Adventures in Extreme Parallel Probing

Roger Sinsheimer, PE

Chief Engineer

The Function of Spring Probes in the ATE Interface

- ***Spring Probes create the separable electrical interconnection between the ATE Pin Electronics and the load board and/or the probe card***

How an Interface Manufacturer Selects a Spring Probe.

- *Size – diameter, overall length, stroke distance, extension, probe tip type*
- *Force required to compress to working height*
- *Pointing Accuracy*
- *DC Resistance – nominal value and consistency/repeatability*
- *RF performance*

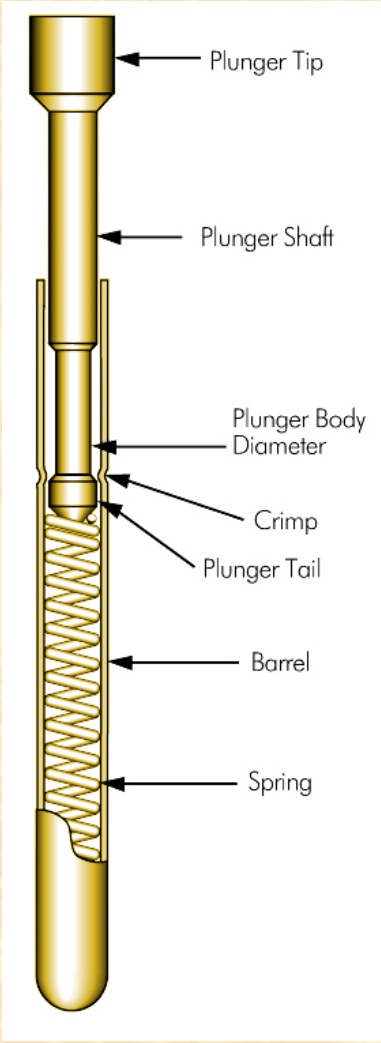


Image courtesy IDI

Why Reliability is Paramount as Pin Count Increases

- ***One failure in 10,000 contact opportunities is a source of concern when there are 680 probes in an ATE interface***

Why Reliability is Paramount as Pin Count Increases

- *One failure in 10,000 contact opportunities is a recipe for disaster when there's 11,000 probes in an interface!*

Statistics and Probe Performance

- *Todd Sargent's paper in 2002, "Dynamic Variation of Contact Resistance in Test Interfaces" demonstrated that spring probe DC resistance has a non-Gaussian distribution*
- *Is Three-Sigma performance sufficient? (66,807 failures {Defects} Per Million Opportunities, or 93% reliability)*

Statistics and Probe Performance

- *How about Four Sigma? (6210 Defects Per Million Opportunities or 99% reliability)*
- *4.5 sigma? (1350 DMPO or 99.87%)*
- *Five? (233 DPMO or 99.977%)*
- *Do I hear Six? (3.4 DPMO or 99.9997%)*

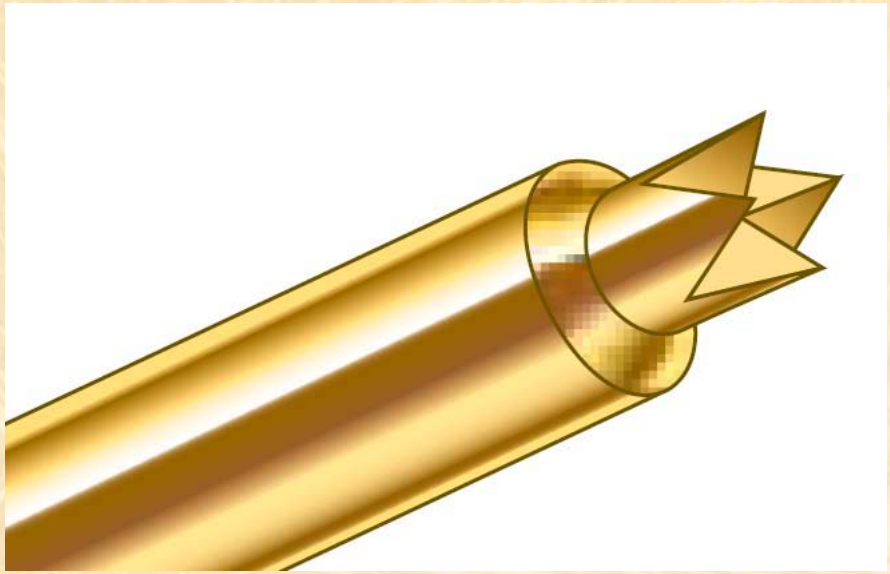
Probe Characteristics

- *Probe Tip Type*
- *Pointing Accuracy*
- *Force*
- *DC Resistance / Reliability*
- *Current Handling*
- *RF Performance*

