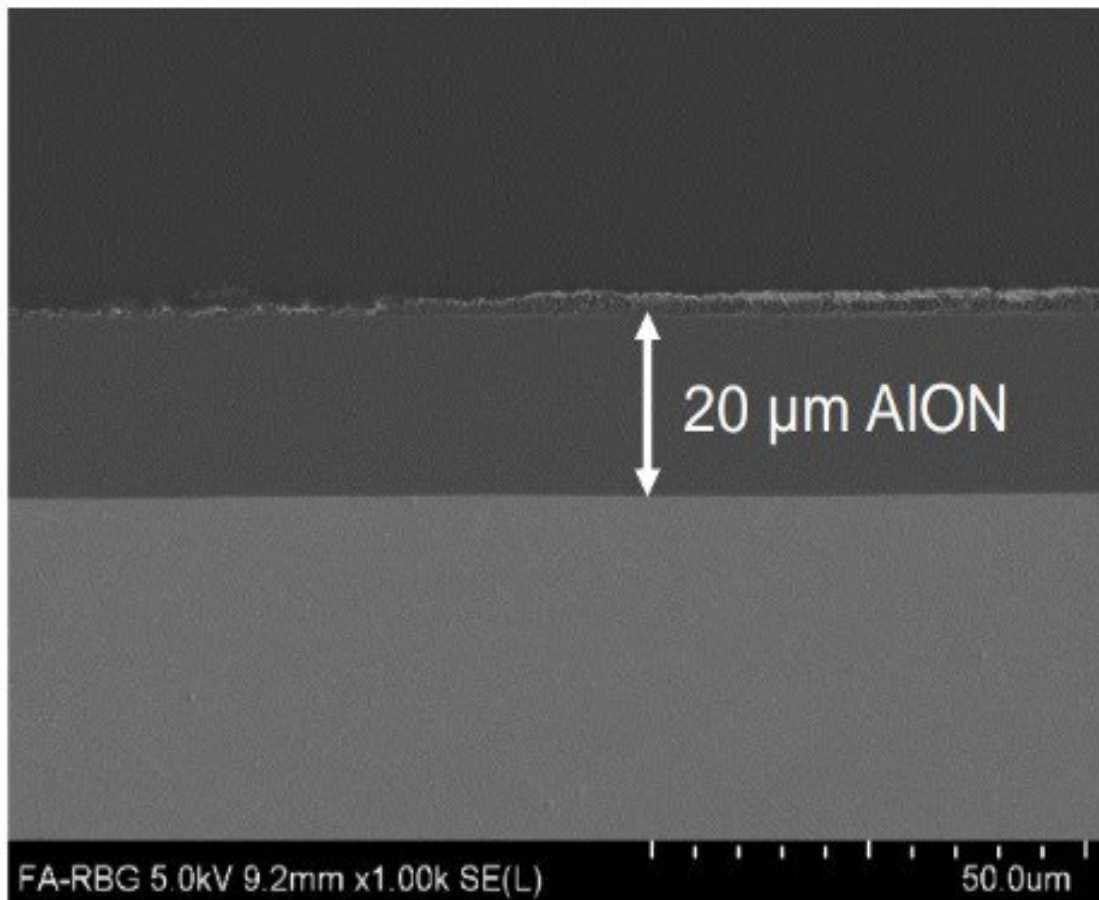
— 03-A-1 — 03-4-2 — 03-4-8
Hardness



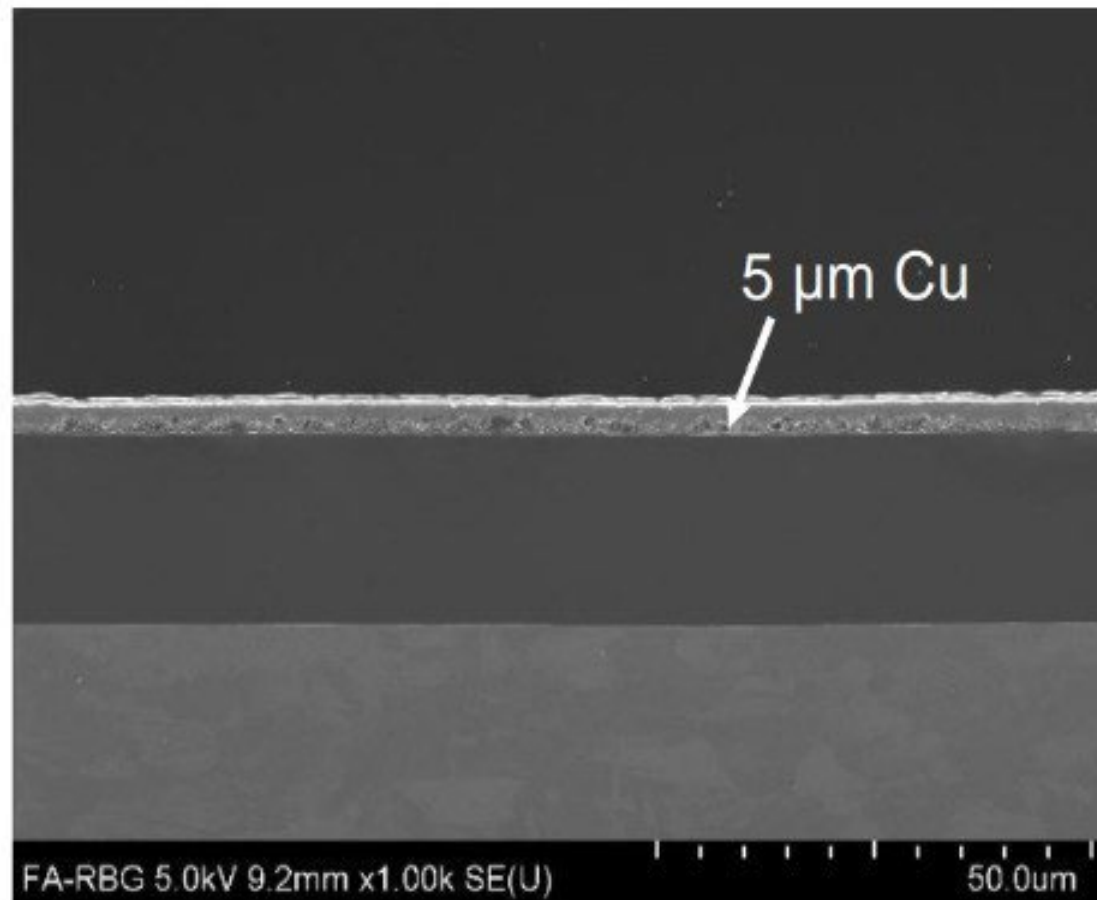
ALON Coating on Cu



20 μm ALON, pinhole free, on a Cu substrate.



