SWTEST ASIA
PROBE TODAY, FOR TOMORROW

Improvement of probe-to-wafer contact resistance for inline automated testing for different technologies

imec

Anton Gavrilov
application engineer
imec

5th Annual SWTest Asia | Fukuoka, Japan, October 24 - 25, 2024

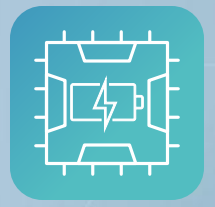
Activities and specifics of imec

Advanced semiconductor scaling

Increased performance

Increased complexity

Reduced cost



reduced power

Automotive

Agritech

Health

Energy

RESEARCH
& DEVELOPMENT
96 nationalities
& 5500 experts

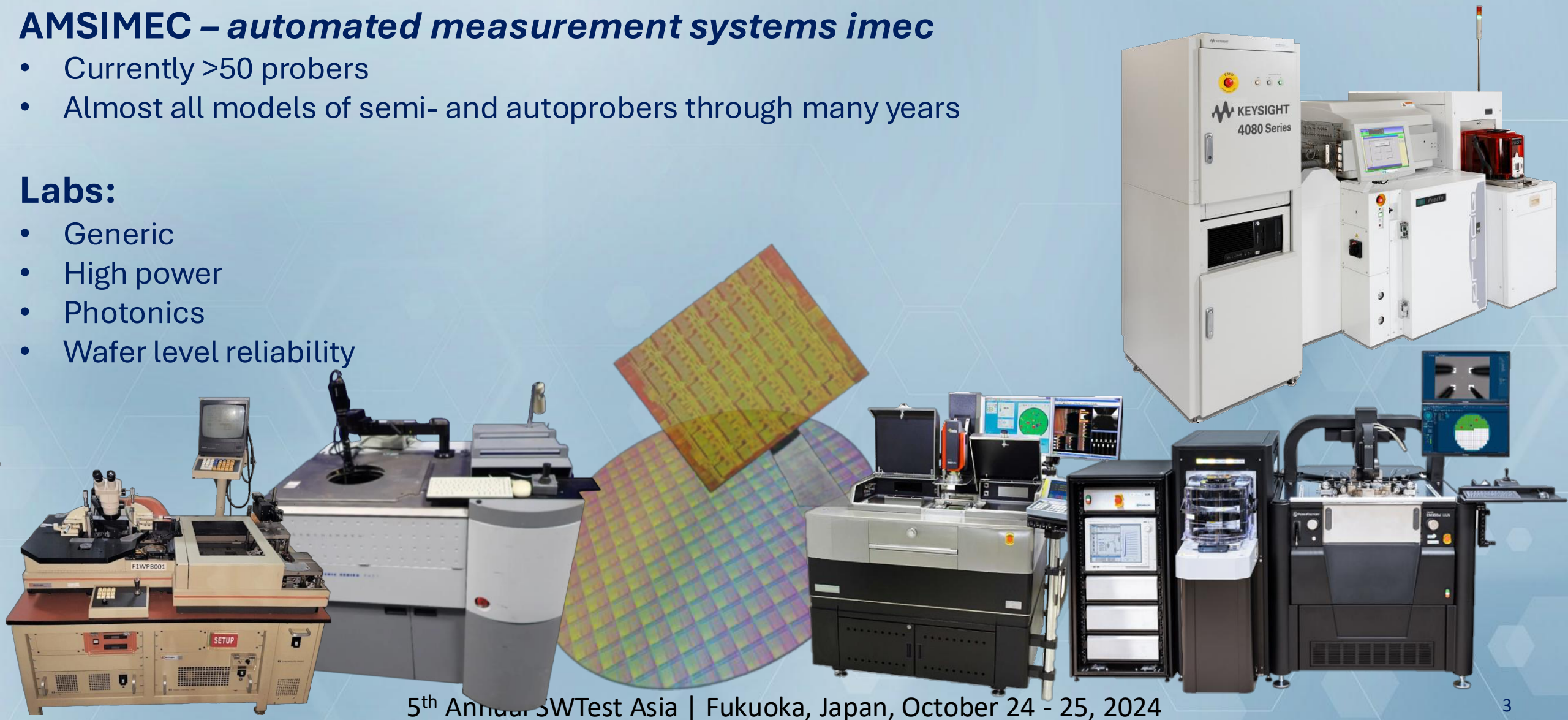
Activities and specifics of imec

AMSIMEC – *automated measurement systems imec*

- Currently >50 probers
- Almost all models of semi- and autoprobers through many years

Labs:

- Generic
- High power
- Photonics
- Wafer level reliability



Problems and goals

Problem statement:

High contact resistance **between probe tips and pads on a wafer has influence on measurements of "low resistance" devices which need to be measured in CR.**

Goal:

Make *damage free*, *reproducible*, *reliable* wafer contact with *good characteristics*, processed in "standard" and experimental way with *gridded pads* during the inline measurements.

How:

Change probing solution

Input:

- **Inline measurements**
- **Gridded pads**
- **Dielectric coating**
- **Experimental wafers**

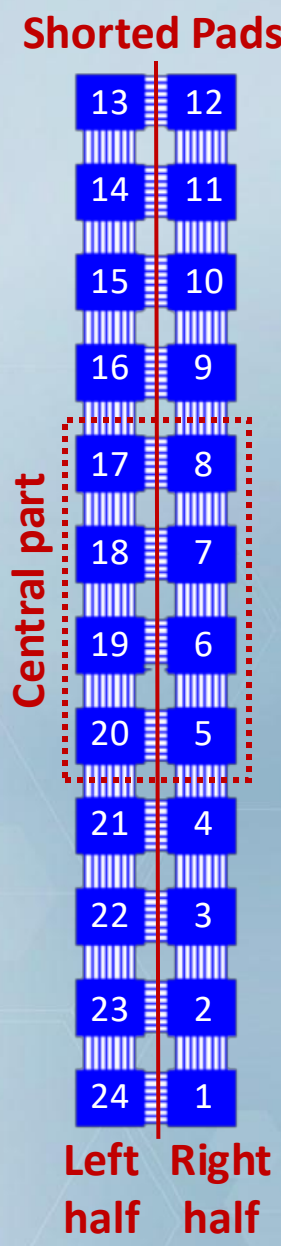
Questions:

- **Good characteristics**
- **Gridded pads**
- **Reproducibility**
- **Reliability**
- **Damage free**

Overview

- Problem cases and criteria of success
- Methodology
- Results and challenges
- Follow-on work and questions

What are good characteristics



Good result

Tip	R, Ohms		Tip
13	1.07	1.03	12
14	1	0.91	11
15	0.97	0.92	10
16	0.96	0.95	9
17	0.9	0.89	8
18	0.9	0.88	7
19	0.94	0.83	6
20	0.95	0.85	5
21	0.97	0.9	4
22	0.98	1.02	3
23	0.95	1	2
24	1.07	1.16	1

- No left/right halves difference
- Low mean value
- No peaks
- Small center/corners difference

High resistance

411	411
264	264
264	264
264	264
264	264
264	264
264	264
264	264
264	264
264	264
264	264
410	410

Disbalance

0.82	0.97
0.73	1.13
0.74	2.58
0.69	1.39
0.65	2.27
0.64	2.9
0.69	1.26
0.68	2.97
0.72	2.84
0.71	3.25
0.69	2.23
0.76	1.75

Bad tip

1.37	1.51
1.18	2.07
1.17	2.03
1.1	1.73
1.08	1.58
1.05	1.67
1.11	2.96
1.11	2.45
1.2	4.88
1.2	3.54
1.25	17.05
1.48	4.35

Edge-to-center distribution

Edge die		Center die	
324	361	3.71	4.37
284	338	2.51	3.03
309	334	2.75	2.55
309	341	2.75	4.64
291	322	2.36	3.3
286	308	2.28	2.42
286	322	2.22	3.05
273	372	2.45	2.97
284	359	2.62	5.6
311	398	2.62	3.76
307	459	3.04	3.78
329	449	8.08	8.71

Mean, maximum and minimum values are not enough
→ **define FOM**

What are good characteristics

To consider shorted pads test measurement like "accepted":

