SWTW 25TH ANNIVERSARY 2015

SW Test Workshop

Semiconductor Wafer Test Workshop

June 7 - 10, 2015 | San Diego, California

Probe Tip and Probe Mark Analysis to Predict Effects on Wire Bonding

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ON Semiconductor®

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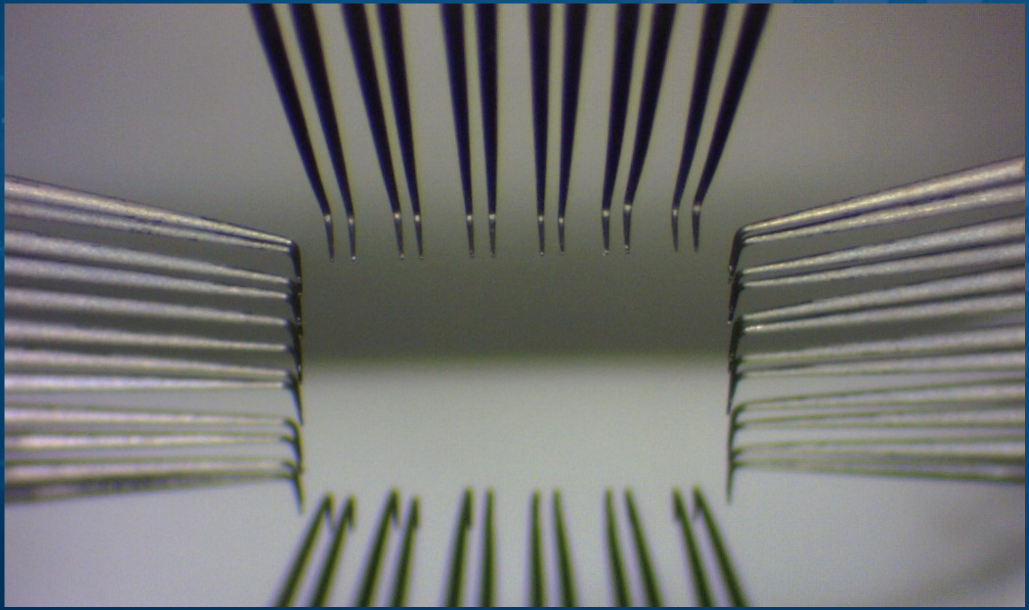
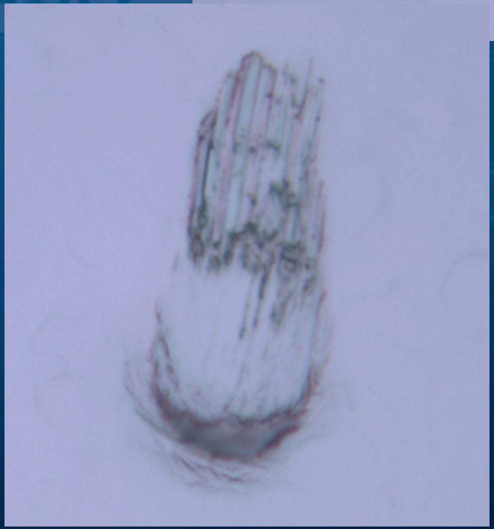
Objective

- Investigate cantilever probe marks and their potential impact on wire bonding





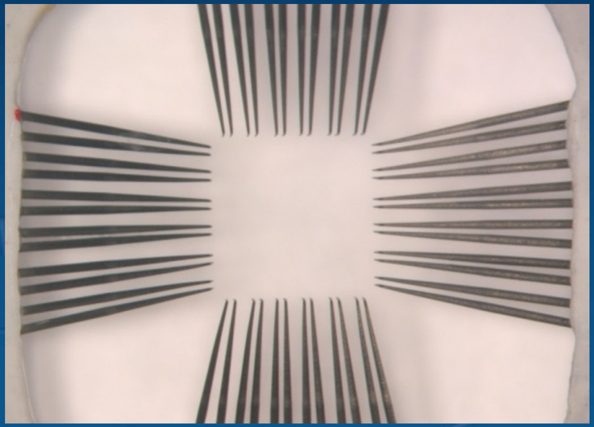
Designed Experiment Setup

- **Cantilever Probe Factors**
  - Probe Contact Force
  - Probe Tip Diameter
  - Probe Tip Surface Texture

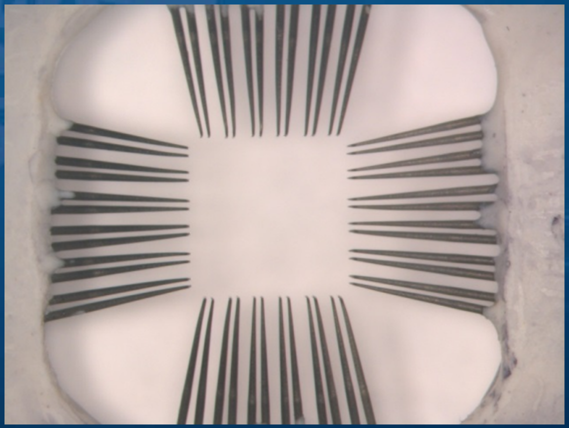
- **Wafer Factors**
  - Wafer Pad Al Thickness

