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Evaluation of a MEMS Solution

Scrub Marks on NiPd Pads

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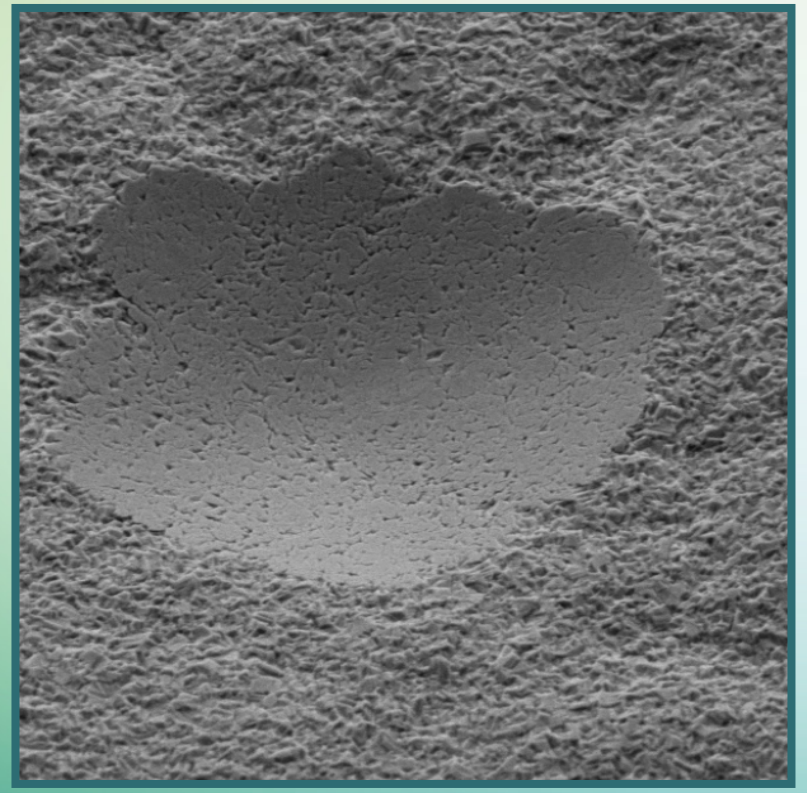


Probe Mark Visibility
Introduction

Quick test!

Q: What is this?
A: *An UNPROBED pad*

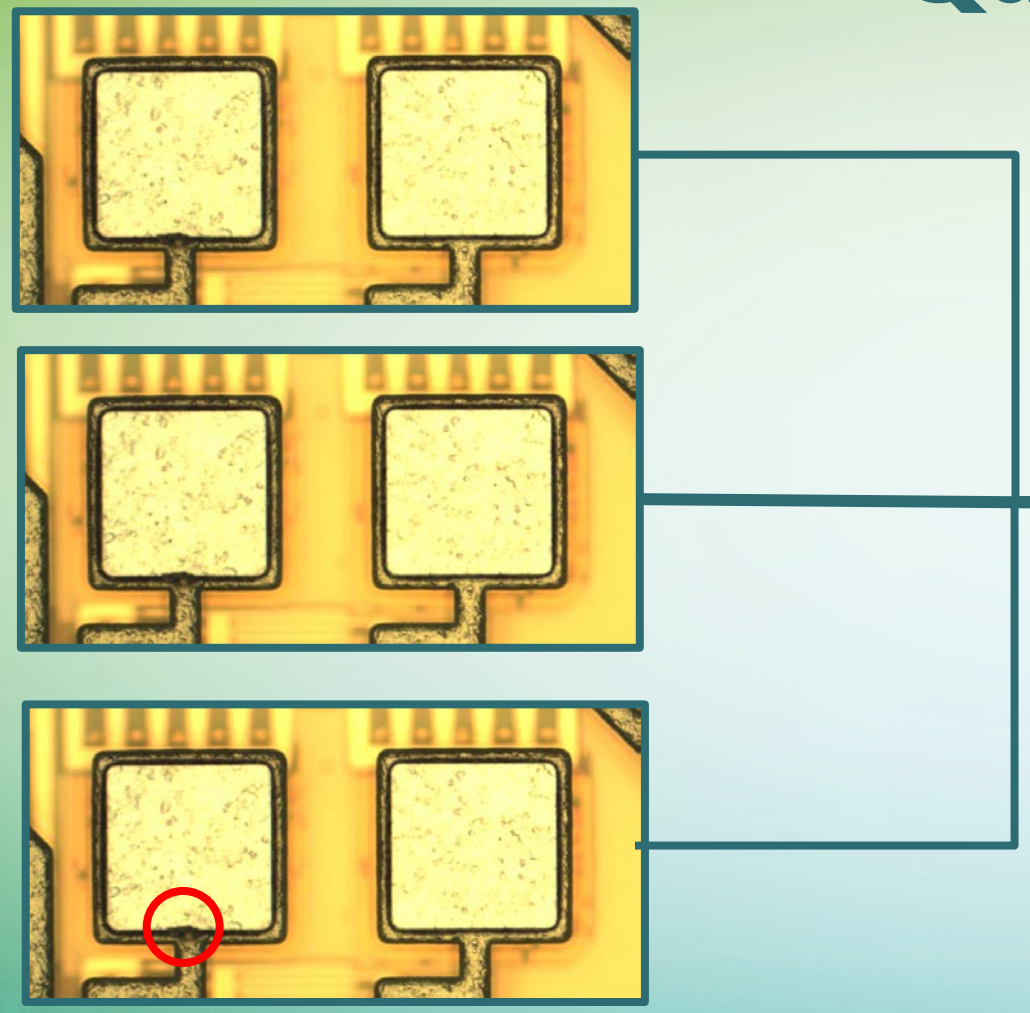
Q: What is this?
A: *A PROBED pad*

Q: What is this?

A: *A PROBED pad, but in the wrong position!*

CONCLUSION: When it is necessary to correct EWS process, the Probe mark position is FUNDAMENTAL.

Quick test!



CONCLUSION: When it is necessary to correct EWS process, the Probe mark position is FUNDAMENTAL.

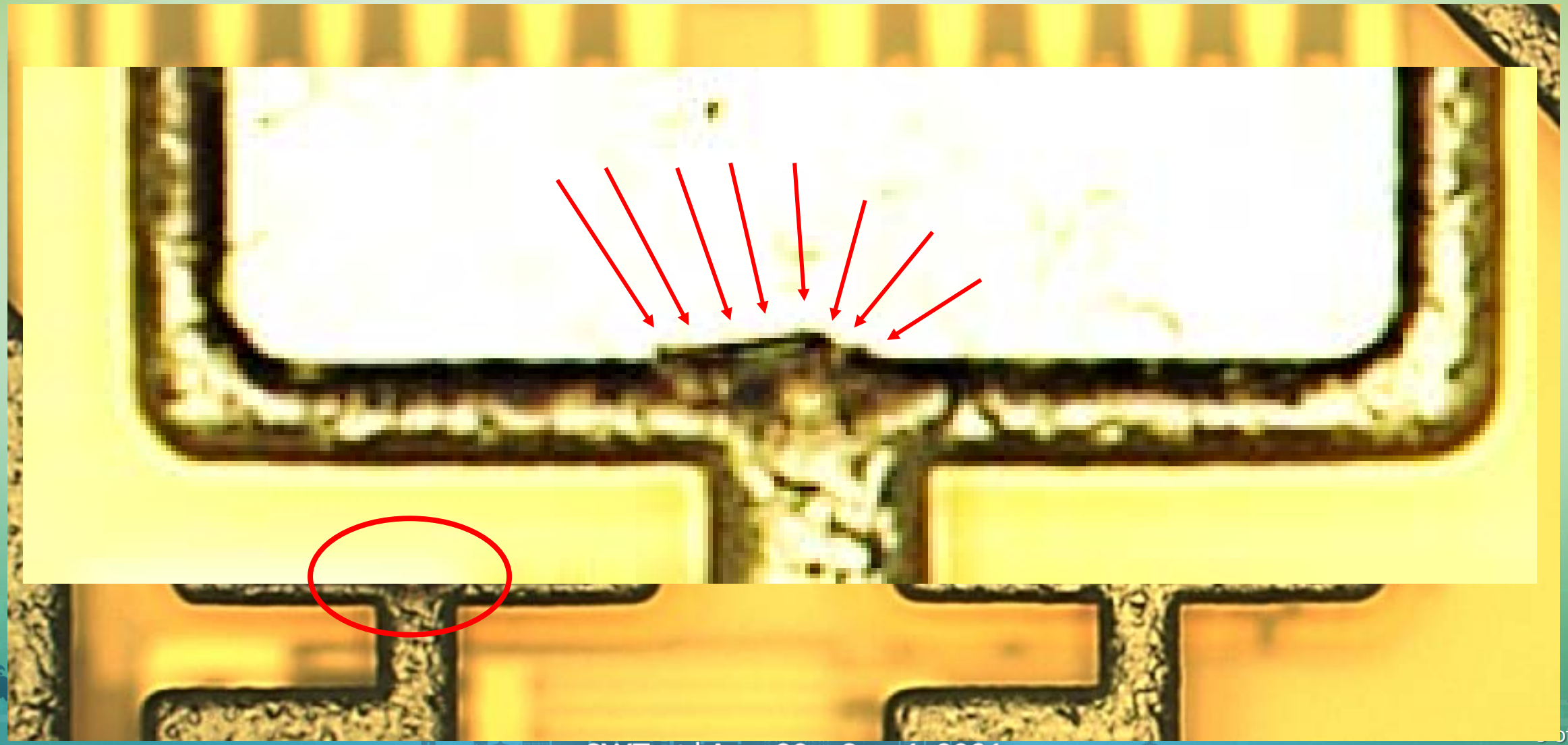
Q: What are these?