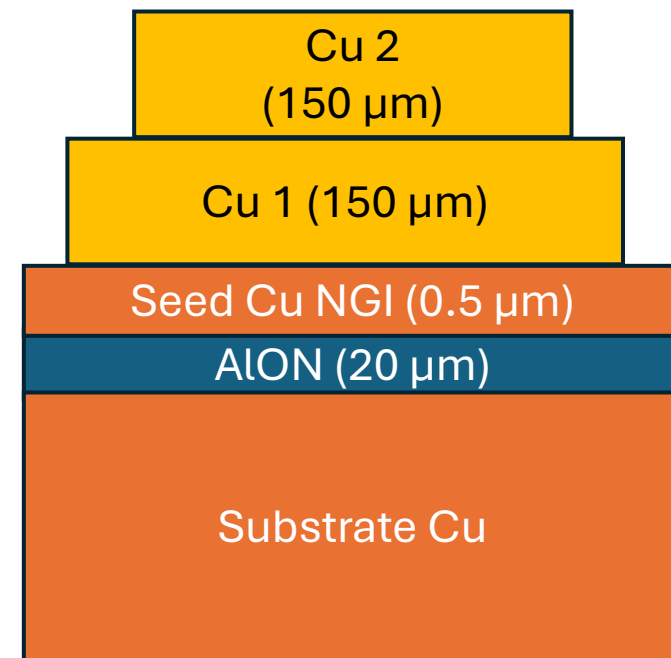
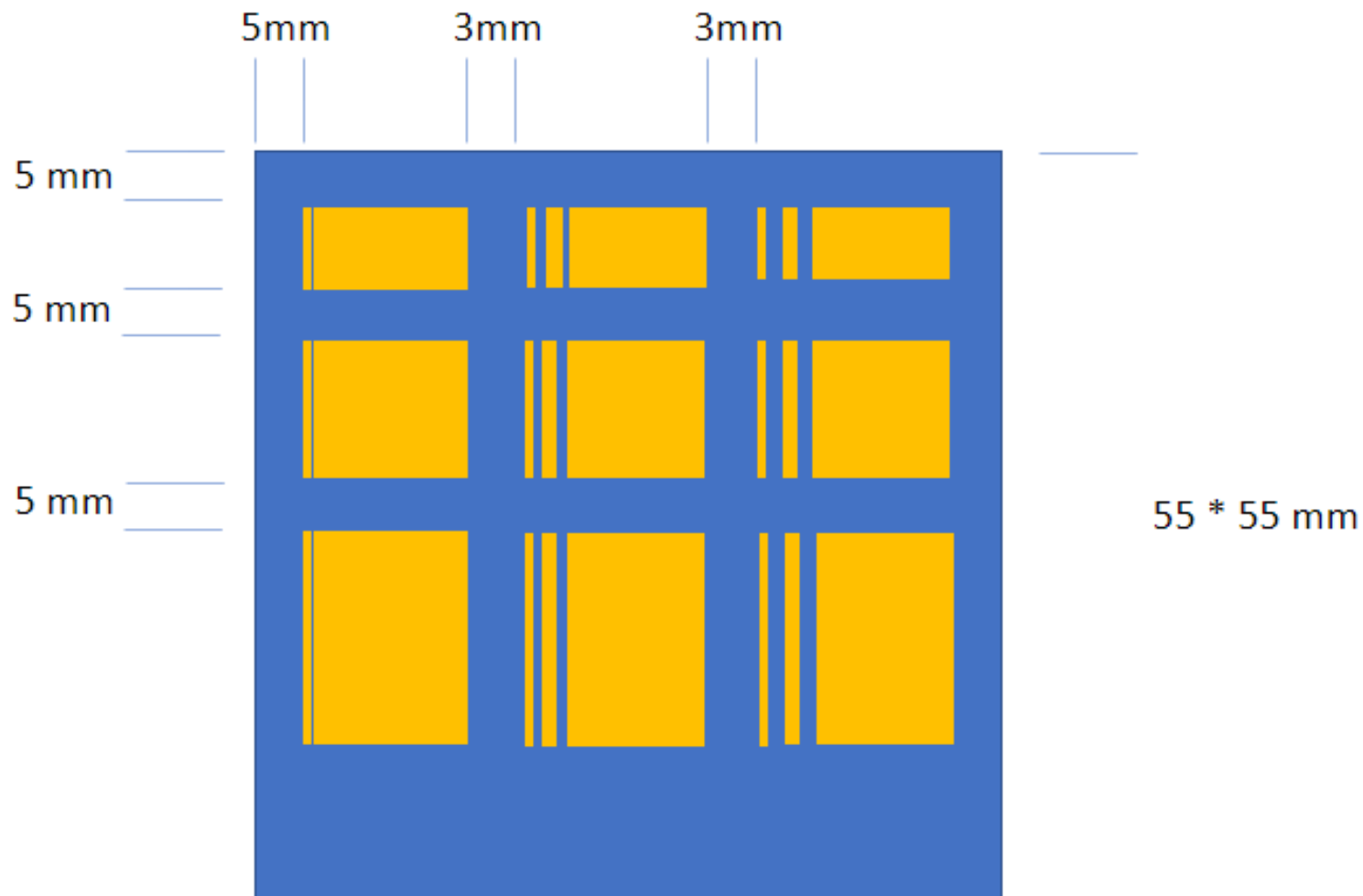
20 μm ALON on a Cu substrate with 5 μm of Cu metallization



