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ICBD, Test Development Engineering
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Contact Resistance Mechanisms

Agilent Technologies
Innovating the HP Way

Intent

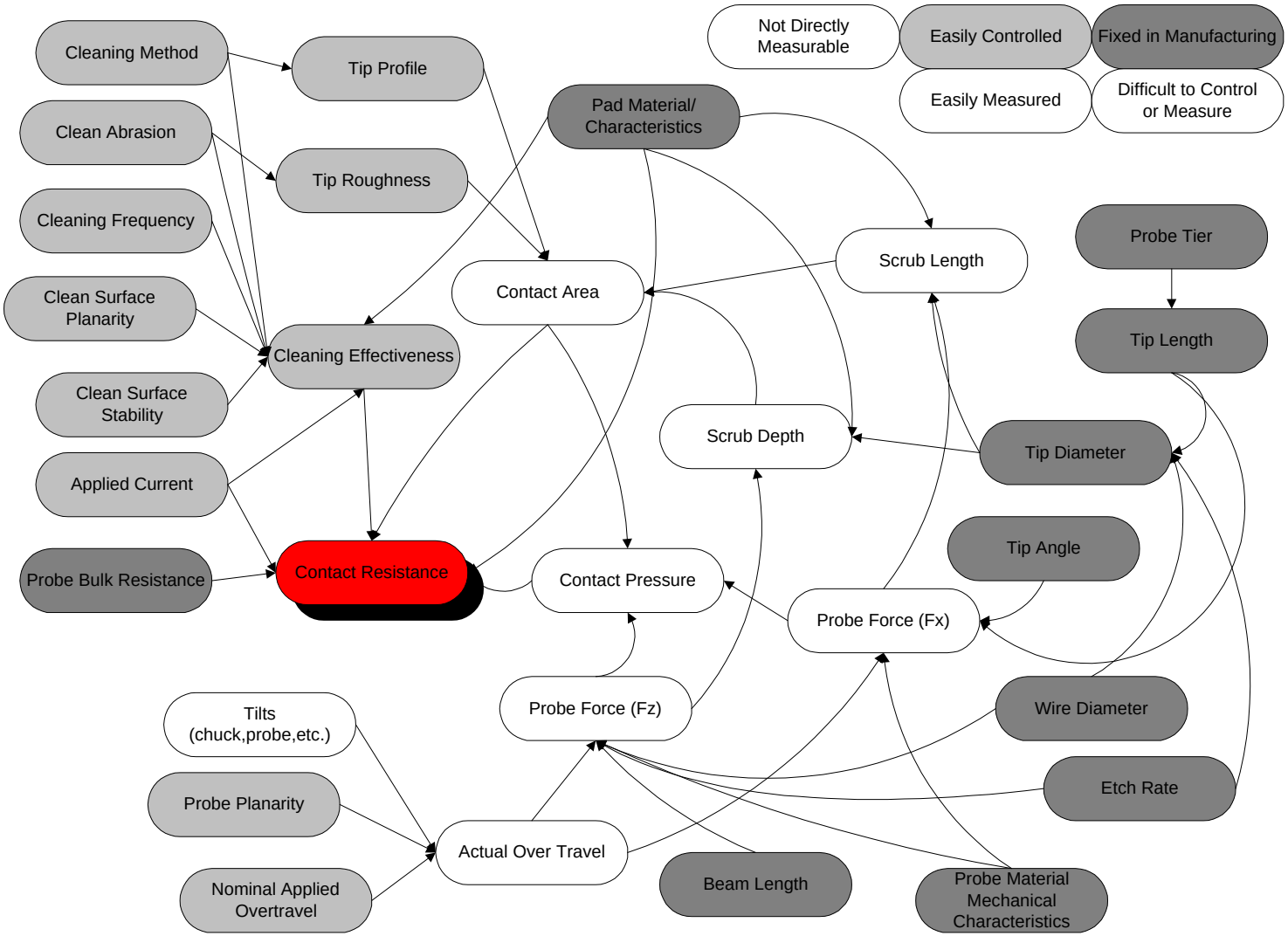
- Understand predictor influence on contact resistance
- Understand probe contact area

For Application to Probe Design and Processes

Discussion

- Large variation may be present in contact resistance data.
- Some predictors difficult to measure well.
- If there is little or no correlation of contact resistance to predictors then contamination can be considered sole or primary issue.
- Contamination from three sources:
  - Present on wafer.
  - Present on clean surface.
  - Current produced film or oxide on probe.

Contact Resistance Variable Gnarl



Resistance Factors

Probe Card

- Tip Diameter
- Planarity
- Tier
- Probe Force

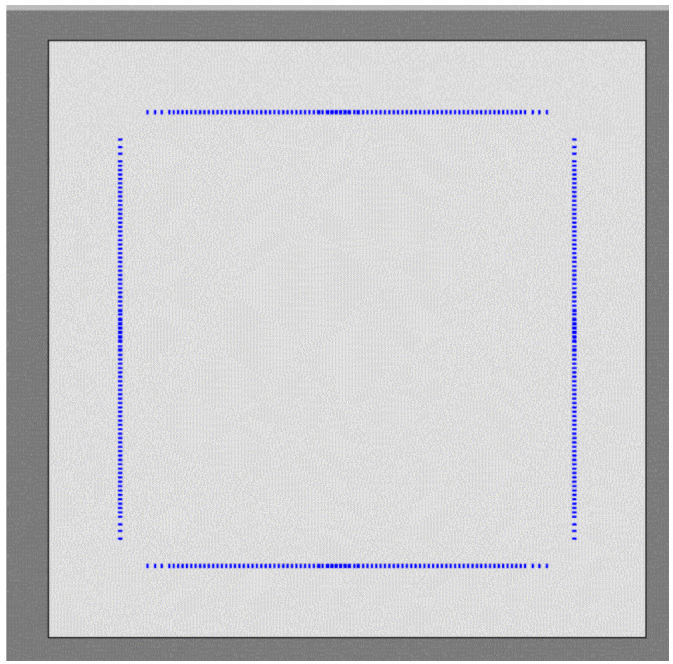
Probing

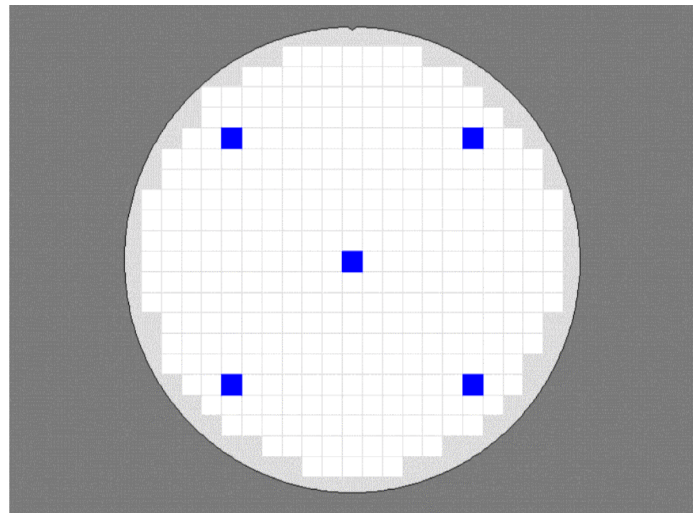
- Scrub Length
- Scrub Depth
- Scrub Width
- Scrub Area

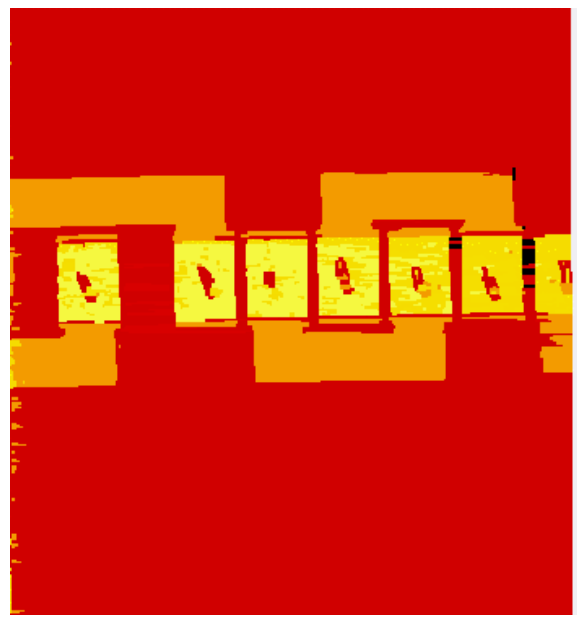
Tools Set

- EG4090 Prober
- API *waferWoRx* scrub analyzer
- Hewlett-Packard F330 Tester
- API PRVII probe card analyzer