A: They are both PROBED pads.

Can you recognize them?

One of the pads is PROBED in the wrong position.
Can you distinguish the good one from the bad one?

Defect Magnification with Optical Microscope

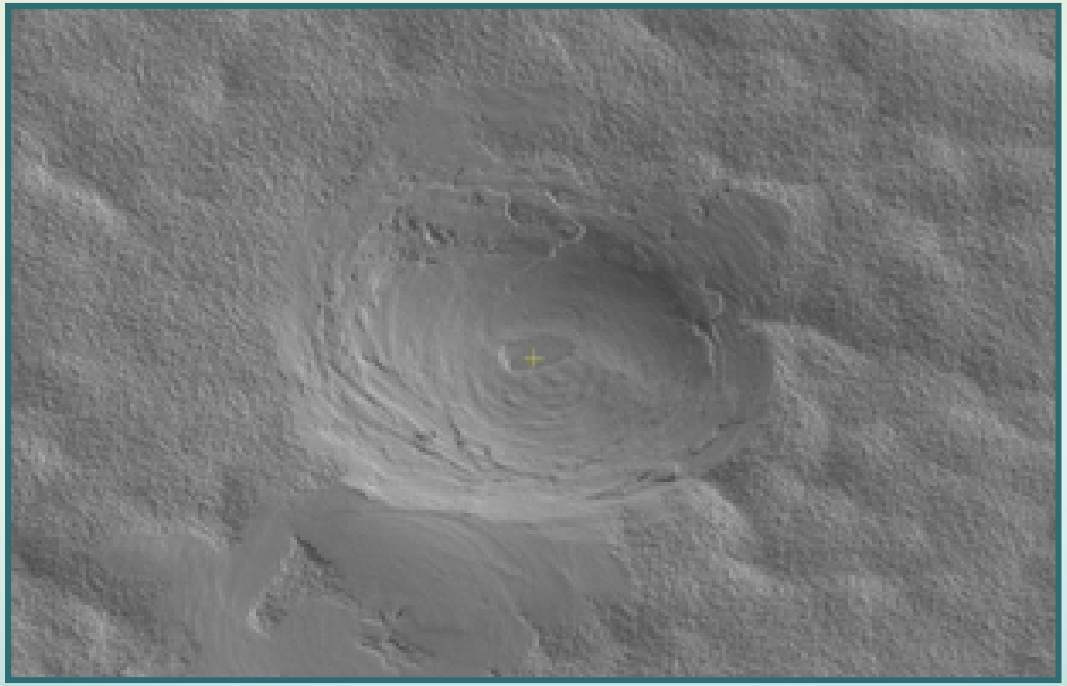


Project Description

- **With this project, we wanted to show that it is possible to make the probe mark visible (both to humans & artificially); thanks to the cooperation with our partner, Nidec SV TCL, we were able to demonstrate visibility on this hard pad finishing material.**
- **Within Nidec SV TCL's product portfolio, we identified a possible "game-changer"; an existing probe that could provide a very promising outcome once applied to our need (a pioneering vision!)**
- **Two different product test vehicles were selected for driving the development of this probe technology:**
  - The first was characterized at Nidec SV TCL's U.S. R&D lab with a low-g-force prototype.
  - The second was turned into an actual production probe card after the lab-prototype demonstrated successful results.

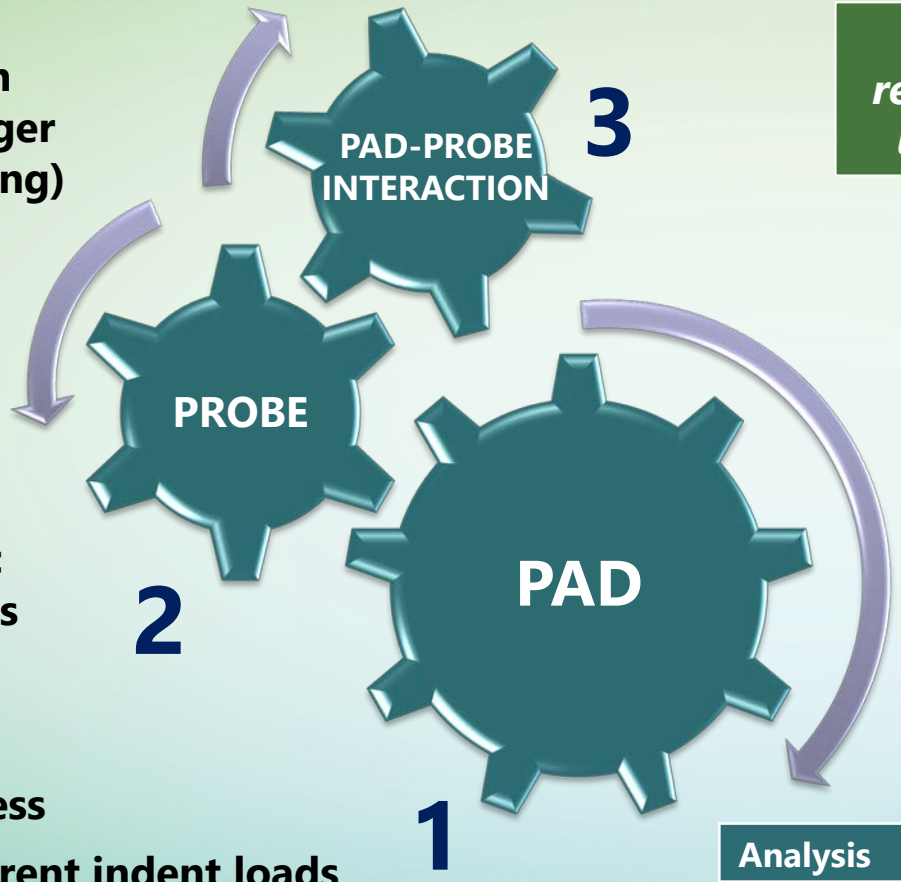
Probe Mark Visibility

on Thick Cu NiPd Pad Finishing



Measurement Plan

- **Probe mark depth**
- **Pad integrity tests on probed pad (XPS Auger and Wet De-processing)**



- **Probe hardness and stiffness of the Nidec SV TCL MEMS needles**

- **Pad Roughness**
- **Pad Hardness, Stiffness**
- **Indent depth at different indent loads**
- **Pad integrity tests on indented pad (XPS Auger and Wet De-processing)**

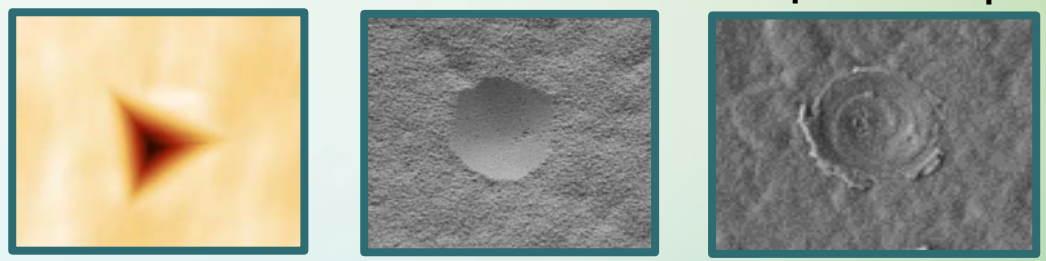
Purpose: to start a case study then share the results with Nidec SV TCL in order to extend and use analysis outputs to build a physical probe card .