$Cres_{mean} \leq 5\ Ohms$

$\sigma \leq 2\ Ohms\ acceptable, \leq 1.5\ Ohms\ better$

$$k_{h1h2} = \left|1 - \frac{Cres_{mean_{h1}}}{Cres_{mean_{h2}}}\right| \leq 0.2$$

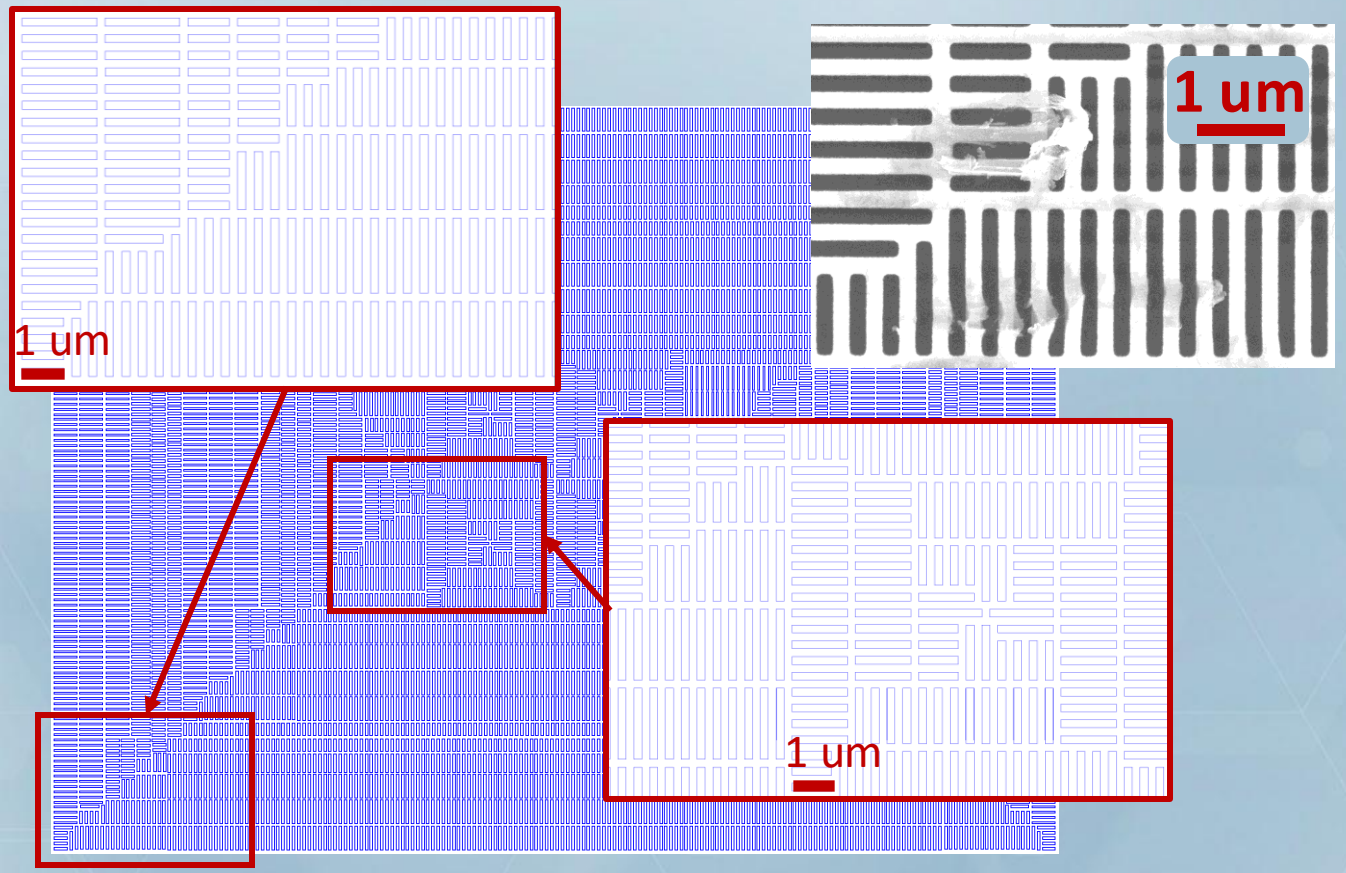
$Cres_{max} \leq 8\ Ohms$

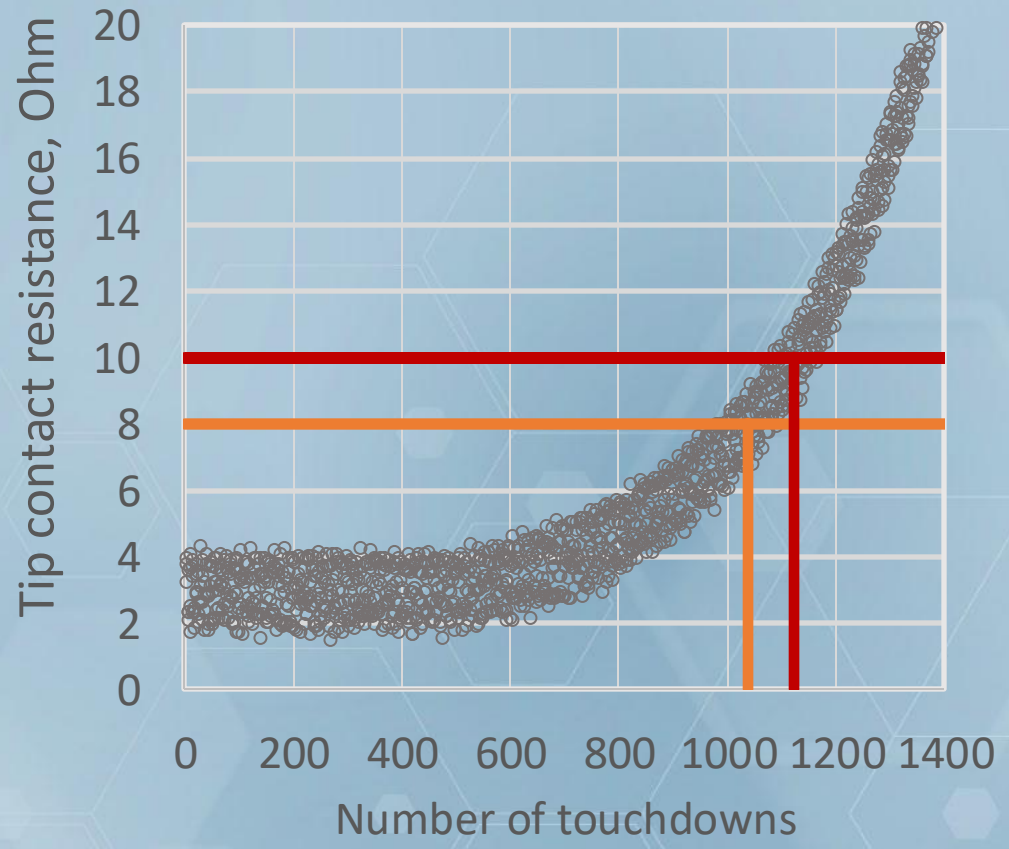
To consider wafer measurements like "accepted" 80% of tests should be "accepted"

To consider probecard like "accepted" 5 wafers should be accepted

Gridded pads and reproducible measurements

Let's assume we have equal wafers. We set some threshold value (red) and take some margin (orange). When we reach orange line cleaning is needed