Test Wafer

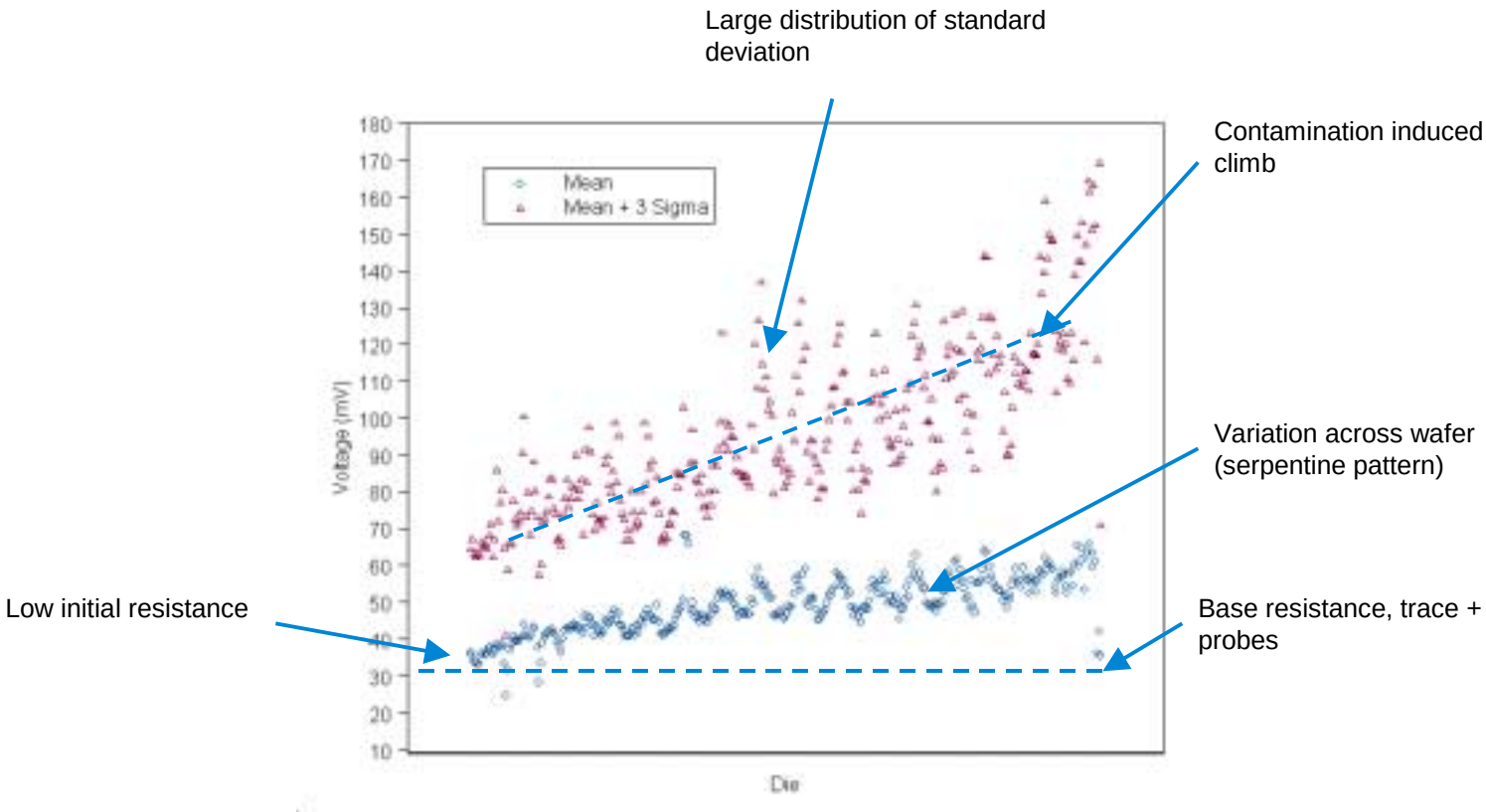






- 8 inch bonding test wafer with 342 die at 352 pads each.
- Daisy-chained aluminum pads 56x73 microns at 65 micron pitch.

Curve Description

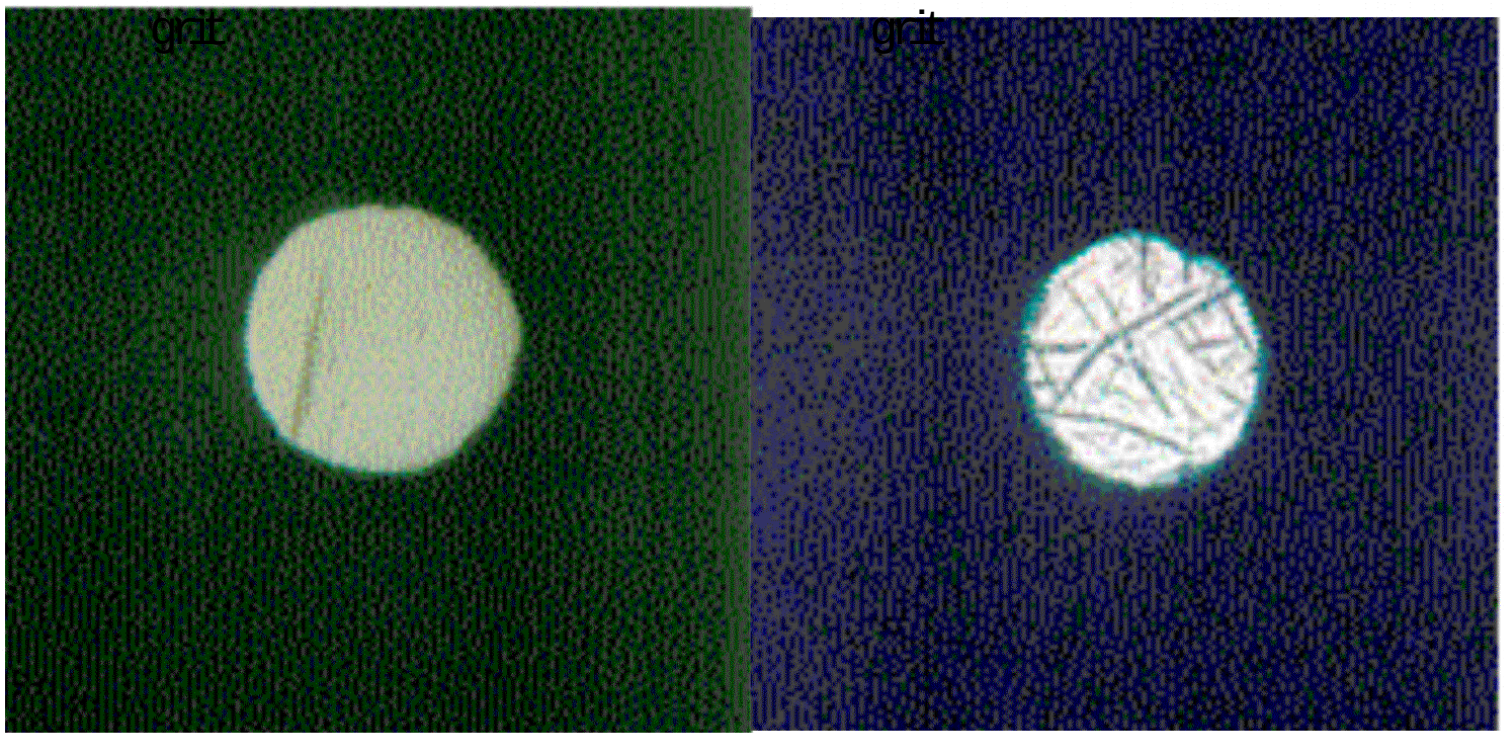


10 mV current, two probes, trace resistance not subtracted.

Probe Tip Profile: Smooth vs Rough

0.3 micron clean grit

3.0 micron clean grit



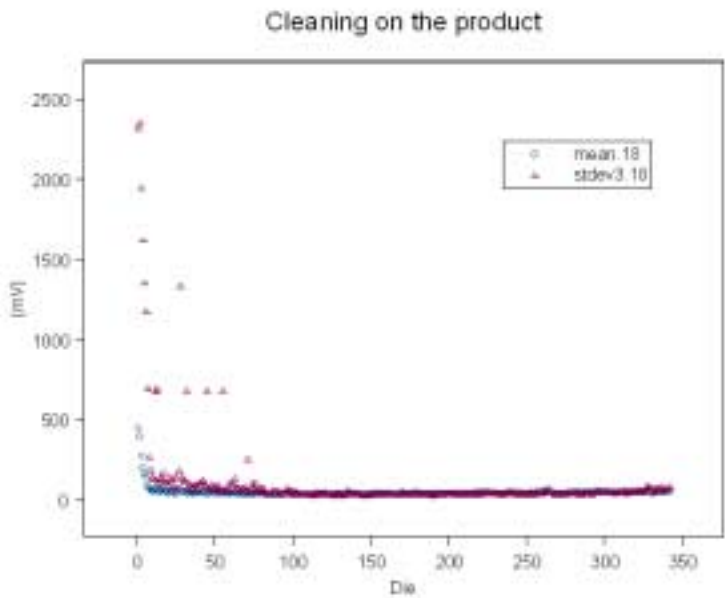
Both probes nominal 1.0 mil diameter. Smooth tip profile produces lower contact area but much more consistent and easier to observe.