Indenter Tips **Nidec SV TCL Solution**

PYRAMIDAL TIP

SPHEROCONIAL 5µm Radius Tip

P80 MEMS Spring 7.5µm Radius Tip

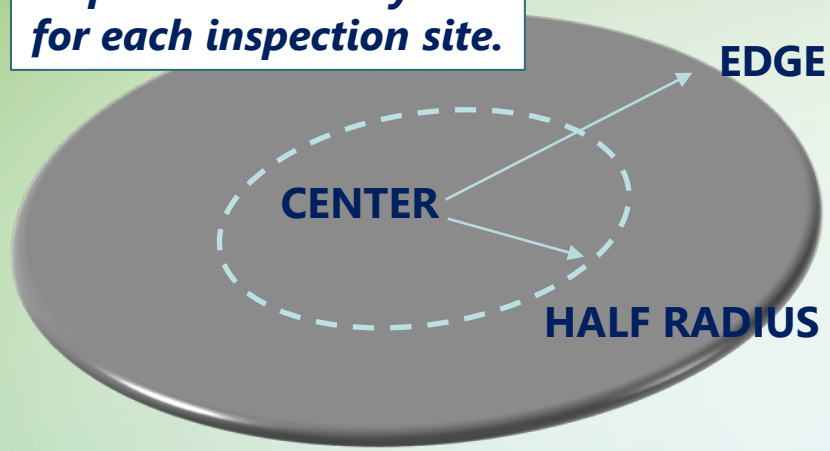


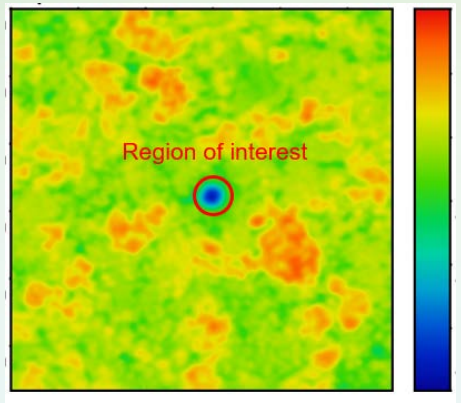
1 gF ~ 10 mN

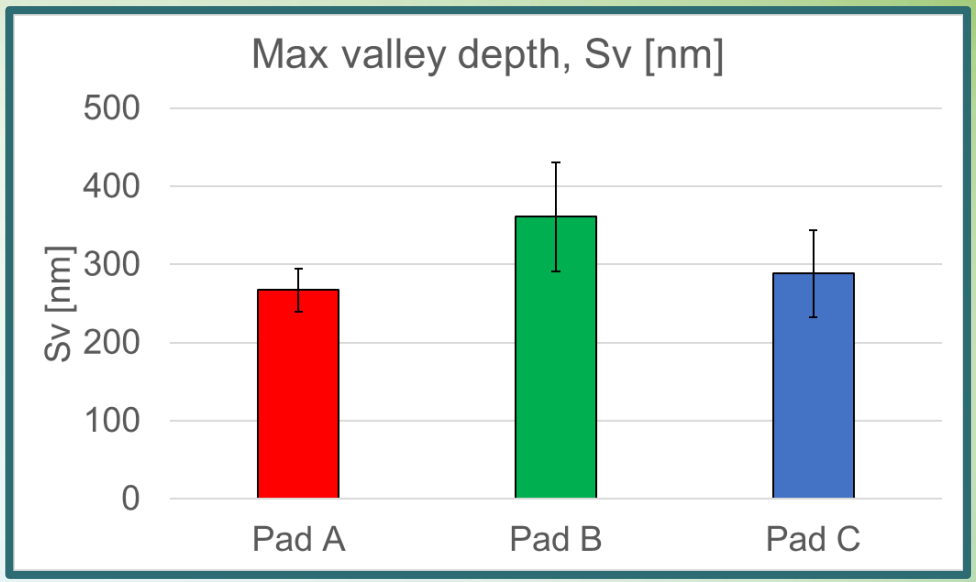
Analysis	Tools
H, Y, Indent Depth	NanoIndenter
Roughness, Probe Depth	Profilometer
Pad Integrity	XPS Auger, FIB, SEM

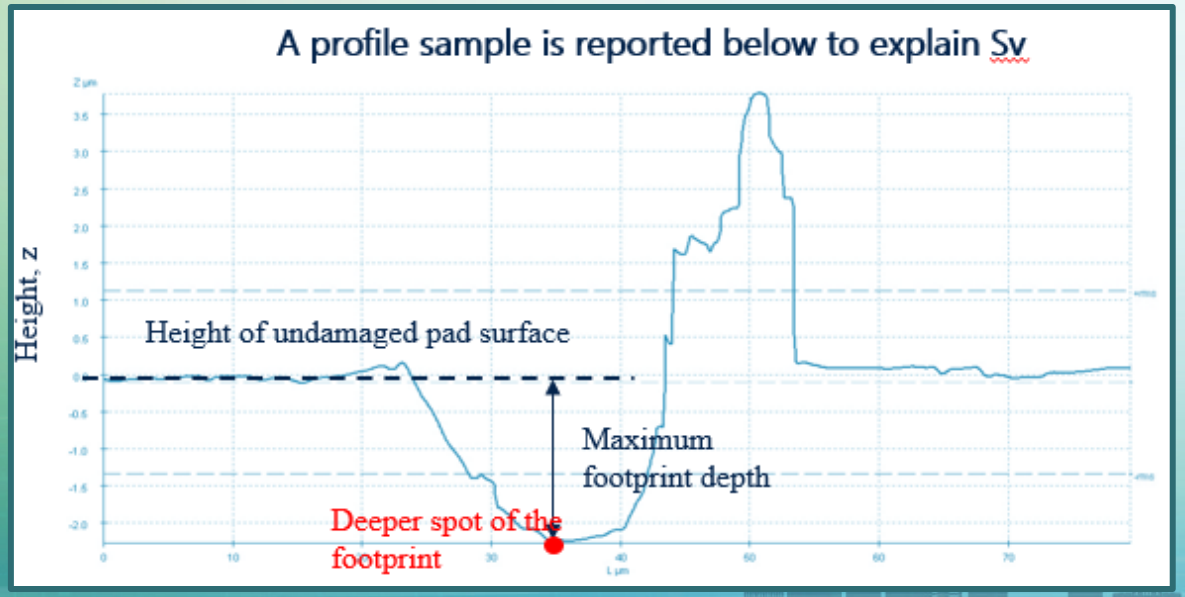
Profilometer Analysis on Pad

3 pads were analyzed for each inspection site.



