Aluminum Probe Pad Thickness and Properties for Stable Parametric "Probe-Ability"

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Background

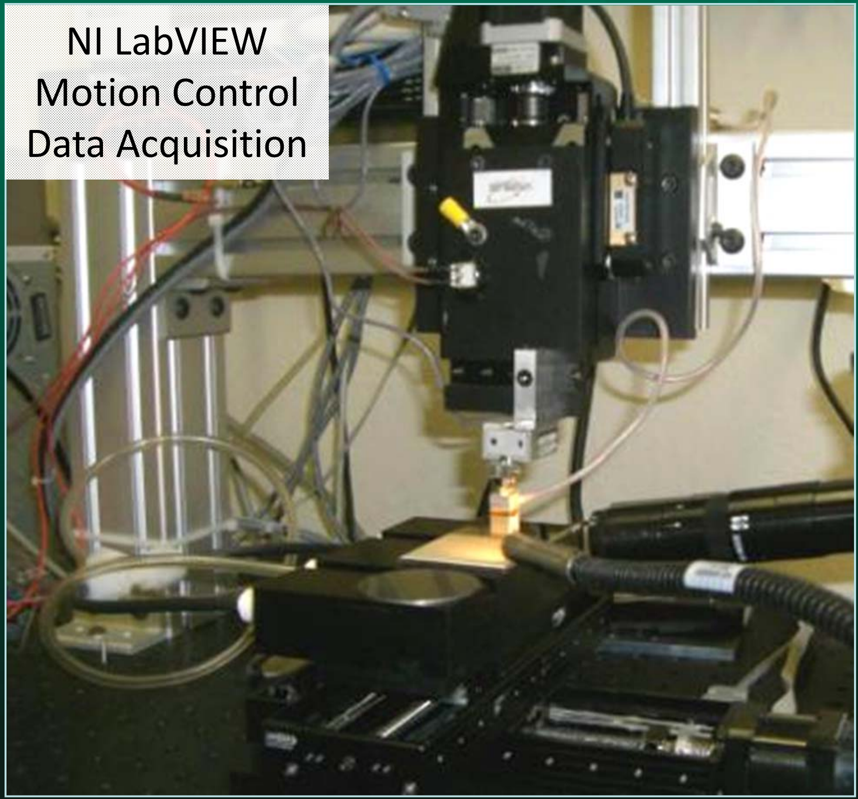
- **Experienced poor life time of Takumi probe cards**
  - High amount of Al debris on the probe tips
  - High amount of cleaning touchdown online
  - Additional cleaning offline / outside
  - Unstable CRES performance
  - Different behavior seen for different pad metal thickness

Overview

- **Objectives**
  - Perform Benchtop Testing using TI Supplied Wafers
    - Execute TDs on Al-wf to assess accumulation and CRES stability for different Al-thickness
    - Execute TDs on Al-wf + Cleaning to assess cleaning efficiency
  - Apply insight and learning from Benchtop testing to Production Environment
- **Materials**
  - Takumi dutlet with two wired pins was provided by HTT/FFI Dresden
    - Four-wire CRES testing was performed across two pins
  - Aluminum wafers supplied by TI Freising FAB representative of technology nodes
    - Al-thickness = 6kA / 15kA / 30kA
- **Methods**
  - Apply overdrives matched to production
    - On wafer: electrical measurements performed from first touch to (1) 30um and (2) 60um
    - On cleaning material: cleaning performed at 60um
  - Assess cleaning performance for CRES and debris removal

Controlled Test Conditions

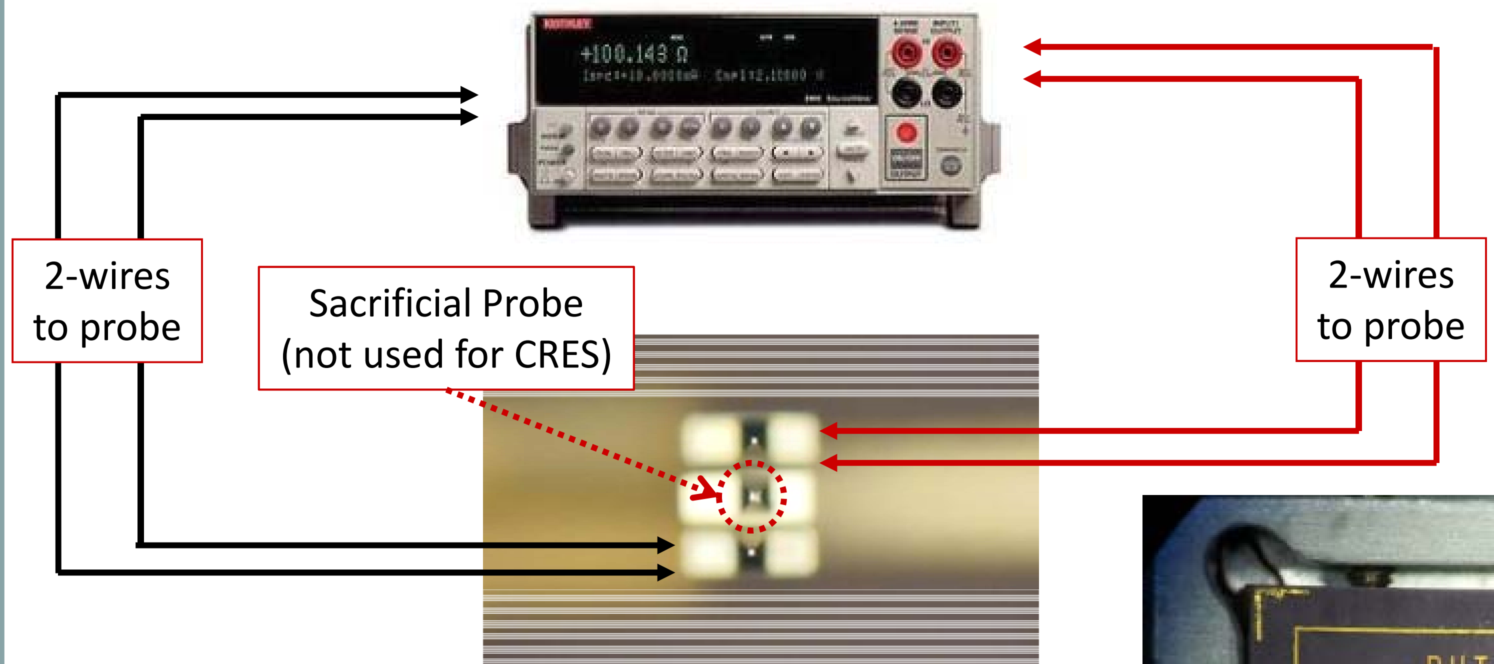
- **ITS Bench-top System for material characterization and probe performance testing**



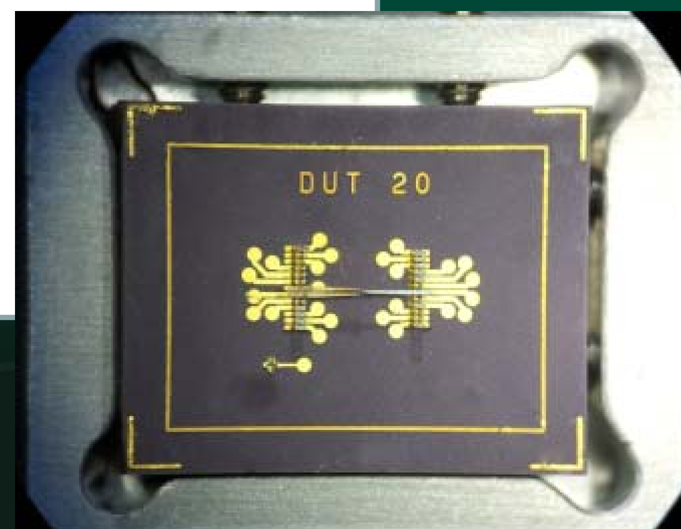
- **Overview**
  - Variable z-speed and z-acceleration.
  - Synchronized load vs. overtravel vs. CRES data acquisition.
  - High resolution video imaging and still image capture.
  - Thermal chuck for elevated temperature testing.
  - Current forcing and measurement with Keithley 2400 source-meter.