Probe Contact Force

- **Regular**
  - 3 grams force

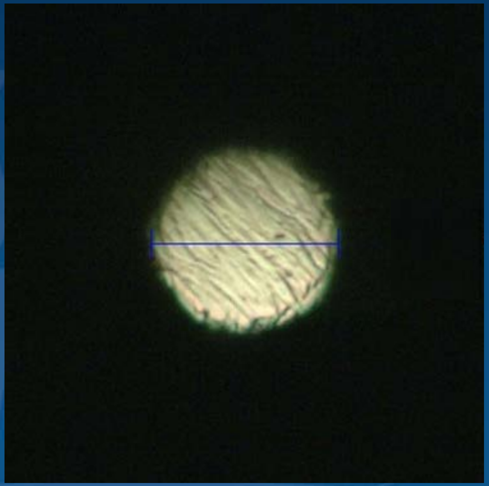


- **High**
  - 6 grams force



Probe Tip Surface Texture

- **Smooth**
  - 3 µm grain

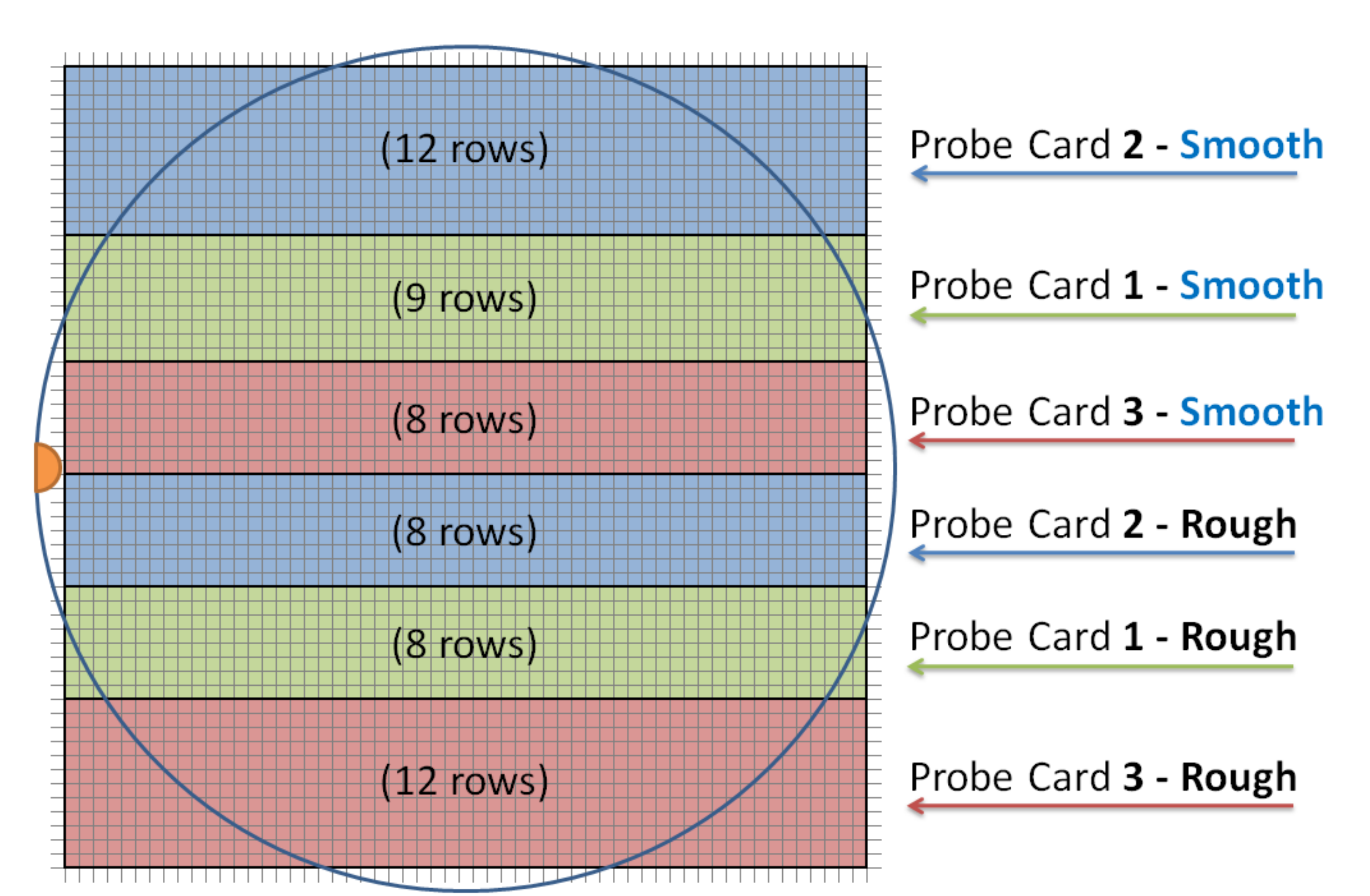


- **Rough**
  - 9 µm grain

Designed Experiment Factors

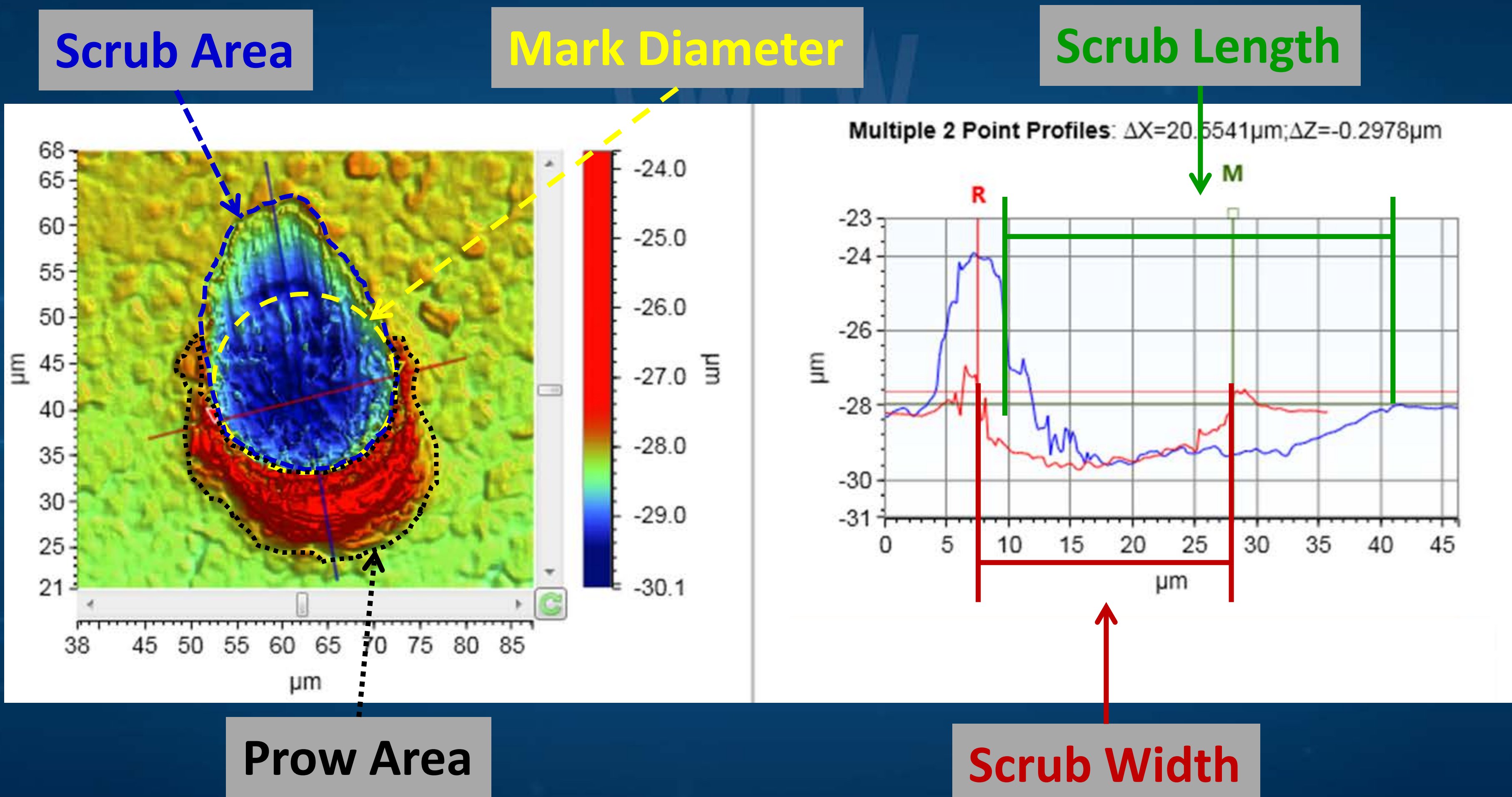
- **Probe Card 1 (LG-Lo)**
  - Large Diameter (30 µm)
  - Low Force (3 grams)
- **Probe Card 2 (SM-Hi)**
  - Small Diameter (22 µm)
  - High Force (6 grams)
- **Probe Card 3 (SM-Lo)**
  - Small Diameter (20 µm)
  - Low Force (3 grams)
- **Wafers A & C**
  - 3 µm pad Al thickness
- **Wafer B**
  - 0.8 µm pad Al thickness

Wafer Probe Diagram



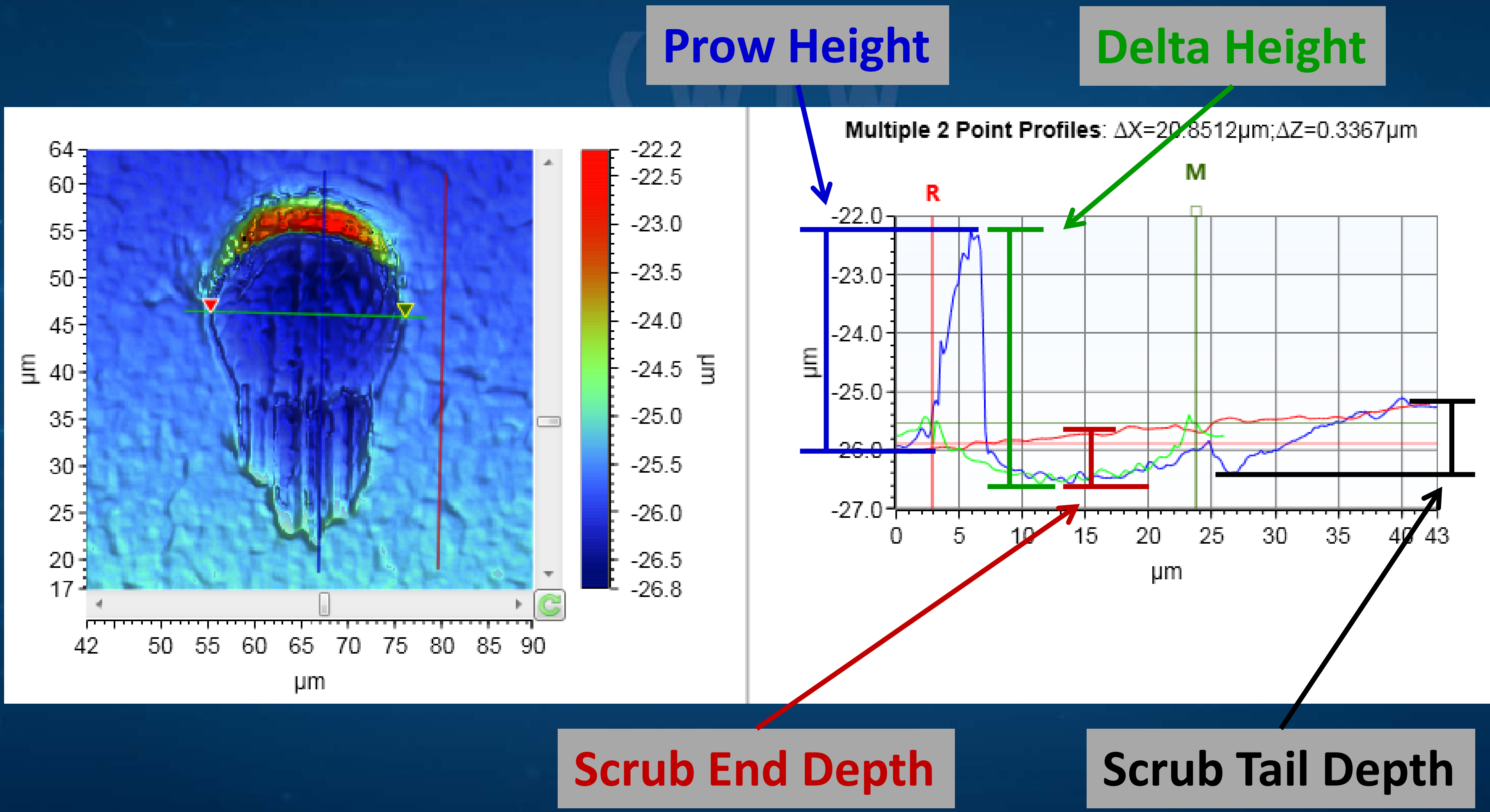
*All probing at 2 mils over travel

Probe Mark Area Analysis



*Optical images taken with Bruker Contour GT-K1 and processed using Vision 64 Software