Probe Tip Type

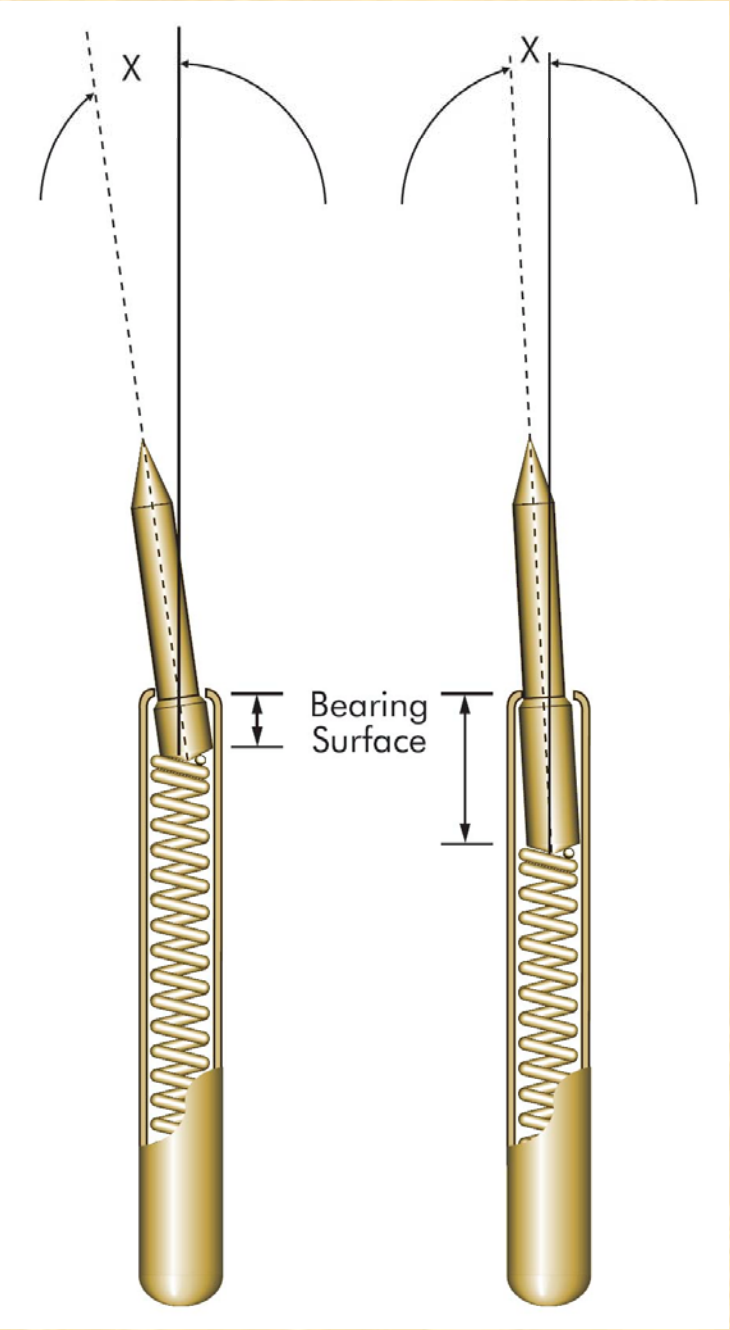
- *Probe tips are selected for various characteristics*
  - *Is the probe tip contacting a via – or a pad?*
  - *Is the surface being contacted truly clean, or might it be contaminated? With what?*
  - *Is RF or DC performance paramount?*
  - *If it's DC, what is the maximum amount of current is being passed through the spring probe?*