ITS LTU Probe-Gen System

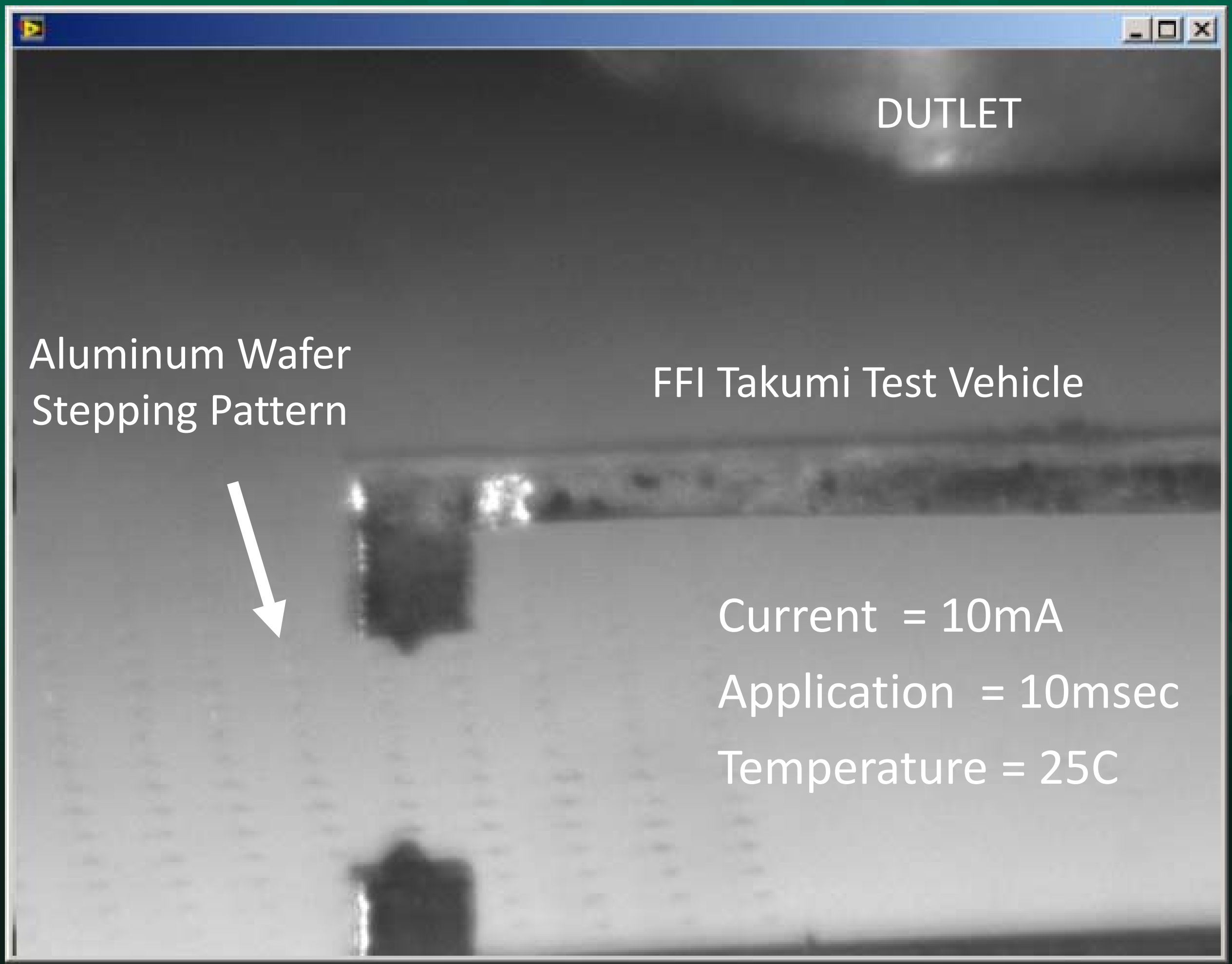
Benchtop CRES Measurement



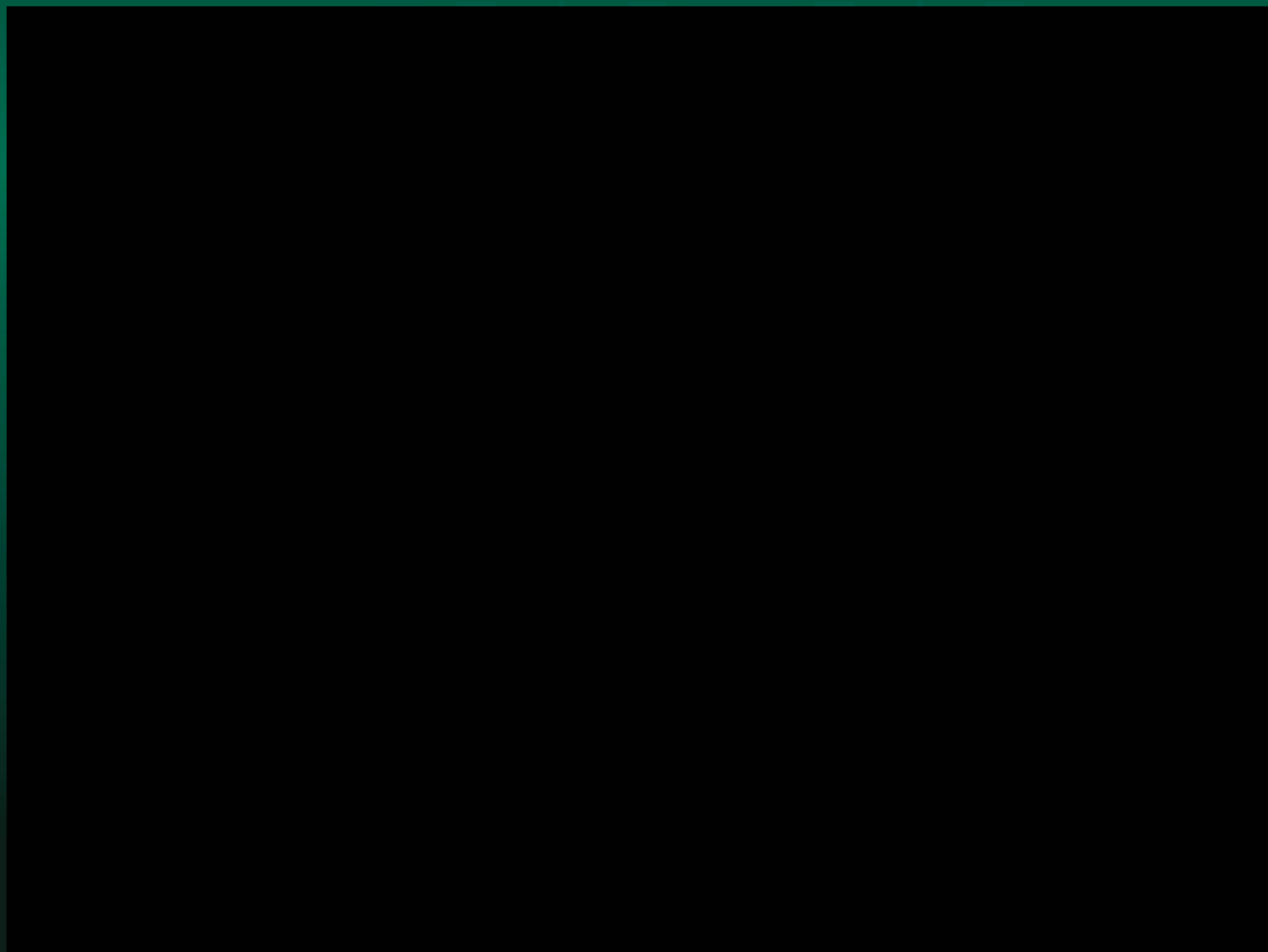
4-wire Kelvin
CRES Measurement



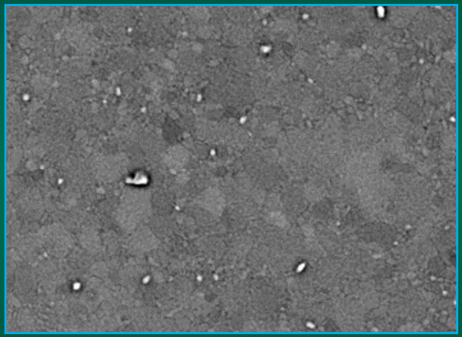
Test Setup Overview



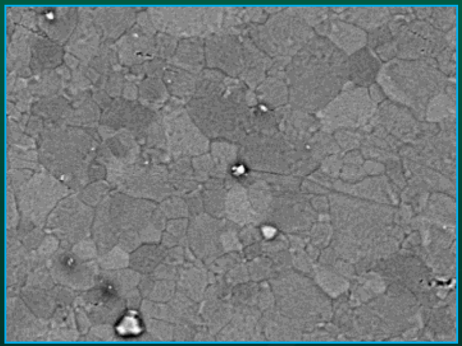
Imaging of Takumi TDs



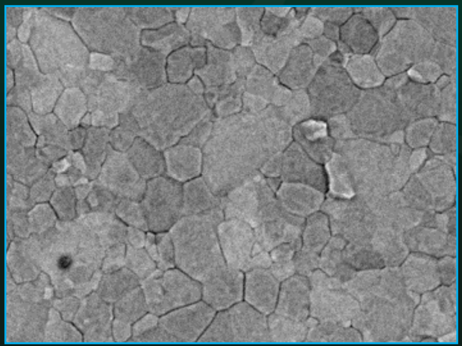
6kÅ/15kÅ/30kÅ Thick Aluminum Wafer



- **6kÅ thick Aluminum Layer**
  - Small grain structures with some hillock-like features
  - EDS shows aluminum and titanium species



- **15kÅ thick Aluminum Layer**
  - Large grain structures
  - EDS shows aluminum and trace titanium species



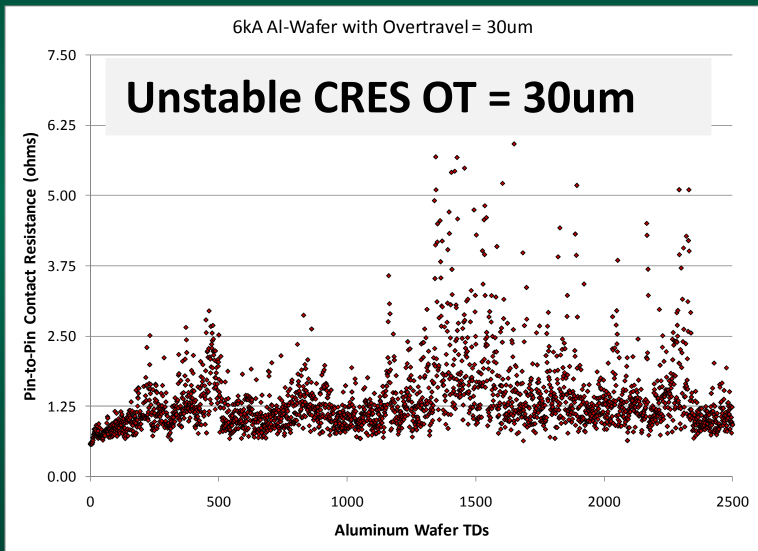
- **30kÅ thick Aluminum Layer**
  - Very large grain structures
  - EDS shows aluminum and no trace titanium species

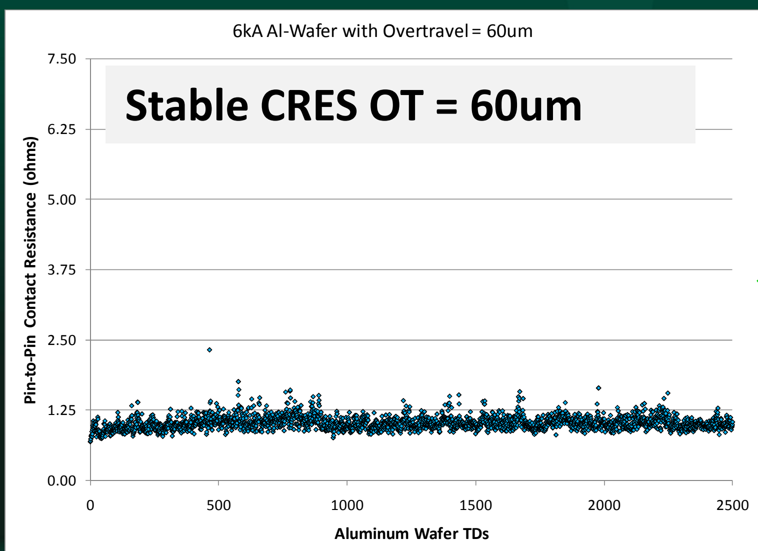
Benchtop Methods for Quantifying CRES Improvement

- **CRES vs. Touchdown Charts –**
  - Scatter plots demonstrate unstable CRES after multiple touchdowns
  - Advantages:
    - Demonstrate CRES stability during wafer test
    - Indicative of when cleaning is required to reduce CRES
  - Disadvantages:
    - Difficult to assess incremental changes in CRES behavior