Probe Mark Depth Analysis

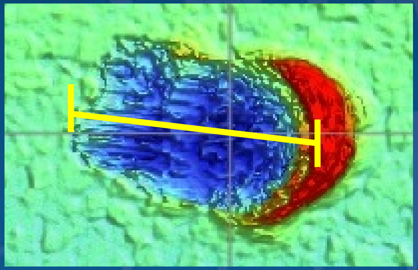


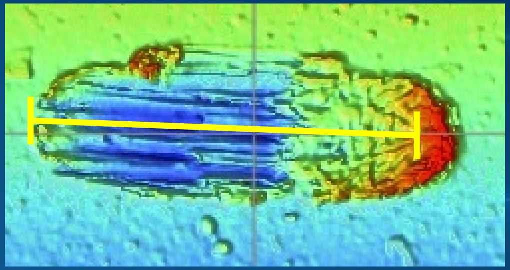
Probe Mark Scrub Length

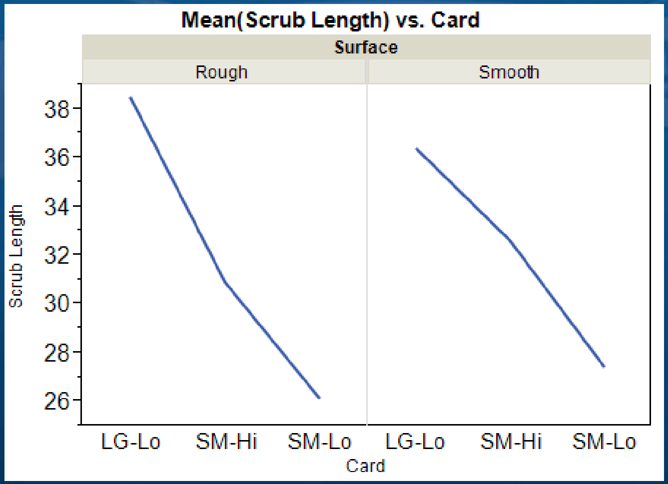
Thick Pad Al: Scrub Length increases as both Tip Diameter and Force increase

Thin Pad Al: Scrub Length increases as Force increases

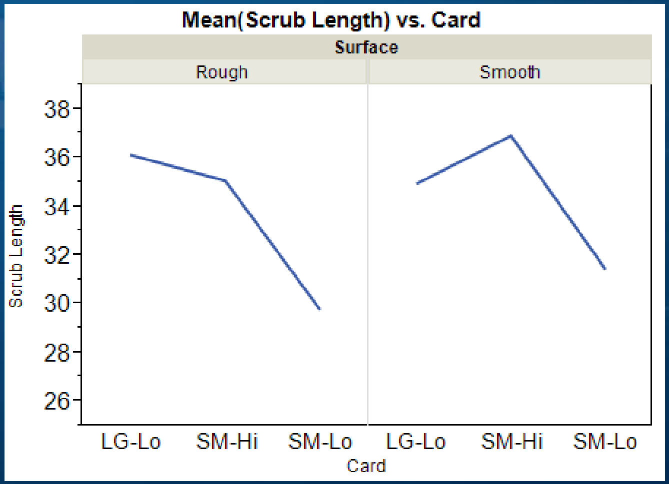
As Tip Texture becomes Rough, larger Tip Diameter increases Length, while higher Force decreases Length





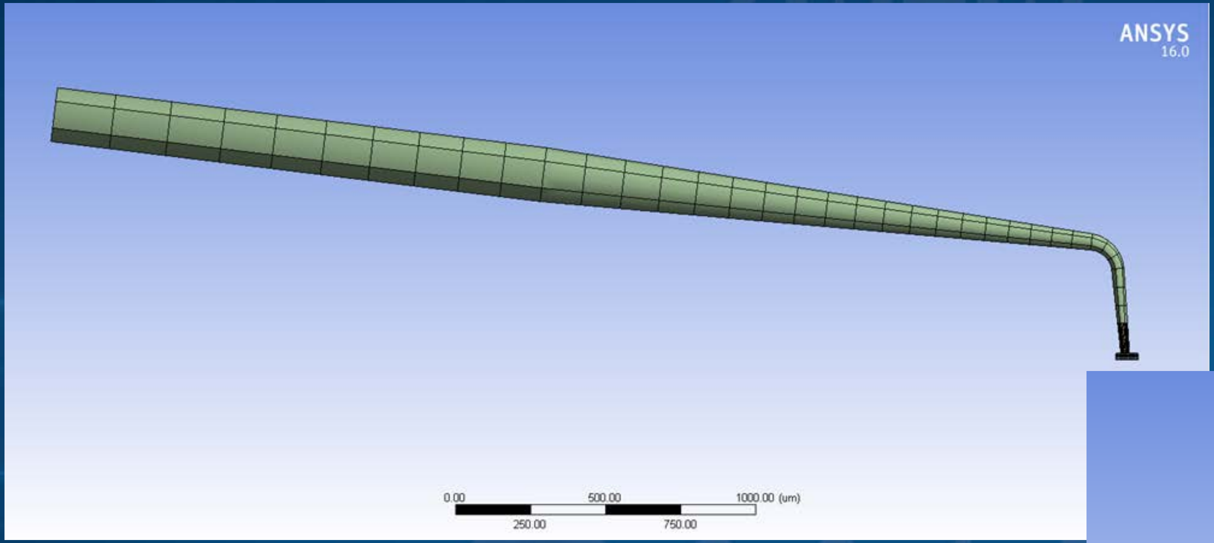


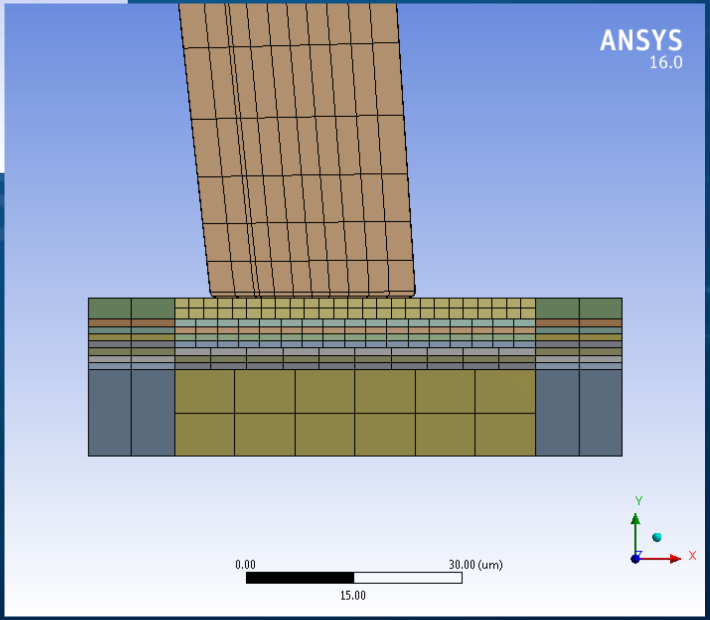
Wafer A (3 µm)



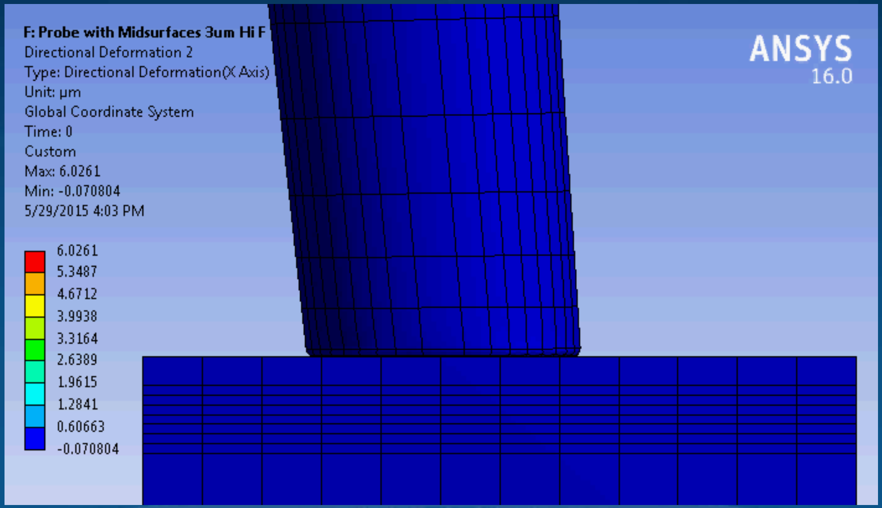
Wafer B (0.8 µm)