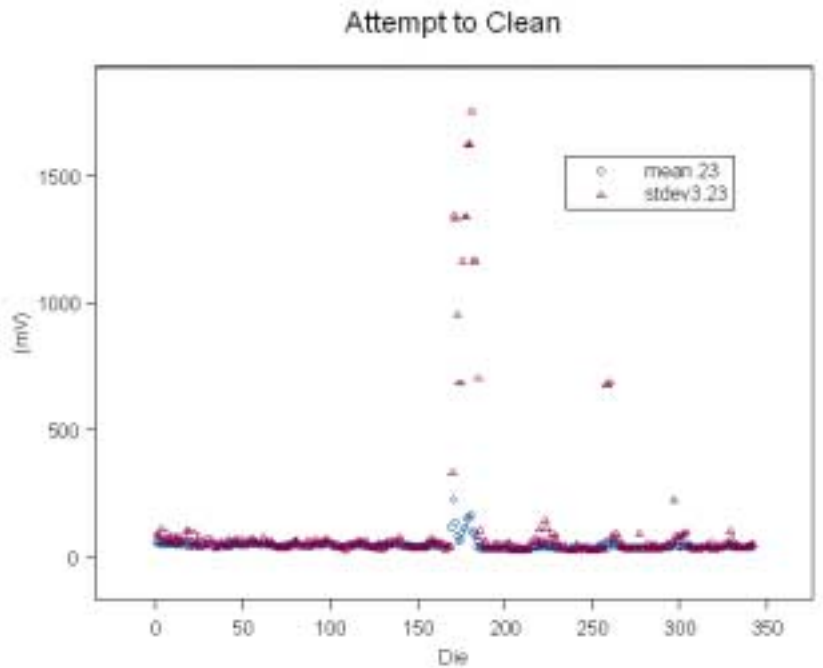
Probe cards

- 0.8 mil diameter tip
- 3 tiers
- tungsten-rhenium
- 1.5 gm/mil OT probe force

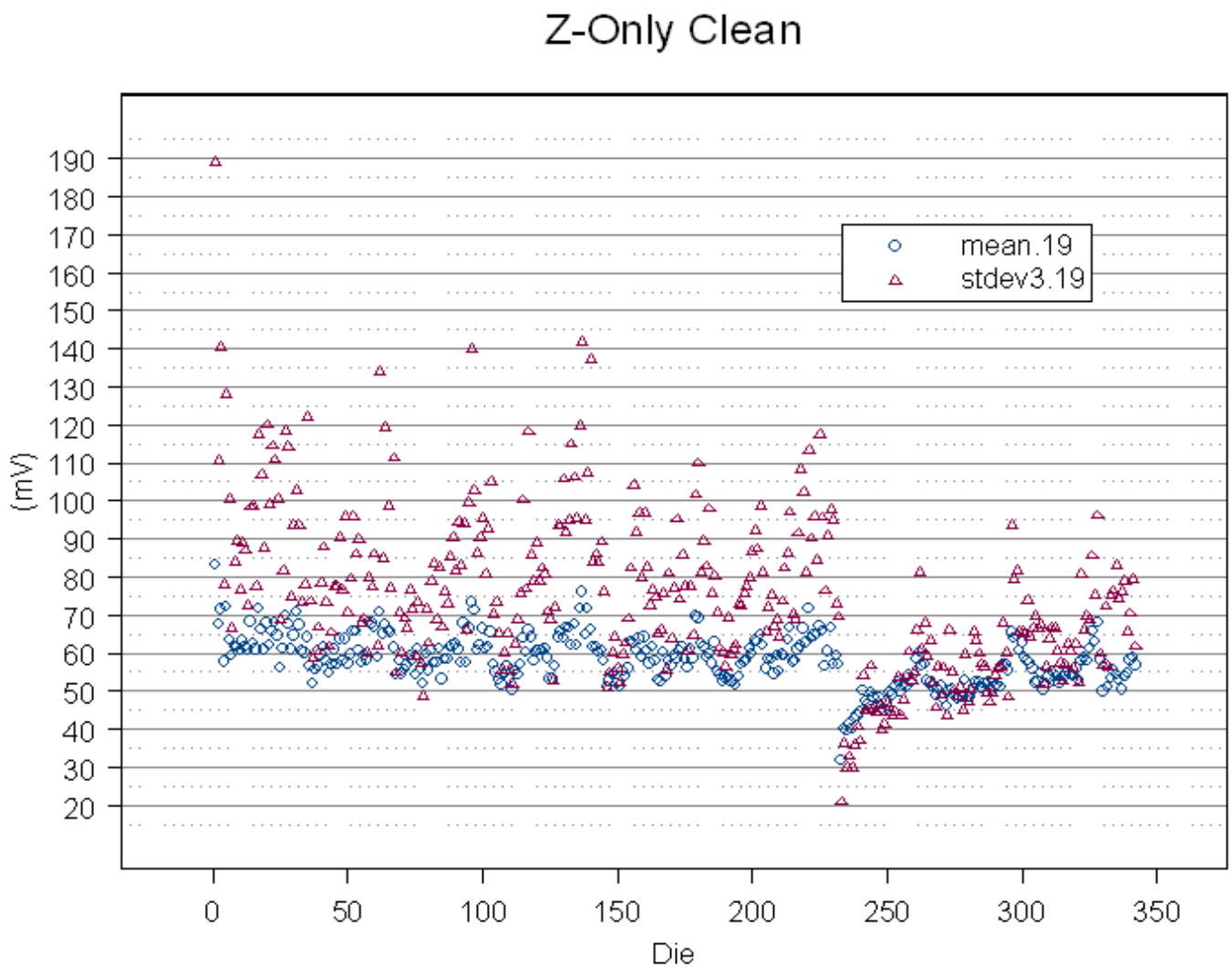
- 1.0 mil diameter tip
- 3 tiers
- tungsten-rhenium
- 1.2 gm/mil OT probe force