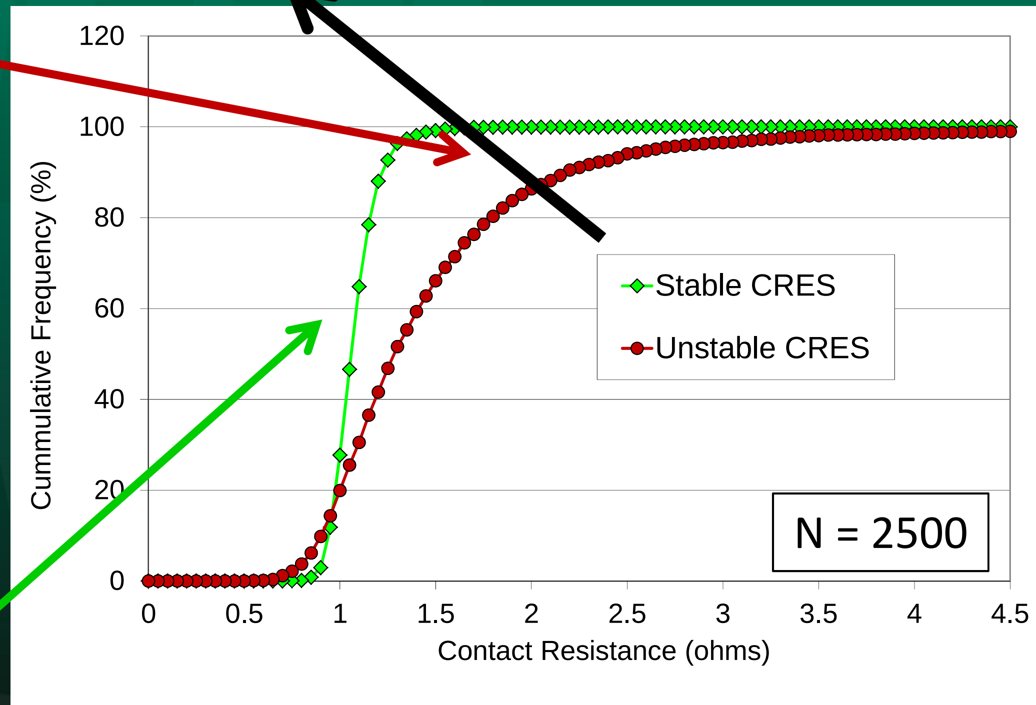
- **Cumulative Frequency Distribution (CFD) Charts –**
  - CFD plots show the observations falling in (or below) a specified limit and the shape of the curve indicates CRES stability "level"
  - Advantages:
    - Provides an easy way to compare different large data sets
    - Incremental changes in CRES behavior can be identified
    - Width of CRES distribution can be determined
  - Disadvantages:
    - Does not include a time component