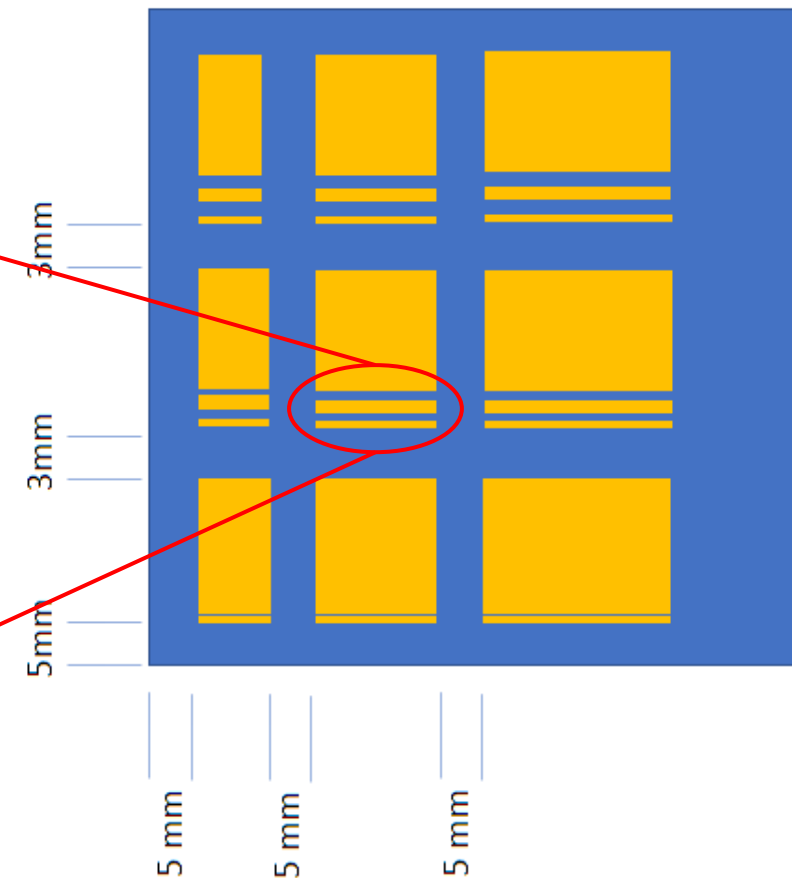
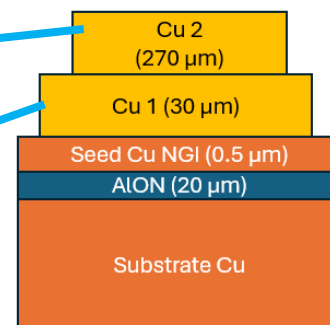
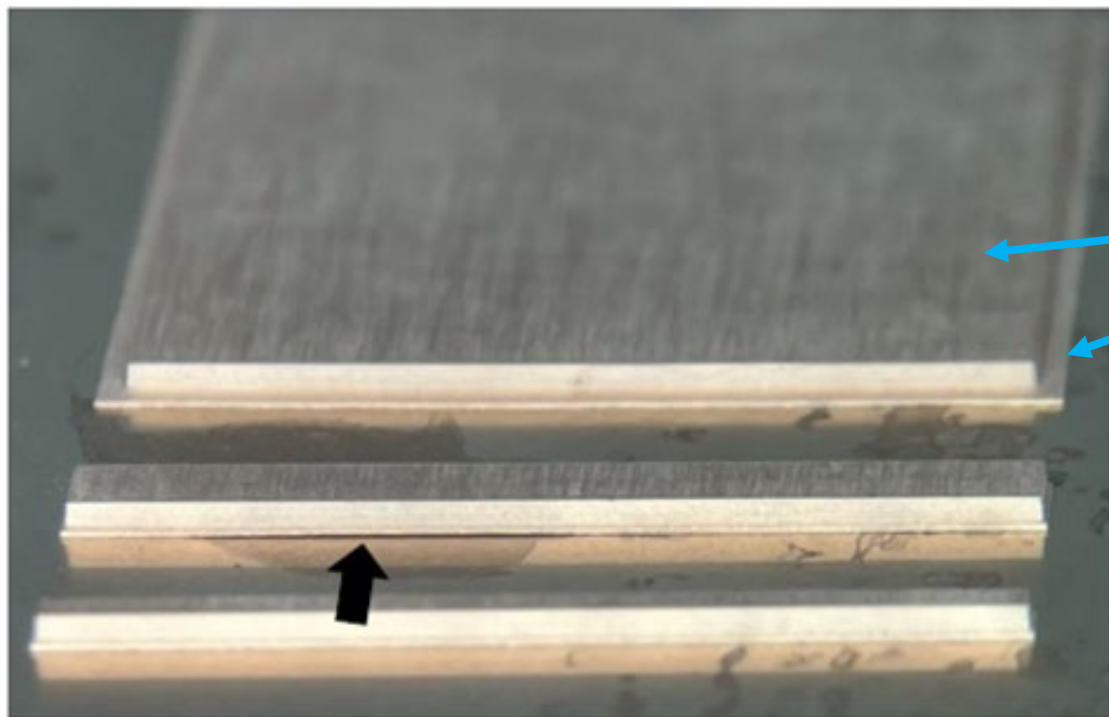
No voids or pinholes in the ALON coating



Metallization of Thick Top Cu

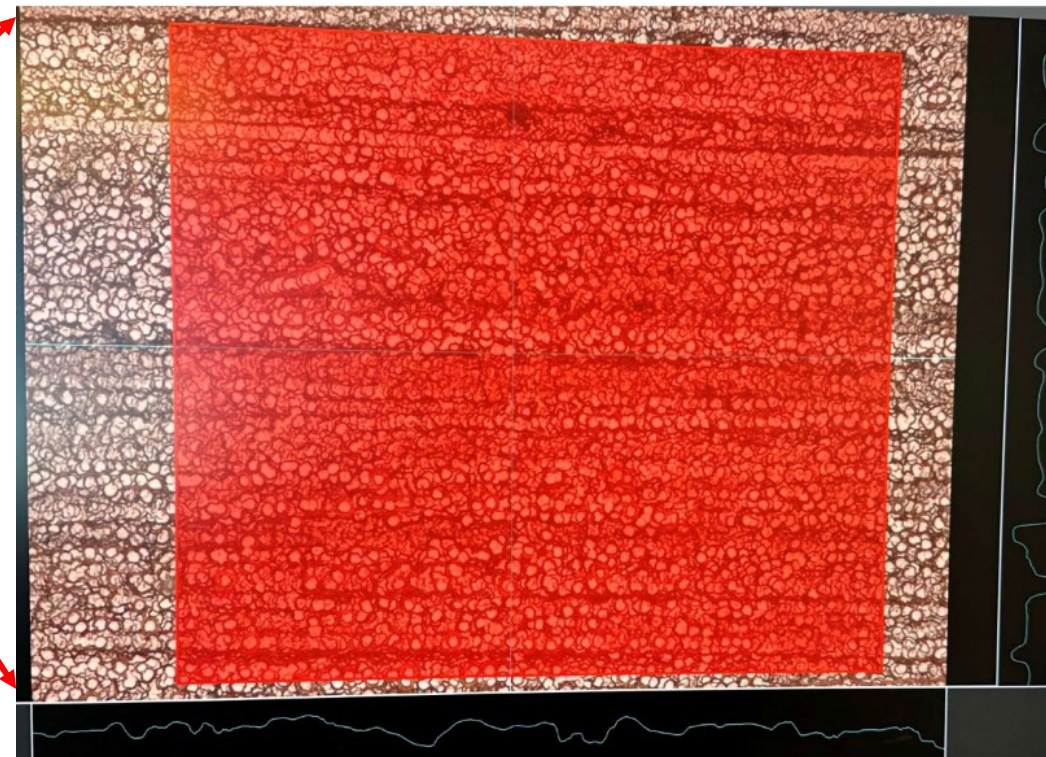
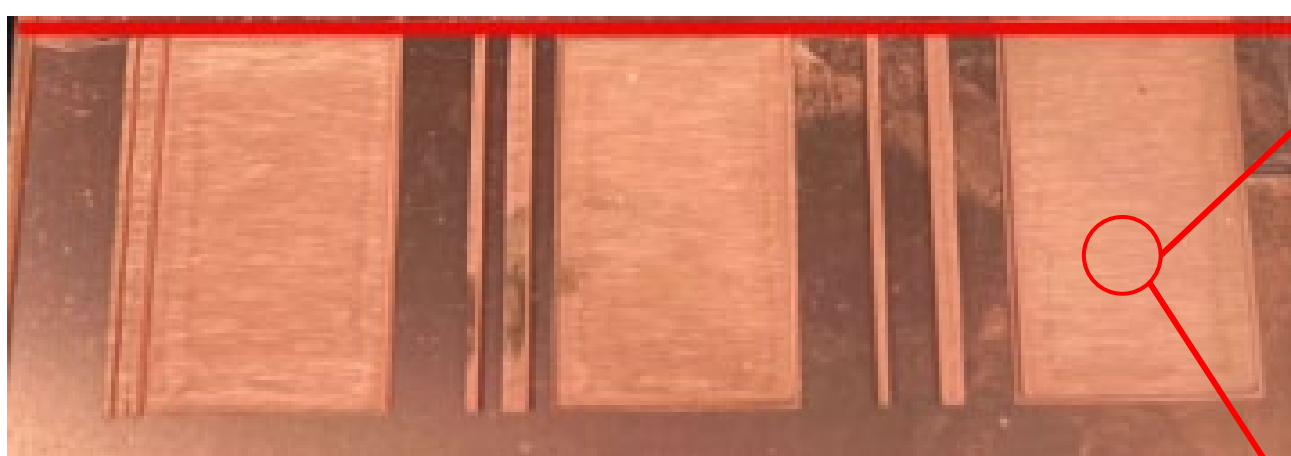