About Contamination

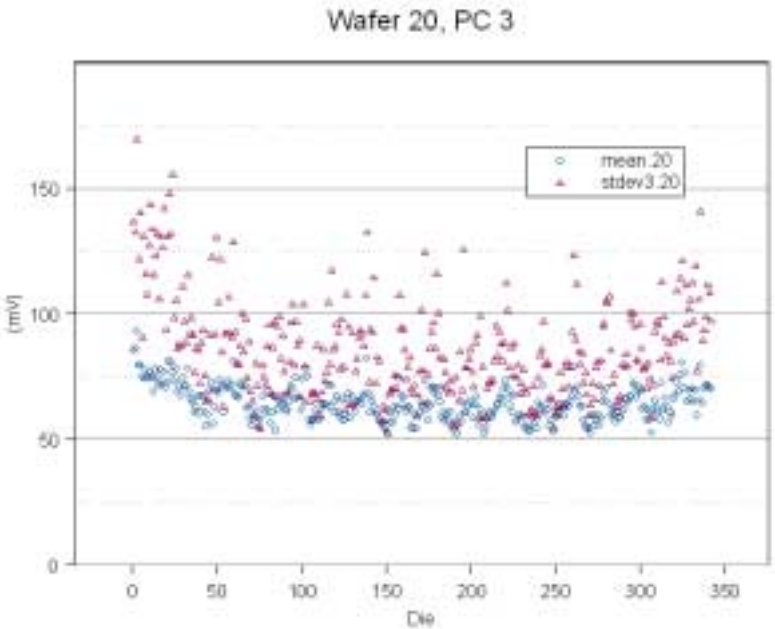


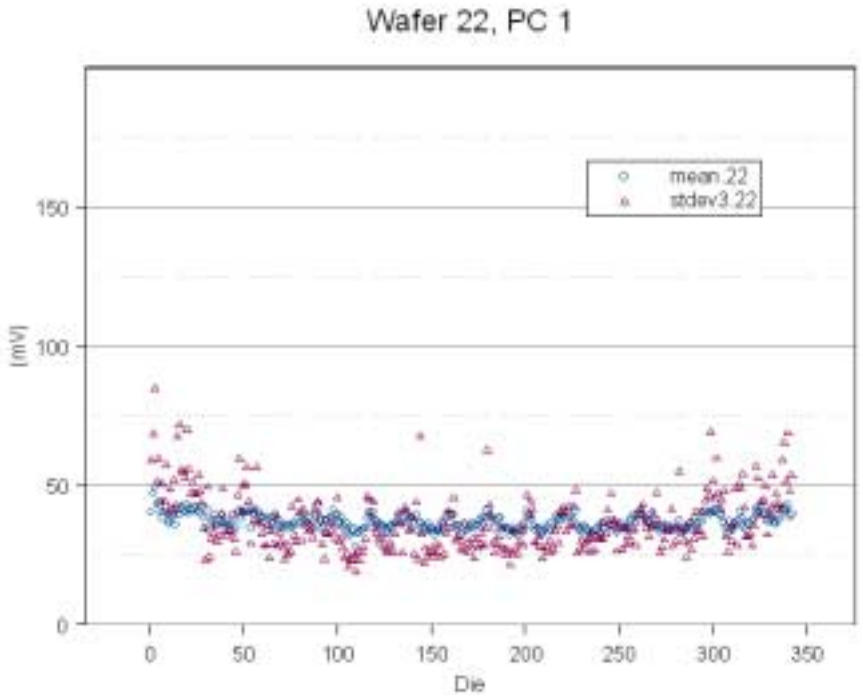


Baseline Contact Resistance

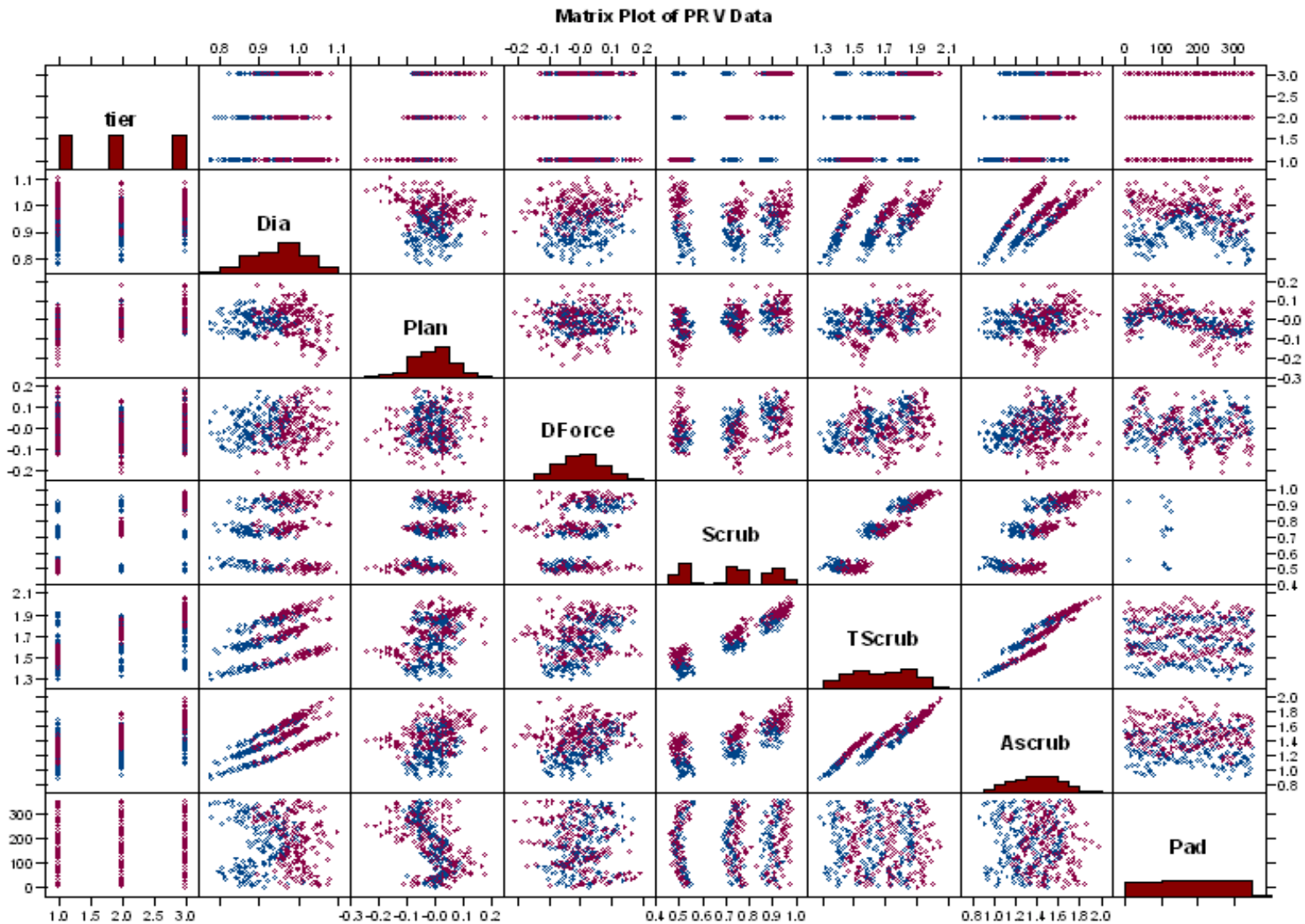


Wafers Selected

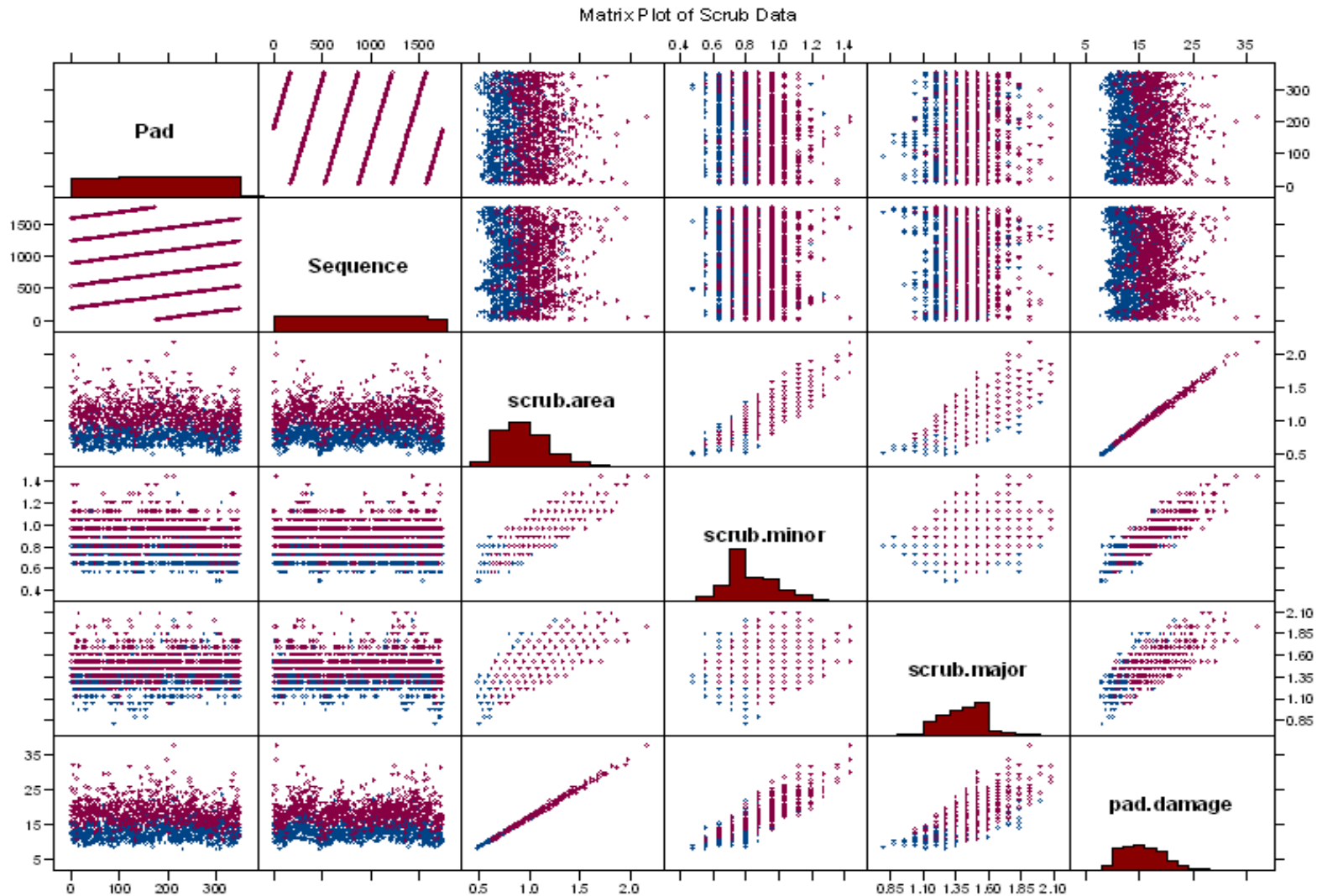