Probe Tip Type



Images courtesy IDI

Pointing Accuracy



Images courtesy IDI

Image provided by IDI

FORCE

- *Consistency*
  - *Having a lot of probes to average the load over can mask problems with inconsistent force*
  - *Smoothness vs. “scratchiness” is an important consideration*

FORCE (cont'd)

- *Magnitude: Effect of high force spring probes on interface design*
  - *The good news: High spring probe force improves DC resistance reliability*

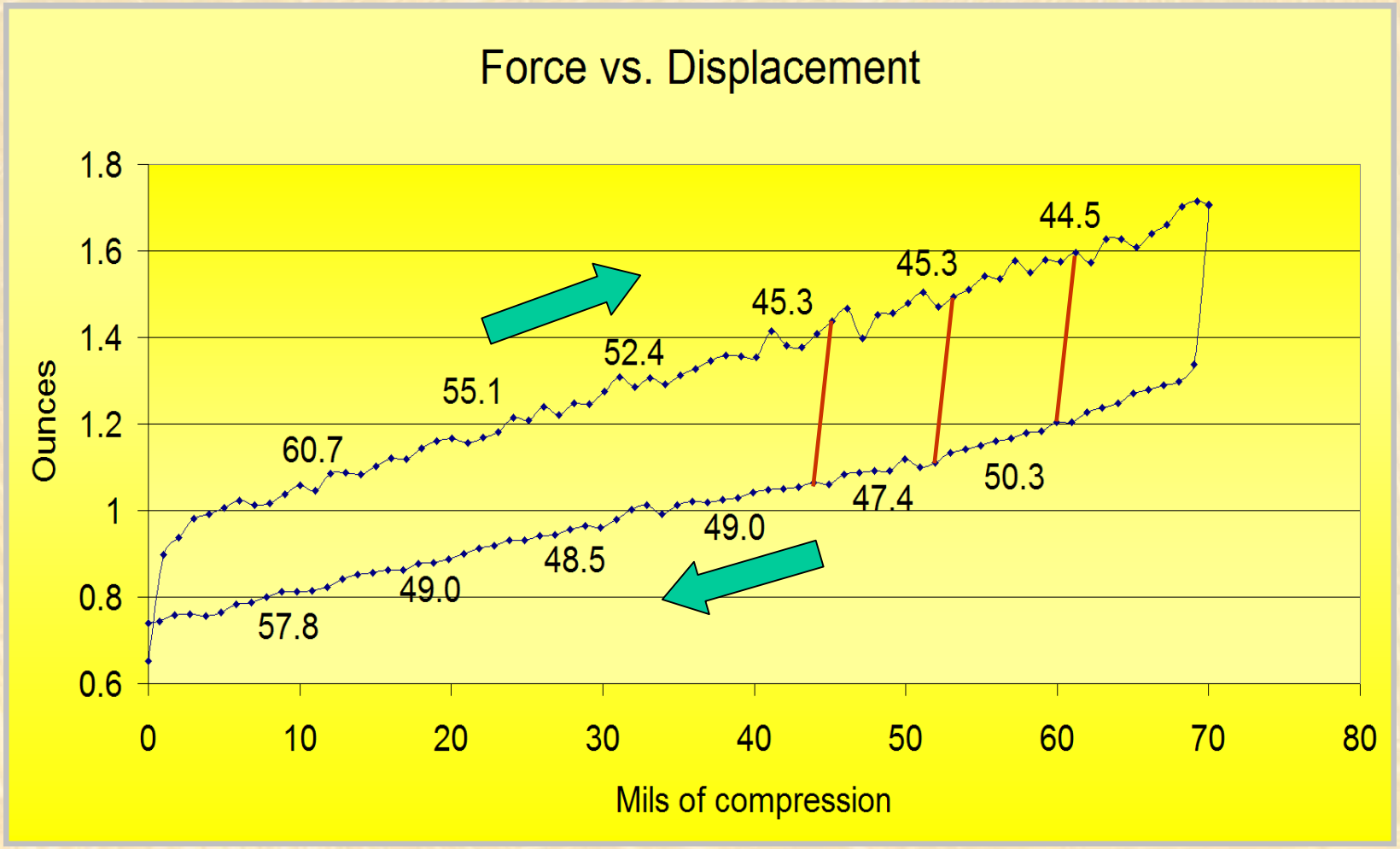
FORCE (cont'd)