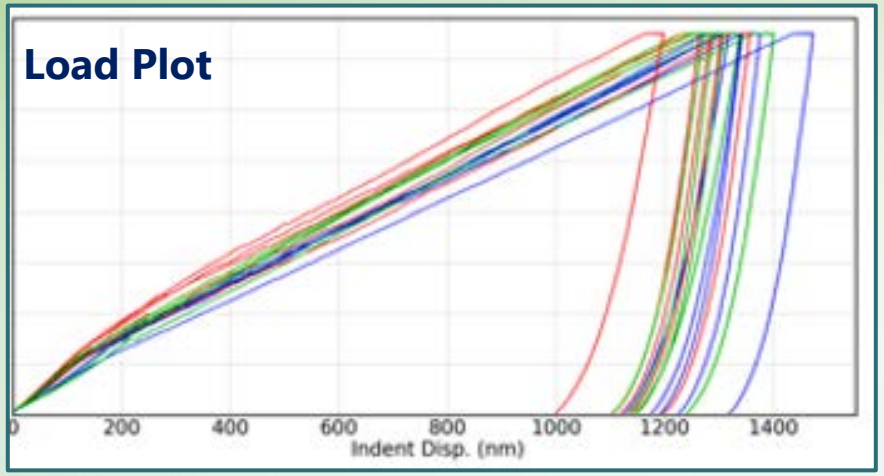


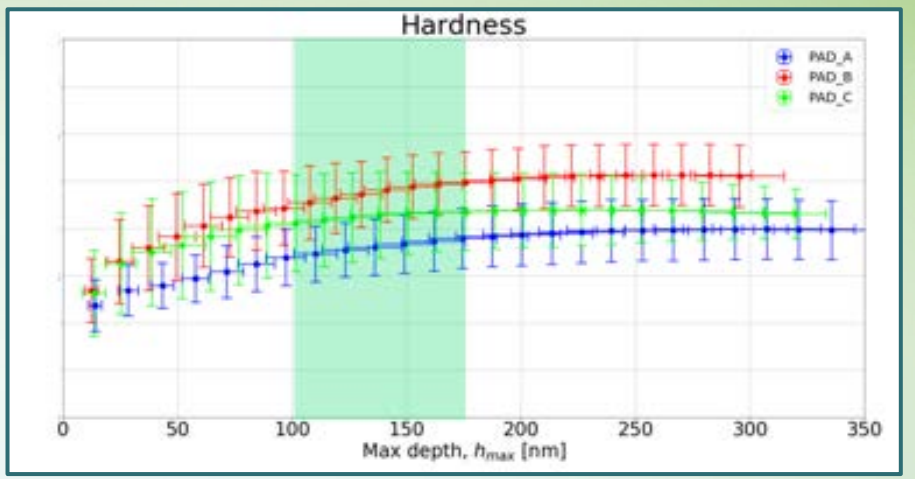


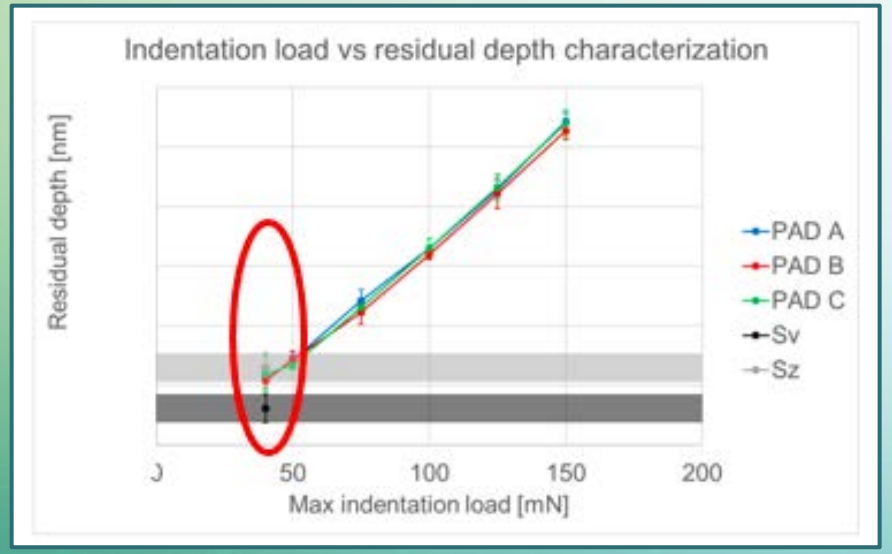


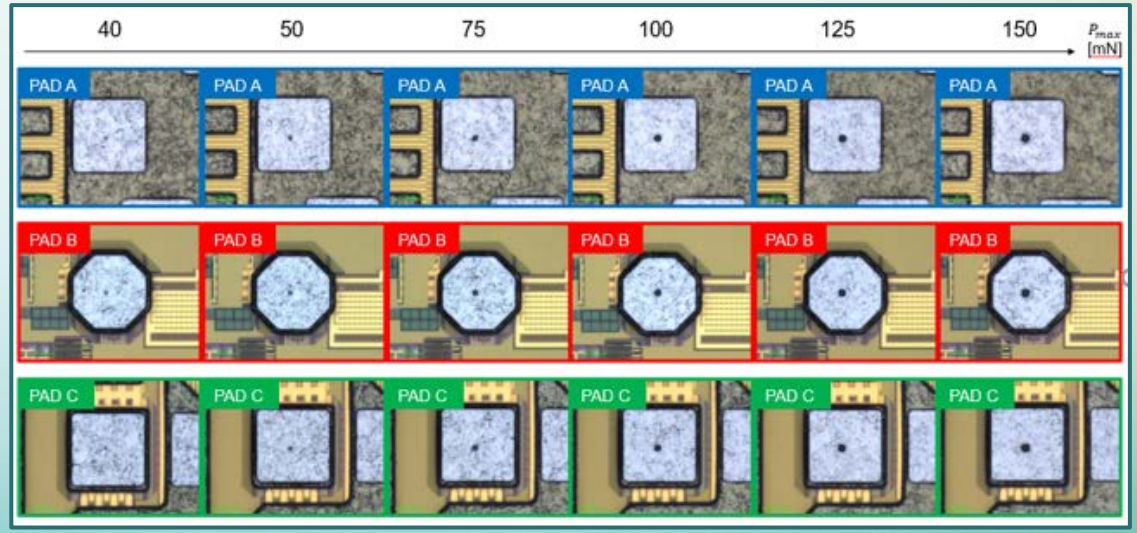
$$Sv = \max\left(-z(x,y)\Big|_{z\leq 0}\right)$$

NanoIndenter Analysis on Pad





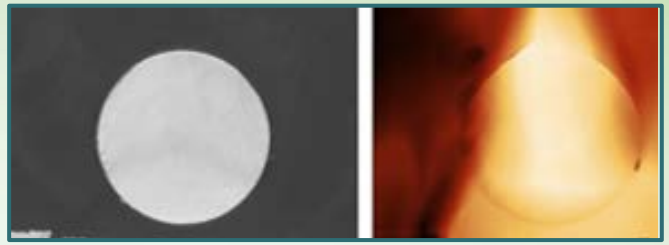


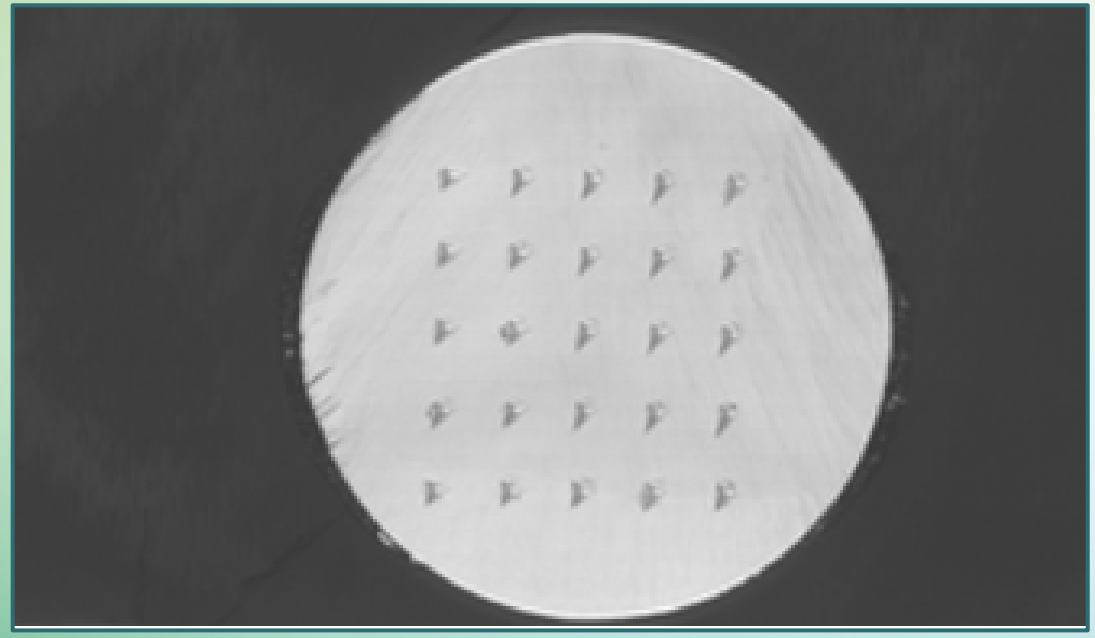


To create a visible probe mark: Sv < Indent mark depth (residual depth)

NanoIndenter Analysis on Needles

Needles	H (GPa)	Y (GPa)
P80 MEMS Spring Rotation	x1,7 harder wrt pad	Very close to pad Y





Sample preparation:

- Sample embedded in resin
- Lapping & ion-milling to smooth the surface

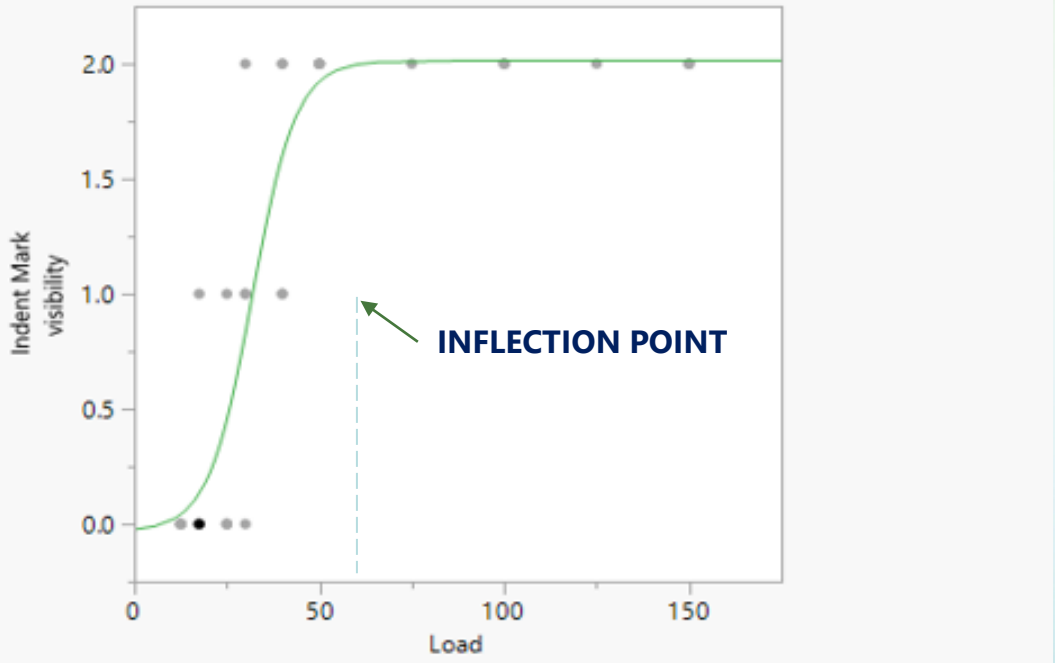
- **Thick Cu NiPd pad finishing is 10 times harder than Al pad finishing.**
- **P80 MEMS spring rotation, is 1.7 times harder then Thick Cu NiPd pad**

Visibility vs Load & Probe Mark Depth

Model Comparison

Model	AICc	BIC	SSE	MSE	RMSE	R-Square
Logistic 4P	43.146517	48.167504	4.9114642	0.1754094	0.4188191	0.8073936