Metallization of Thick Top Cu



300 um of good metallization with high aspect ratios and clean edges

Metallization of Thick Top Cu



Ra 0.32 μm
Rv 1.75 μm

Sa 0.335 μm
Sv 2.77 μm



0.1 mm pitch
spacing

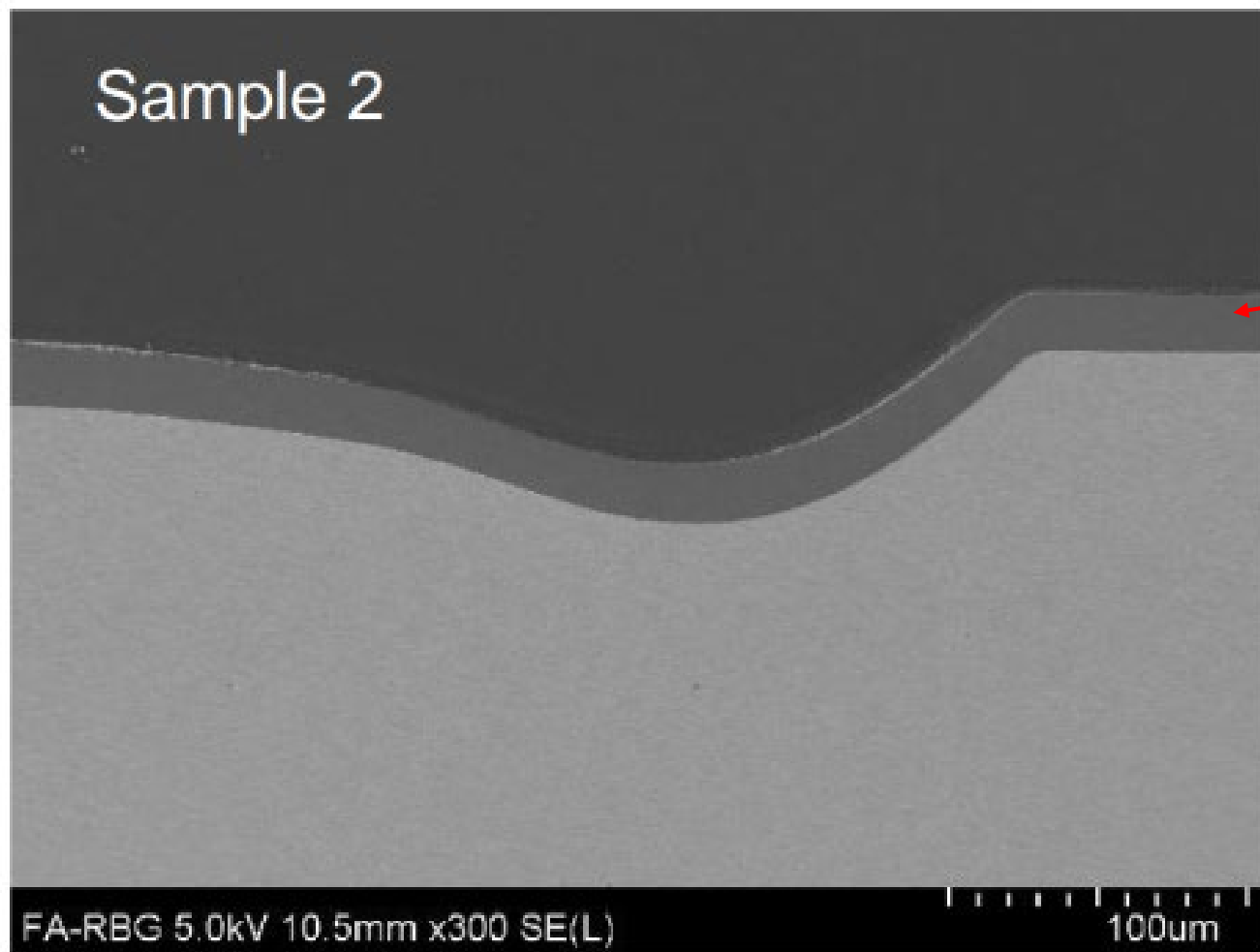


1 mm pitch
spacing

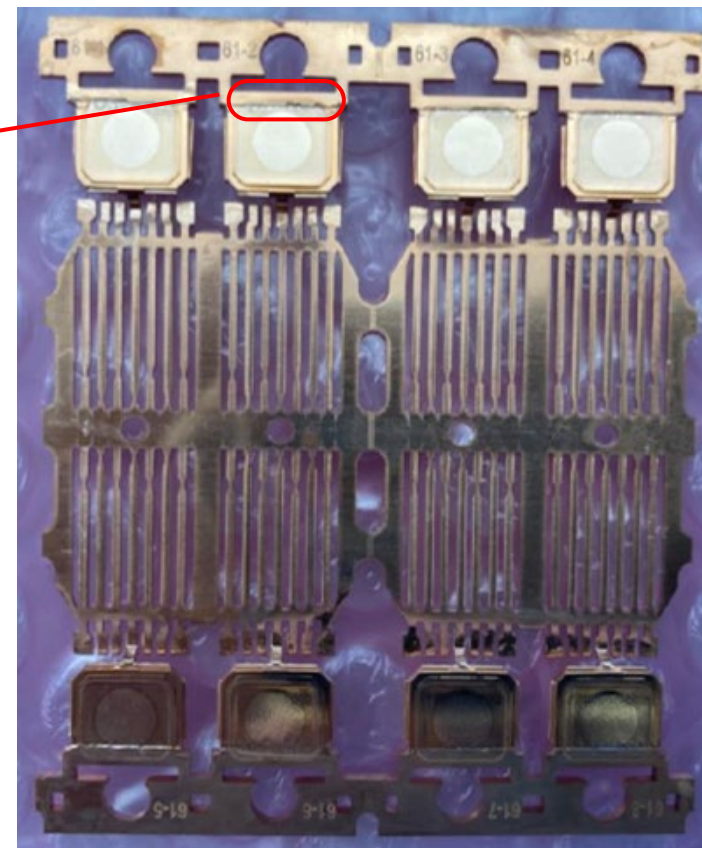


3 mm pitch
spacing

AlON on Leadframe Testing



SEM of 20 μ m AlON on leadframe (diepack)
Conformal deposition also on curved substrates