Finite Element Model of Cantilever Probe and Pad Al

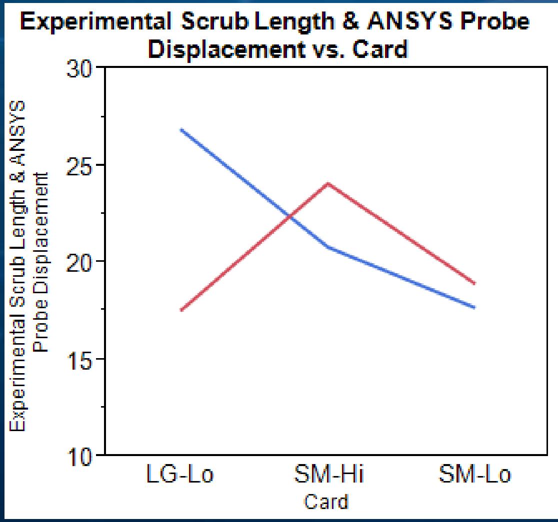




Comparison of Scrub Length FEA



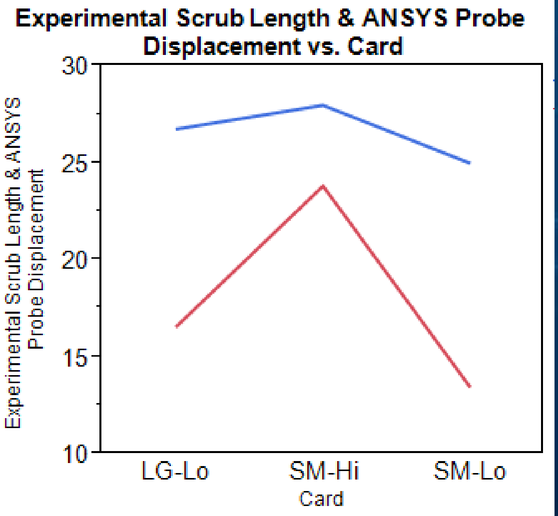
3 µm pad Al



Experimental Scrub Length

FEA Probe Displacement

0.8 µm pad Al

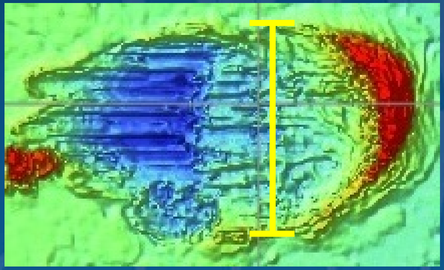


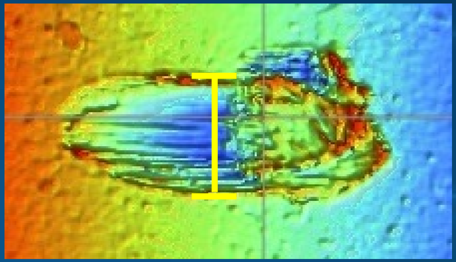
Probe Mark Scrub Width

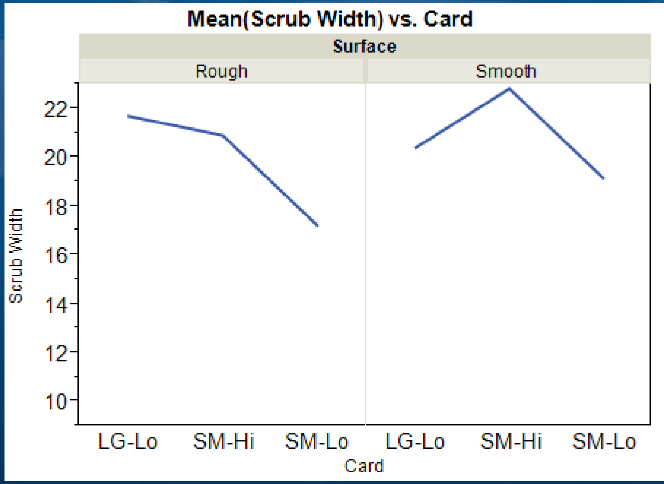
Thick Pad Al: Scrub Width increases as both Force and Tip Diameter increase

Thin Pad Al: Scrub Width increases as both Tip Diameter and Force increase

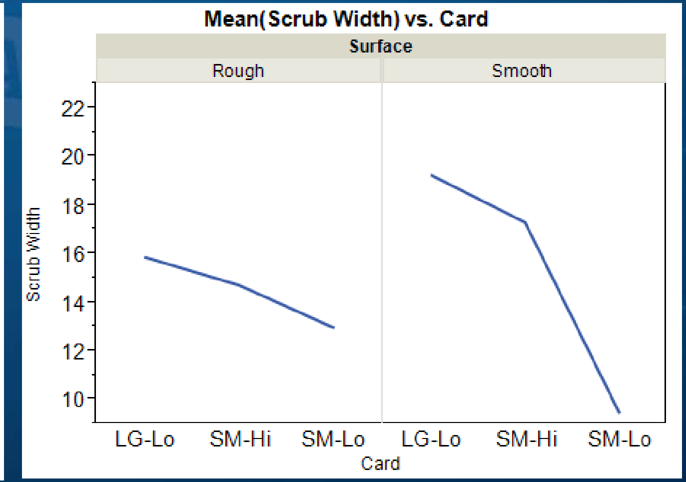
Scrub Width decreases with higher Force as Tip Texture becomes Rough







Wafer A (3 µm)



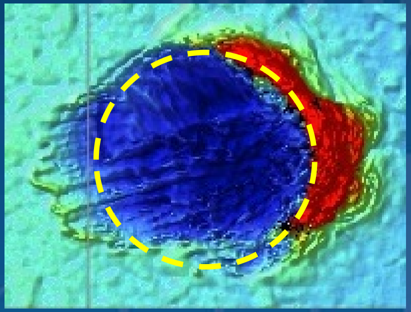
Wafer B (0.8 µm)

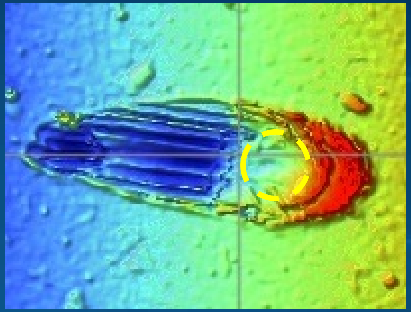
Prow Diameter

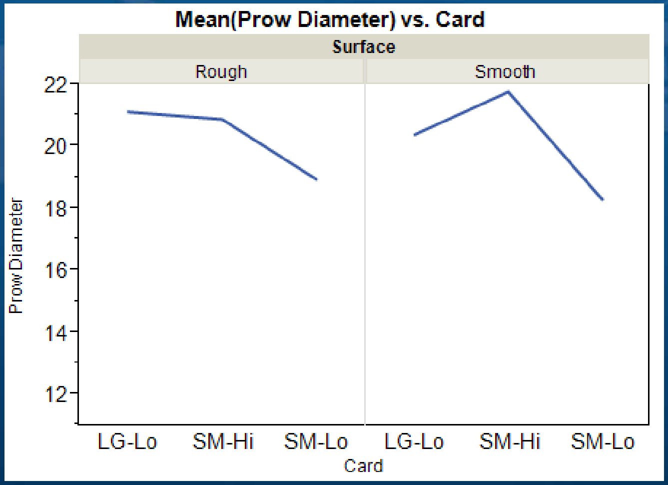
Thick Pad Al: Prow Diameter increases as both Force and Tip Diameter increase

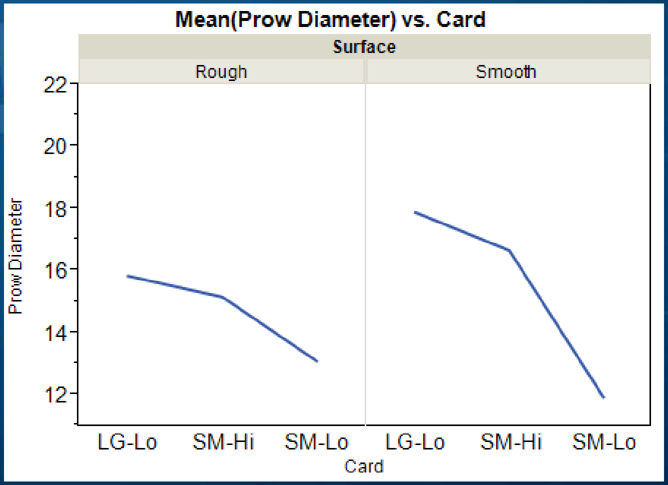
Thin Pad Al: Prow Diameter increases as both Tip Diameter and Force increase

Prow Diameter decreases with higher Force as Tip Texture becomes Rough









Wafer A (3 µm)

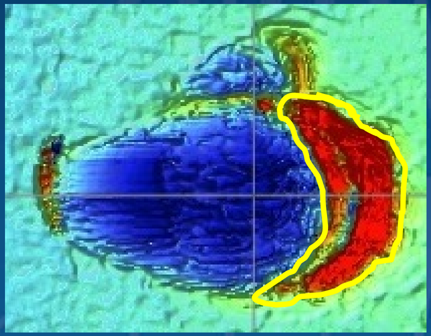
Wafer B (0.8 µm)

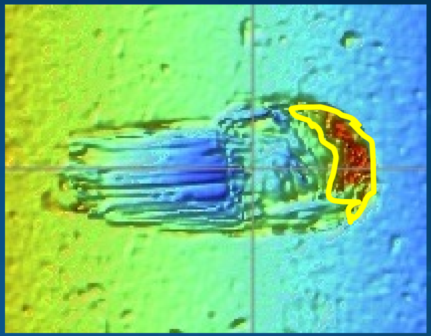
Prow Area

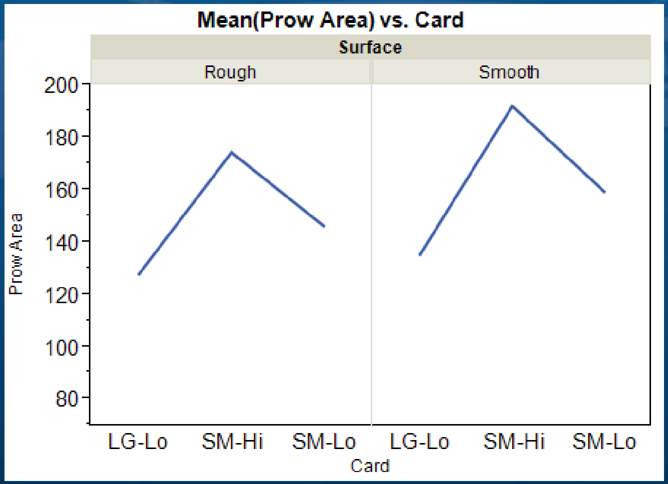
Thick Pad Al: Prow Area increases with higher Force and decreases with larger Tip Diameter