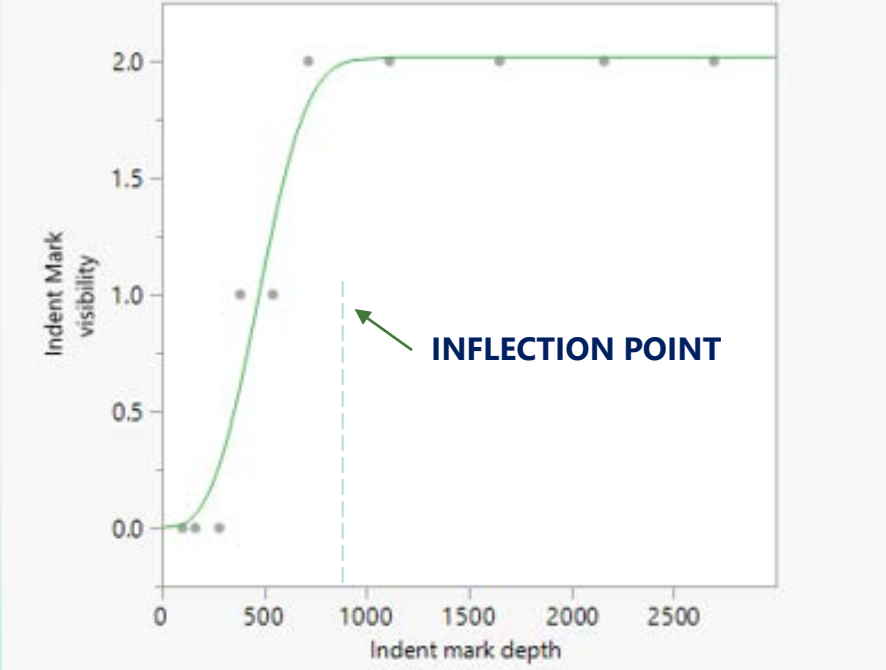
Plot



Indenter mark visibility vs Load

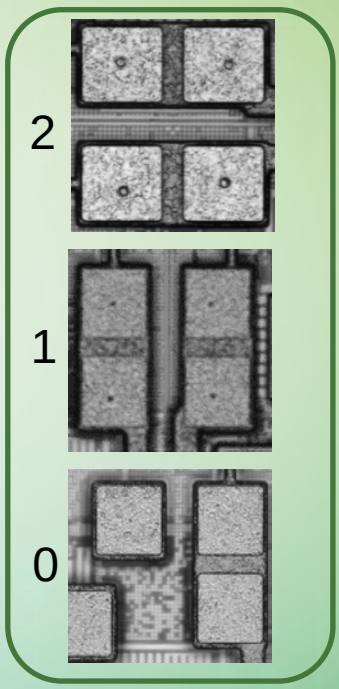
Logistic Plots

Plot



Indenter mark visibility vs Indenter mark depth

2 - Fully visible
1 - Slightly visible
0 - Not visible

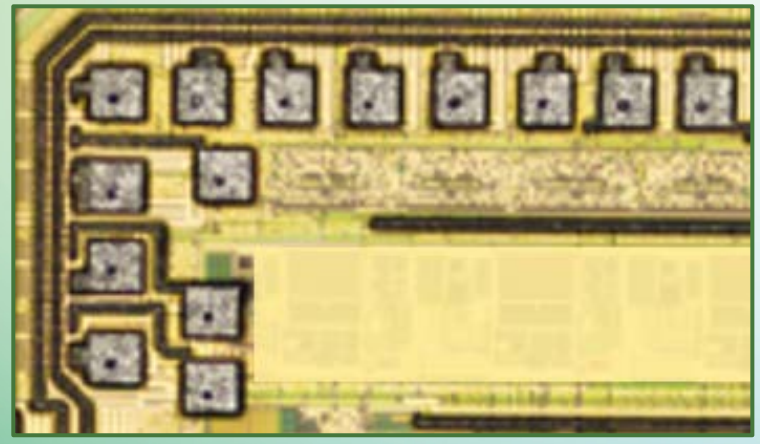


For a visible probe mark: *given the max pad roughness and hardness (tips and pads), load should be higher than 40mN and mark depth higher than 450nm.*

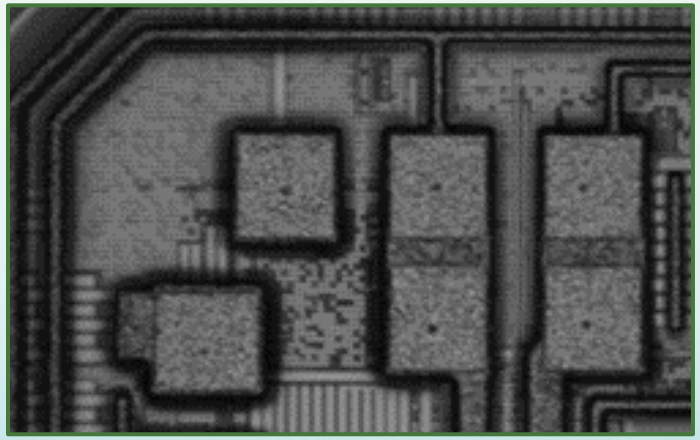
Conclusion

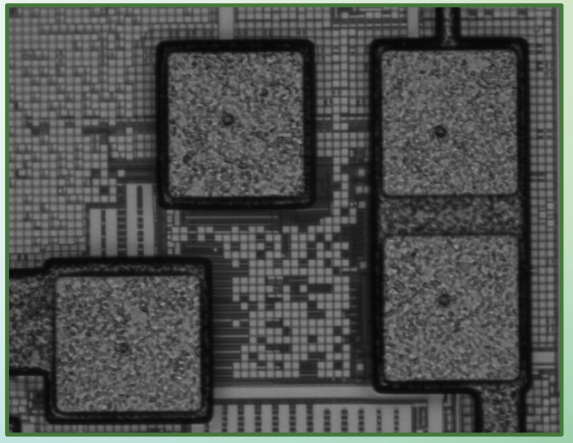
- Minimum load (so gram force) must be guaranteed to have a visible mark on pad (>40mN)
- Minimum mark depth must exceed the pad roughness Sv to have a visible mark on pad (>450nm)
- N[illegible]