CRES Performance Charts

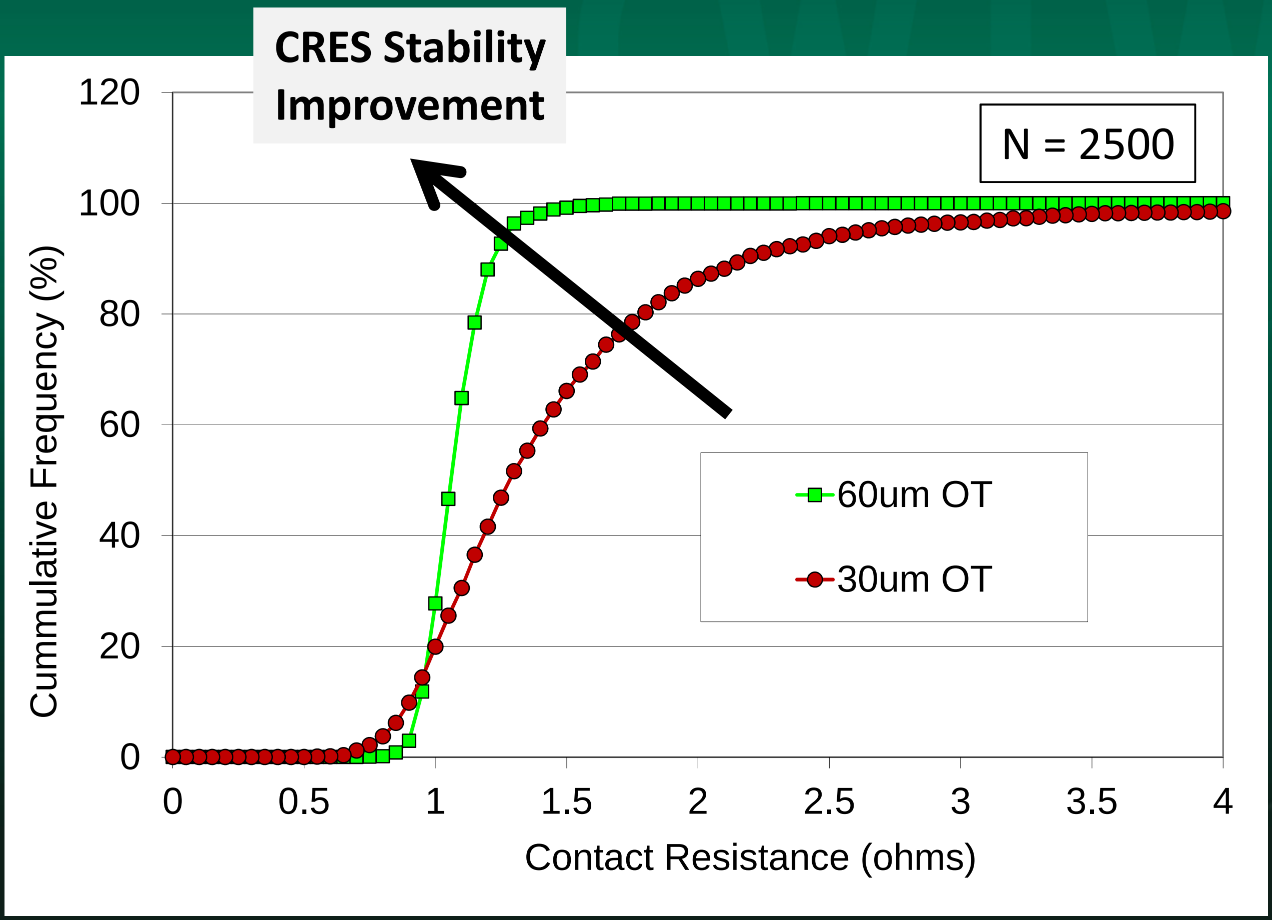




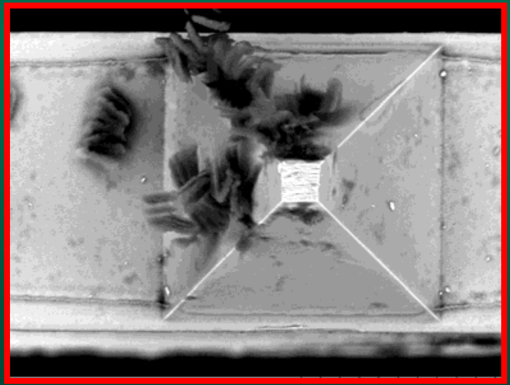
CRES Stability Improvement



6kÅ Thickness Wafer - No Cleaning

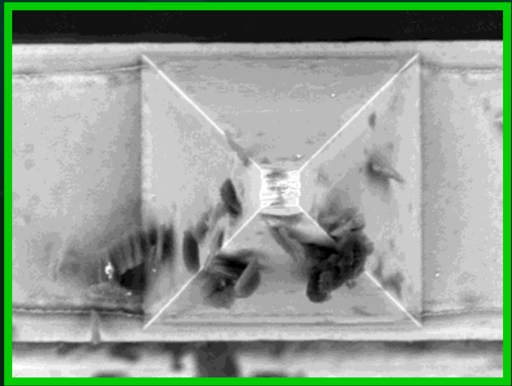


Wfr Overdrive = 30um

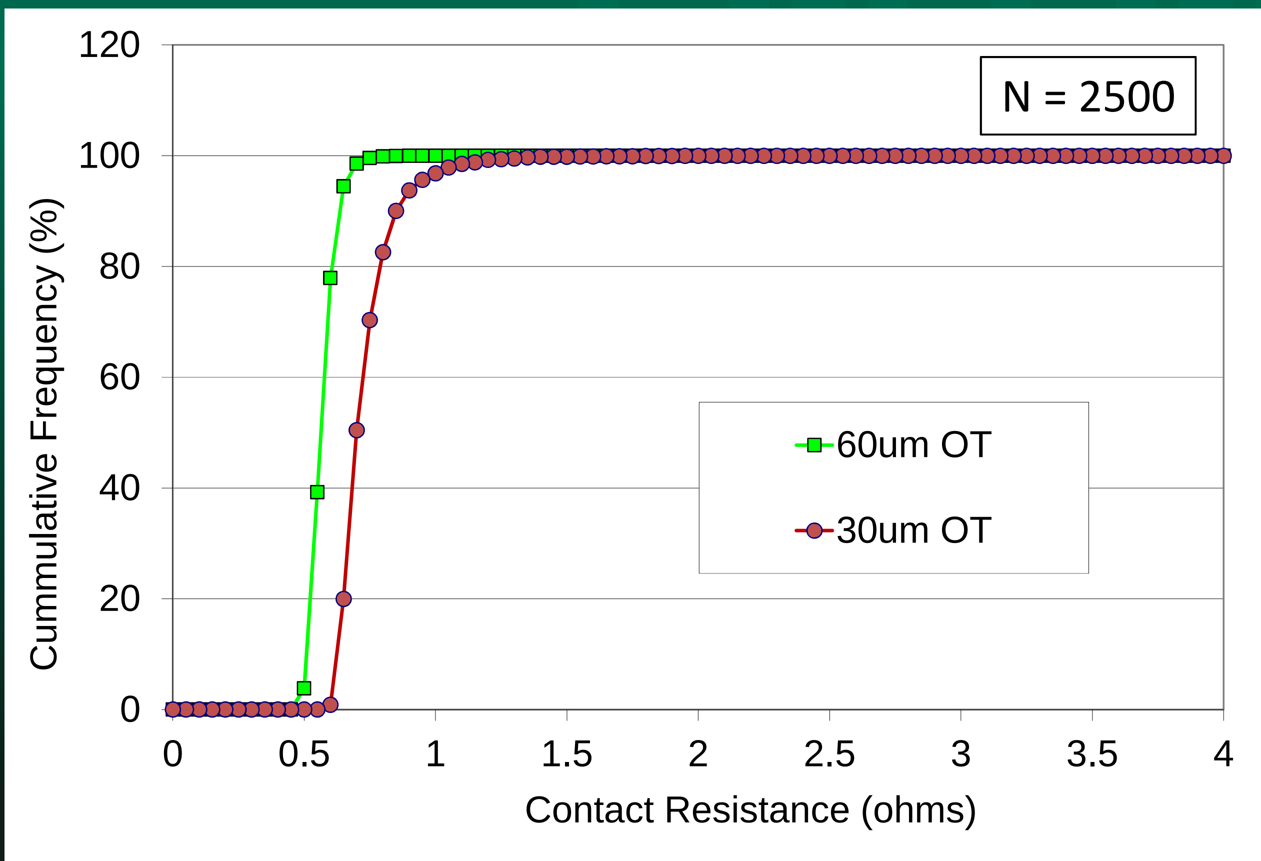


Scrub Direction

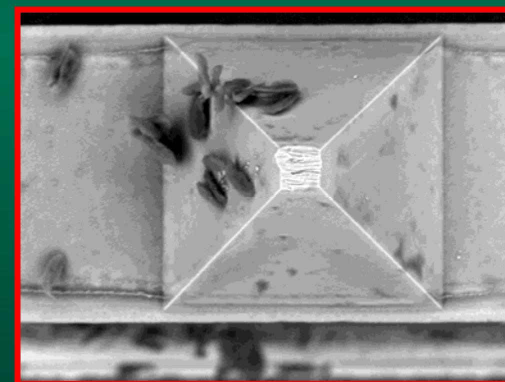
Wfr Overdrive = 60um



15kÅ Thickness Wafer - No Cleaning

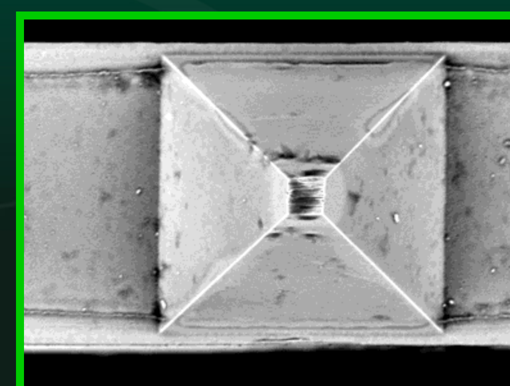


Wfr Overdrive = 30um

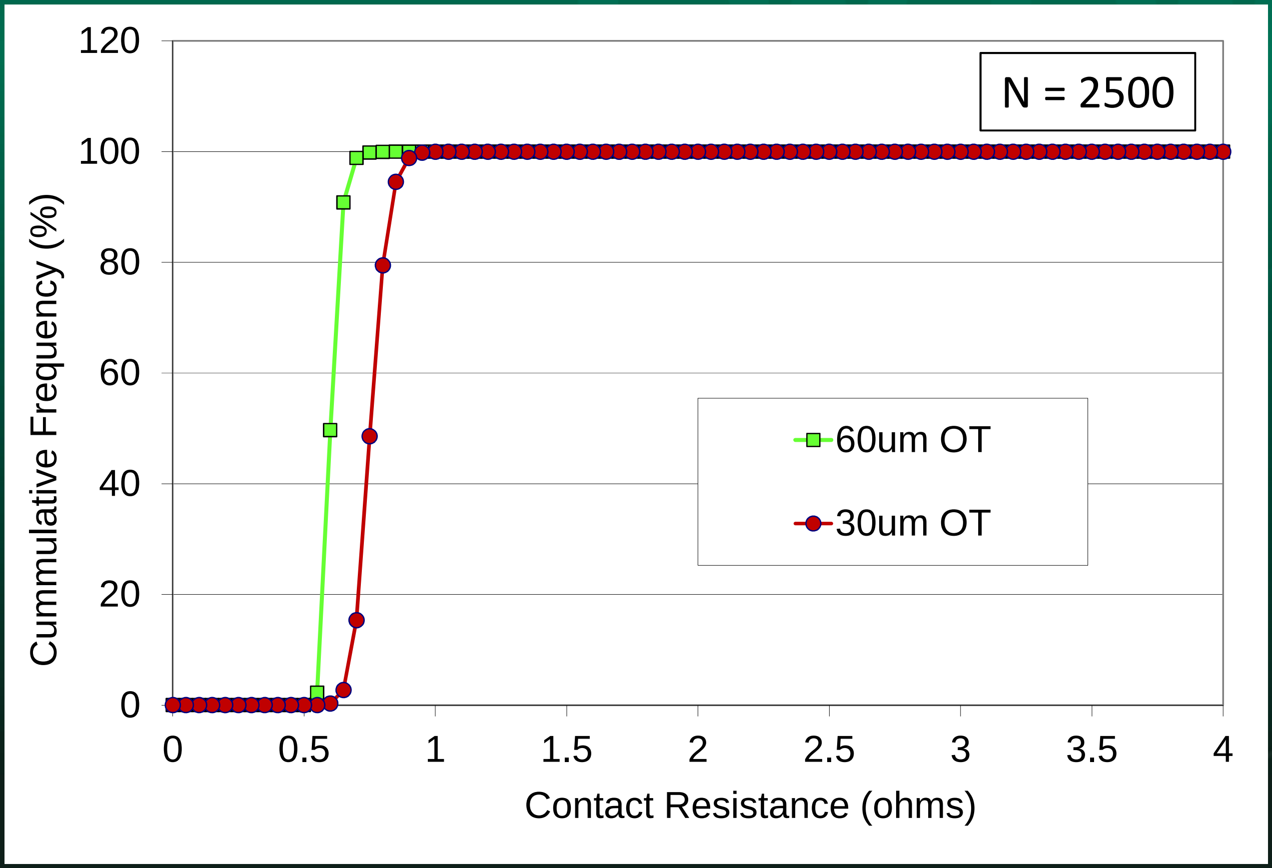


Scrub Direction

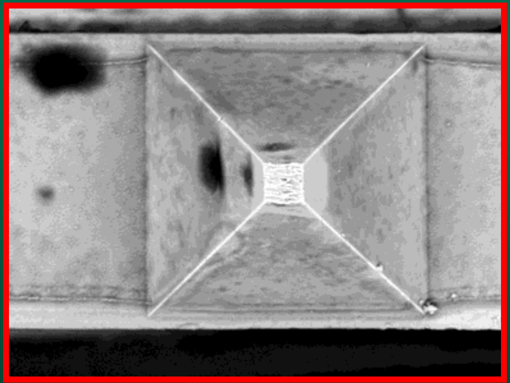
Wfr Overdrive = 60um



30kÅ Thickness Wafer - No Cleaning



Wfr Overdrive = 30um



Scrub Direction

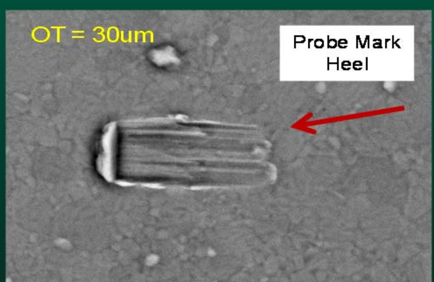
Wfr Overdrive = 60um

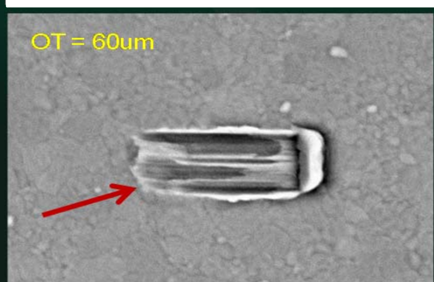
Probe Mark Assessment

6kÅ Wafer

- OT = 30um
- Length = ~10 to ~14um
- Depth = ~3.5 to ~3.8kÅ

- OT = 60um
- Length = ~18 to ~20um
- Depth = ~5.0 to 5.4kÅ

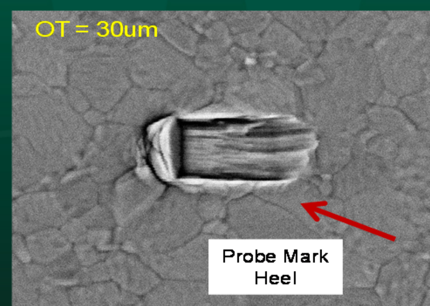


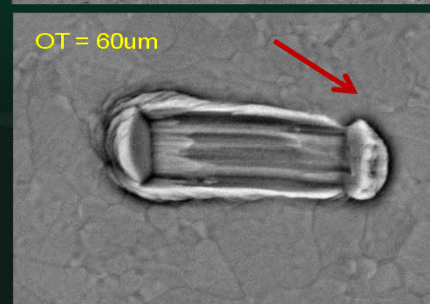


15kÅ Wafer

- OT = 30um
- Length = ~12 to ~14um
- Depth = ~8.0 to ~8.3kÅ

- OT = 60um
- Length = ~20 to ~22um
- Depth = ~12.0 to 12.3kÅ

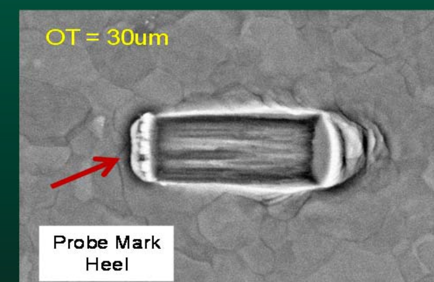


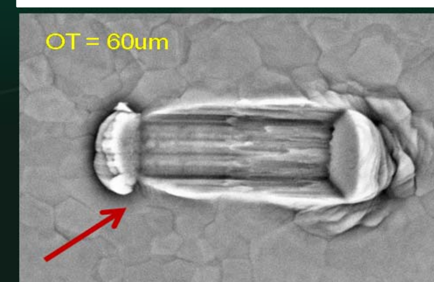


30kÅ Wafer

- OT = 30um
- Length = ~16 to ~18um
- Depth = ~14.6 to 16.2kÅ

- OT = 60um
- Length = ~22 to ~24um
- Depth = ~20.0 to 22.3kÅ





First summary …

- **Three wafers received TI-Freising**
  - 6kA, 15kA, and 30kA thick aluminum
- **SEM showed differences in the grain sizes, structures, and boundaries.**
  - 6kA had small grains and a large number of grain boundaries
  - 15kA had large grain structures and fewer grain boundaries
  - 30kA has very large grain structures
- **CRES performance and debris accumulation was different between wafers**
  - 6kA showed unstable CRES with a large amount of debris build-up.
  - 15kA showed relatively stable CRES with some debris build-up.
  - 30kA showed relatively stable CRES with minor debris build-up.
- **Probe marks size and depth differed.**

Cleaning Matrix Overview

- **Objectives**
  - Assess cleaning performance vs. Metal thickness
  - Obtain cleaning effects / efficiency with minimum cleaning parameter
  - Implement Probe Polish 150 (PP150) to maximize cleaning efficiency
- **Cleaning recipes executed for 30um and 60um probing OD**
  - 6kA = 100TD interval with PP150 at 60um with 5TD per cycle.
  - 15kA = 1000TD interval with PP150 at 60um with 5TD per cycle.
  - 30kA = 1000TD interval with PP150 at 60um with 5TD per cycle.