Thin Pad Al: Prow Area increases as both Tip Diameter and Force increase

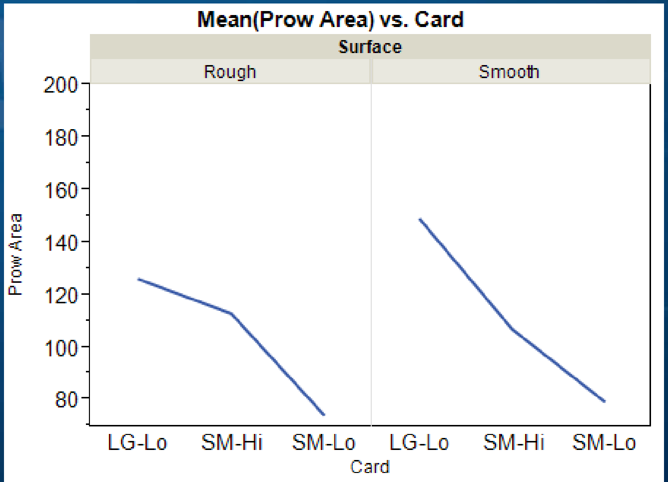
Prow Area generally decreases as Tip Texture becomes Rough







Wafer A (3 µm)



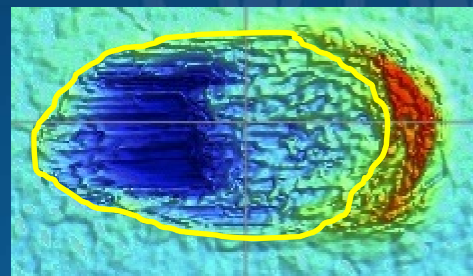
Wafer B (0.8 µm)

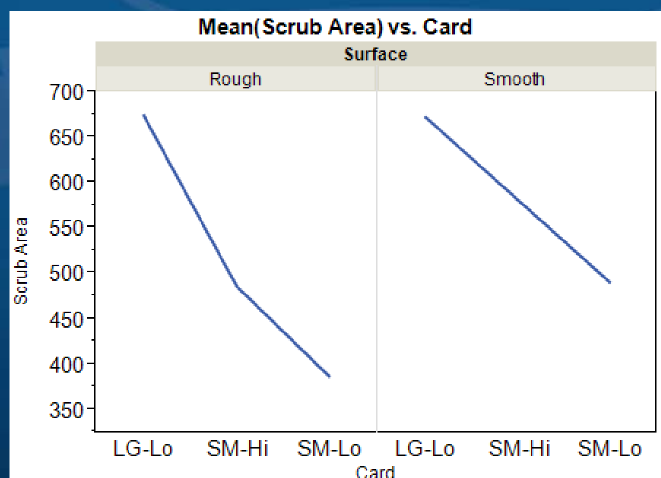
Scrub Area

Thick Pad Al: Scrub Area increases as both Tip Diameter and Force increase

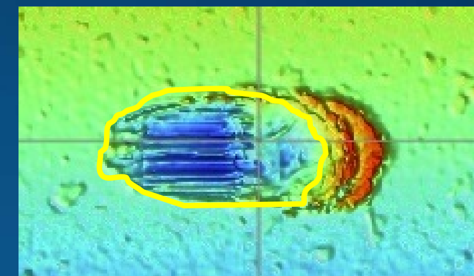
Thin Pad Al: Scrub Area increases as both Force and Tip Diameter increase

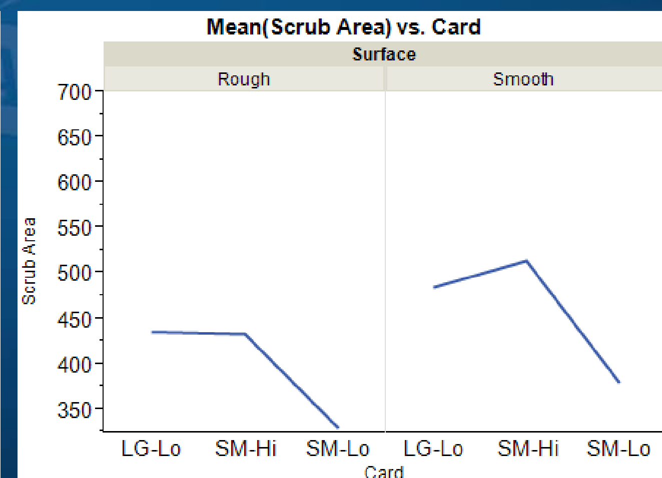
Scrub Area generally decreases as Tip Texture becomes Rough





Wafer A (3 µm)





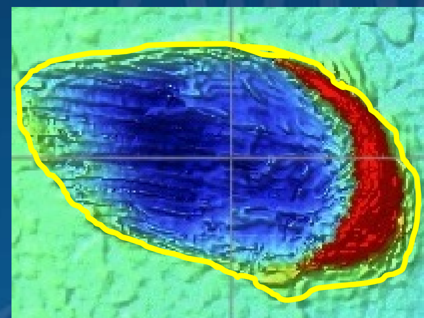
Wafer B (0.8 µm)

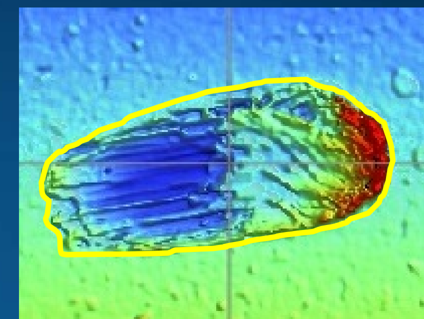
Total Area

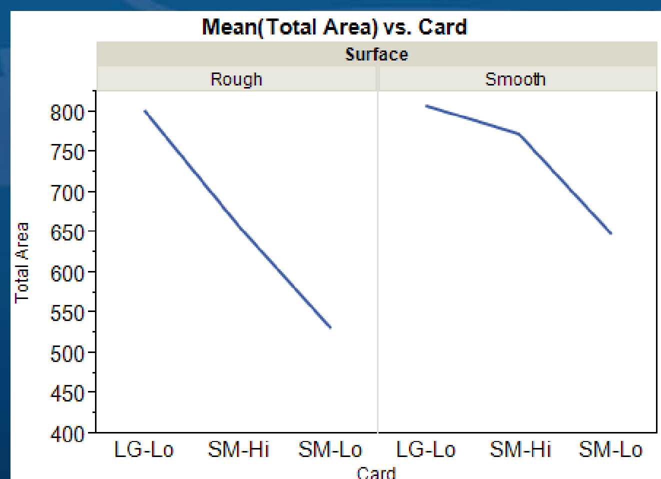
<u>Thick Pad Al</u>: Total Area increases as both Tip Diameter and Force increase

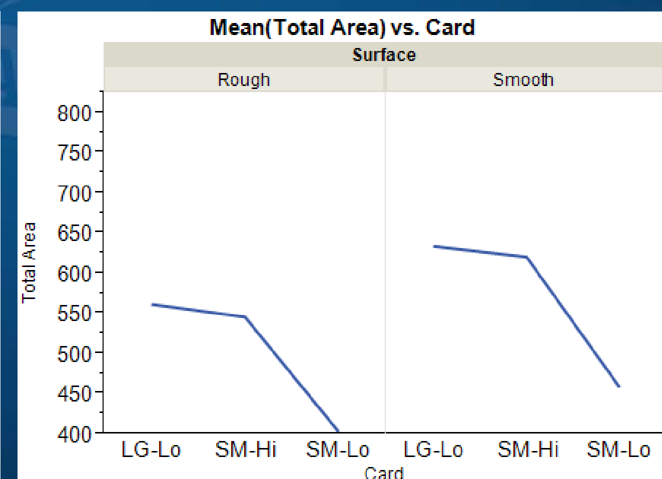
<u>Thin Pad Al</u>: Total Area increases as both Force and Tip Diameter increase

Total Area generally decreases as Tip Texture becomes Rough







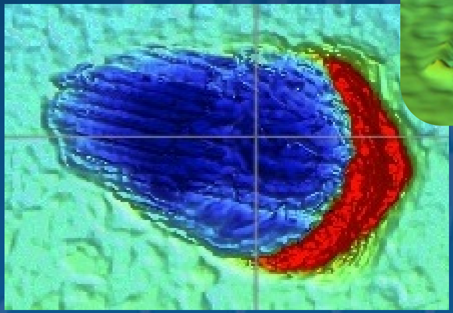


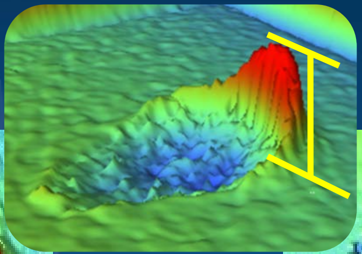
Wafer A (3 µm)

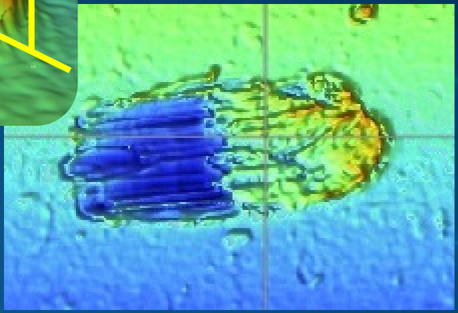
Wafer B (0.8 µm)