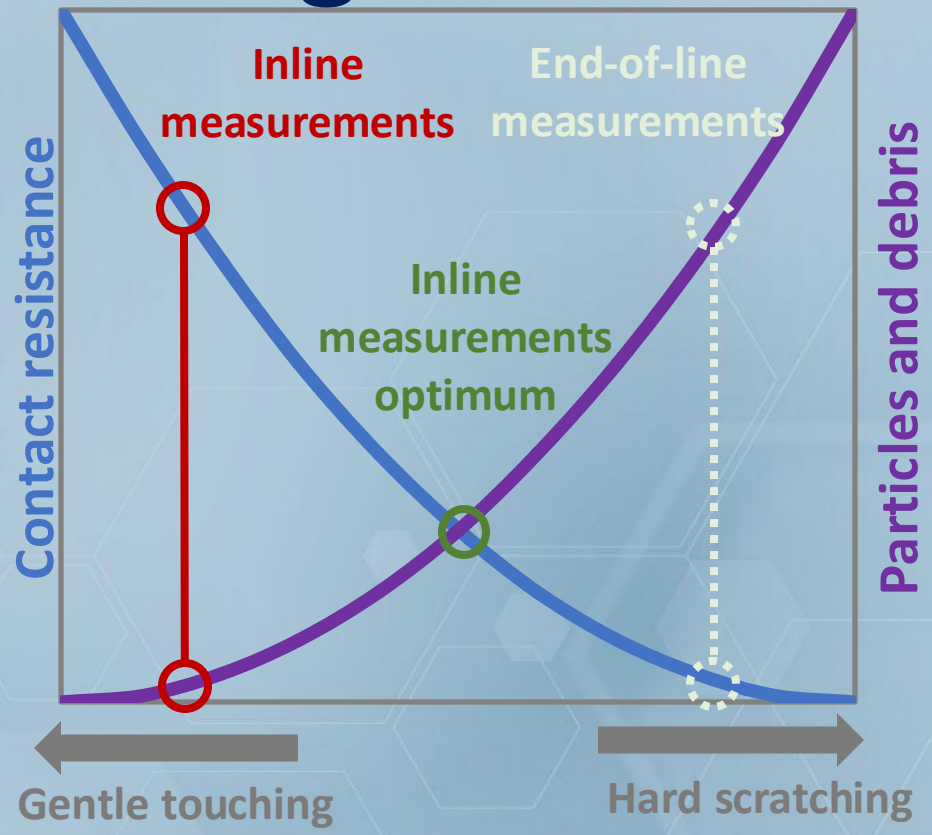
Reproducible contact = proper method on equal wafers

What is reliable and damage free

Wafer+Prober system full of variations:

Wafer variations	Prober variations
• Layout • Dielectric thickness • Metal+Diel hardness • Planarity • …	• Probecard • Positioning • Overtravel • Cleaning • …
Technology + Design	Testing

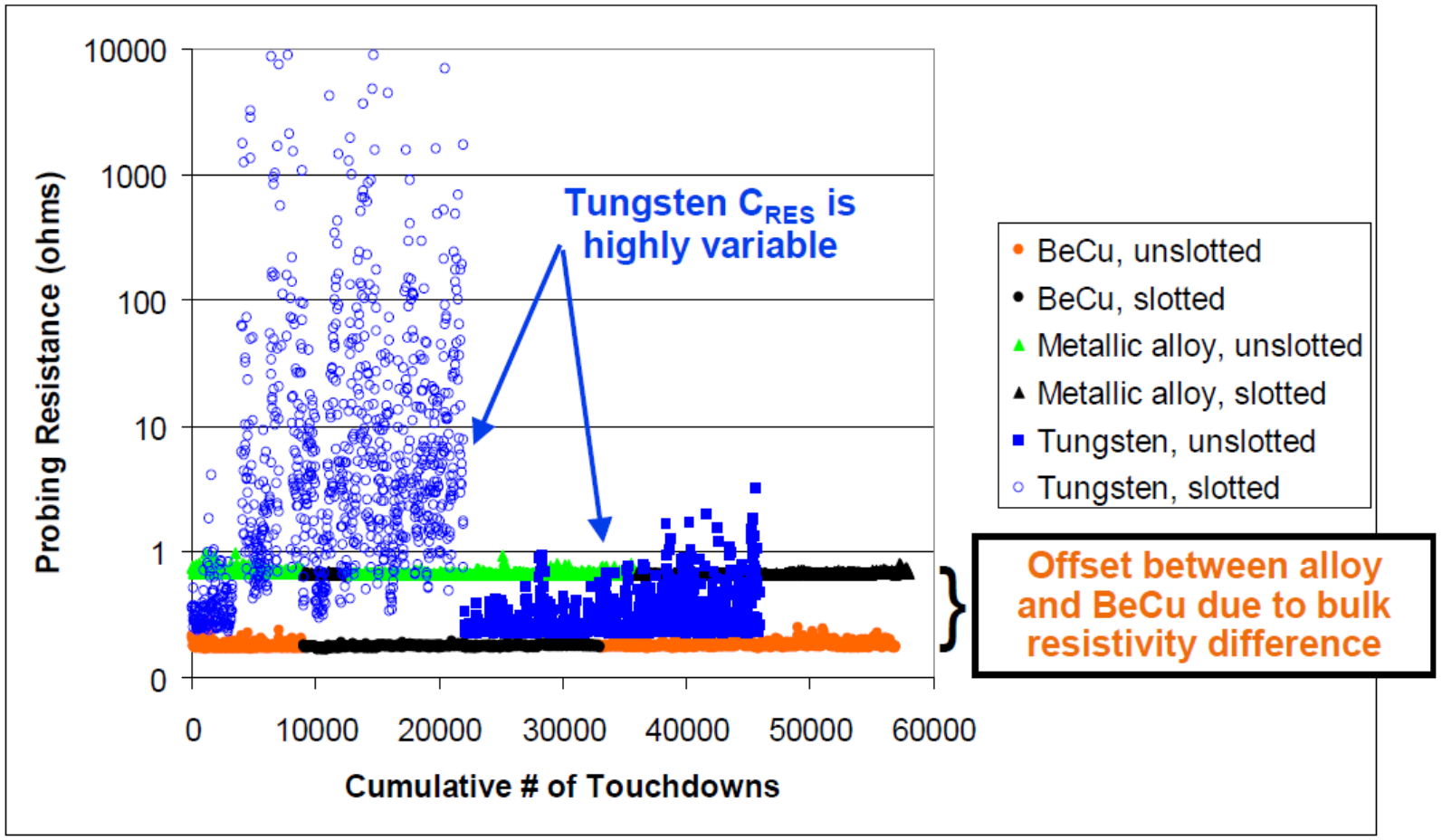
Reliable contact = no dependance on process variation



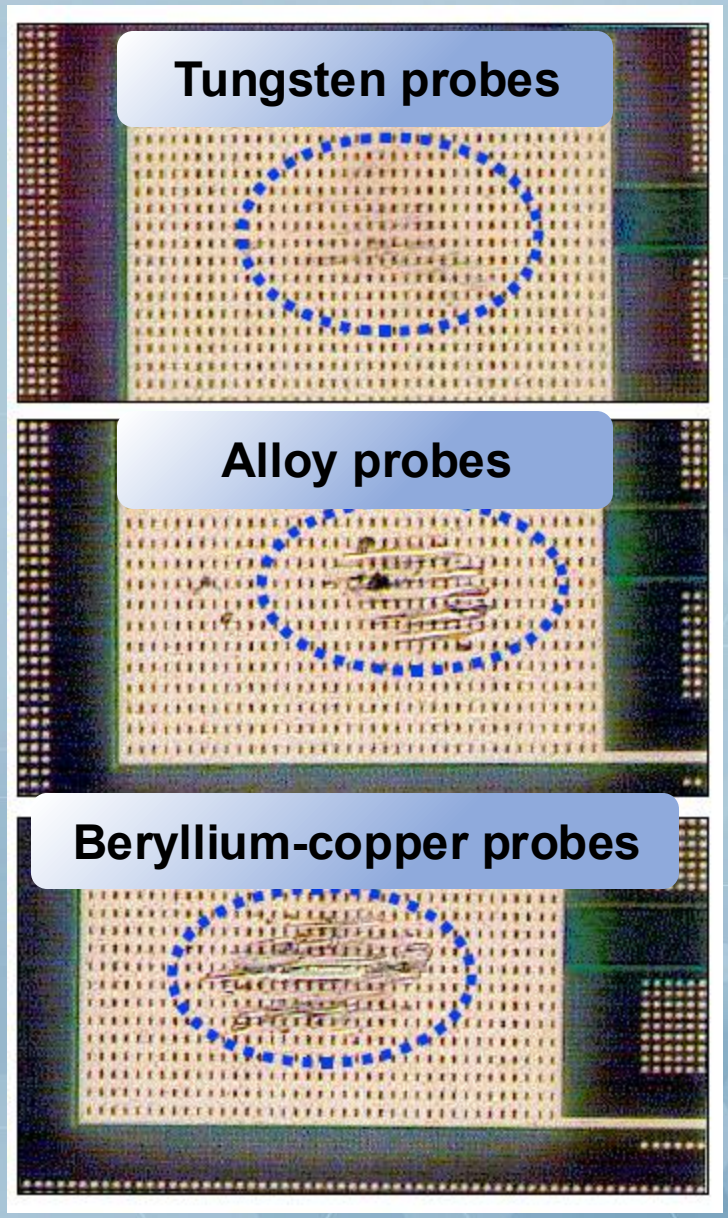
Critical points:

- **Underlying metal layer**
- **Material on wafer**
- **Airborne particles**

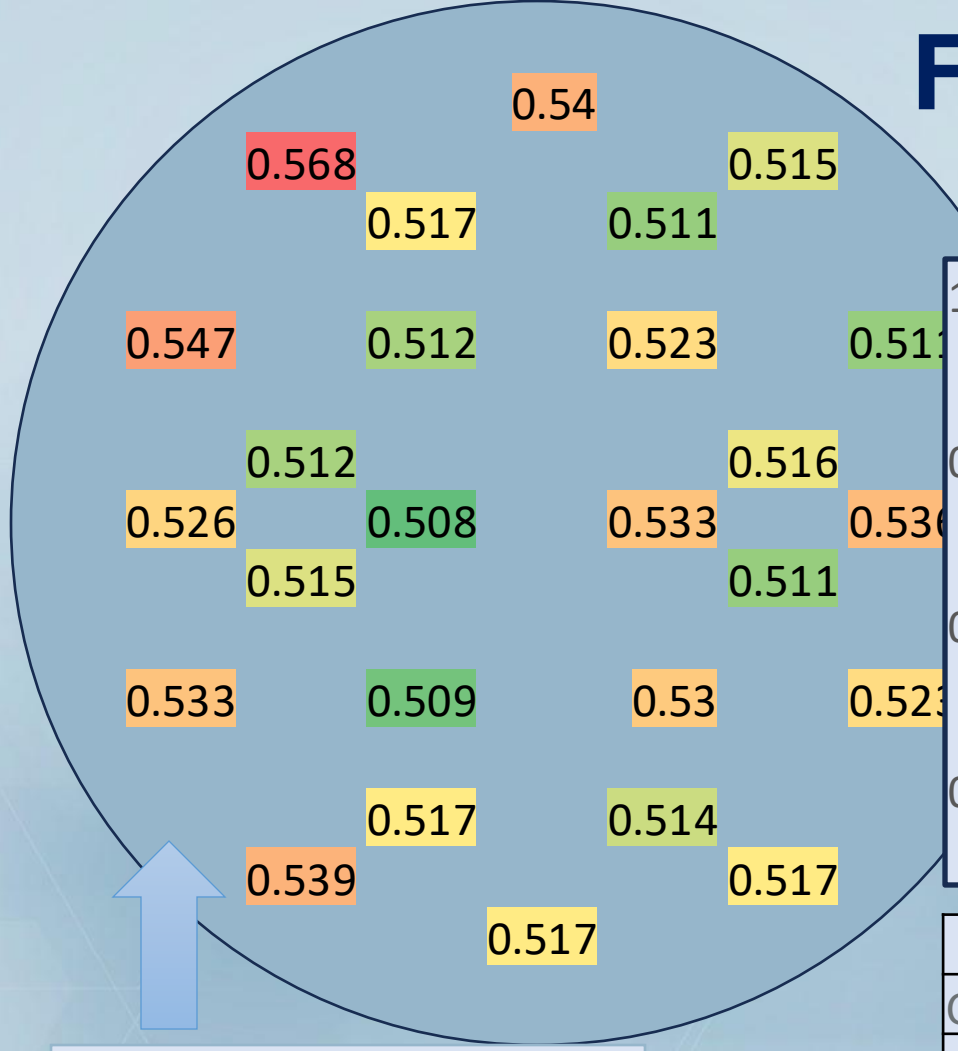
Are we alone?



In-line probing of bare copper pads, Intel, Texas Instruments, Jerry Broz, Chrissie Manion, Rey Rincon, SWTW 2000, 14th of June