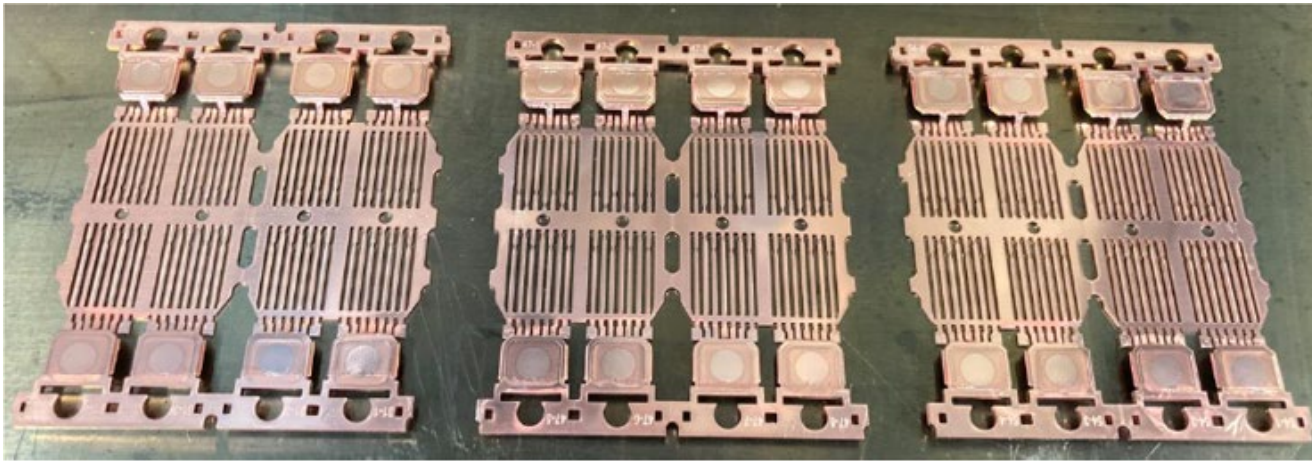


Solder testing



SOLDER TESTING:

- Lead solder profile was chosen due to most demanding process condition
 - Forming gas, 400°C peak



RESULTS:

- No ceramic cracks or other damages visible after soldering

indication for sufficient robustness of coating along
the process chain



Thermal cycling test

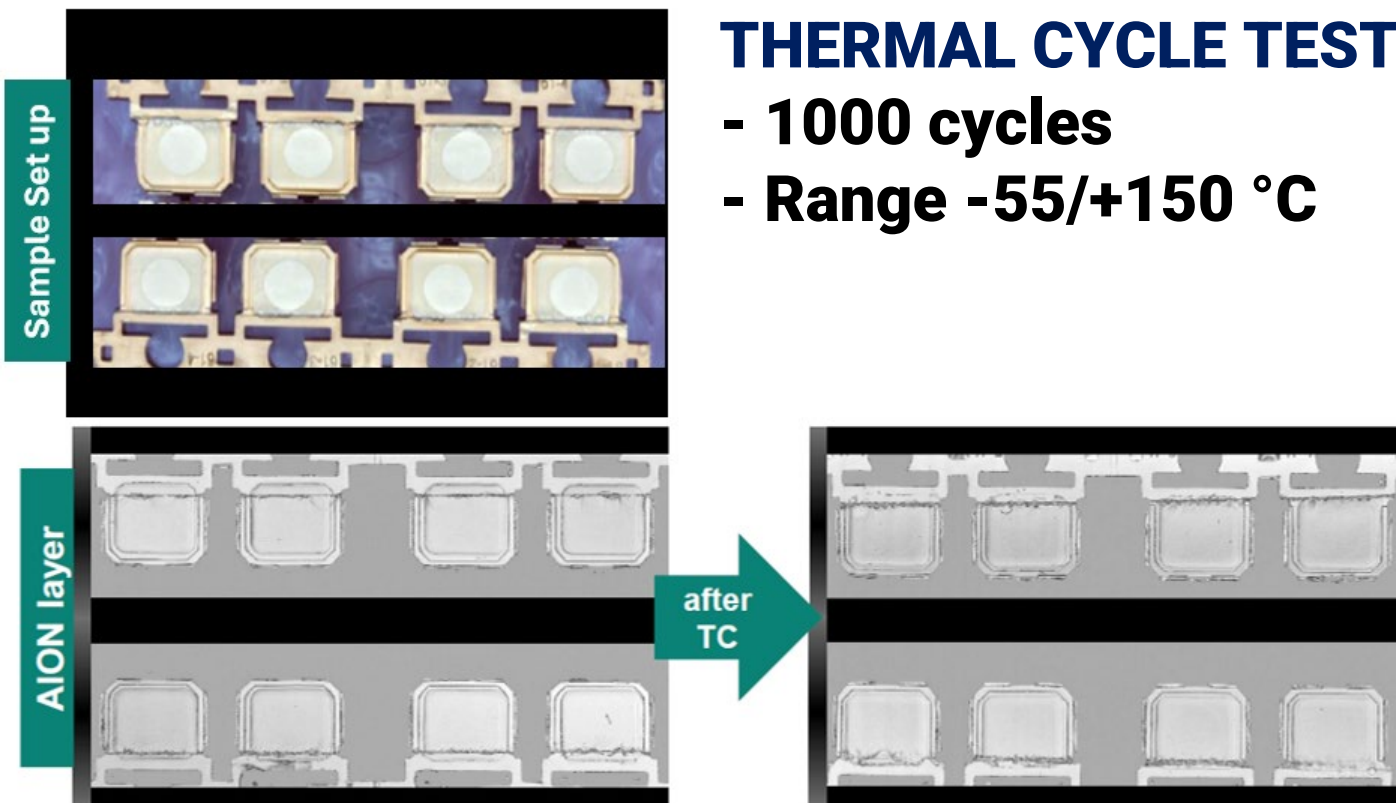


THERMAL CYCLE TESTING

- 1000 cycles
- Range -55/+150 °C

RESULTS:

- No degradation / cracking in AlON layer after thermal cycling test



TC test indicates thermomechanical stability of 20 µm AlON coating

Cu Die Attach

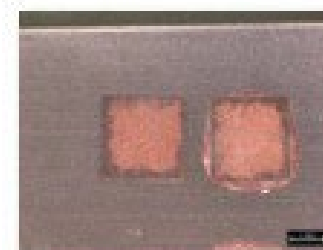
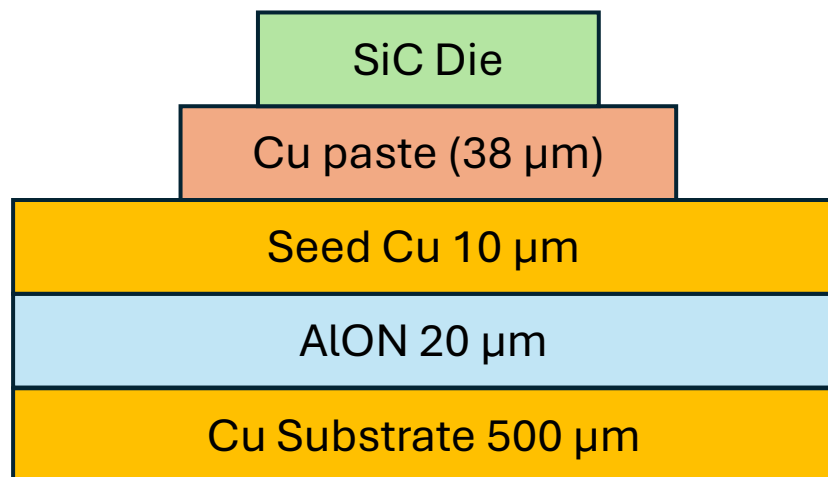


BOND TESTING

- SiC & Si dies onto AlON substrate using low temperature Cu paste:
 - Dies are 3 x 3 mm, Au coating
 - Substrates are Cu/AlON/Cu

PROCESS

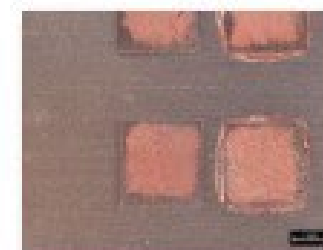
- Paste: stencil printing, 3 x 3 mm ~38um thickness.
- Shear tester is used to test the bond strength.



✓ post shear run
1 die 1



✓ post shear run
1 die 2



✓ post shear run
1 die 3

RESULTS

- Bonded dies attained more than 2 kg/mm² shear strength.
- ActiveCopper™ from Kuprion bonded at 235°C
- Samples sheared had cohesive failure mode.



Humidity Testing

100 / 100 testing



Coating Parameters

- 15 μ m of AlON and 0.5 μ m Al electrical pads

Before Humidity Test

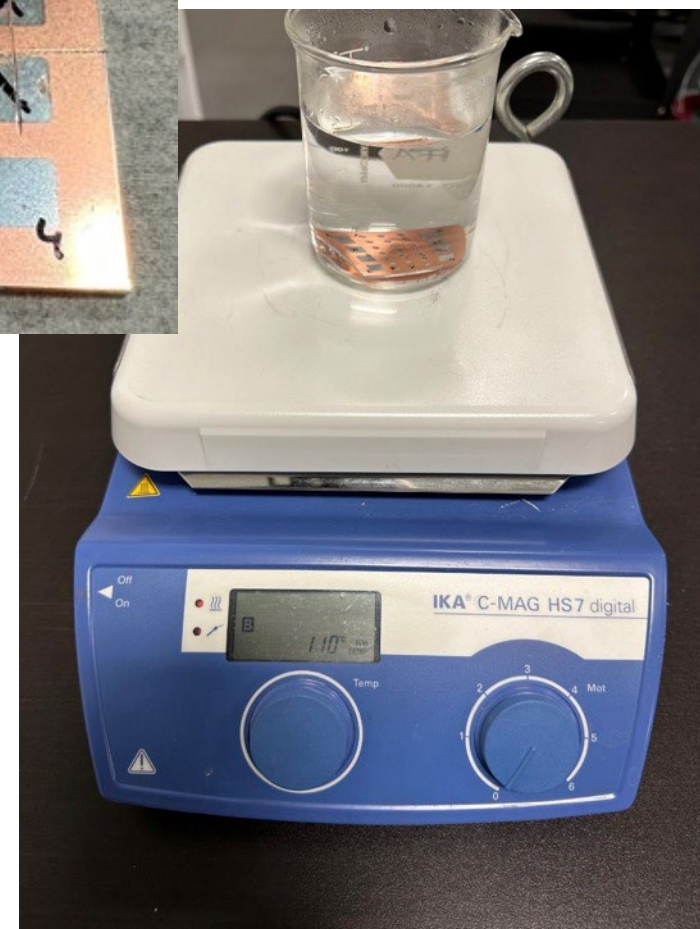
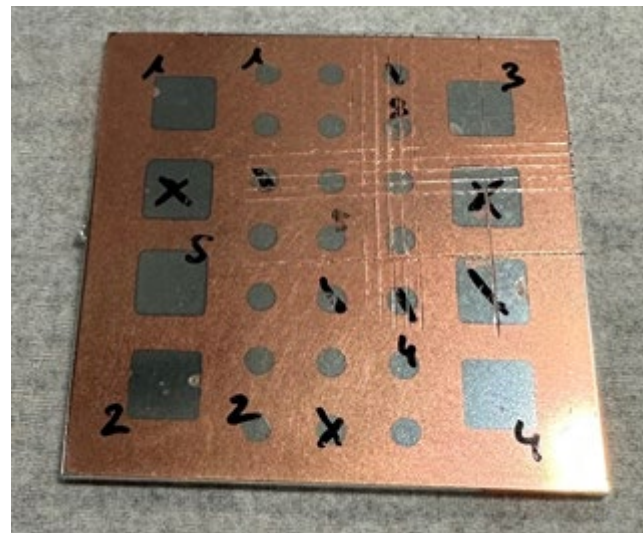
- Sample was crosscut and tape pulled (ISO2409)
- Sample was tested for V_{bd} before humidity

Testing Parameters

- Water was heated to 100°C
- Sample was placed in at 100°C for 30 minutes
- Sample was removed to cool