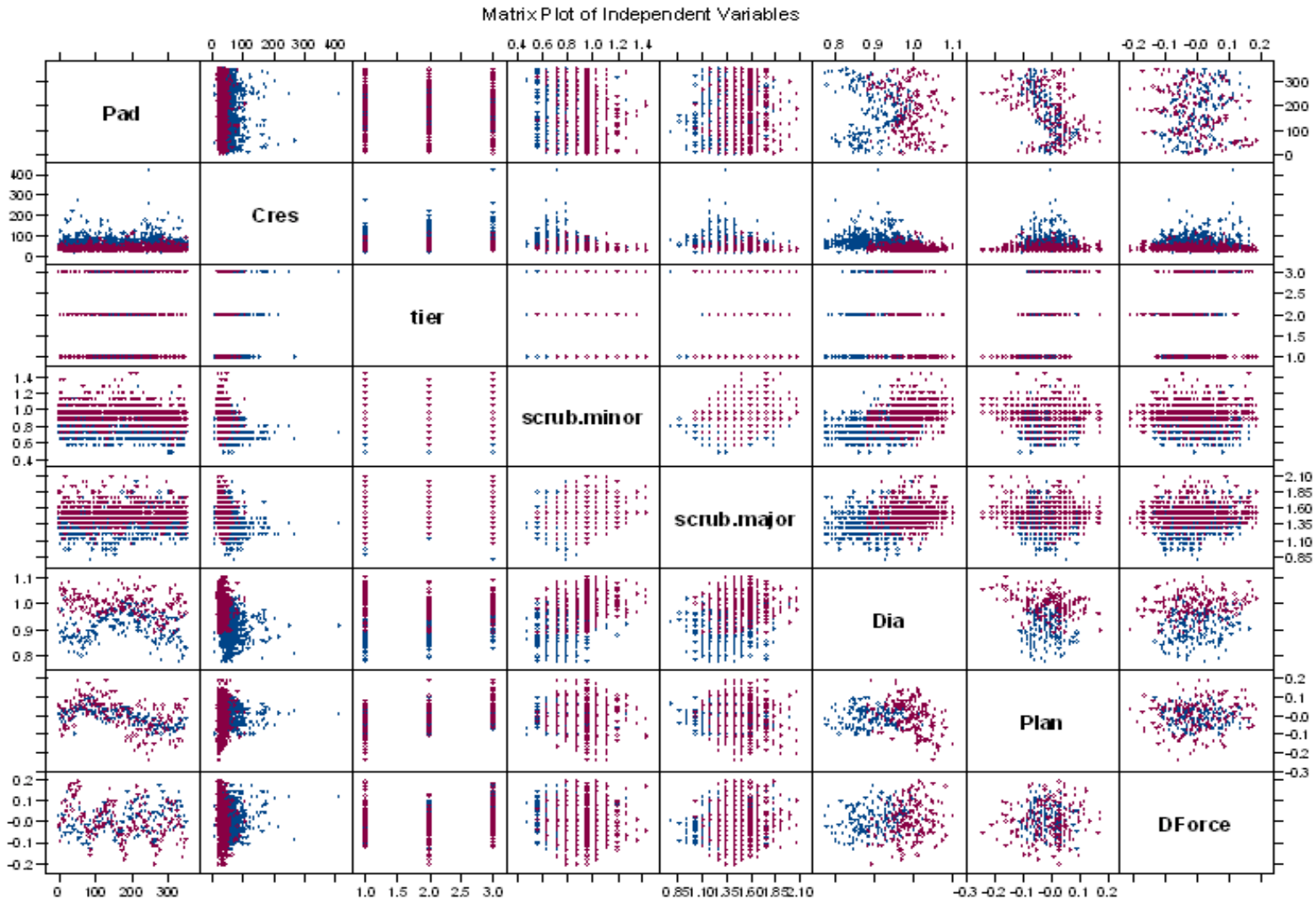
PRV Data


Matrix Plot of PRV Data
tier
Dia
Plan
DForce
Scrub
TScrub
Ascrub
Pad

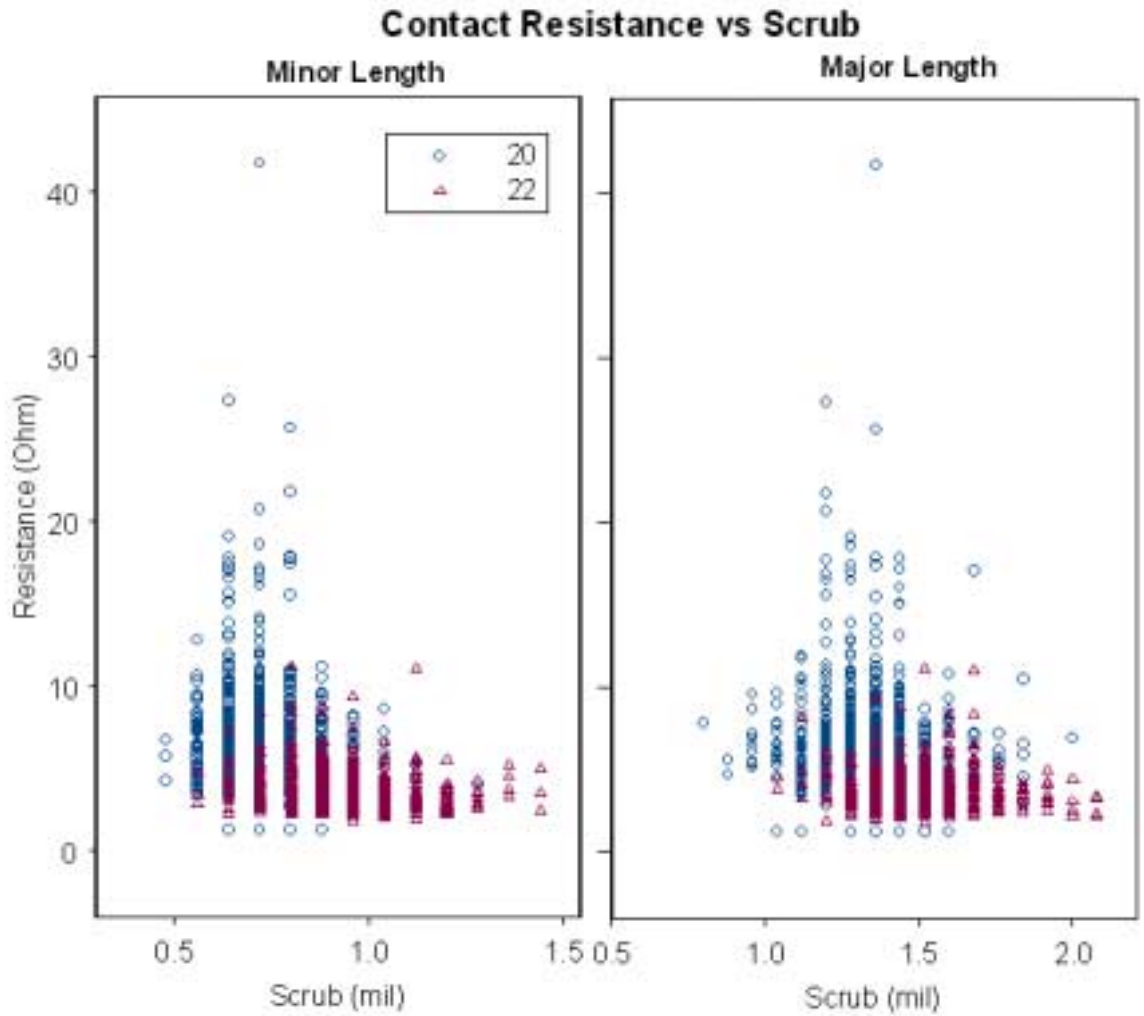
waferWoRx Data



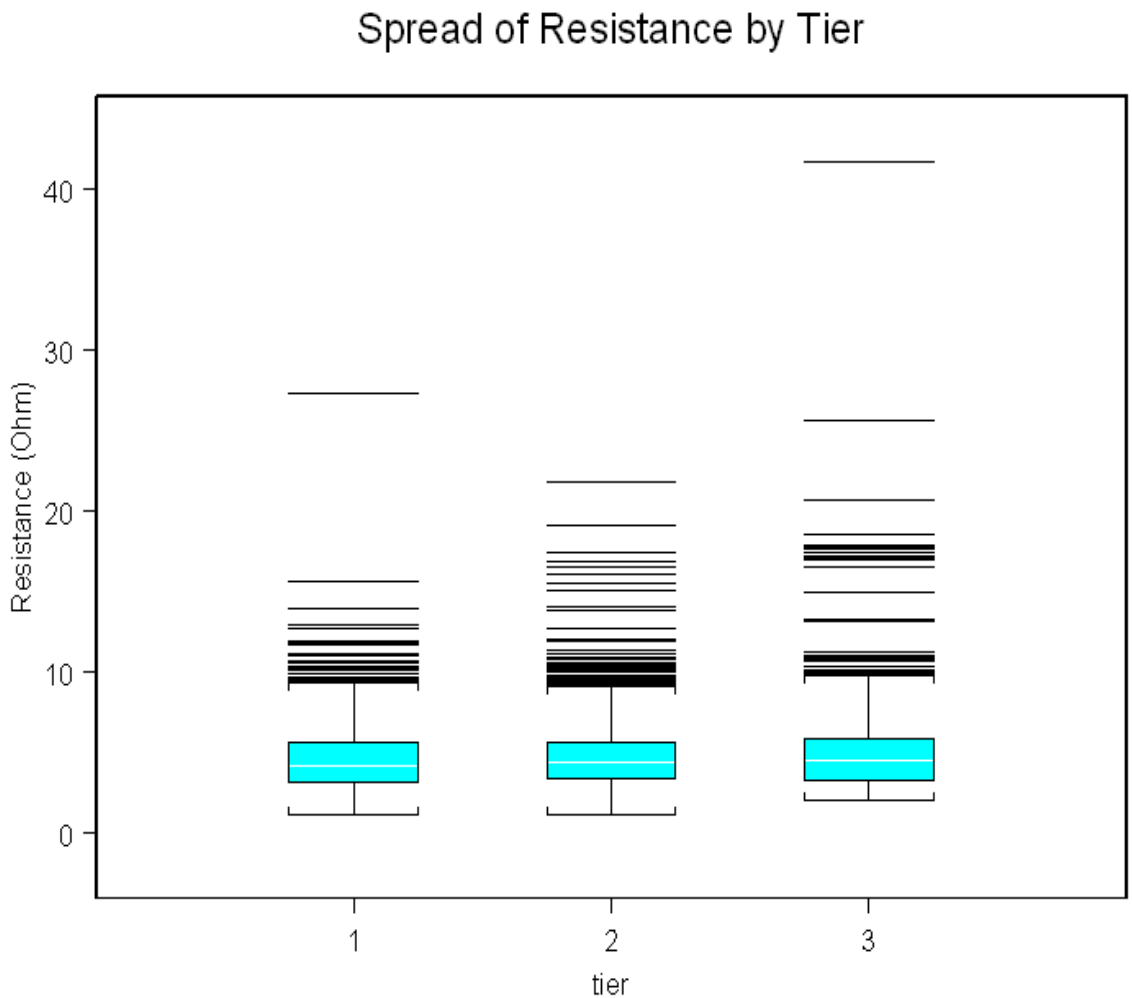
Cres


Matrix Plot of Independent Variables