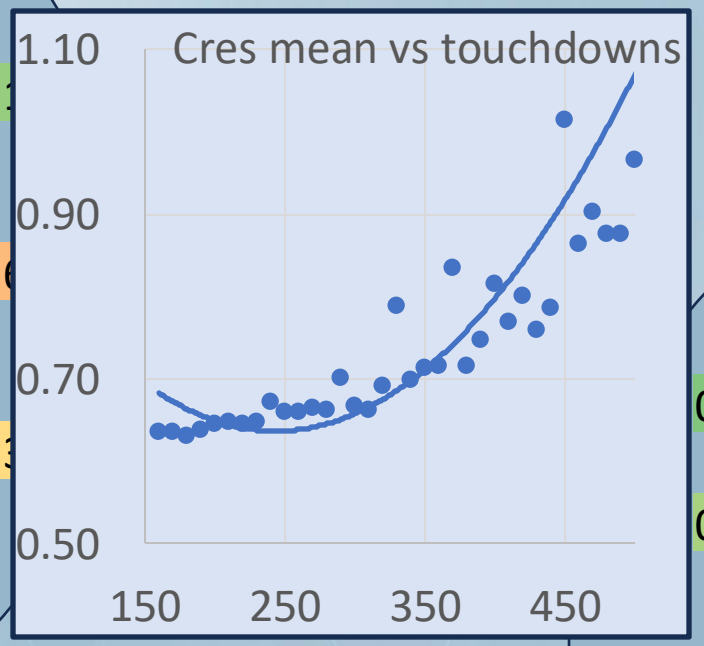


First measurement results



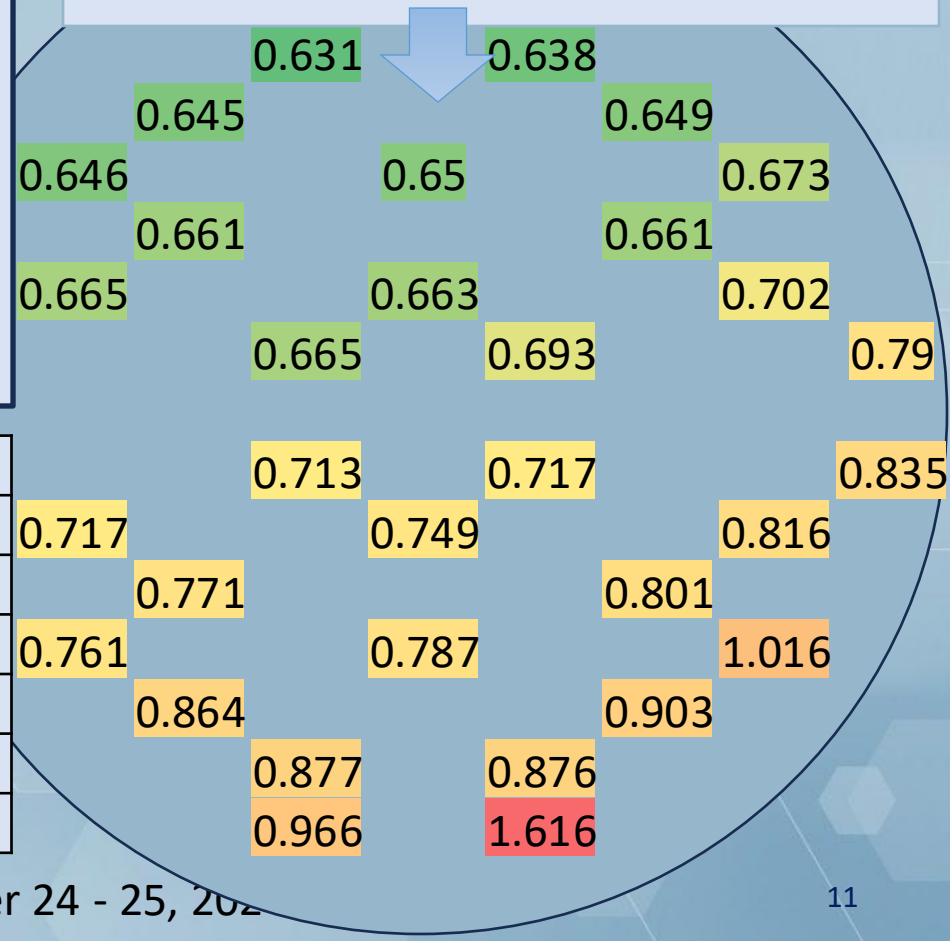
Result of 26 shorted pads tests

We will start from recommended frequency of cleaning to be safe



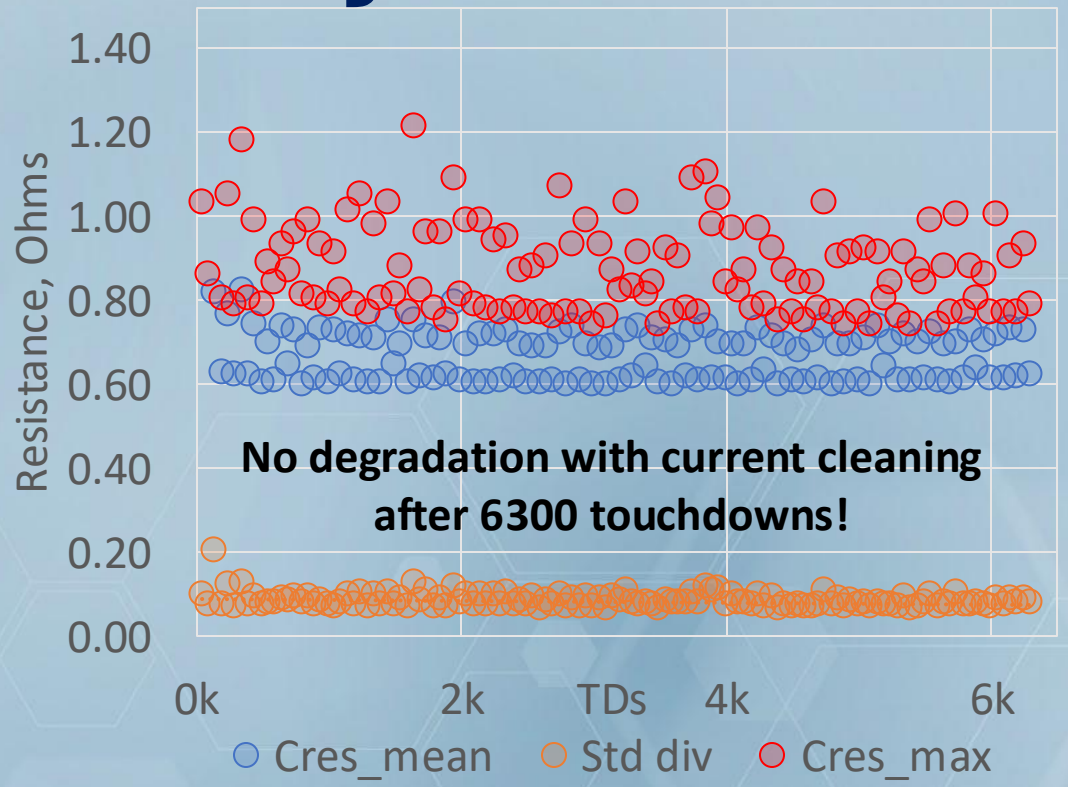
	Result	Criteria
Cres_mean	0.71	5
Mean h1	0.73	-
Mean h2	0.70	-
Std div	0.11	1.5
Kh1h2	0.04	0.2
Cres_max	0.96	8

- Standard wafers
- 9 TDs, 10th is shorted pad test, 36 dies.
- R mean +10% after 300 touchdowns.
- Recommended TD before cleaning is 100

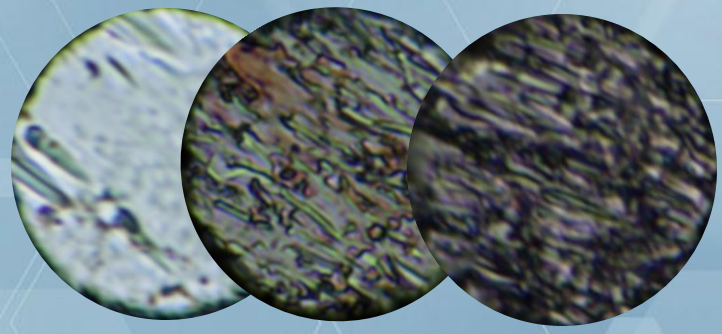


First reproducibility check

				0.76	0.66			
		0.82	0.63	0.77	0.62	0.82		
	0.62	0.74	0.6	0.7	0.61	0.74	0.65	
	0.73	0.6	0.69	0.61	0.73	0.6	0.73	
0.62	0.72	0.61	0.71	0.6	0.71	0.6	0.75	0.65
0.69	0.6	0.75	0.62	0.71	0.61	0.71	0.62	0.8
0.61	0.69	0.6	0.72	0.6	0.72	0.61	0.73	0.62
0.69	0.6	0.69	0.6	0.69	0.61	0.72	0.6	0.74
0.61	0.69	0.6	0.68	0.6	0.69	0.61	0.72	0.61	0.73	0.64
0.71	0.6	0.7	0.6	0.69	0.62	0.72	0.61	0.74	
0.61	0.7	0.61	0.7	0.6	0.69	0.61	0.73	0.63	
0.71	0.6	0.69	0.61	0.68	0.6	0.7	0.61	0.74	
0.6	0.69	0.6	0.69	0.61	0.71	0.6	0.73	0.64	
	0.7	0.61	0.72	0.61	0.7	0.61	0.72		
	0.61	0.69	0.6	0.7	0.61	0.73	0.64		
		0.7	0.61	0.72	0.61	0.73			
			0.61	0.73	0.62				