Post Exposure Testing

- Sample was taped pulled
- Sample was checked for electrical resistance





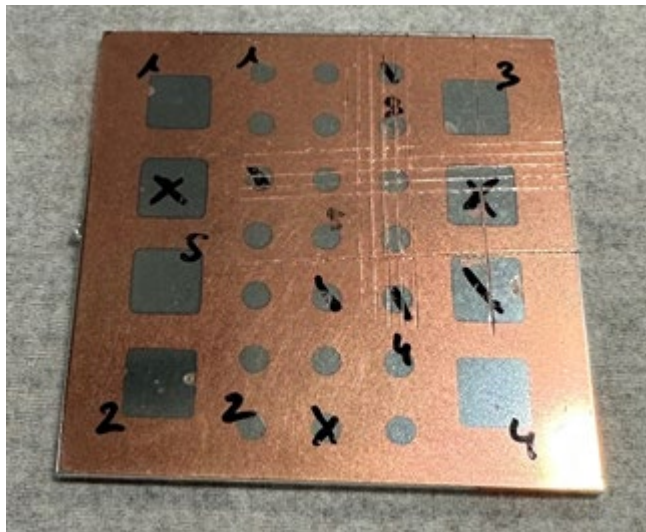
Humidity Testing

100 / 100 testing

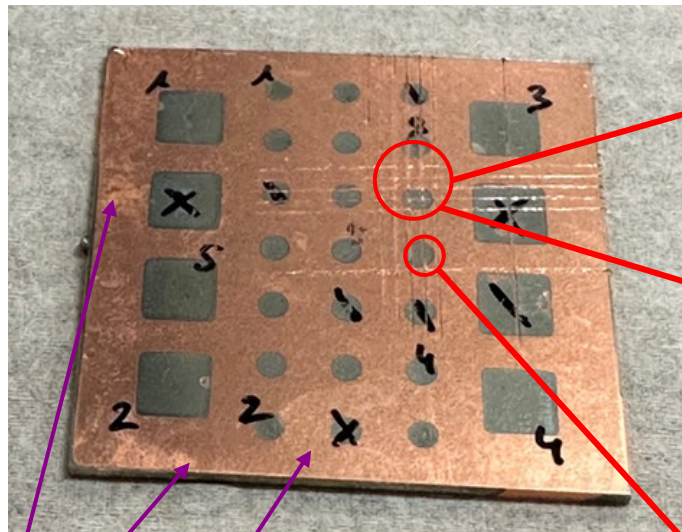
2025 Joint HITEC/CICMT/APPE Conferences | Albuquerque, New Mexico | April 14-17, 2025



Before

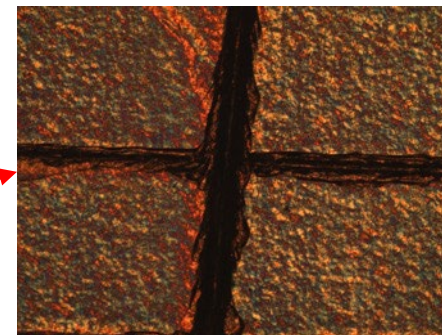


After

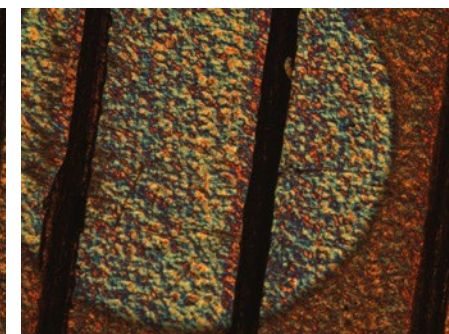
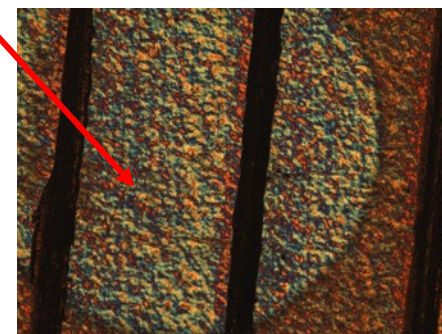
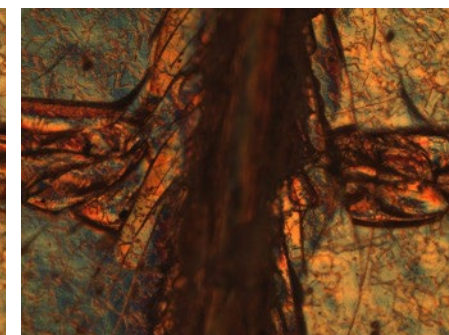
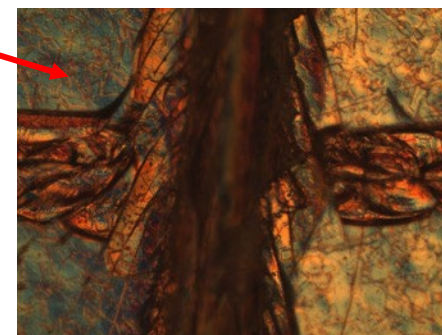
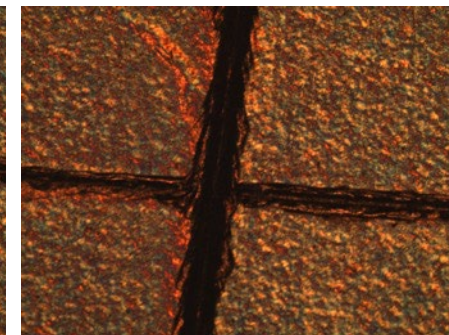


Surface Water Staining

Before



After



No change in AlON's surface, electrical resistance or adhesion



Thermal molding



Fachhochschule Kiel
Hochschule für Angewandte Wissenschaften

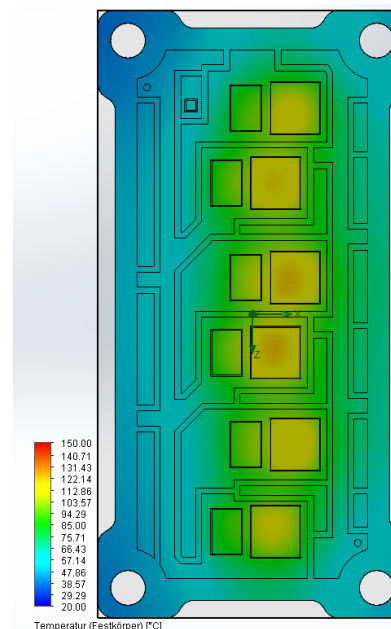
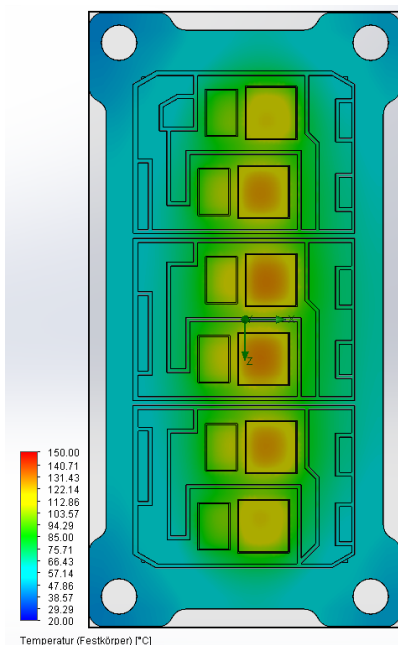
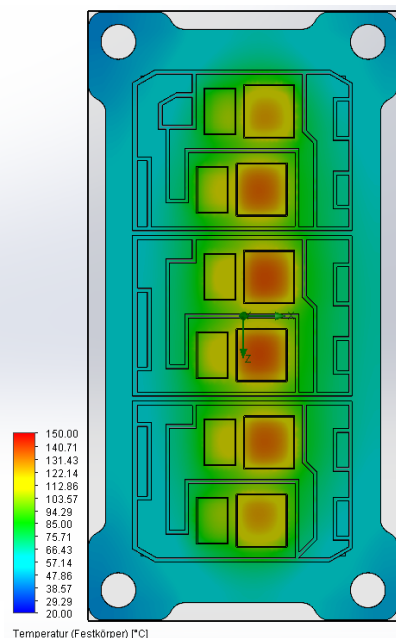