Effect on Pad with Second Test Vehicle



Prober: Color camera, Low magnification





Prober: Black & White camera, High magnification

ST Microelectronics UR8A Technology

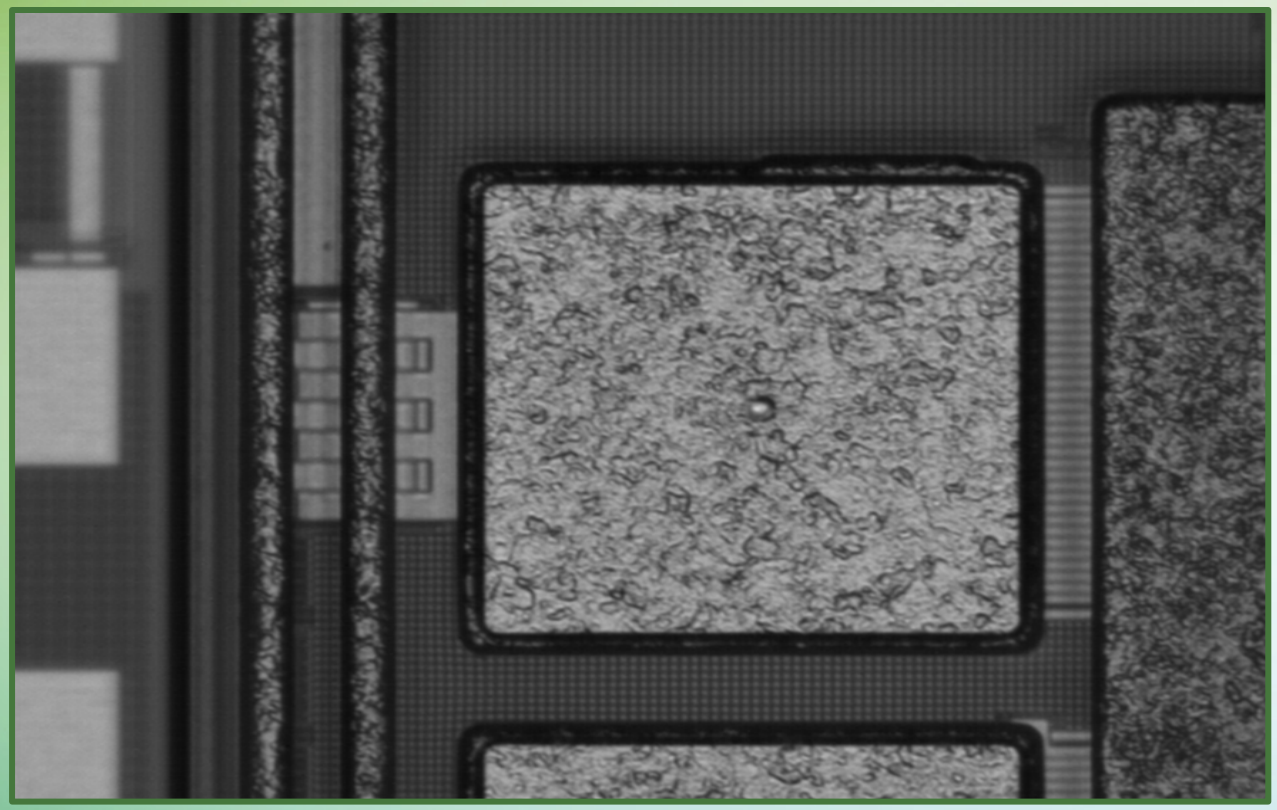
Evaluation

TV1 – DOE Table

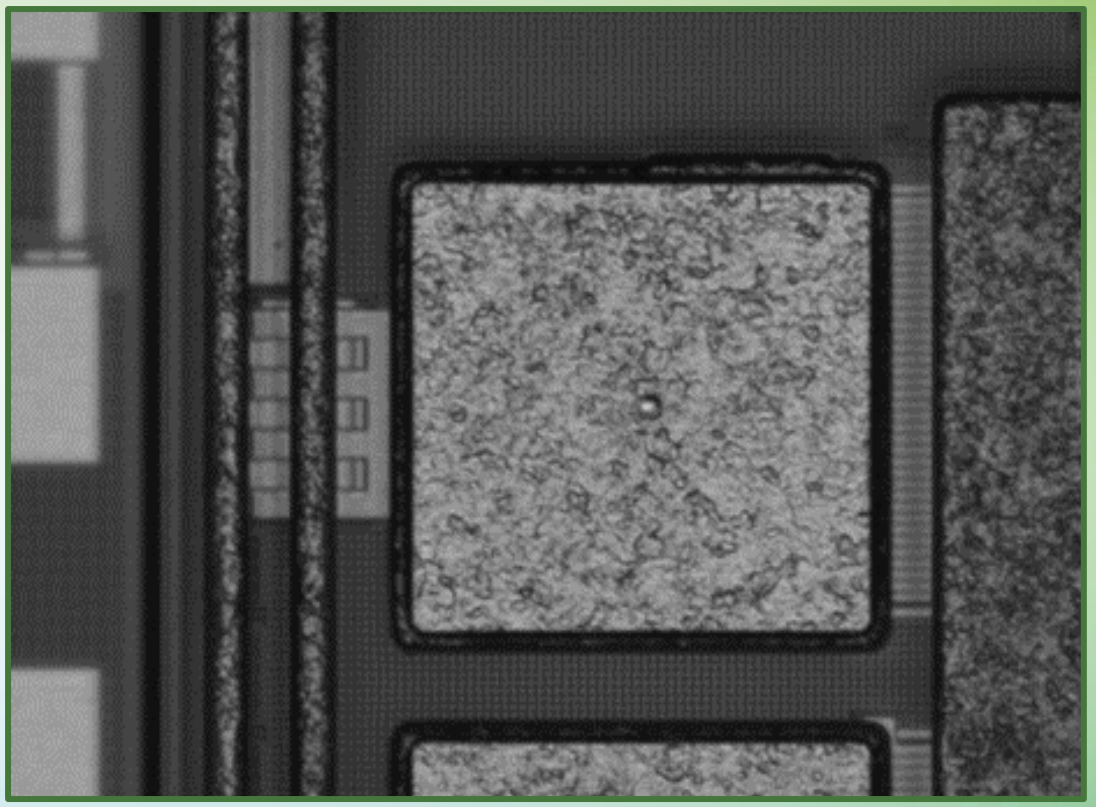
Probe Type	Temperature	Overdrive (micron)	Scrub Mark Visibility
Non-Rotational Probes	Room	100	Yes
	150°C	100	Yes
Rotational Probes	Room	100	Yes
		175	Yes
	150°C	100	Yes
		175	Yes

- **DOE was performed with different tip shapes and probes.**
- **Initial DOE concluded that a specific tip shape definitely increases the visibility of probe marks.**
- **After evaluation, it was determined that probes with a specific shape and more rotational scrub provided results with better visibility of the probe marks on the NiPd pads.**

DOE Results – Probe Mark Visibility TV1



150°C



Room Temperature

- Visible probe mark seen on Ni Pd pads both at room temperature and hot temperature

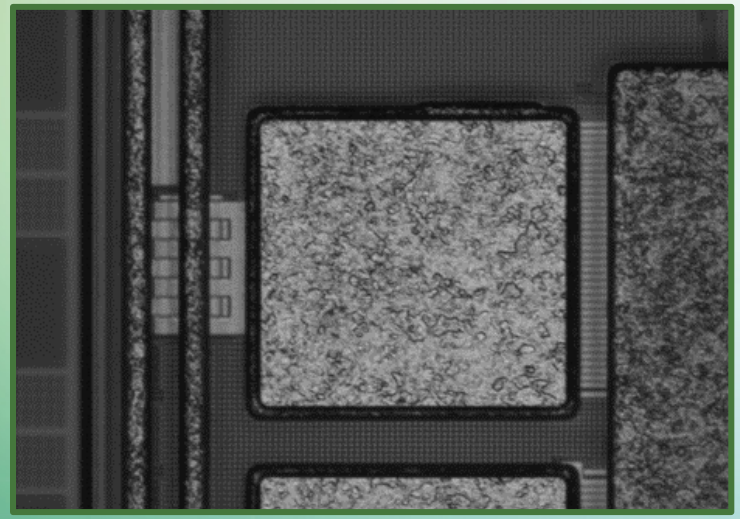
DOE Test Results – TV1 – Probe Mark Depth

Probe Marks	Probe Mark Depth
Rotational Low Force Pins	338.31 nm
	411.095 nm
	422.47nm

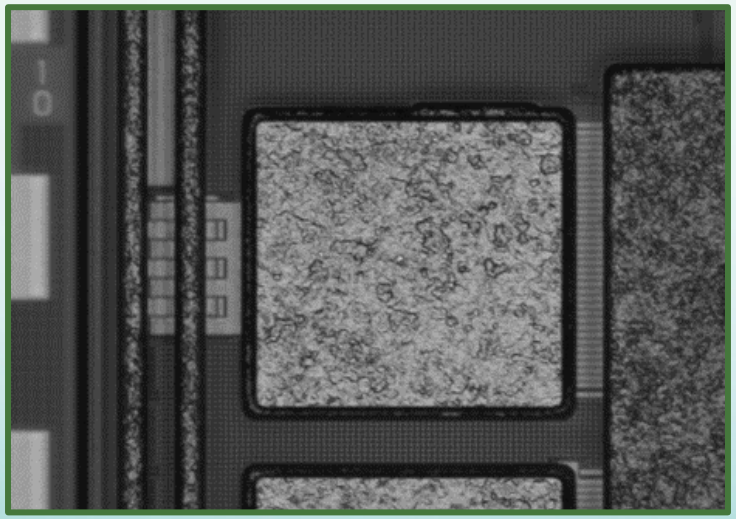
- **We see the variability in the scrub mark depths varying from 338.31nm to 422.47nm.**
- **Based on some indenter studies performed by ST Micro, it was determined that we would require a minimum of 450nm scrub mark depth to have visible marks on the wafer.**
- **However, we did observe some variation in visibility of the marks because of some variation in scrub mark depths.**

DOE Test Results – TV1

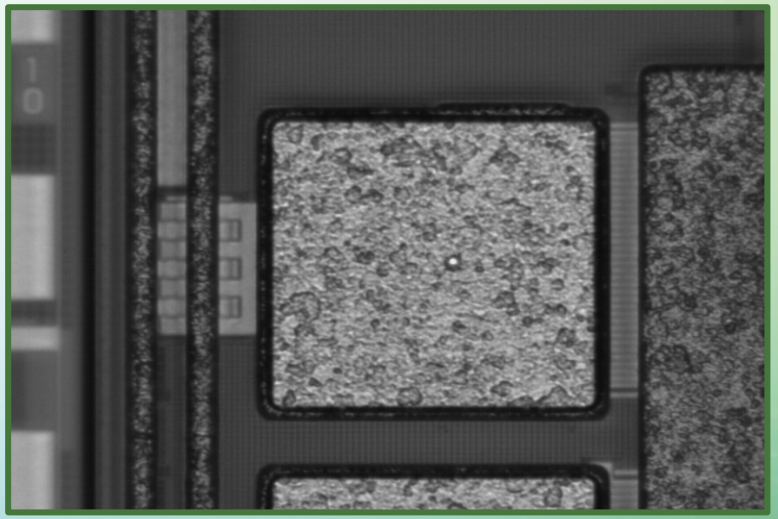
- TV1 was initially characterized with a standard low force probe.
- As seen from the images below, there was a variability in visibility from one die to the next.
- When observed under the interferometer, the probe marks were visible, however, it is difficult to view marks under the prober camera.
- Another characterization on TV1, done by our partner ST, was completed and the conclusion is that a minimum force of 40mN (4gf) is required.
- Because our MEMS probe is easily customizable TV2 was developed with a higher force to achieve better consistency in probe mark visibility from one die to the next