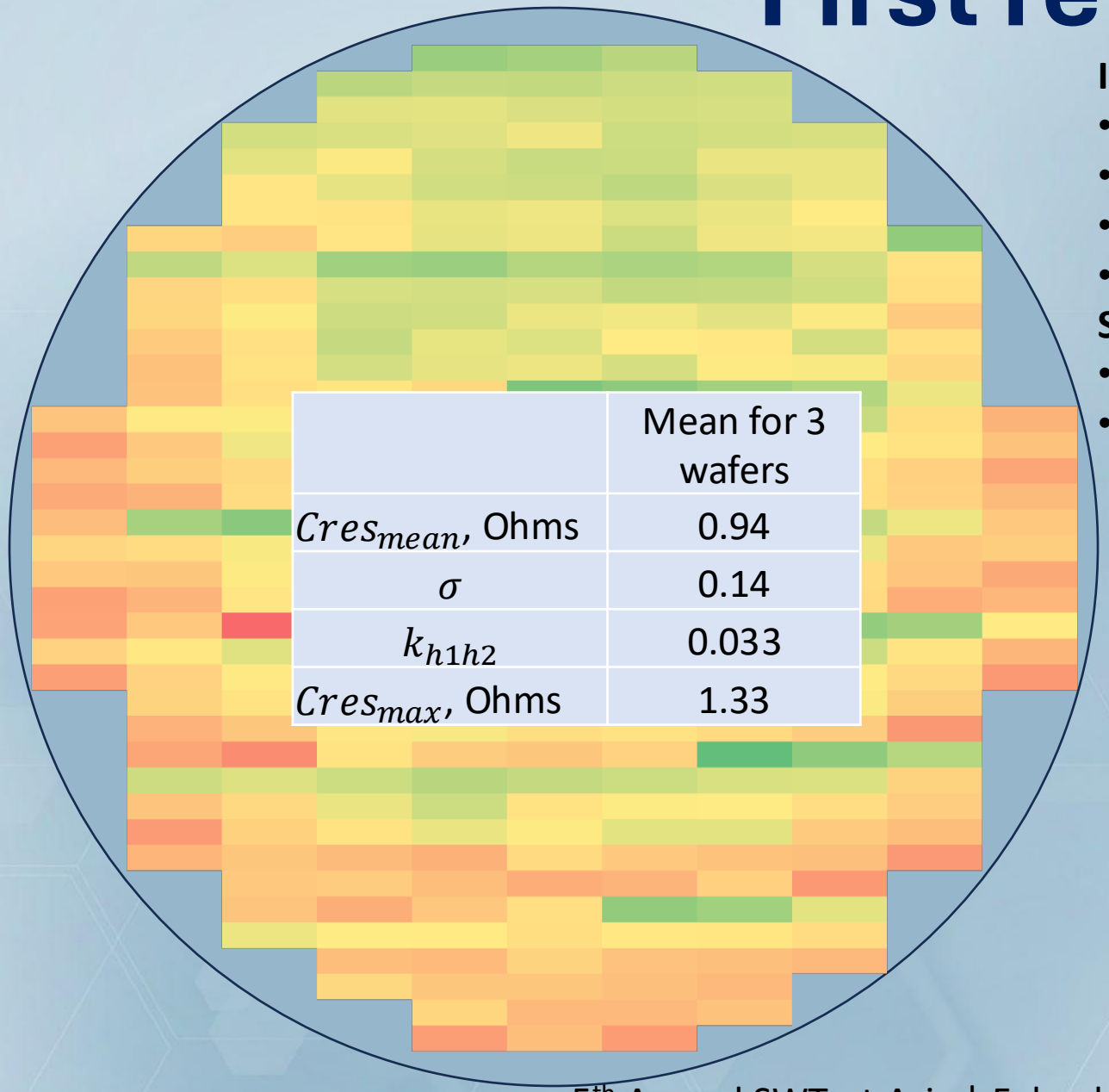


Several iterations for cleaning with presented cleaning materials



Fresh, used and cleaned tip of probecard

First reliability check



	Mean for 3 wafers
$Cres_{mean}$, Ohms	0.94
σ	0.14
k_{h1h2}	0.033
$Cres_{max}$, Ohms	1.33

Input:

- **3** experimental wafers **type A**
- **Gridded pads**
- **330 touchdowns** per wafer
- **24 pins** on probecard

Summary:

- **990** touchdowns
- **23760** data points

	Percentage of good tests		
	Wafer 1	Wafer 2	Wafer 3
$Cres_{mean}$	100%	100%	100%
σ	96%	91%	96%
k_{h1h2}	100%	100%	100%
$Cres_{max}$	99%	98%	99%
$Total$	95%	90%	94%

Criteria of good test:

$Cres_{mean} \leq 5\ Ohms$

$\sigma \leq 1.5$

$k_{h1h2} =\leq 0.2$

$Cres_{max} \leq 8\ Ohms$

Criteria of good wafer:
80% of tests are good

After 2 more wafers of type A probecard was considered like accepted

Particles generation

Automated check of particles > 1µm

Pre-measurements: 5246 defects

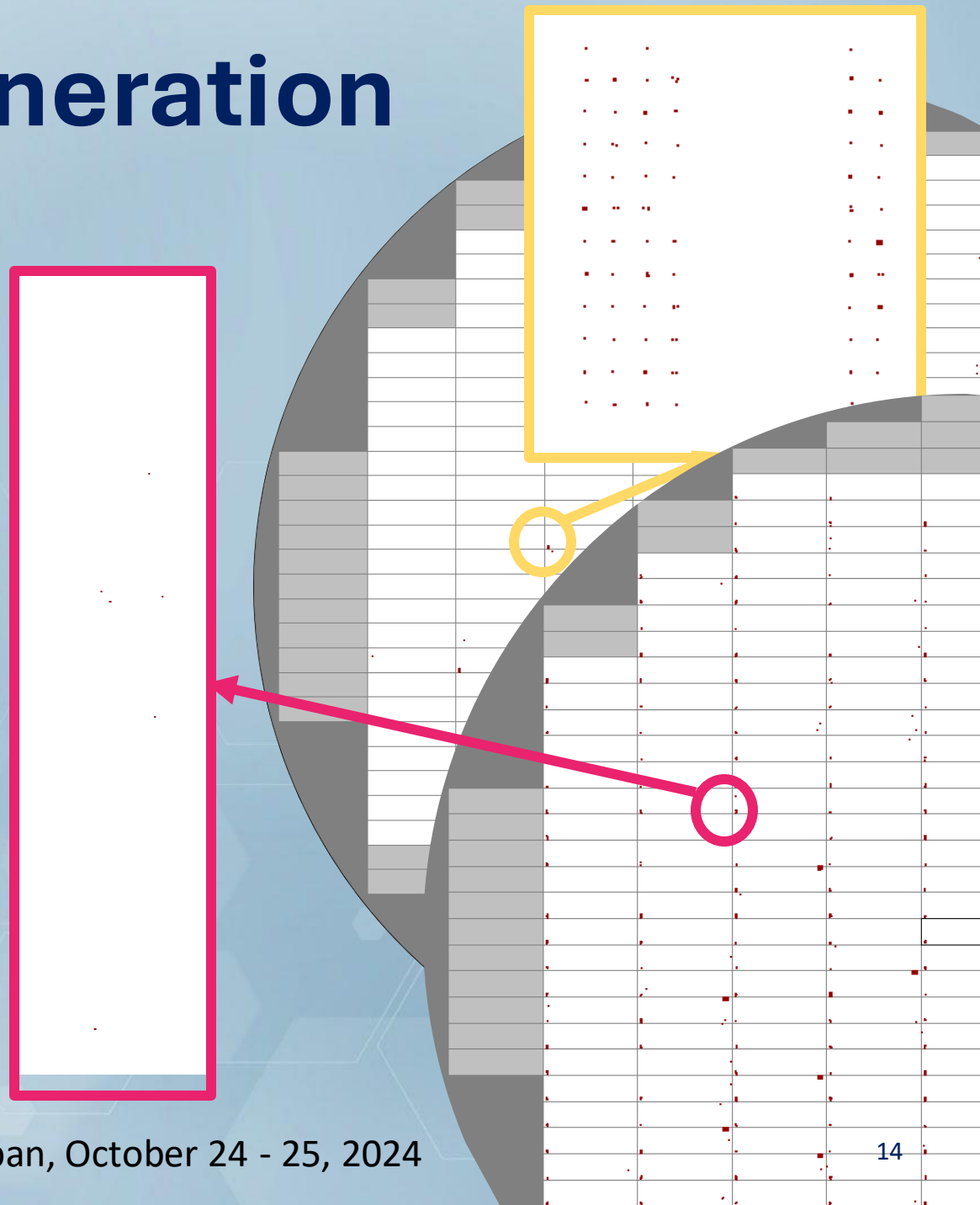
Baseline: 4622 defects

330 shorted pad tests x 24 needles → >**7920** adders **expected** because of scratching