Prow Height

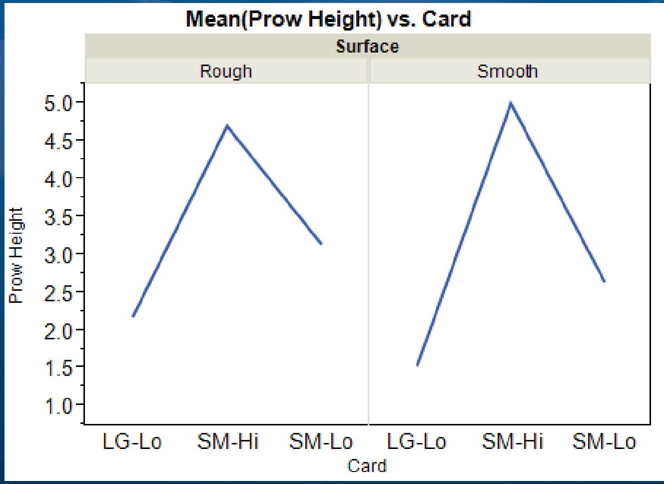
Both Thick and Thin Pad Al: Prow Height increases with higher Force and decreases with larger Tip Diameter



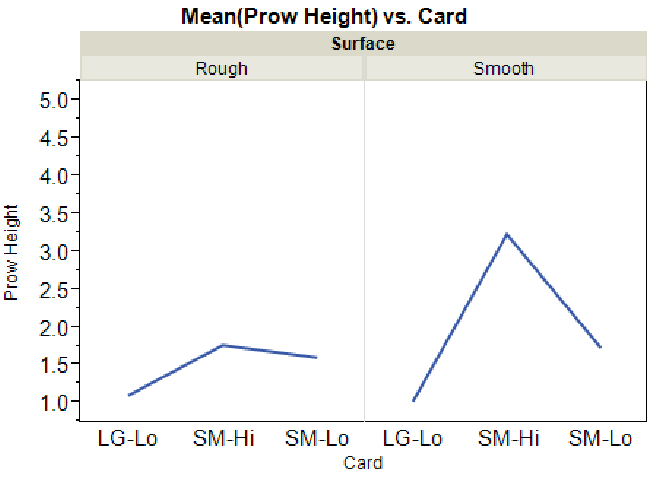




Overall effects on Prow Height decrease as Tip Texture becomes Rough



Wafer A (3 µm)



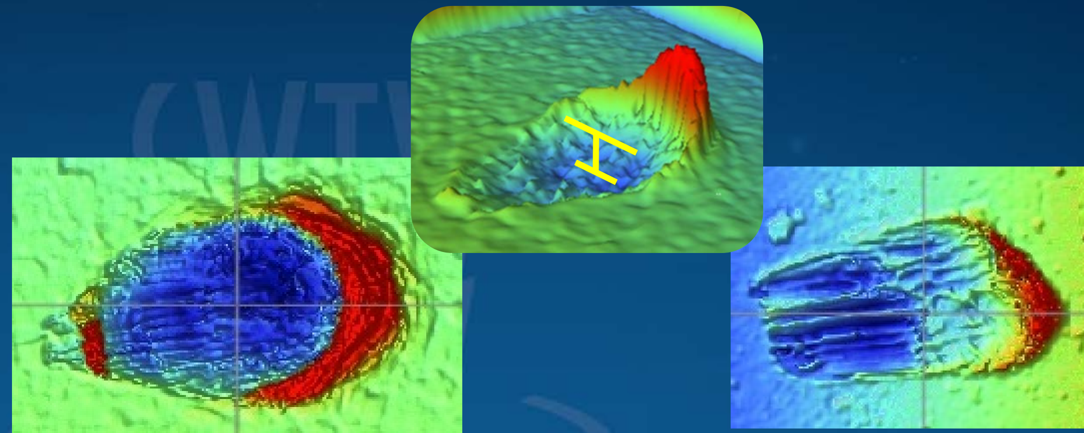
Wafer B (0.8 µm)

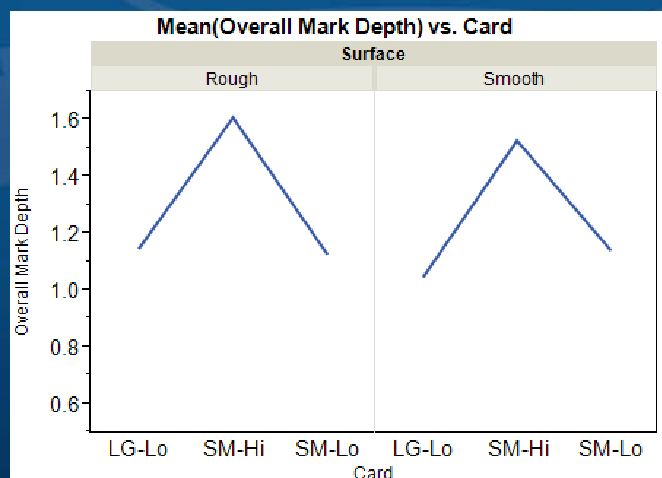
Overall Mark Depth

Thick Pad Al: Overall Mark Depth increases with higher Force

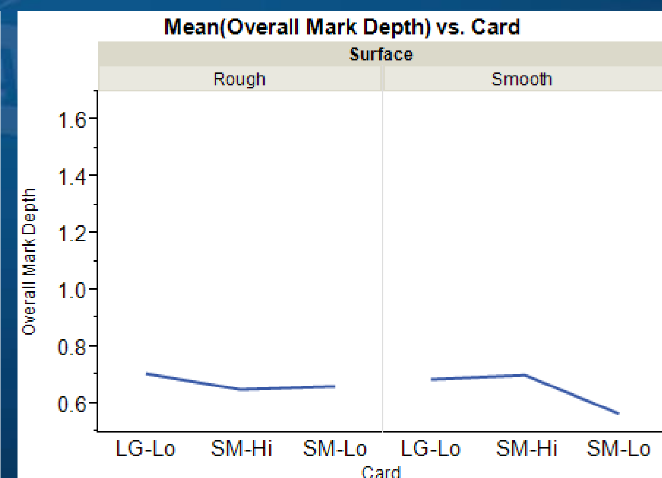
Thin Pad Al: Overall Mark Depth increases with larger Tip Diameter

Overall Mark Depth increases as Tip Texture becomes Rough





Wafer A (3 µm)



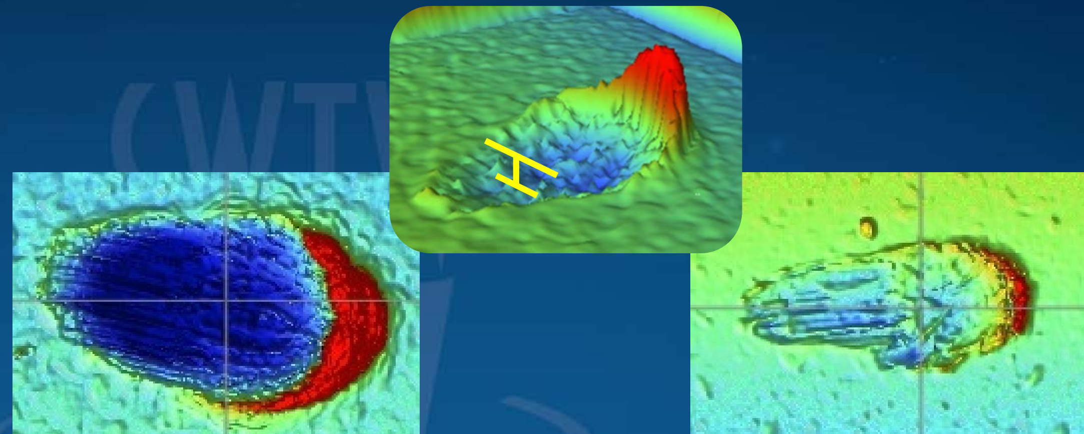
Wafer B (0.8 µm)

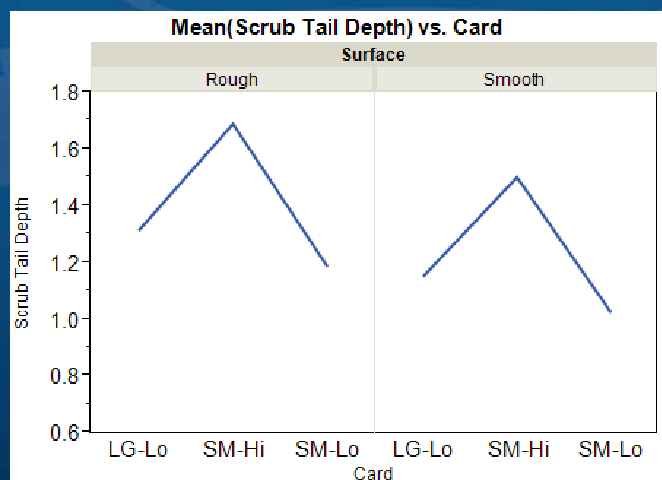
Scrub Tail Depth

<u>Thick Pad Al</u>: Scrub Tail Depth increases with higher Force and larger Tip Diameter