Pad
Cres
tier
scrub.minor
scrub.major
Dia
Plan
DForce

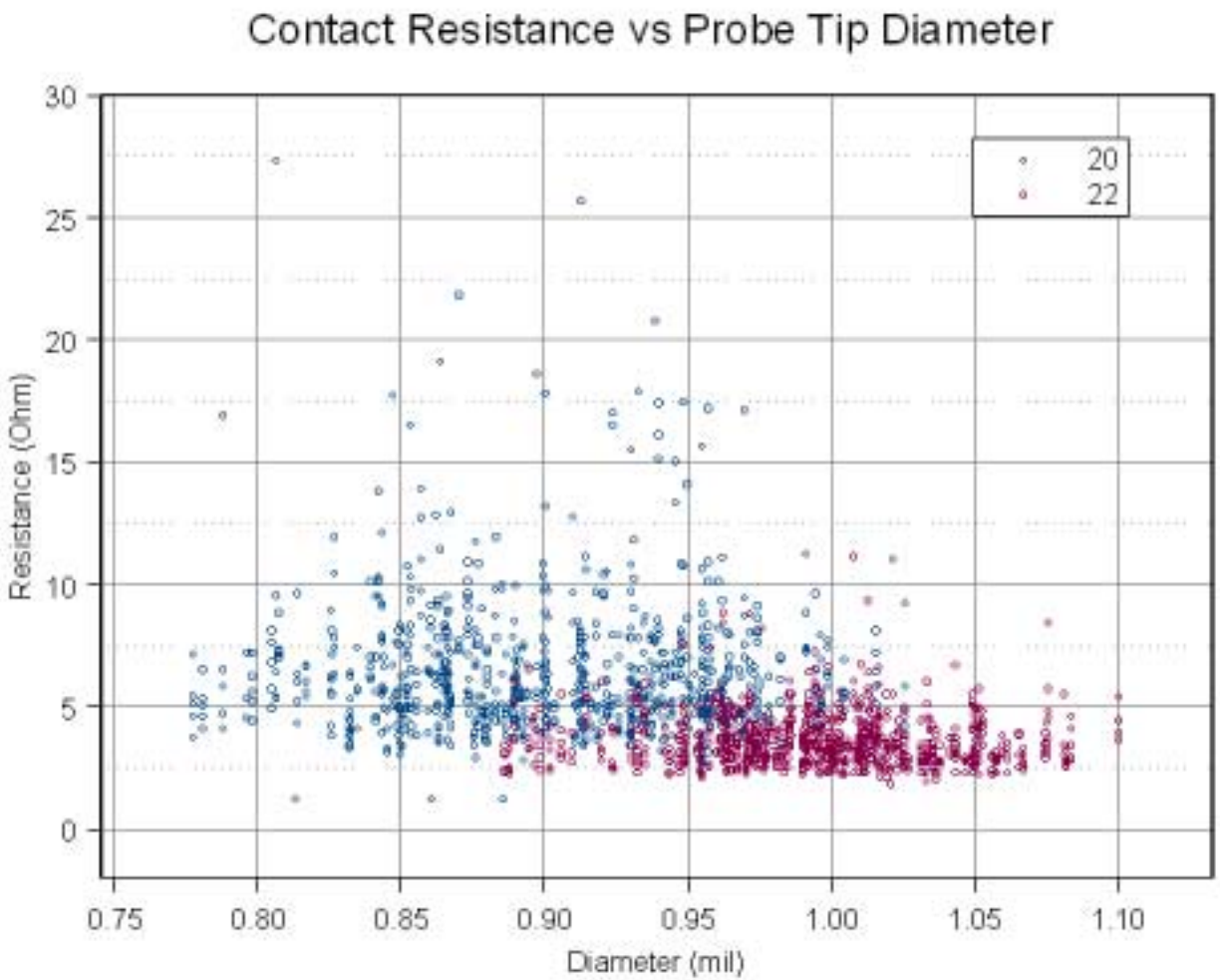
Scrub


Contact Resistance vs Scrub
Minor Length
Major Length
20
22
Resistance (Ohm)
0
10
20
30
40
0.5
1.0
1.5
2.0
Scrub (mil)
Scrub (mil)