6kA Aluminum Wafer with Cleaning OD = 60um

PP 150 / 30um production OD

cleaning TDs	Cleaning Interval - x3 times repeated				
	50TDs	100TDs	200TDs	500TDs	1000TDs
5 TDs	x	1	x		
10 TDs					
20 TDs		reference	x		
40 TDs					

PP 150 / 60um production OD

cleaning TDs	Cleaning Interval - x3 times repeated				
	50TDs	100TDs	200TDs	500TDs	1000TDs
5 TDs	x	1	x		
10 TDs					
20 TDs		reference	x		
40 TDs					

15kA Aluminum Wafer with Cleaning OD = 60um

30kA Aluminum Wafer with Cleaning OD = 60um

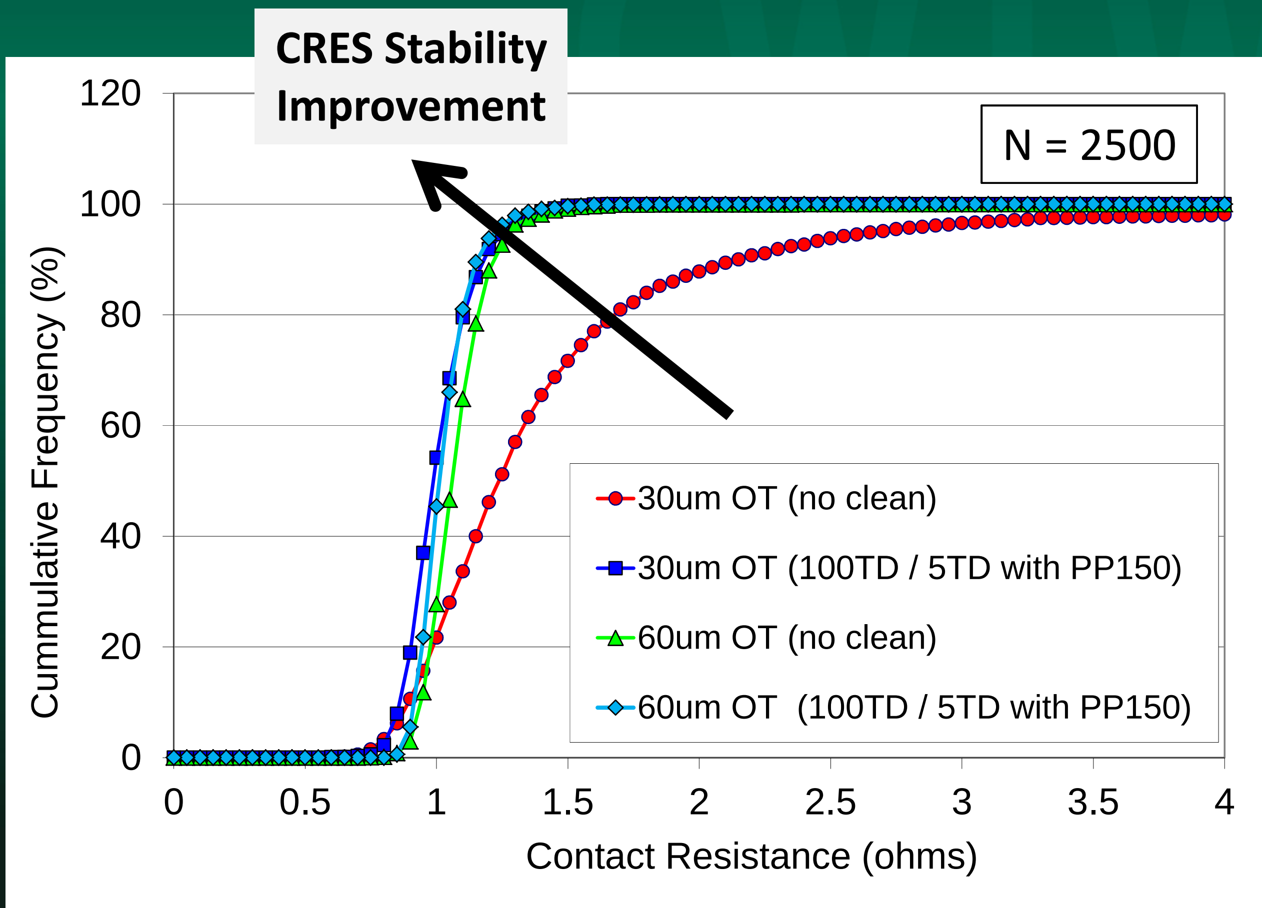
PP 150 / 30um production OD

cleaning TDs	Cleaning Interval - x3 times repeated				
	50TDs	100TDs	200TDs	500TDs	1000TDs
5 TDs		x			1
10 TDs					
20 TDs		reference			x
40 TDs					

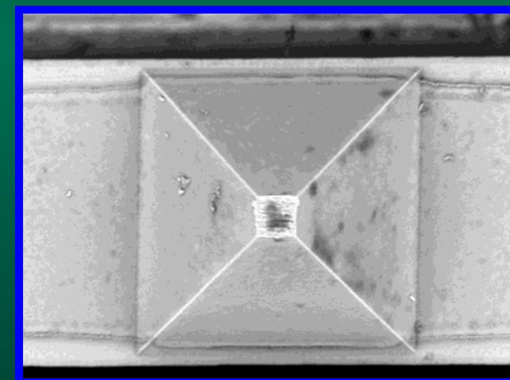
PP 150 / 60um production OD

cleaning TDs	Cleaning Interval - x3 times repeated				
	50TDs	100TDs	200TDs	500TDs	1000TDs
5 TDs		x			1
10 TDs					
20 TDs		reference			x
40 TDs					

6kÅ Thickness Wafer
PP150 Cleaning Performed

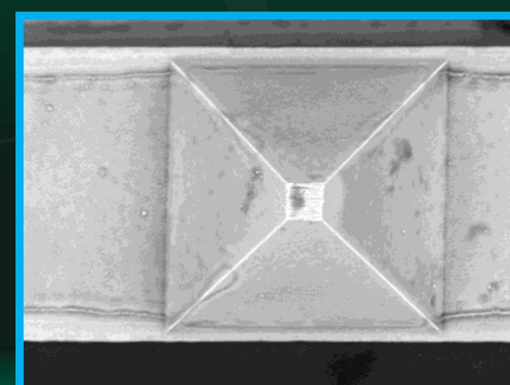


Wfr Overdrive = 30um
Cleaning = 60um (100 / 5)



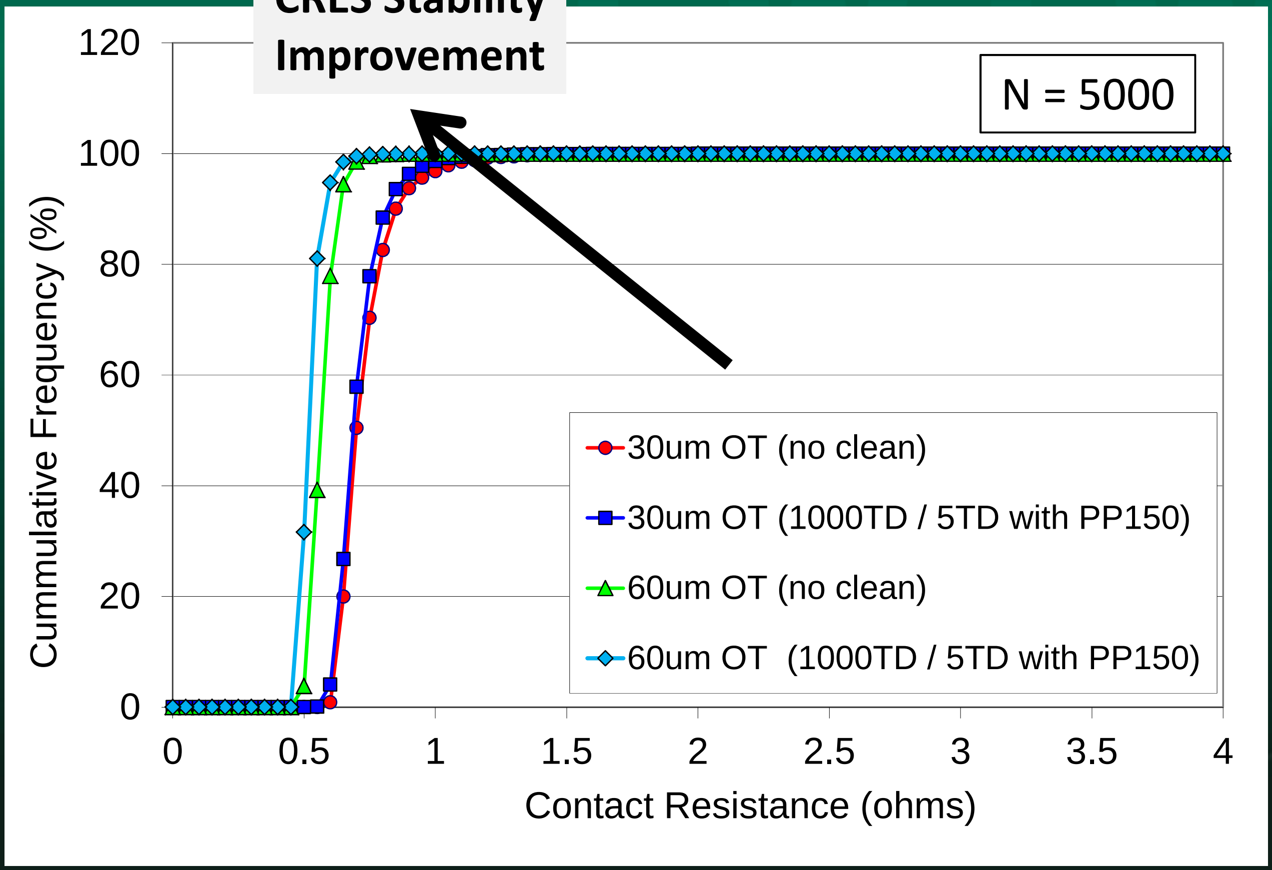
Scrub Direction

Wfr Overdrive = 60um
Cleaning = 60um (100 / 5)