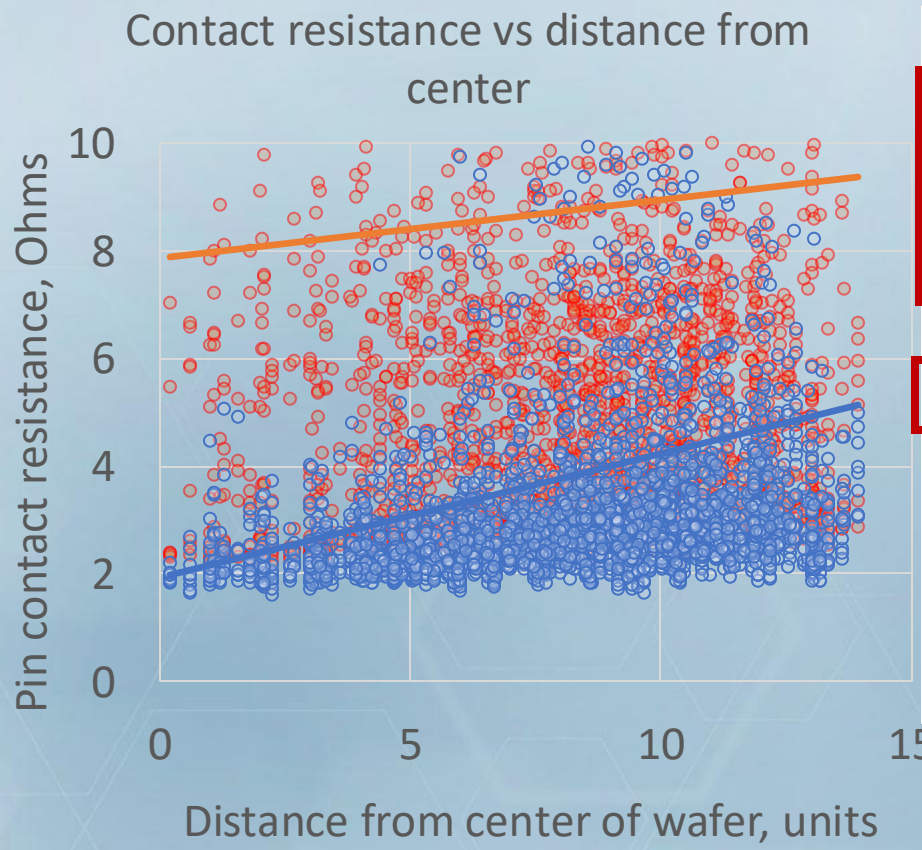
Post-measurements: 6075 defects

Total number of adders 1453

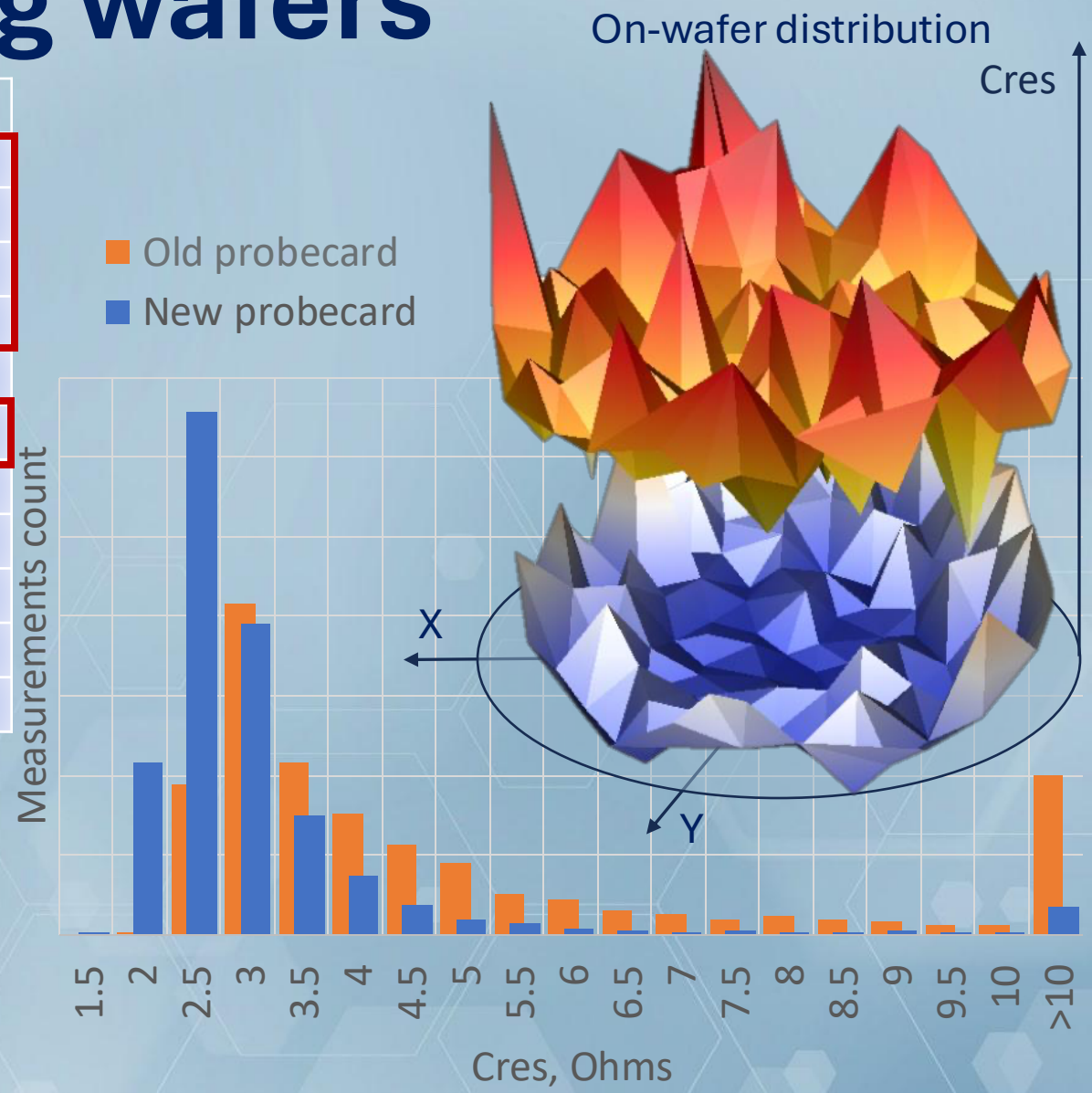
Better electrical results achieved with more gentle contacting!



Challenging wafers



	Old	New
max	118	59
99.5%	71	28
97.5%	41	17
90.0%	22	5.32
75.0%	7.94	3.43
50.0%	4.62	2.76
25.0%	3.00	2.32
10.0%	2.66	2.07
2.5%	2.42	1.88
0.5%	2.29	1.78
min	2.15	1.59



Results of probecard on experimental wafers type B:

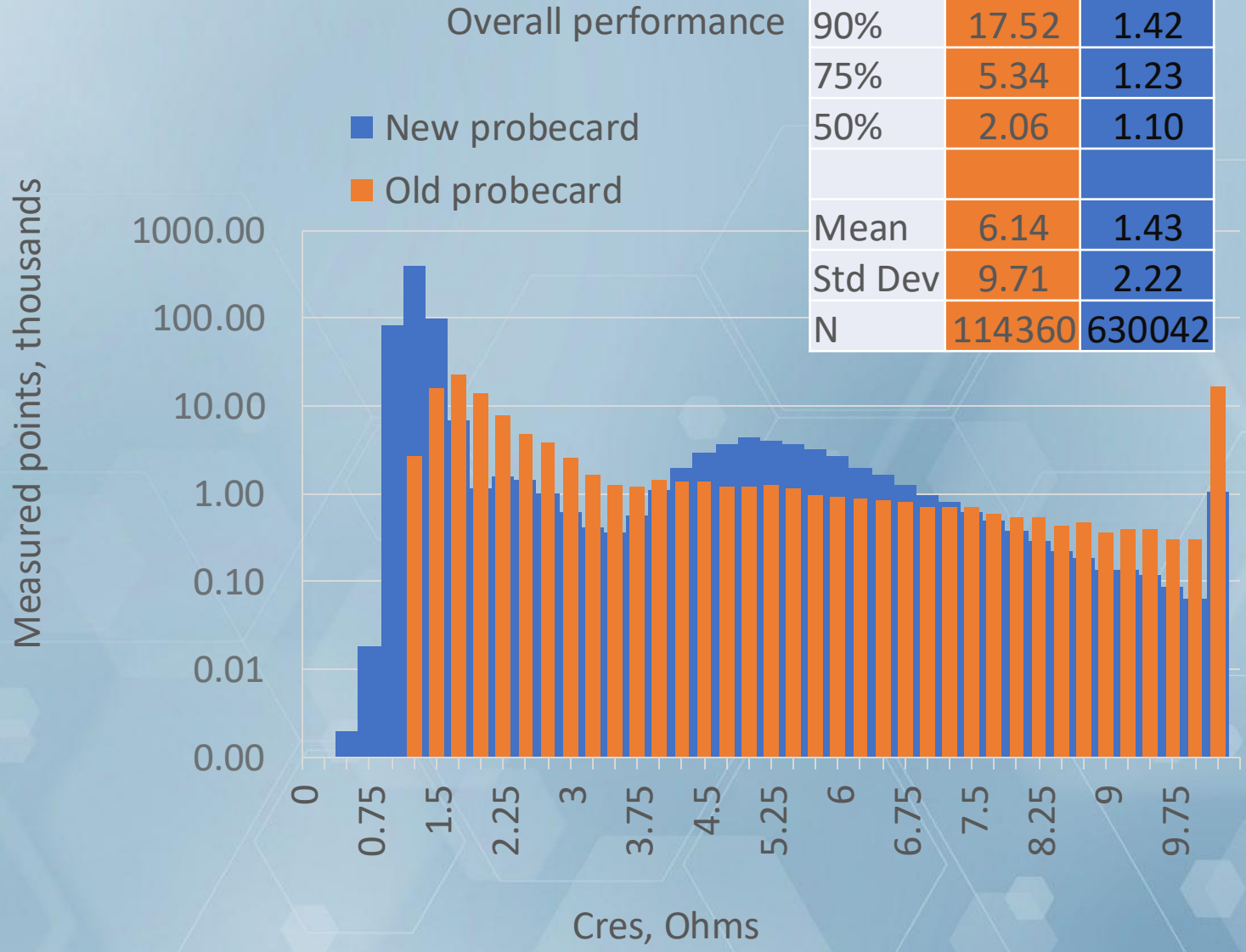
- Lower mean value
- 90% of points <5.3 Ohms
- Problems with resistance only near the edge of wafers