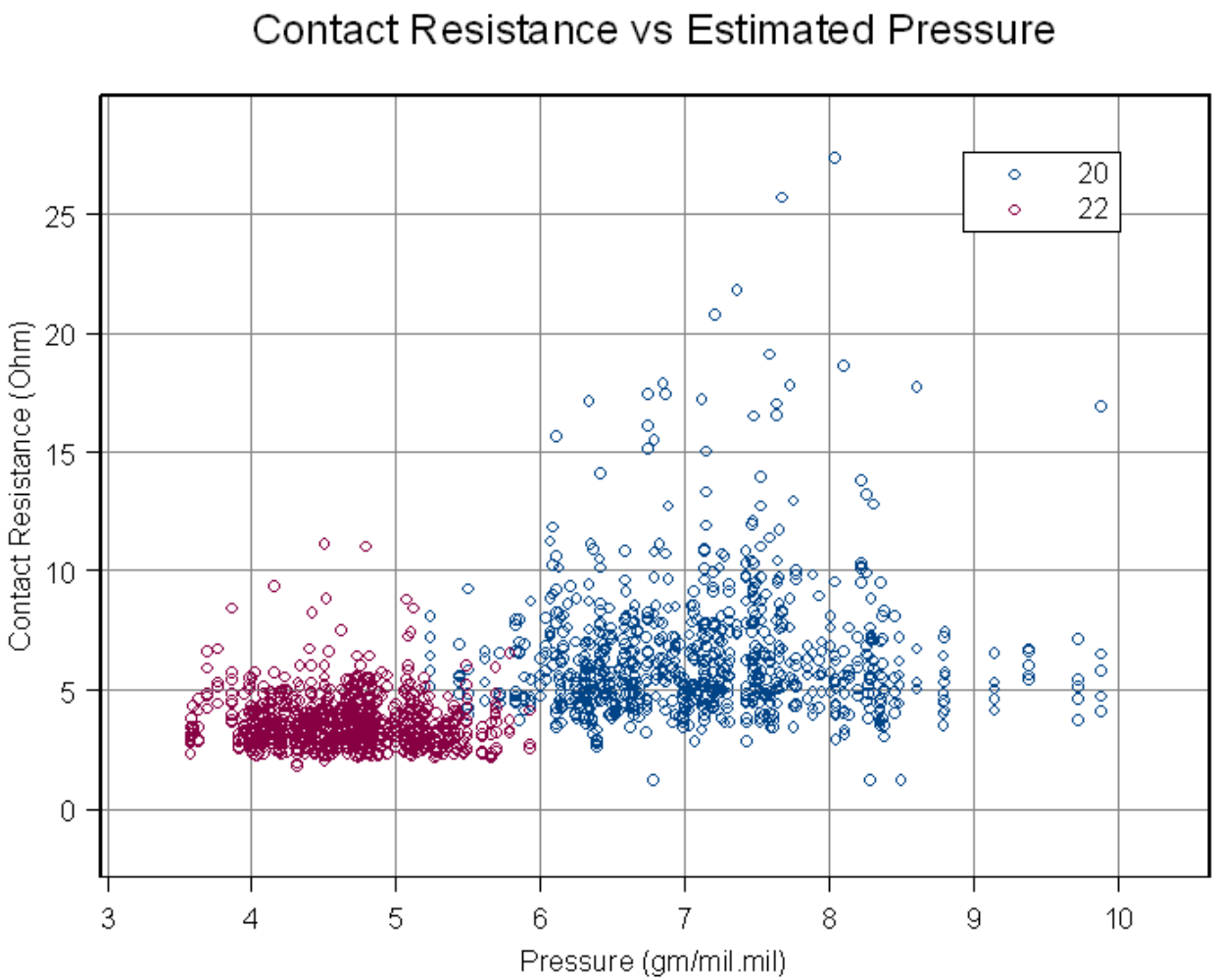
Tier


Spread of Resistance by Tier
Resistance (Ohm)
0
10
20
30
40
1
2
3
tier

Tip Diameter



Calculated Pressure



Contact Calculations

Carbonero et al

Probe resistance is the sum of effects due to constriction and contamination,

$$R_{tot} = R_{\text{constriction}} + R_{\text{contamination}} = \frac{\rho_{\text{probe}} + \rho_{\text{pad}}}{4na} + \frac{\sigma}{A} \quad (1)$$

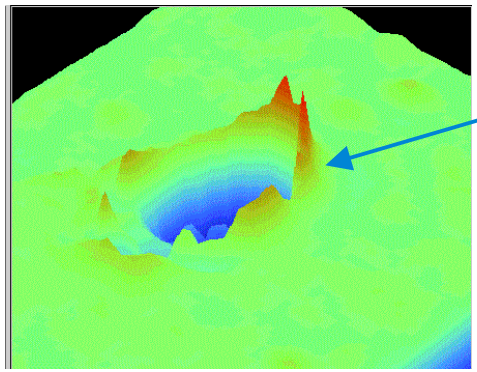
If the area considered is covered with resistive film we have $A = n\pi a^2$ and $R_{tot} = \frac{\rho_{\text{probe}} + \rho_{\text{pad}}}{4na} + \frac{\rho_{\text{film}} l_{\text{thickness}}}{n\pi a^2}$. (2)

Assuming $R_{\text{constriction}} = \text{Constant}$ and $R_{\text{consticton}} << R_{\text{contamination}}$ the contact resistance is dictated by the thickness of the film and the radius of the "A-spots", $R_{tot} \cong \frac{\rho_{\text{film}} l_{\text{thickness}}}{n\pi a^2}$. (3)

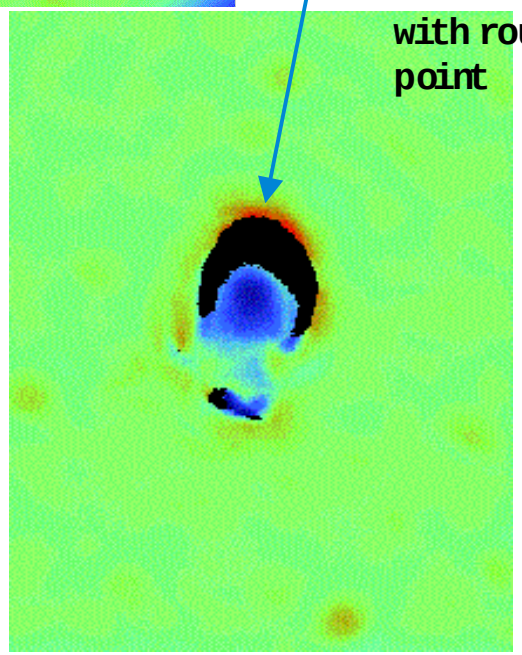
Actually, the tip is not a homogenous surface so $R_{tot} \cong \sum_i \frac{\rho_i l_i}{\pi a_i^2}$, but that's not very useful.

Contact resistance should vary with the film thickness and inversely with the contact area.

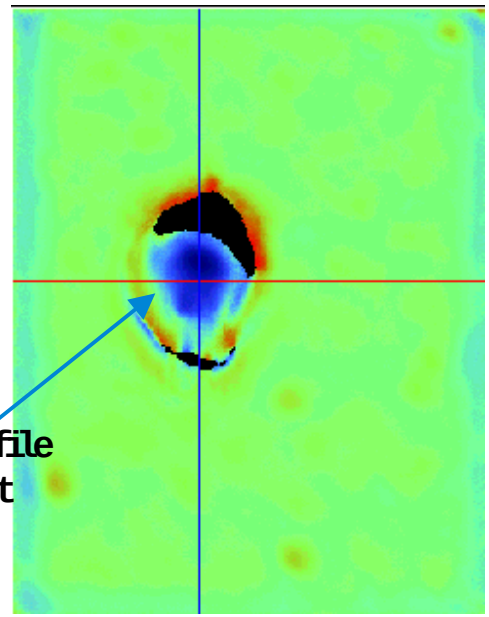
Scrub Profiles: Where is that contact area?

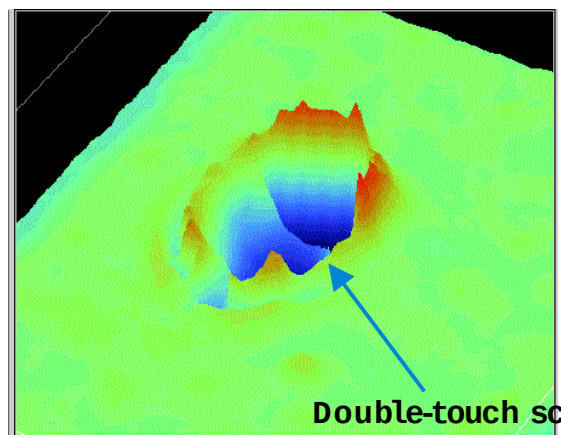


Vertical end walls



Rounded bottom profile with rounded deepest point

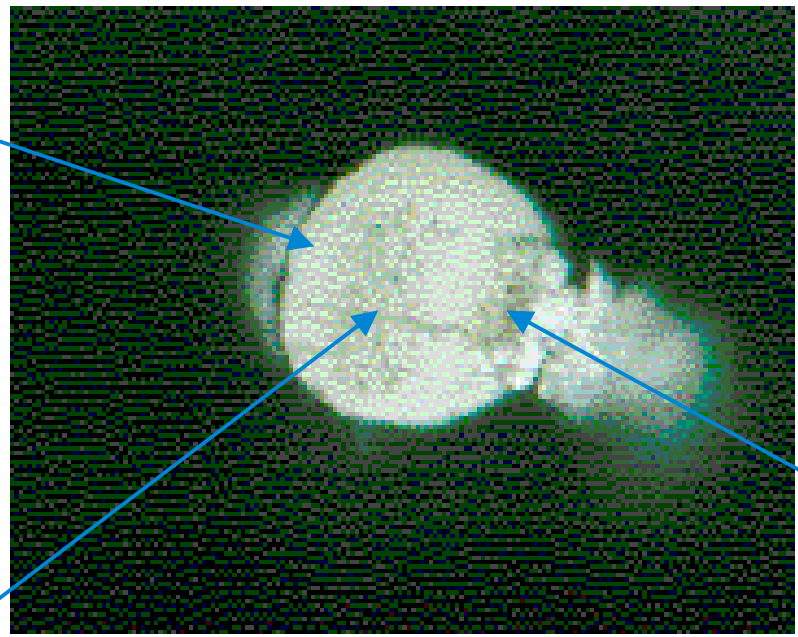




Double-touch scrubs: Note interior second end wall

Probe Tip Profile: Contact Zones

Toe: leading edge, free of adhered metal, film contamination



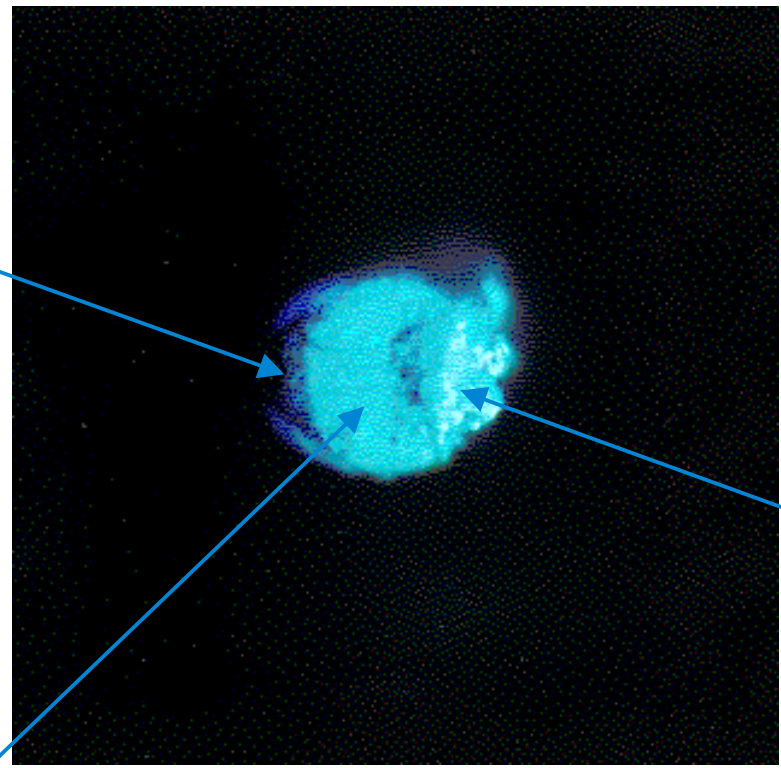
Low level of contamination on wafers

Heel: trailing edge, some adhered metal, particulate contamination

Crown: lowest before probing, highest pressure, adhered metal, film contamination