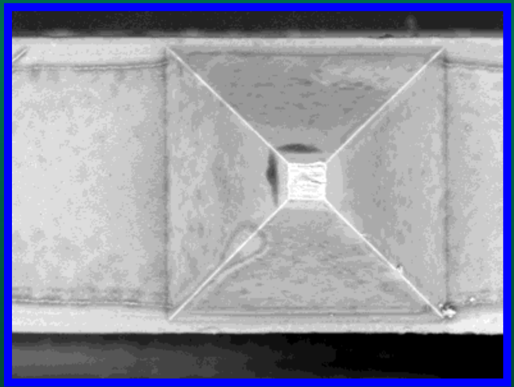


15kÅ Thickness Wafer
PP150 Cleaning Performed

CRES Stability Improvement



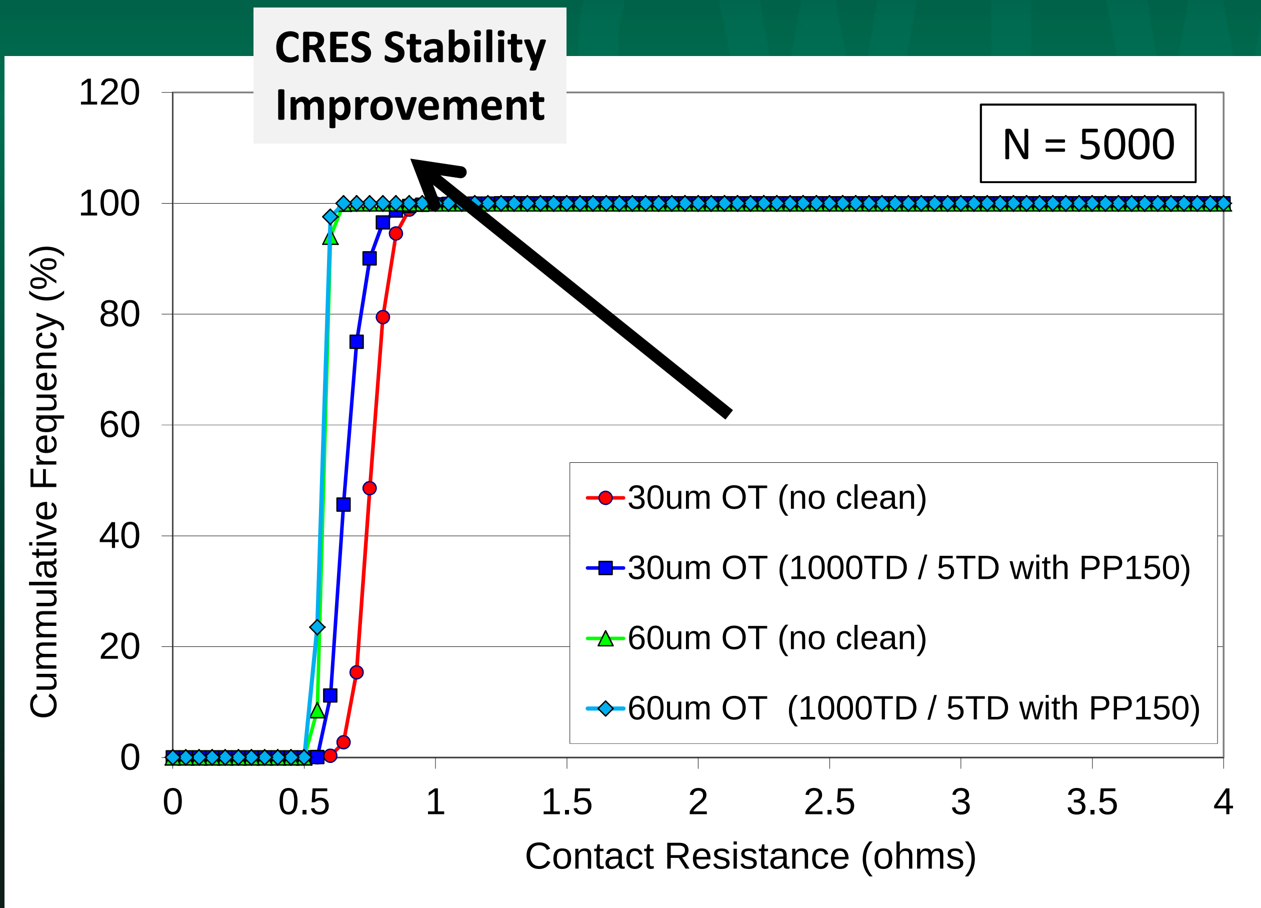
Wfr Overdrive = 30um
Cleaning = 60um (1000 / 5)



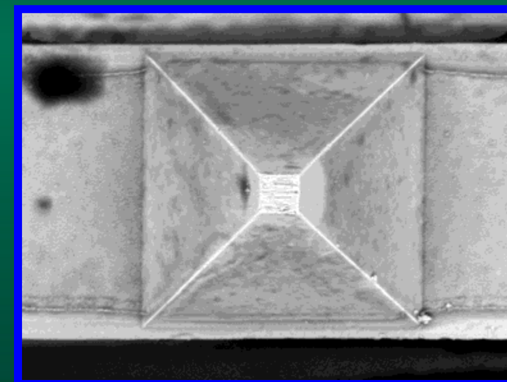
Scrub Direction

Wfr Overdrive = 60um
Cleaning = 60um (1000 / 5)

30kÅ Thickness Wafer
PP150 Cleaning Performed

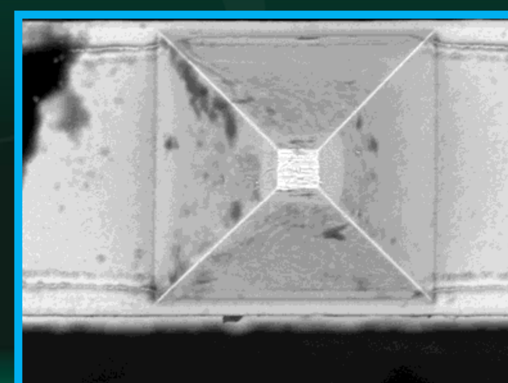


Wfr Overdrive = 30um
Cleaning = 60um (1000 / 5)



Scrub Direction

Wfr Overdrive = 60um
Cleaning = 60um (1000 / 5)



Conclusions / Recommendations I

- **Conclusion …**
  - Pad aluminum properties (6kA, 15kA, and 30kA) affected CRES stability and debris generation for two different production level overdrives (OT = 30um and 60um)
  - Pad aluminum thickness and properties will have direct affect on the overall probe process
  - Pad aluminum thickness dependent cleaning regimes are needed for optimal performance and to meet production requirements as well as maximize the probe card lifetime
- **Cleaning recipes …**
  - Improved CRES stability at the lower overtravel values
  - Collected / controlled debris from the pyramid and contact area
  - Small amounts of aluminum residuals on the contact surfaces

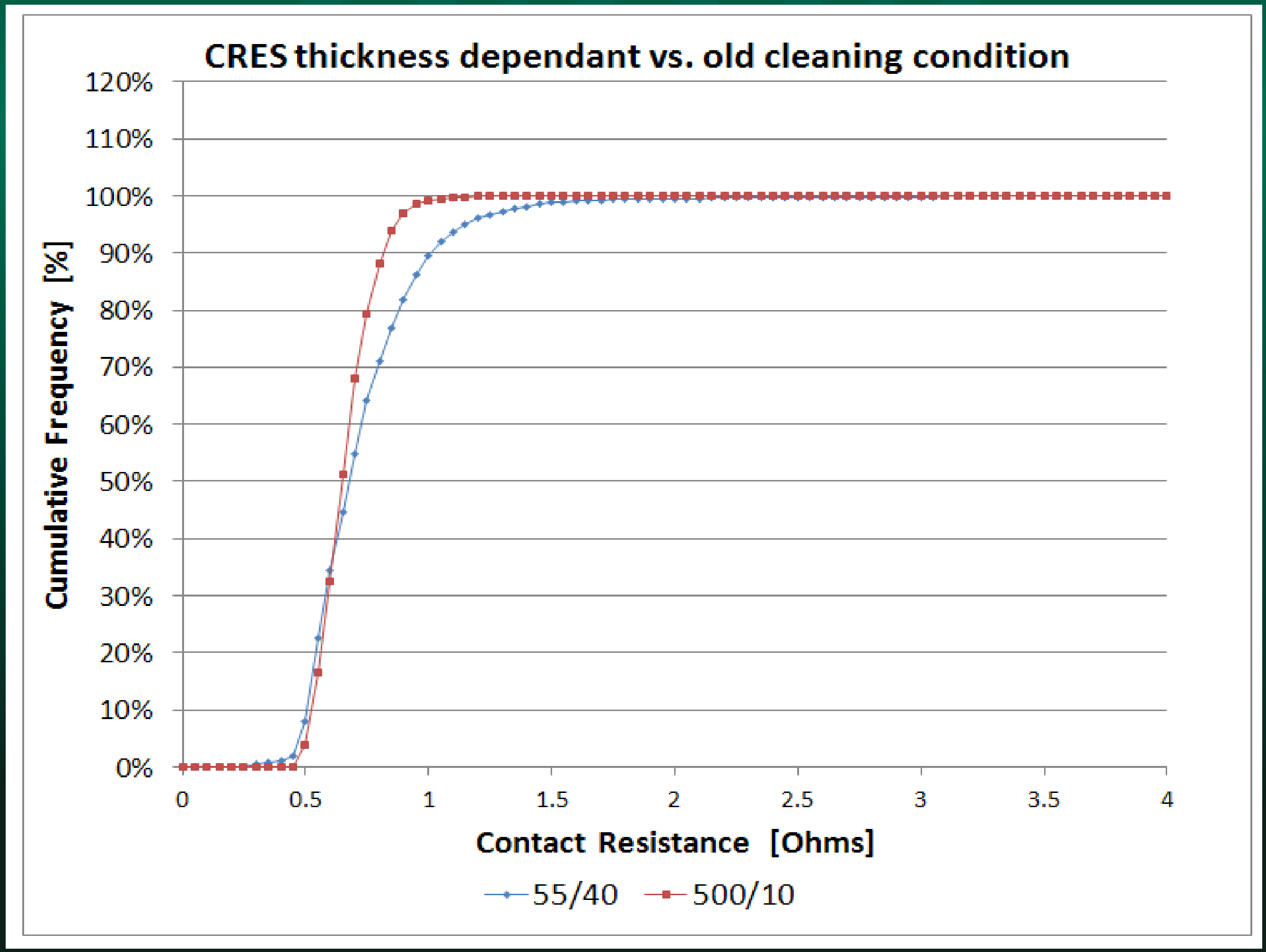
Conclusions / Recommendations II

- **CRES results and probe tip surface inspection (based on aluminum wafers studied in the project)**
  - 5 clean TDs are insufficient and should be increased
  - 100TD interval for 6kA is sufficient for debris control
  - 1000TD interval for 15kA for improved debris collection; more frequent execution suggested
  - 1000TD interval for 30kA might be sufficient for controlling debris
- **Recommendations to increase probe card lifetime from 55TD interval / 40 clean TD recipe**
  - 20TDs per cleaning cycle + 100TD interval for 6kA
    ➔ ~4X potential probe card lifetime extension over 55TD interval
  - 20 TD per cleaning cycle + 500TD interval for 15kA
    ➔ ~5X potential probe card lifetime extension over 55TD interval
  - 20TDs per cleaning cycle + 500TD interval for 30kA
    ➔ ~5X potential probe card lifetime extension over 55TD interval