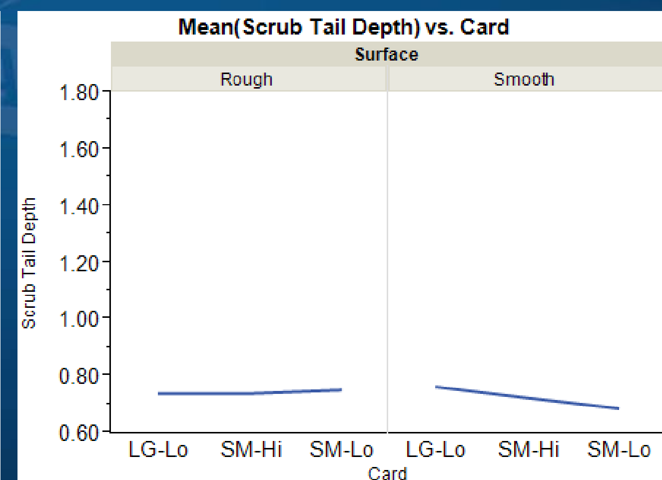
<u>Thin Pad Al</u>: Scrub Tail Depth affected very little by either Force or Tip Diameter

Scrub Tail Depth increases as Tip Texture becomes Rough





Wafer A (3 µm)

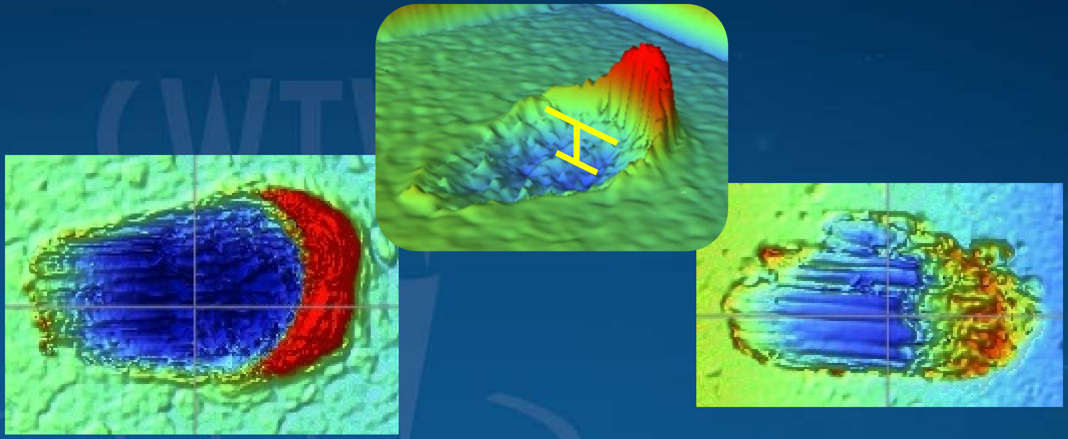


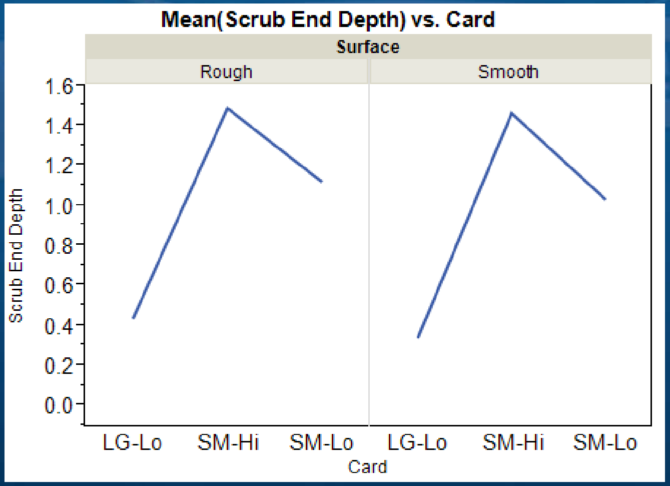
Wafer B (0.8 µm)

Scrub End Depth

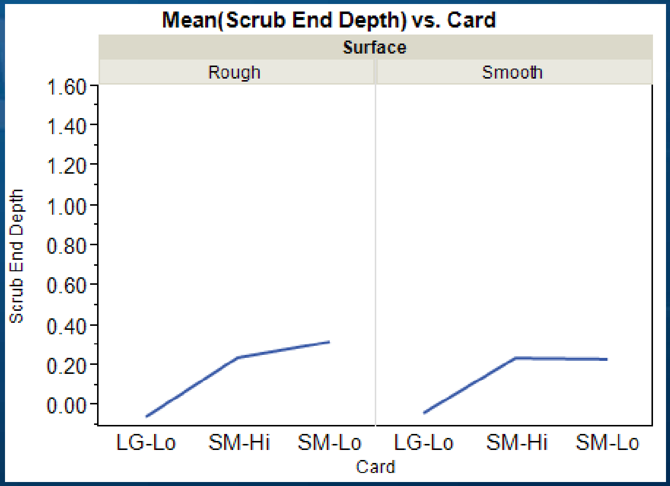
<u>Both Thick and Thin Pad Al</u>: Scrub End Depth decreases with larger Tip Diameter and increases with higher Force

No apparent effect from Tip Texture





Wafer A (3 µm)



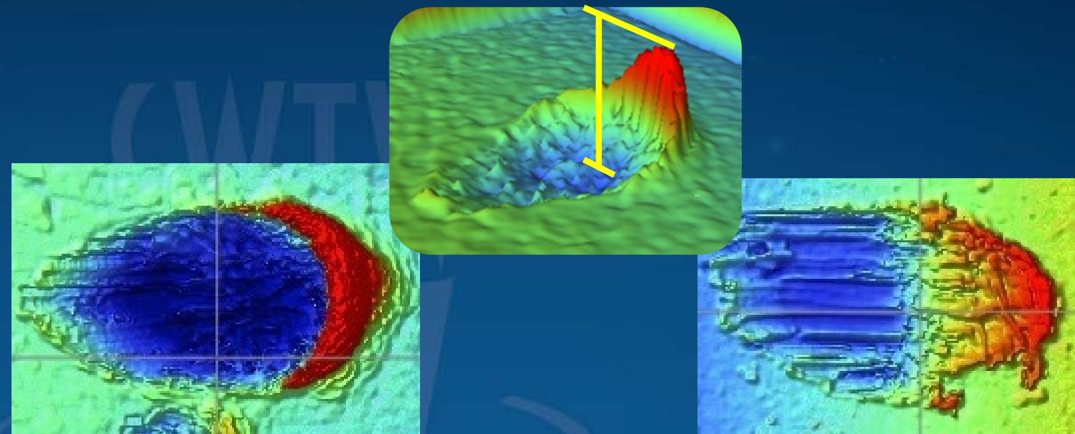
Wafer B (0.8 µm)

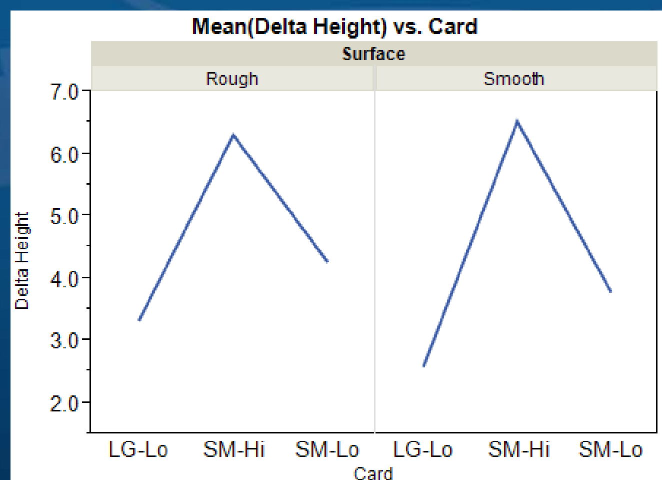
Delta Height

Thick Pad Al: Delta Height increases with higher Force and decreases with larger Tip Diameter

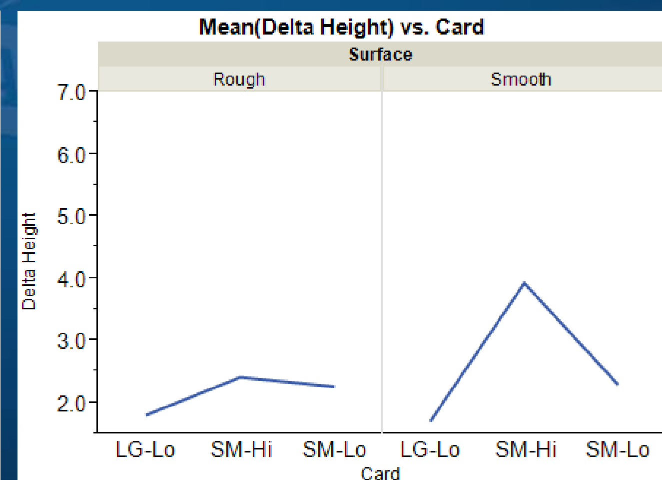
Thin Pad Al: Delta Height increases with higher Force and decreases with larger Tip Diameter

Overall effects on Delta Height decrease with Rough Tip Texture





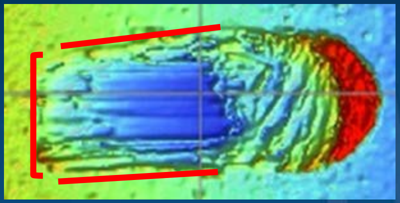
Wafer A (3 µm)



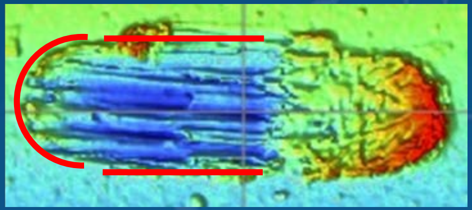
Wafer B (0.8 µm)