Summary

New probecard:

- **Improvement in contact resistance of standard and experimental wafers**
- **Less pad damage**
- **Less outliers**
- **Better uniformity**
- **Better electrical characteristics**

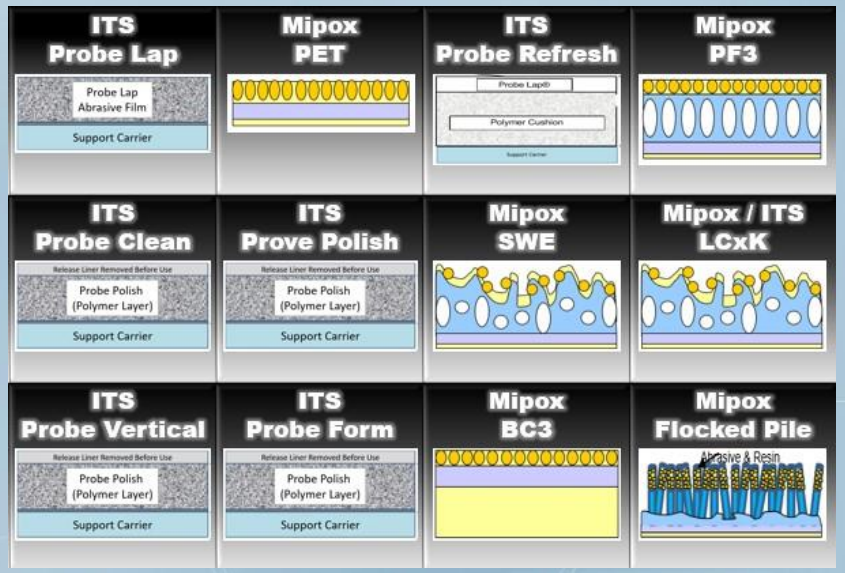
	Old PC	New PC
99.5%	51.92	7.48
97.5%	36.28	5.53
90%	17.52	1.42
75%	5.34	1.23
50%	2.06	1.10
Mean	6.14	1.43
Std Dev	9.71	2.22
N	114360	630042



Roadmap

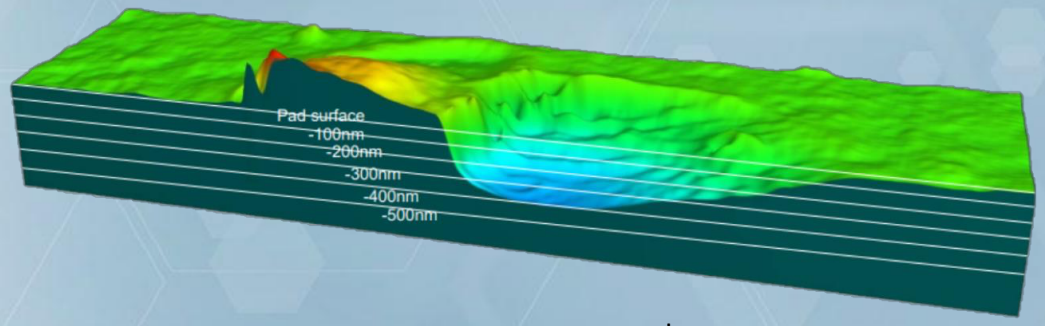
Still challenging:

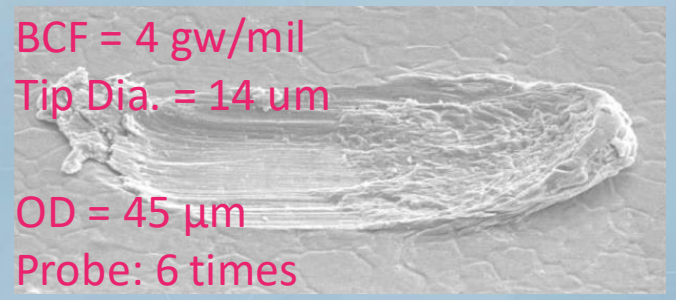
- Research nature doesn't allow to collect big statistics on same types of wafers
- One probecard fits all technologies
- Cleaning strategy for different BEOL materials

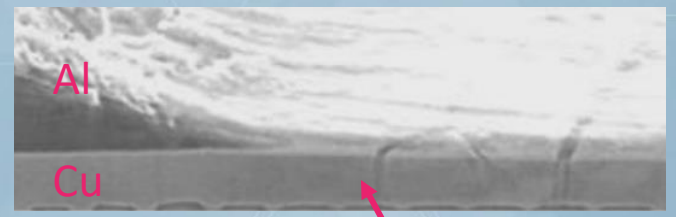


Next steps:

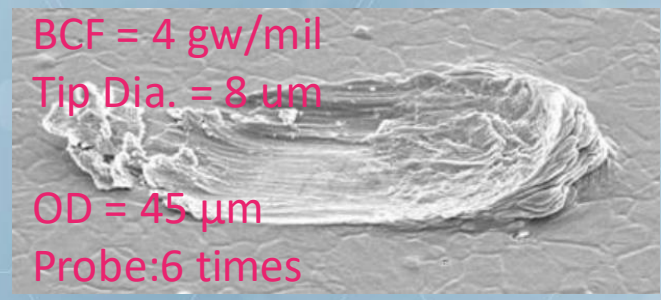
- Optimize cleaning: new material + touchdowns
- Wafers with exotic materials
- Other overdrive, double touch, undertravel
- Optical inspection procedure and criteria
- Statistics

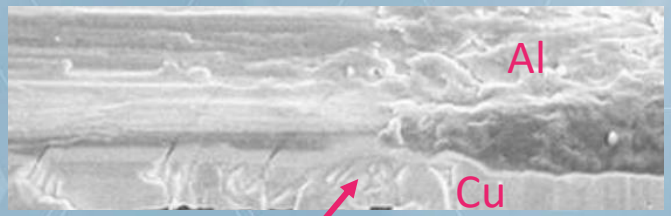






No deformation of underlayer





Damage of underlayer

Bond Pad Damage Tutorial, Ken Karklin, Jerry Broz, Bill Mann, IEEE SWTW

Thank you!

SW Test Asia 2024 chairs, Steering Committee and coordinators

Especially Jerry BROZ, Masatomo TAKAHASHI

and Haruko YOSHII

for invitation, opportunity to present and support

Participants and speakers

for attention and interesting presentations

imec

Especially my colleagues Geert GOUWY, Marc Van DIEVEL and my manager Gregor VERCAIGNE

For the great teamwork and ability to be a part of the team