Probed Dies, But Mark not Visible

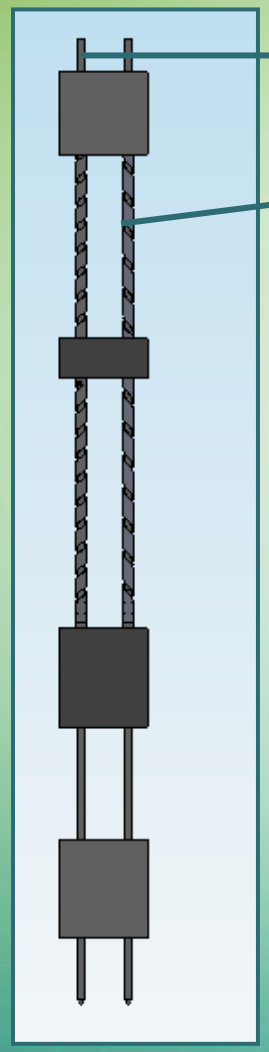


Probed Dies, But Mark is Barely Visible

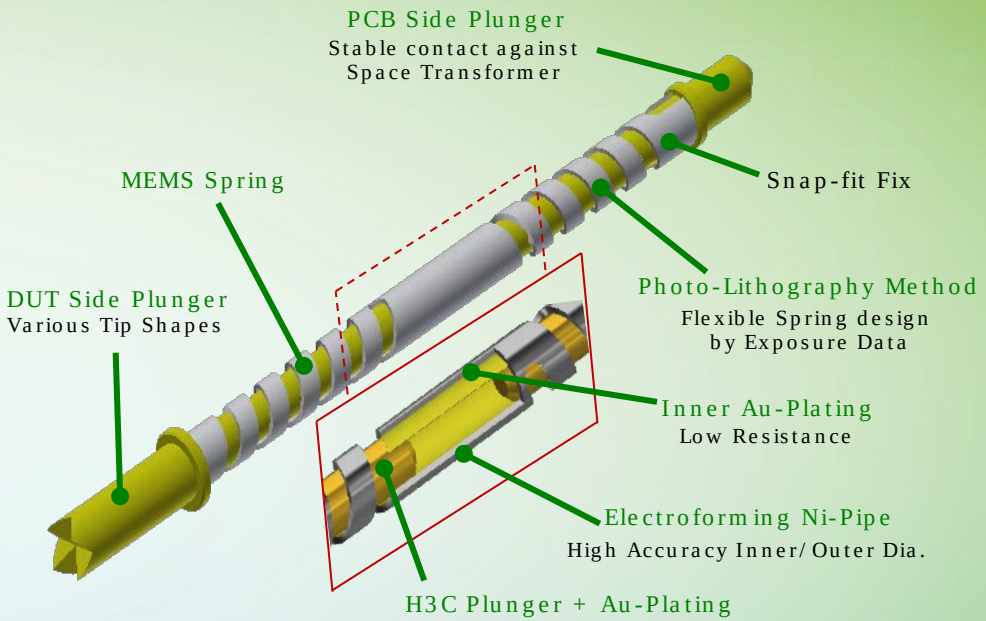


Probed Dies, With Fully Visible Mark

MEMS Probe Customization TV1 & TV2



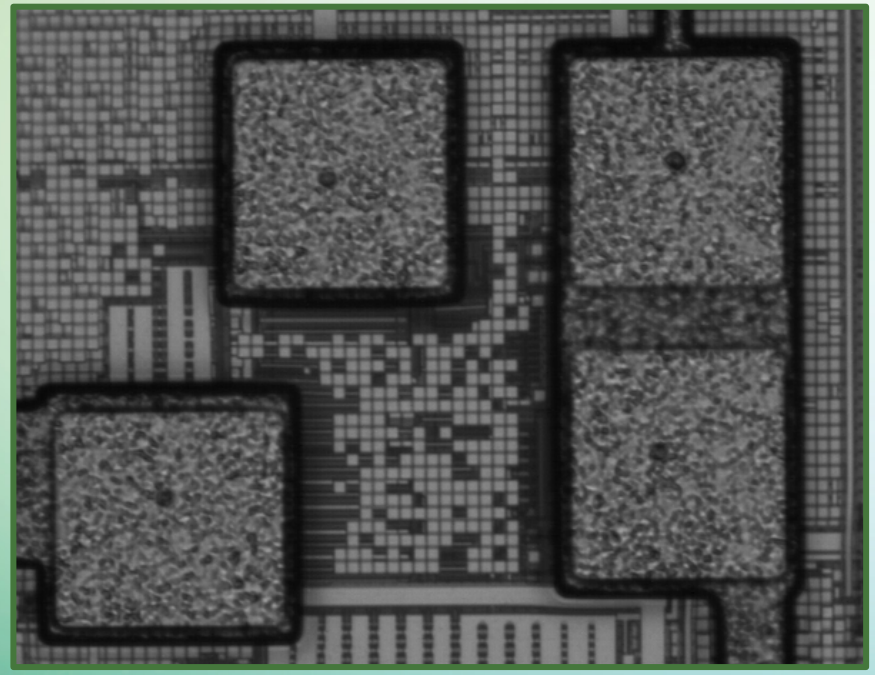
Pin	Force	Length
Low Force	4.5gf	4.704mm
High Force	8gf	4.704mm

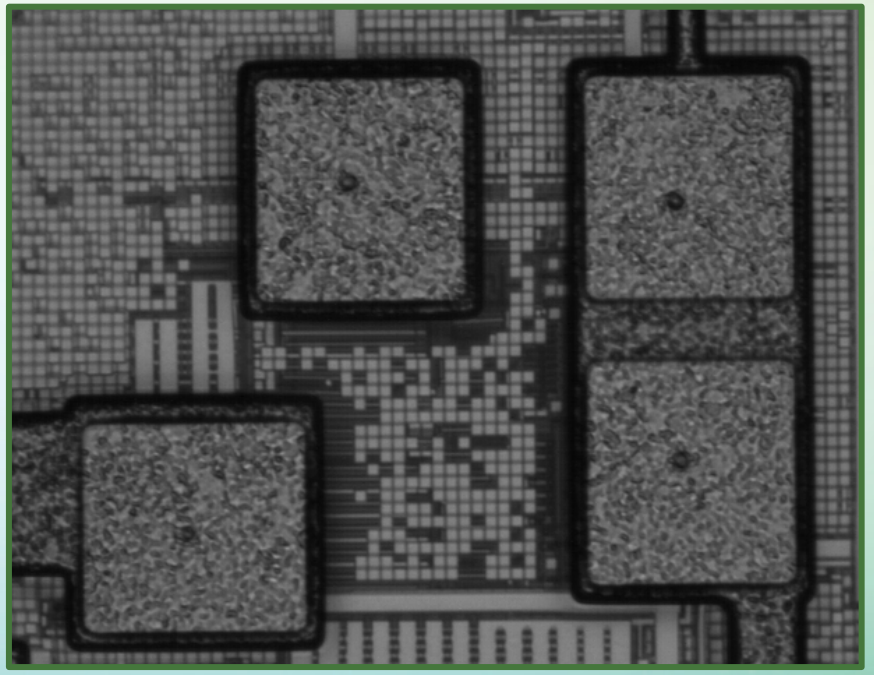


- **The findings and results from the DOE on TV1 determined that the MEMS probe needed to be designed with higher force for better consistency of visibility of probe marks.**
- **With easily updated input parameters to customize the MEMS probe, we were able to redesign the probe with higher force while maintaining the same length as the original probe and as a result use the same probe head stack up for both TV1 and TV2. Eliminating all possible variabilities between TV1 or TV2.**

TV 2 – Design Improvements

- **MEMS Probes are easily customizable; Pins were redesigned to increase the probe force but maintain the same probe length.**
- **New probes were designed in order to achieve a higher force than the 40mN (4gf).**
- **The higher force probe will help to obtain probe marks which are consistently more visible than the 450nm.**





Initial Scrub Marks With TV 2

TV2 – Scrub Mark Visibility and Depth

Probe Marks	Probe Mark Depth
Rotational High Force Pins	700.012 nm
	650.558 nm
	705.897 nm

- **With the TV2, the scrub marks were consistent from site to site.**
- **With the 450nm target we demonstrated more consistent visibility of the probe marks on the pads.**