Max Temp IGBT:

138,313 °C

130,899 °C

122,647 °C



Every 10°C reduction
doubles lifespan

Electronic Device

Silver sintering paste

Top Cu (DBC or AMB)

Al₂O₃ or Si₃N₄

Bottom Cu

Solder

Cu baseplate 3 mm

DBC soldered on Cu-baseplate

AMB soldered on Cu-baseplate

Top Cu thickness: 0,1 mm, 20 µm AlON, 10 W/m*K

Electronic Device

Silver sintering paste

Top Cu

AlON 20µm

Cu baseplate 3 mm

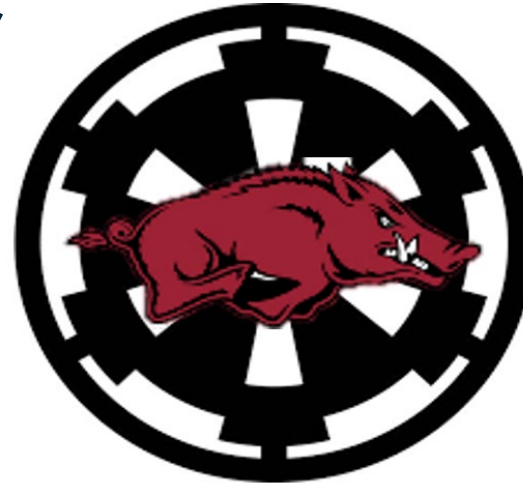
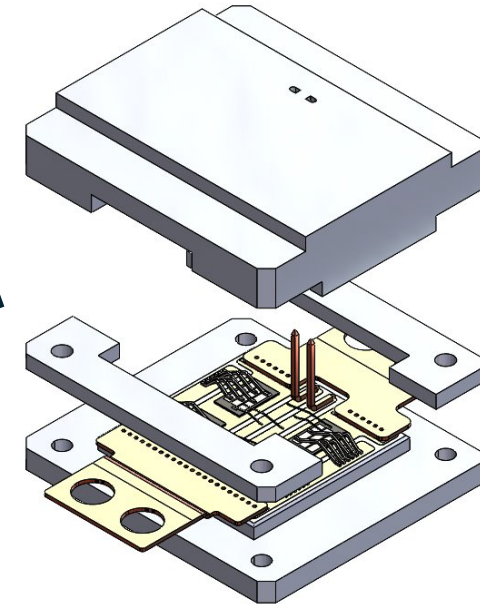
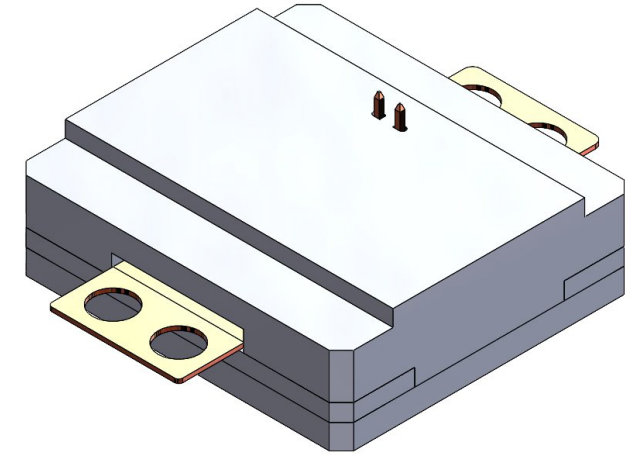
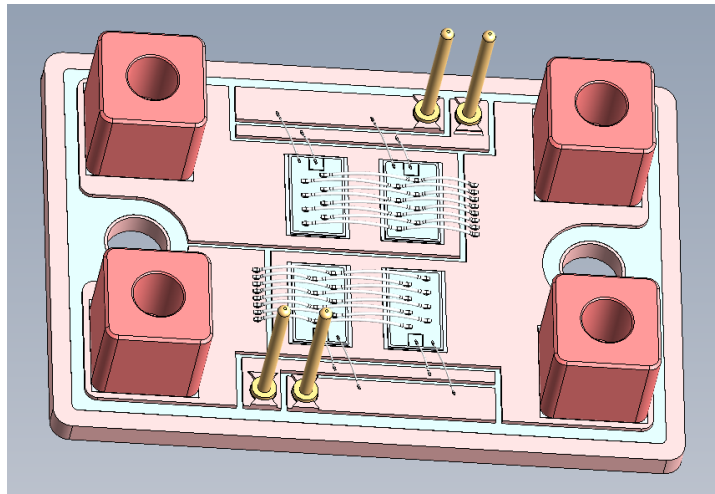
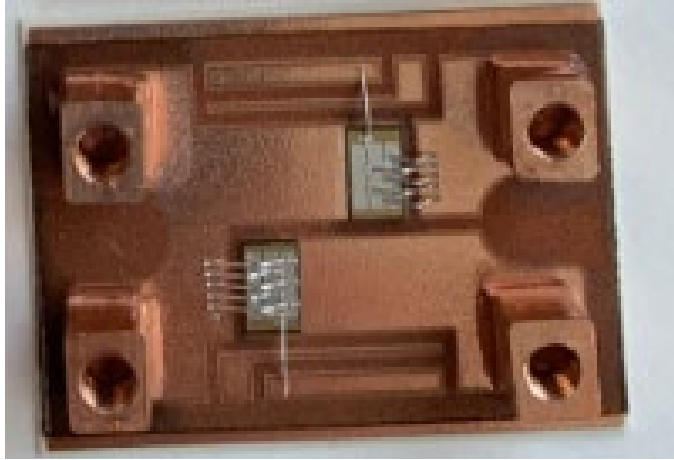


Nitride Global Inc.





Next Steps





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