Tail Type Classification

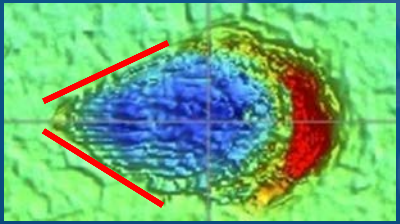
- Flat



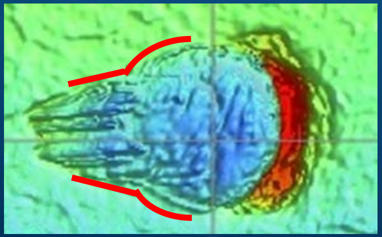
- Round



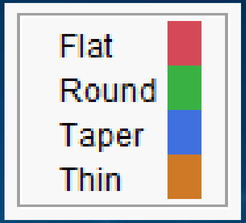
- Taper

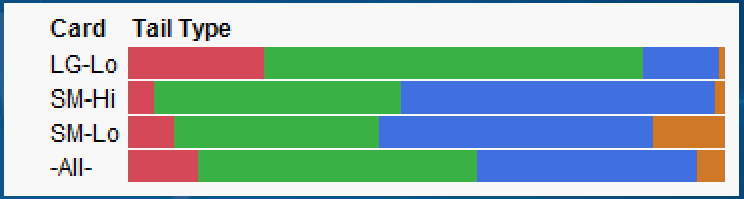


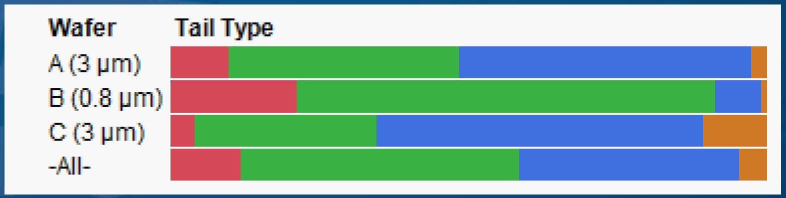
- Thin



Tail Type Frequency by Card and Wafer



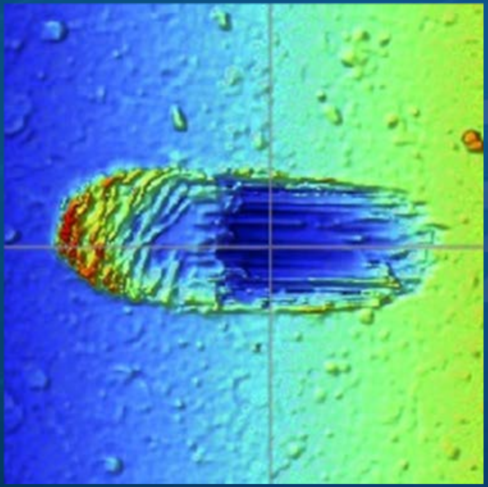




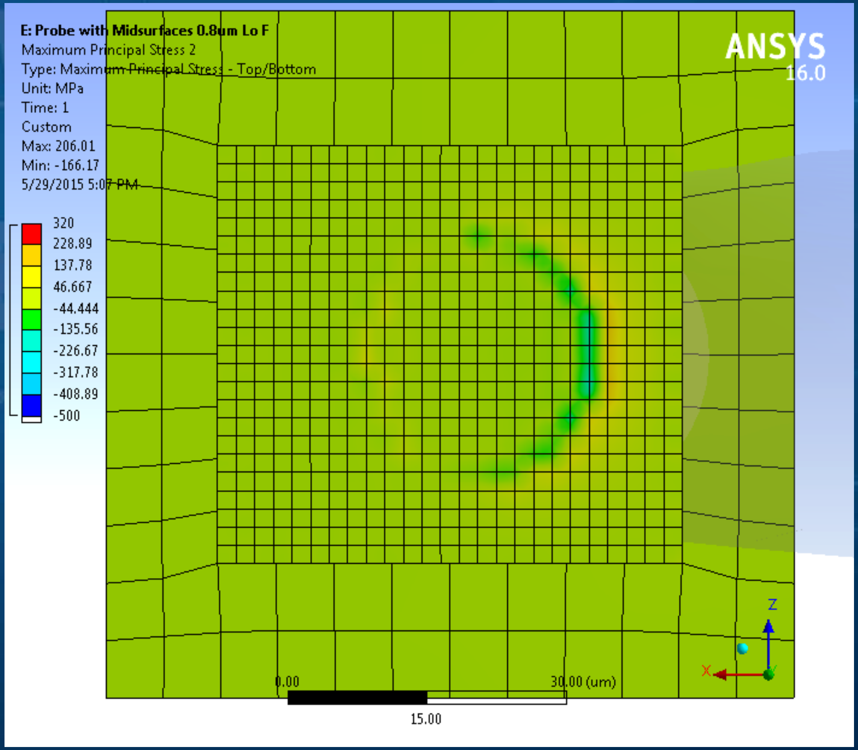
Round Tail Type appears most often in Thin Pad Al or with Large Probe Tip Diameter

Round Tail Probe Mark Comparison

Experimental Results of Small Dia. Low Force Probe Mark on 0.8 µm Pad Al

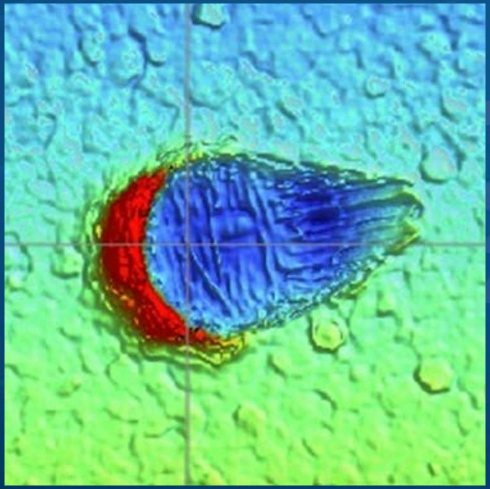


FEA Results from Equivalent Probe Setup after 0.5 mil OT

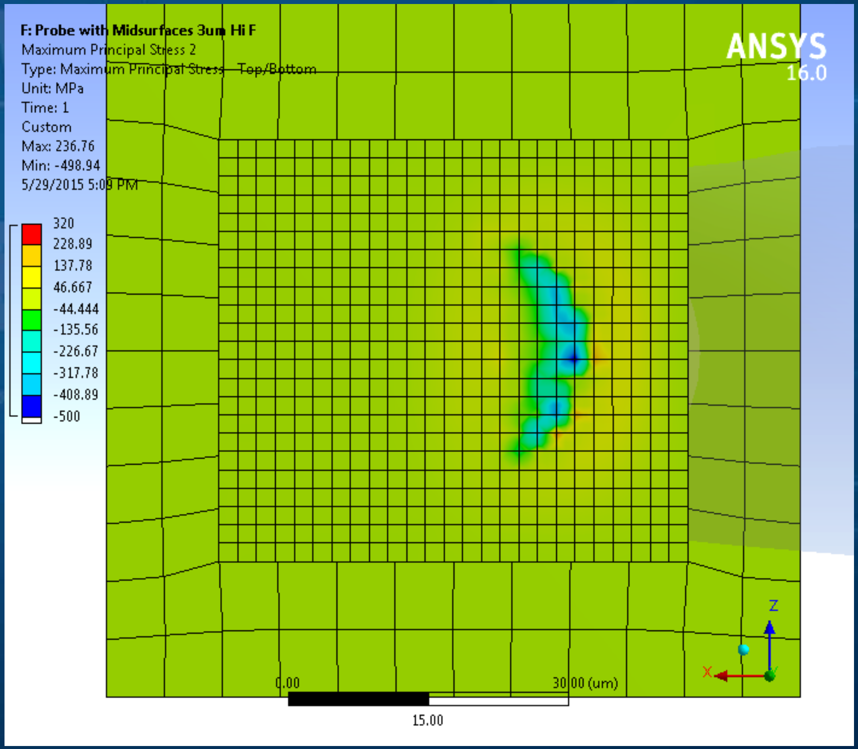


Taper Tail Probe Mark Comparison

Experimental Results of Small Dia. High Force Probe Mark on 3 µm Pad Al



FEA Results from Equivalent Probe Setup after 0.5 mil OT



Conclusions for Probe Mark Results

- **Thin Pad Al reduced all results except Scrub Length**
- **Rough Tip Texture reduced all results except Overall Depth and Scrub Tail Depth**
- **Main Effects on Thick Pad Al**
  - Higher Force increases Width, Prow Diameter, Prow Area, Prow Height, Overall Depth, Scrub Tail Depth, and Delta Height
  - Larger Diameter increases Length, Scrub Area, Total Area, and Scrub End Depth
- **Main Effects on Thin Pad Al**
  - Higher Force increases Length, Scrub Area, Prow Area, Total Area and Delta Height
  - Larger Diameter increases Width, Prow Diameter, Prow Area, Overall Depth, Scrub Tail Depth and Scrub End Depth

Apply Results to Wire Bonding

- **Minimize Prow Height**
  - Thin Pad Al, Low Force, Large Diameter, and Smooth Probe Tip Texture
- **Minimize Mark Area**
  - Thin Pad Al, Low Force, Small Diameter, and Rough Probe Tip Texture
- **Minimize Scrub End Depth**
  - Thin Pad Al, Low Force, Large Diameter, and Either Probe Tip Texture

Further Study

- Eliminate Experimental Noise (Streamlined Probing)
- Factor in Probe Tip Length
- Copper Wire Bonding Over Marks
- Implement Dynamic FEA Modeling