Test Vehicles

Results

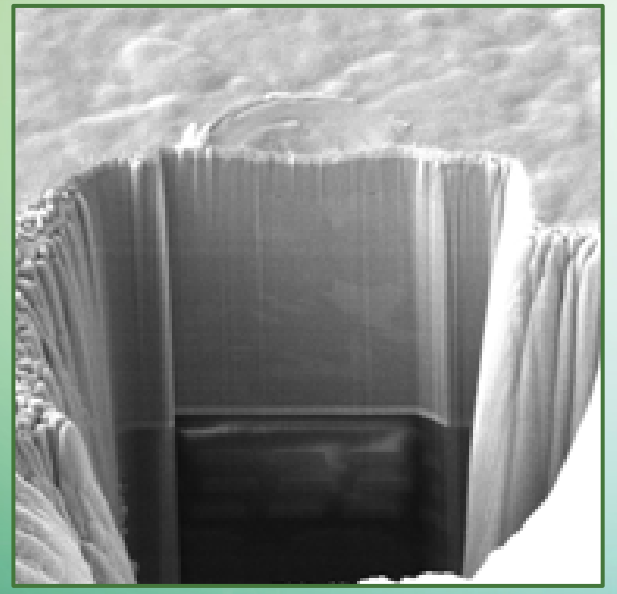
Prototypes EWS Qualification – TV1

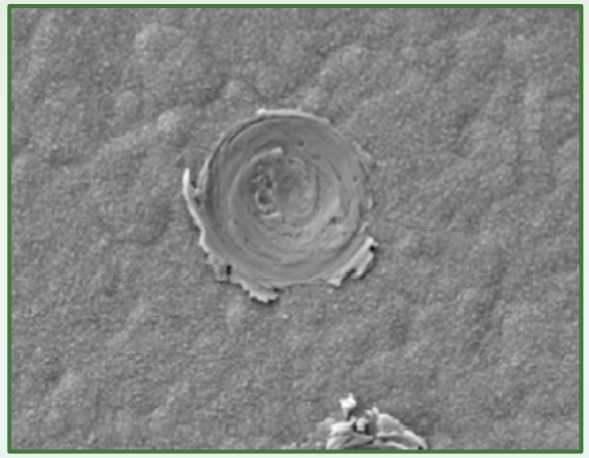
Auger & Integrity Tests on Pad

Test Vehicle 1: Thick Cu NiPd

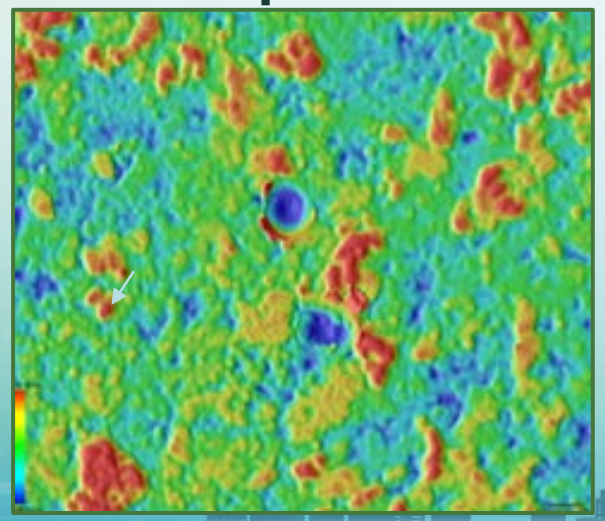
All integrity tests performed on indented pads by probing D.o.E. successfully passed. Below are the reported results from the probed pads with P80 MEMS rotation.

X-section, SEM

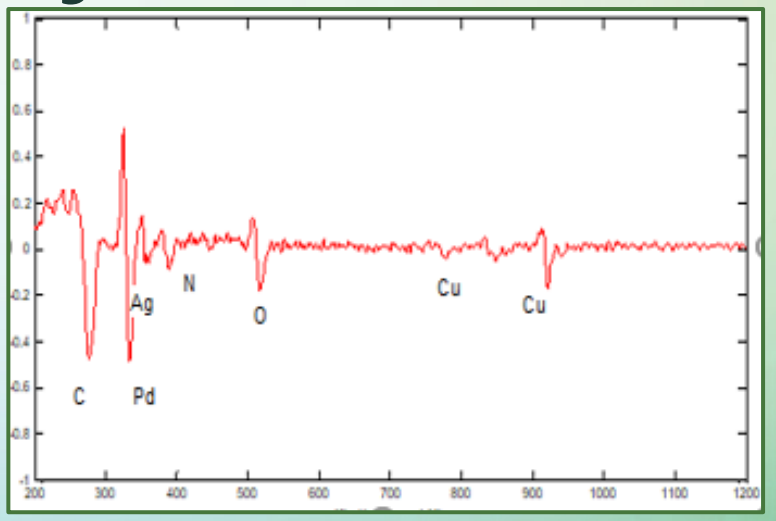




Profile Map



Auger



Prototypes EWS Qualification – TV2

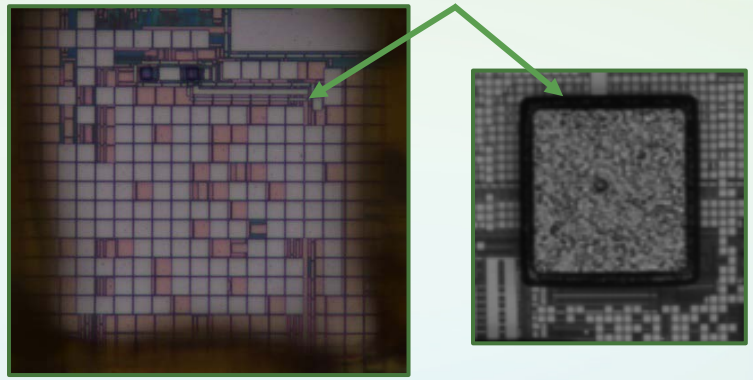
Auger & Integrity Tests on Pad

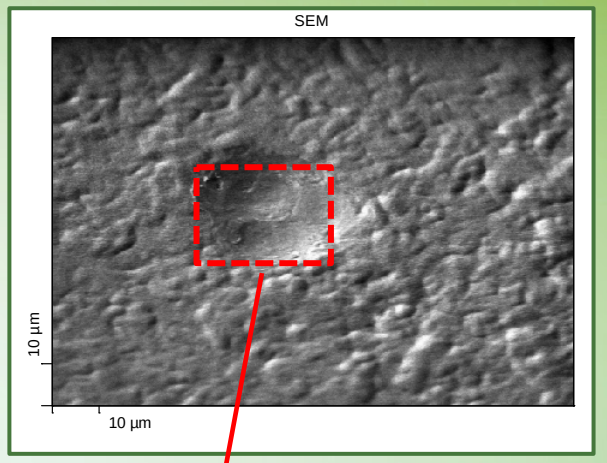
Test Vehicle 2: Thick Cu NiPd

X-section, SEM

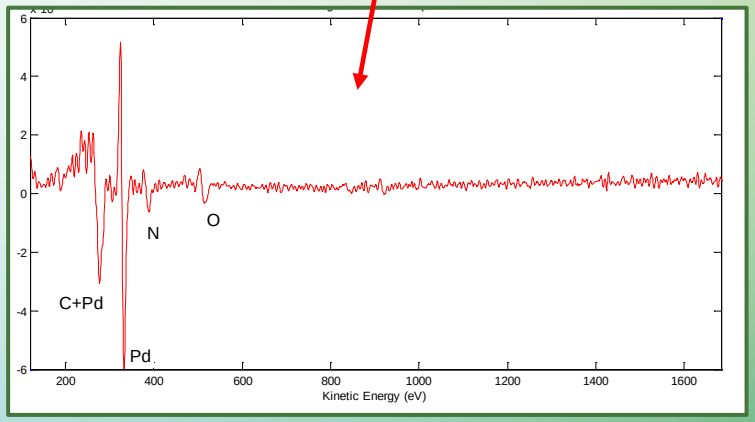
- **Cross section confirmed no cracks or damaged structures under probe mark**

Wet De-processing (etching): structure under pad view

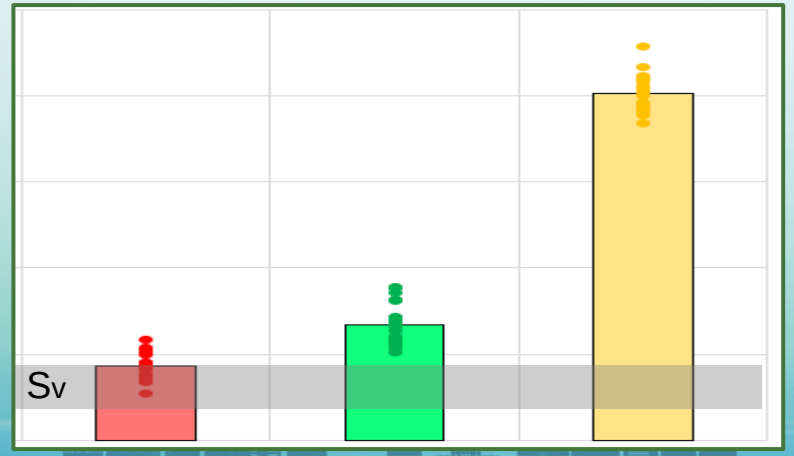




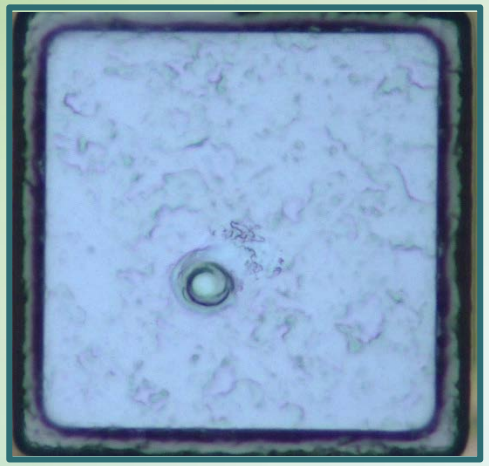
Auger

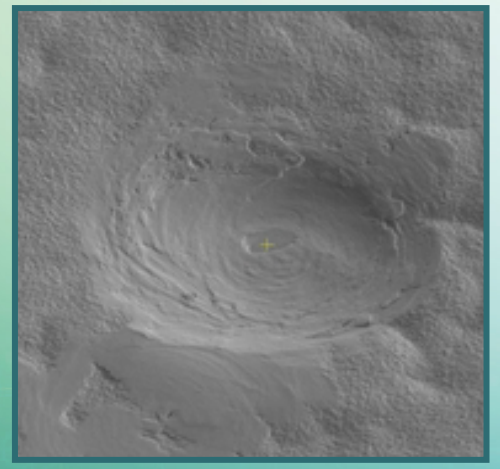


Profile: Depth Results vs SV



Probe Mark Visibility
Next Steps





1) Consolidate EWS qualification results.

2) Assess FE/BE compatibility, address the bondability risk and perform relevant trials (pad surface is deeply changed from the bonding point of view).

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Thank you!