Production test with new cleaning conditions

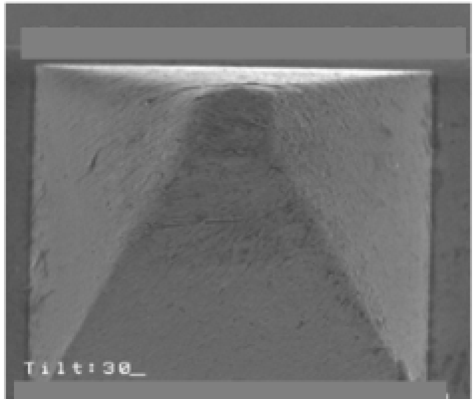
Production cleaning conditions	old	intermediate	thickness dependant
cleaning media	PP99	PP150	PP150
cleaning TD interval	55	120	>= 10kA => 500 < 10kA => 120
cleaning TD	40	20	10
cleaning OD	60 um	60 um	60 um

CRES data vs. metal thickness and cleaning conditions

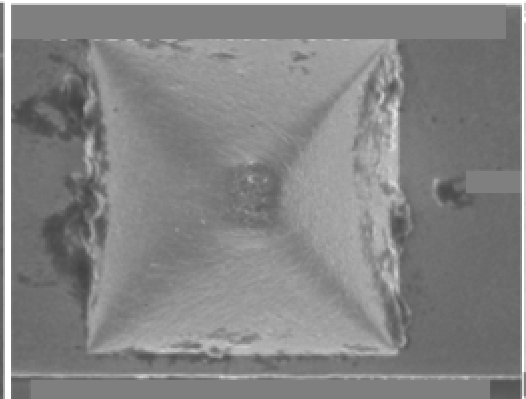


Tip status @ life TD

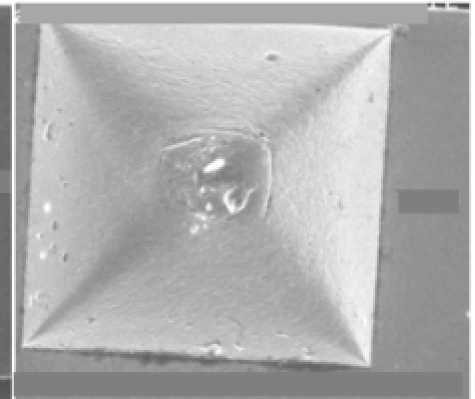
Head 5: ~10um



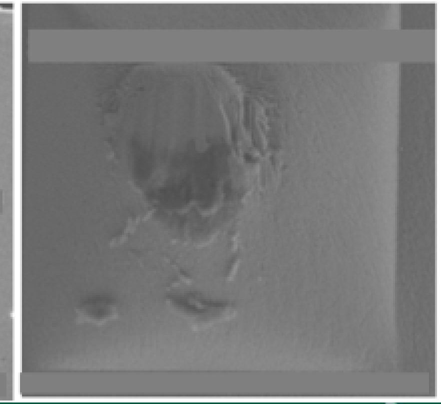
Head 8: ~ 8 - 10um



Head 7: ~ 7 -10um

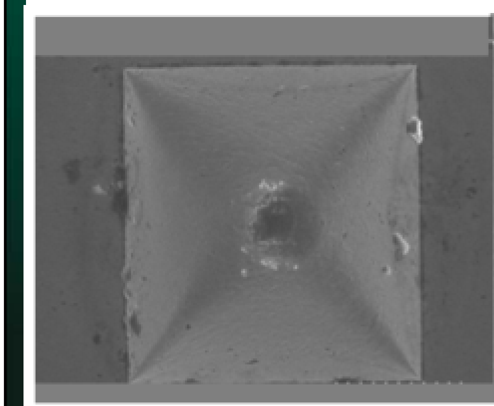


Head 2: ~ 15 -19um

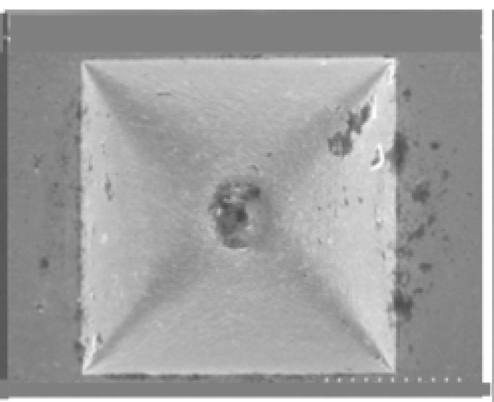


332078 TD | 528951 TD | 858777 TD | 1041886 TD

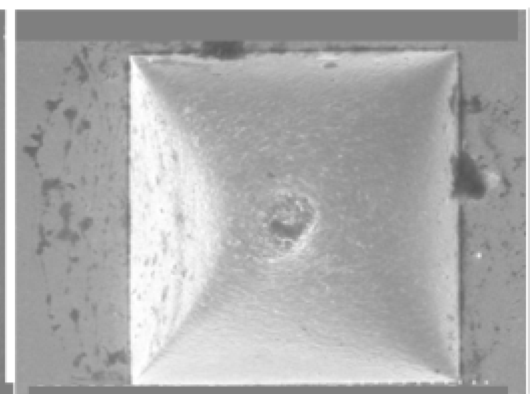
Head 6: ~11um



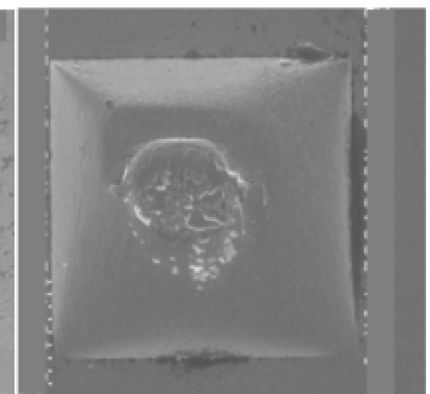
Head 8: ~ 10 - 11um



Head 7: ~ 9um

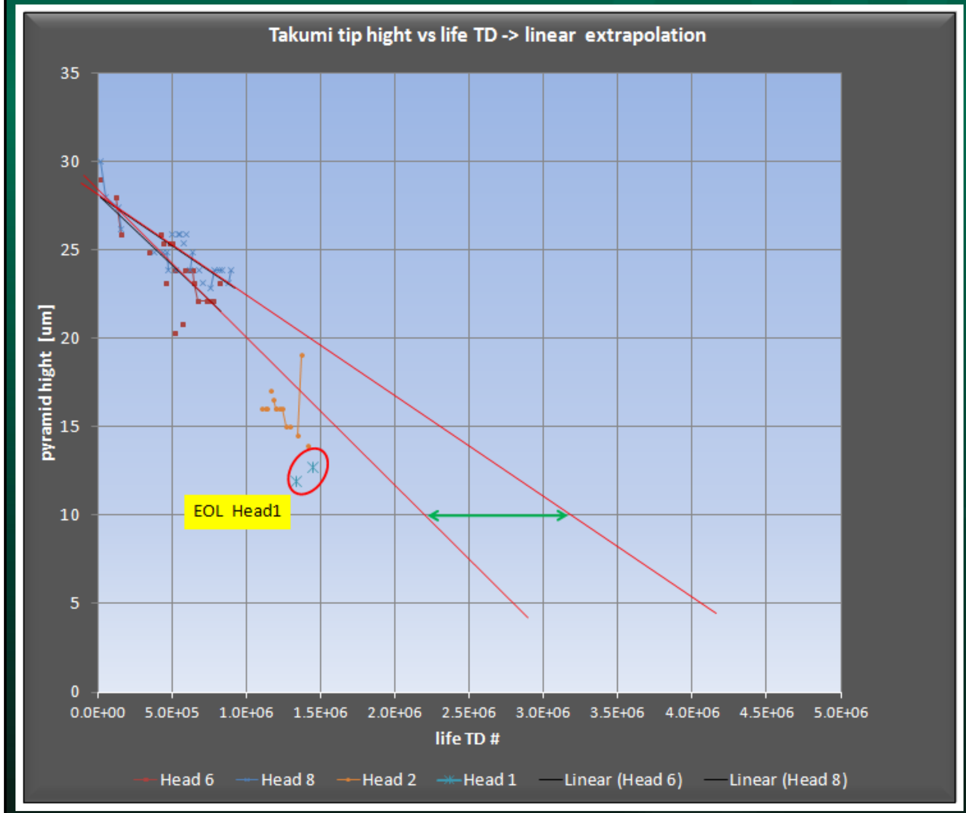


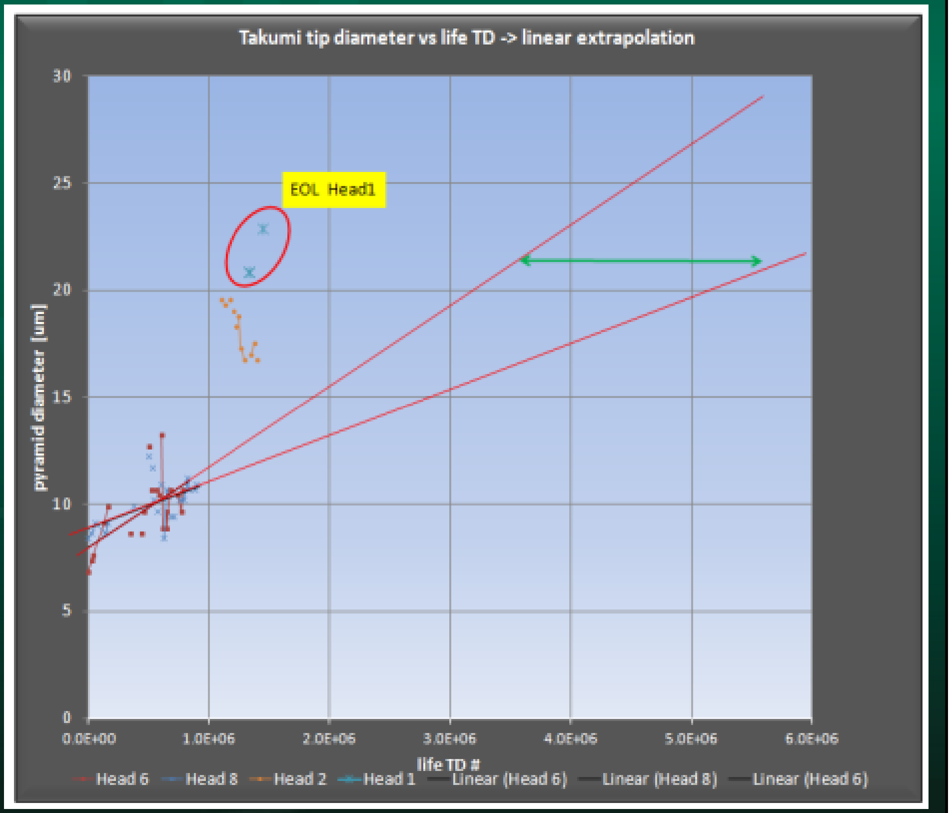
Head 2: ~ 16 -20um



855680 TD | 927154 TD | 1231233 TD | 1496386 TD

Expected life TD increase from geometry

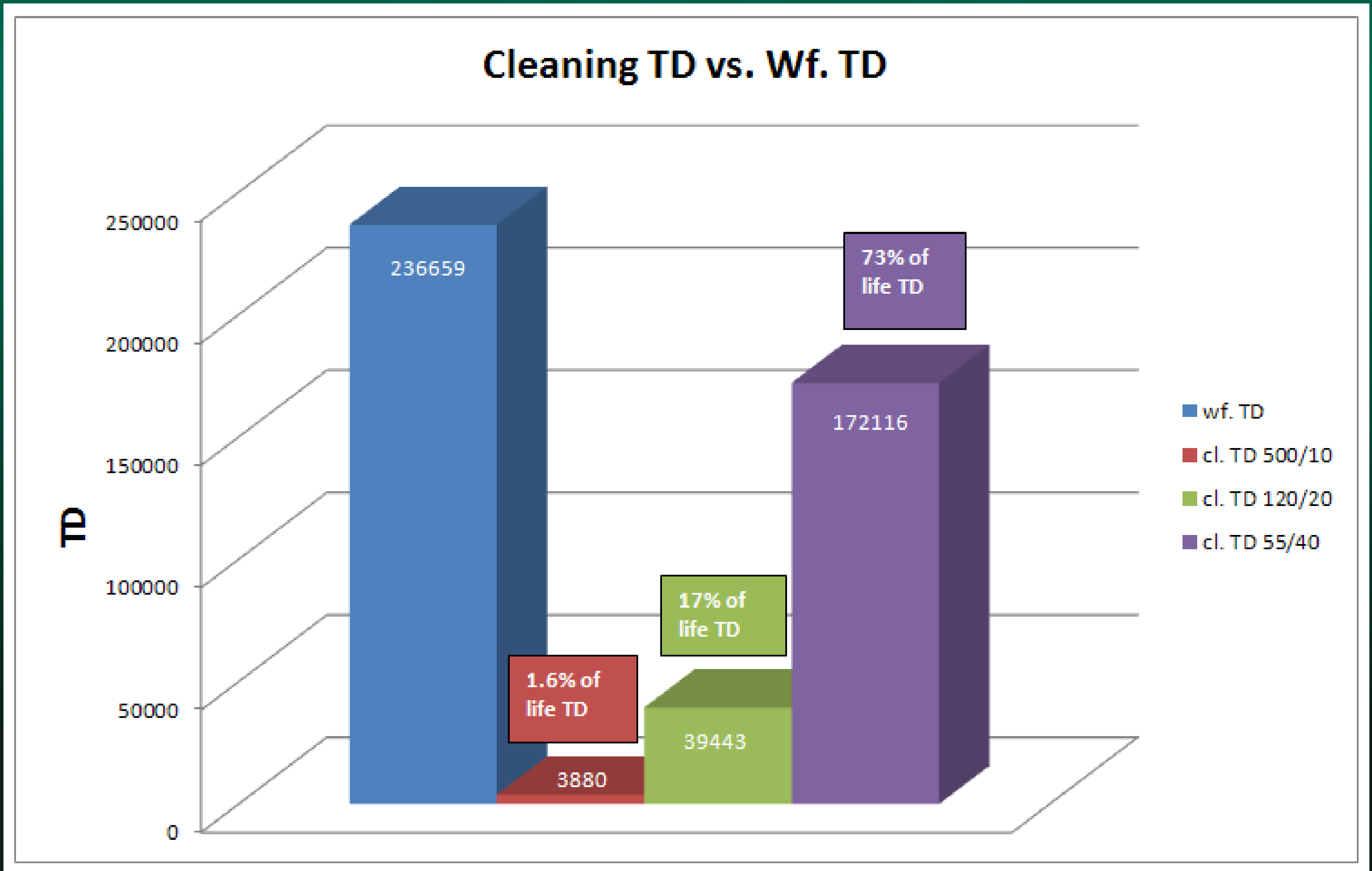




Expected life TD limited by tip hight ~ min. 2.5Mio

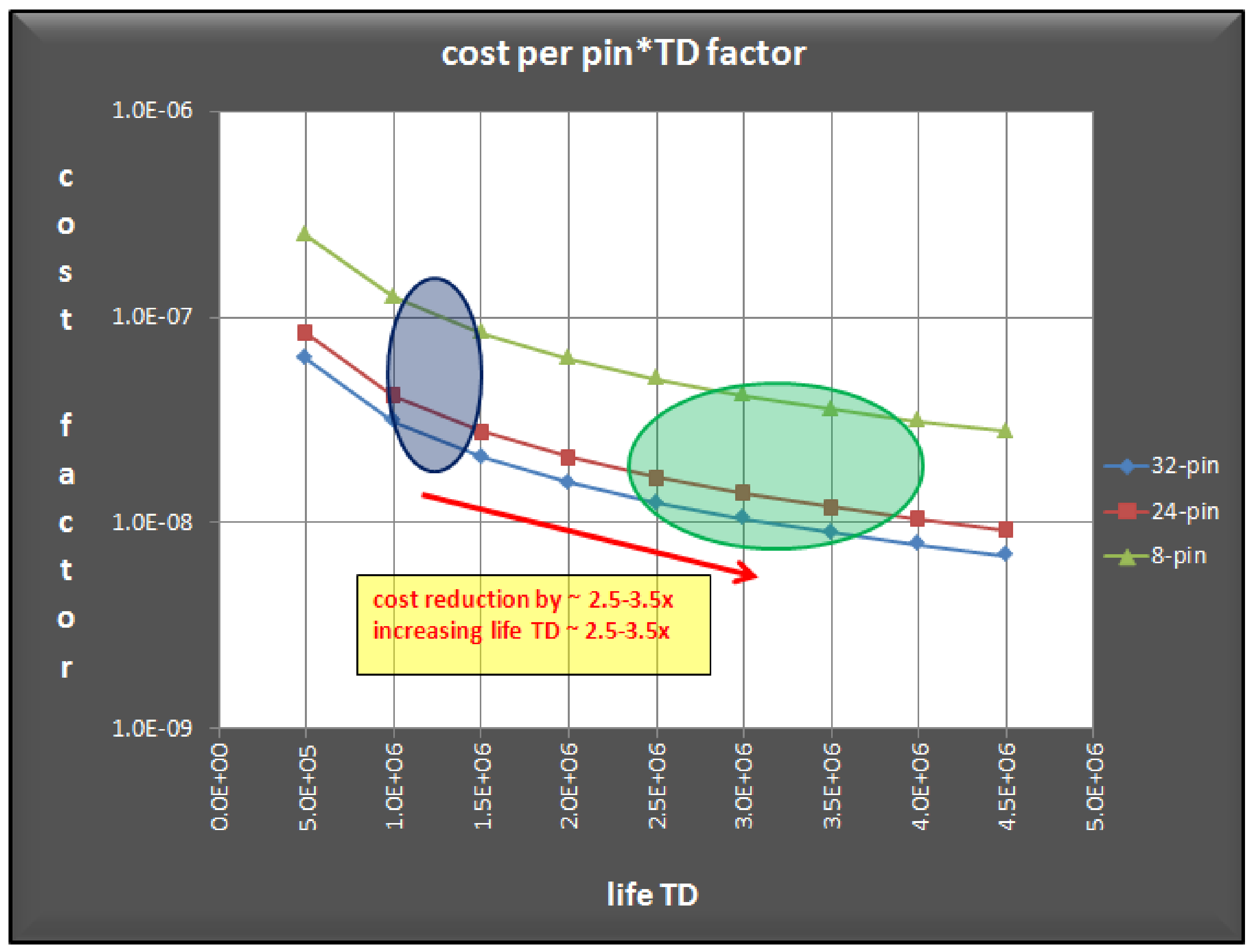