Probe Tip Profile: Contact Zones

Toe: leading edge, free of adhered metal, film contamination



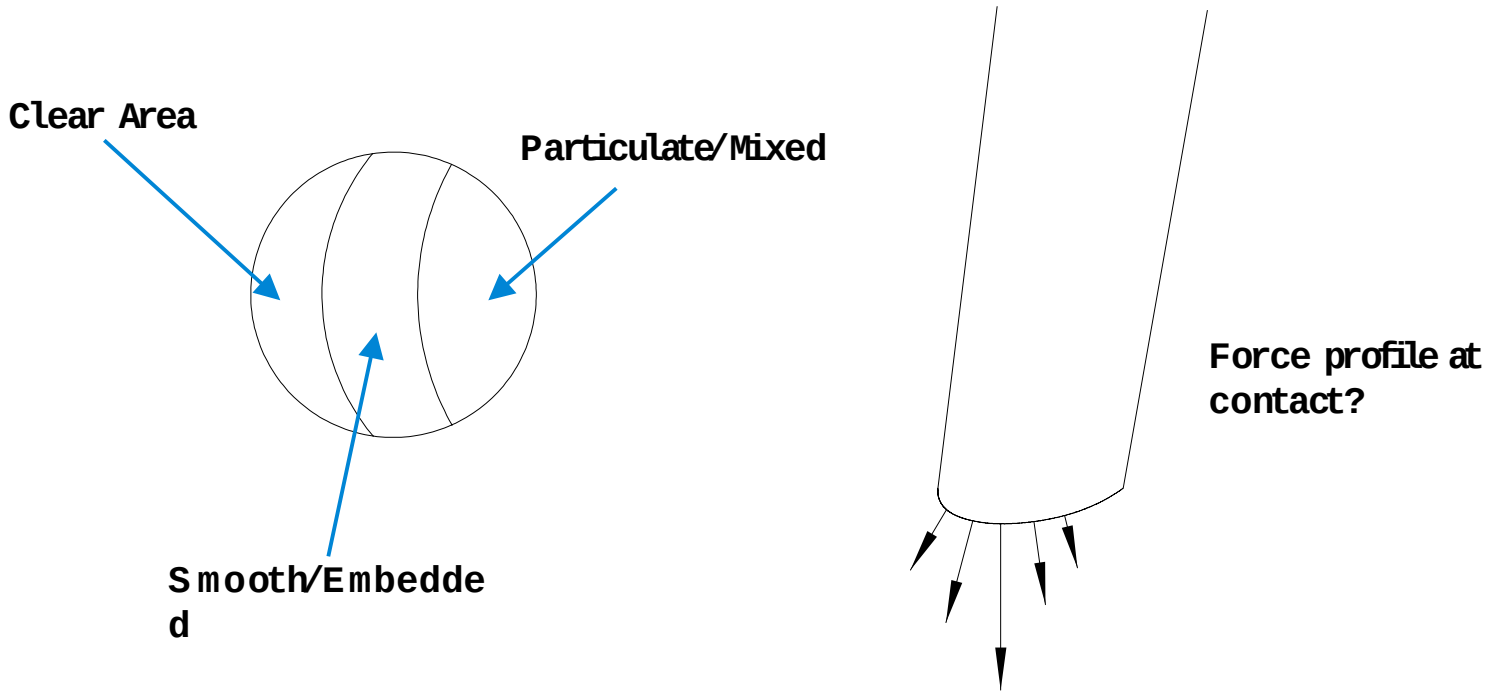
High level of known contamination on wafers

Heel: trailing edge, some adhered metal, particulate contamination

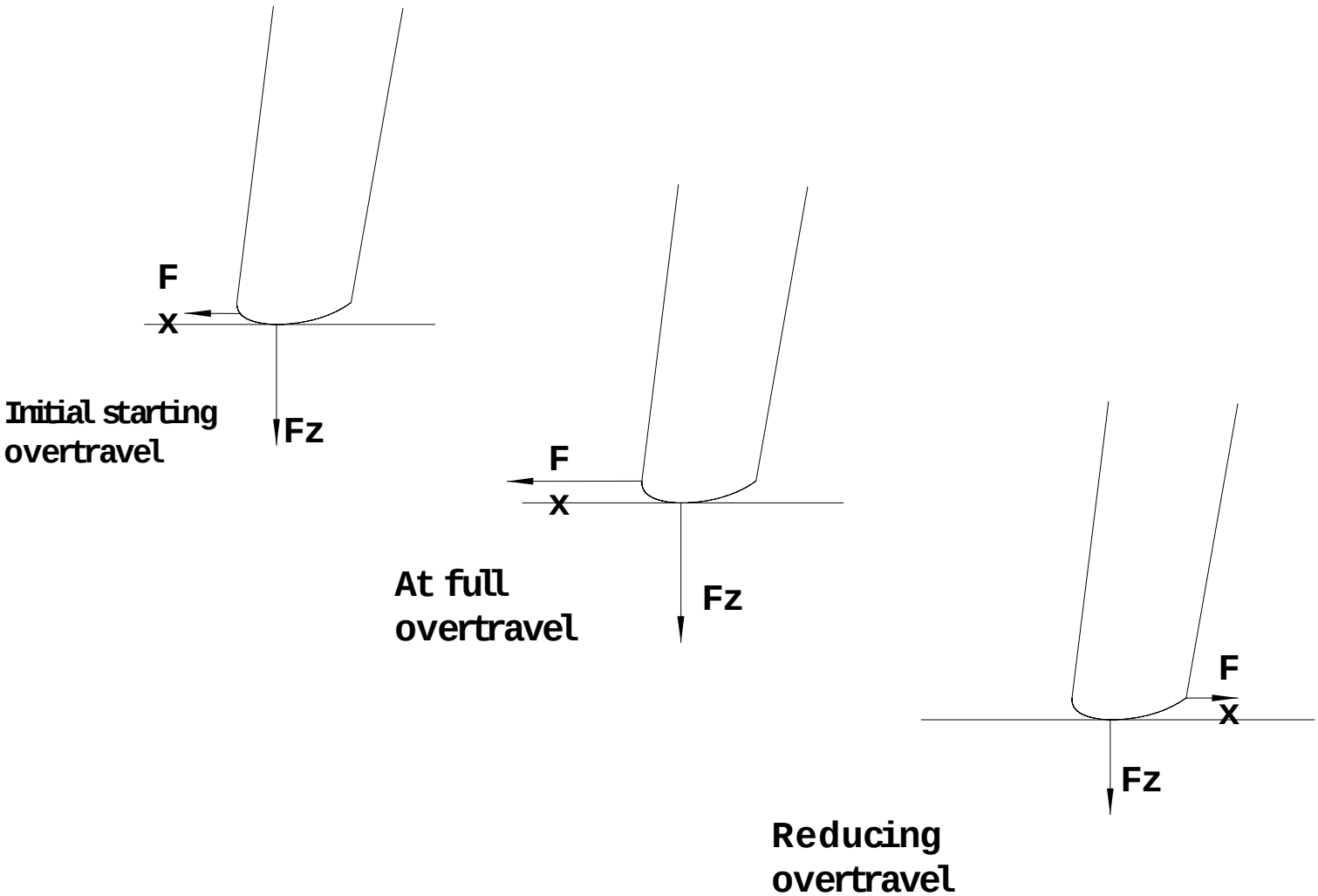
Crown: lowest before probing, highest pressure, adhered metal, film contamination

Shape, size and placement vary depending on tip diameter, tip profile, probe tier and pad contamination

Probe Tip Profile: Contact Zones



Probe Tip Profile: Force Directions



Summary

- Contact resistance due to contamination is much greater that innate probe resistance.
- Probe diameter is most important to low contact resistance due to influence on contact area.
- Force required may be just enough to break the oxide layer, produce good contact and maintain self cleaning. After breaking oxide more force may not necessarily reduce contact resistance.
- Primary conductive area may be crown of probe in steady conditions.