Expected life TD limited by tip diameter ~ min. 3.5Mio

Expected life TD increase from number of cleaning TDs



Expected cost reduction

Cost factor = 1/ (pin# * TD#)



Summary / Conclusion

- **From bench top experiments on Alu-wafer**
  - Pad Alu-thickness / test overdrive dependent CRES behavior
  - Cleaning recipes for improved CRES stability and debris control
  - Expectation to increase lifetime by min. 4X

- **From production test with recommended cleaning recipes**
  - More stable CRES behavior
  - Dramatically less number of online cleaning TD
  - Less maintenance work, increase maintenance interval by 2X
  - Till now less damage on pyramids
  - Life time expectations is ~ min. 2.5X to 3.5X
  - Cost reduction expectation is ~ 2.5x to 3.5x

Follow-On Work

- **Finalize production life time test**
  - Stable CRES
  - Life TD vs. Cleaning TD
  - Tip geometry
  - EOL → expected cost reduction achieved?
- **Apply pad aluminum thickness dependent cleaning regime to other probe card technologies for parametric and wafer probe**

Acknowledgement

- **Thanks to:**
  - ITS: Jerry Broz & Seyedsoheil Khavandi
  - FFI: Swen Harder
  - HTT: Gernot Zieschang
  - TI: Uwe Schiessl & process engineers