- *Magnitude: Effect of high force spring probes on interface design*
  - *The bad news: High spring probe force means more mechanical stress on the interface and the probe card and/or load board*
    - *High spring probe force can result in reduced RF performance due to the resulting distortion of the load board and/or probe card*

FORCE (cont'd)

- *Hysteresis*
  - *The "real" force (the one that determines the force applied to create electrical contact) is the force delivered on the upstroke (probe extension), not the downstroke*

FORCE (cont'd)

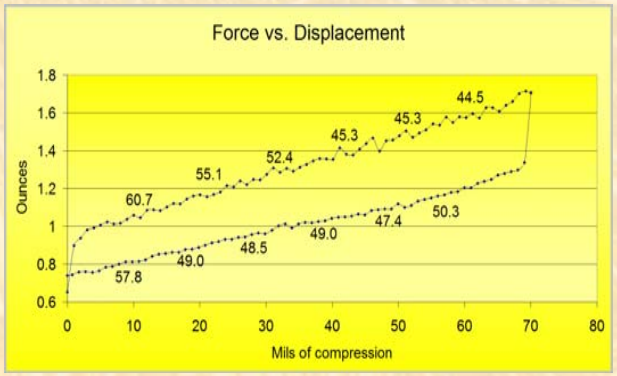

Force vs. Displacement
Ounces
1.8
1.6
1.4
1.2
1
0.8
0.6
0
10
20
30
40
50
60
70
80
Mils of compression
60.7
55.1
52.4
45.3
44.5
45.3
50.3
47.4
49.0
48.5
49.0
57.8

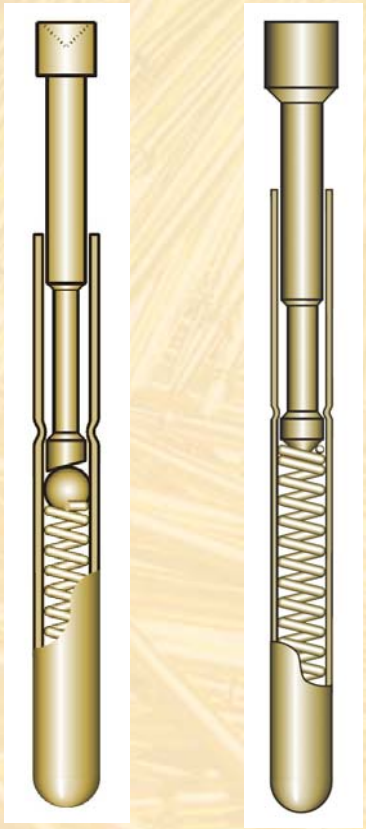
DC Resistance

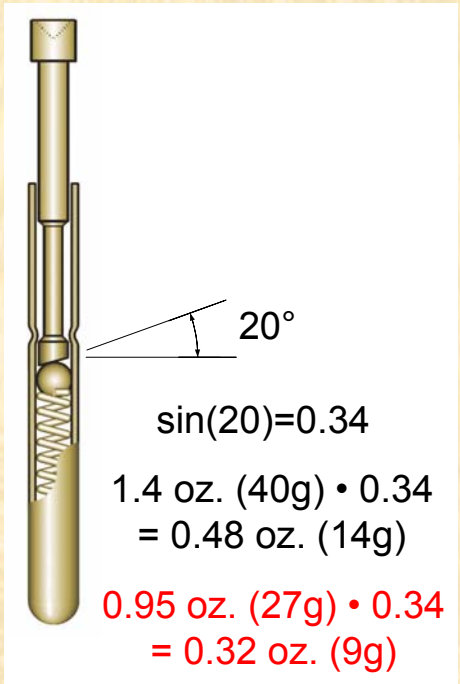
- Construction
  - Force Delivery
  - Physical Size
  - Material Choices / Surface Condition
  - Manufacturing Techniques
  - Springs
  - Bias Balls

DC Resistance: Construction

- *Force Delivery*
  - *Ball Bias*
  - *Bias Cut*
  - *Straight*
  - *Other tricks*



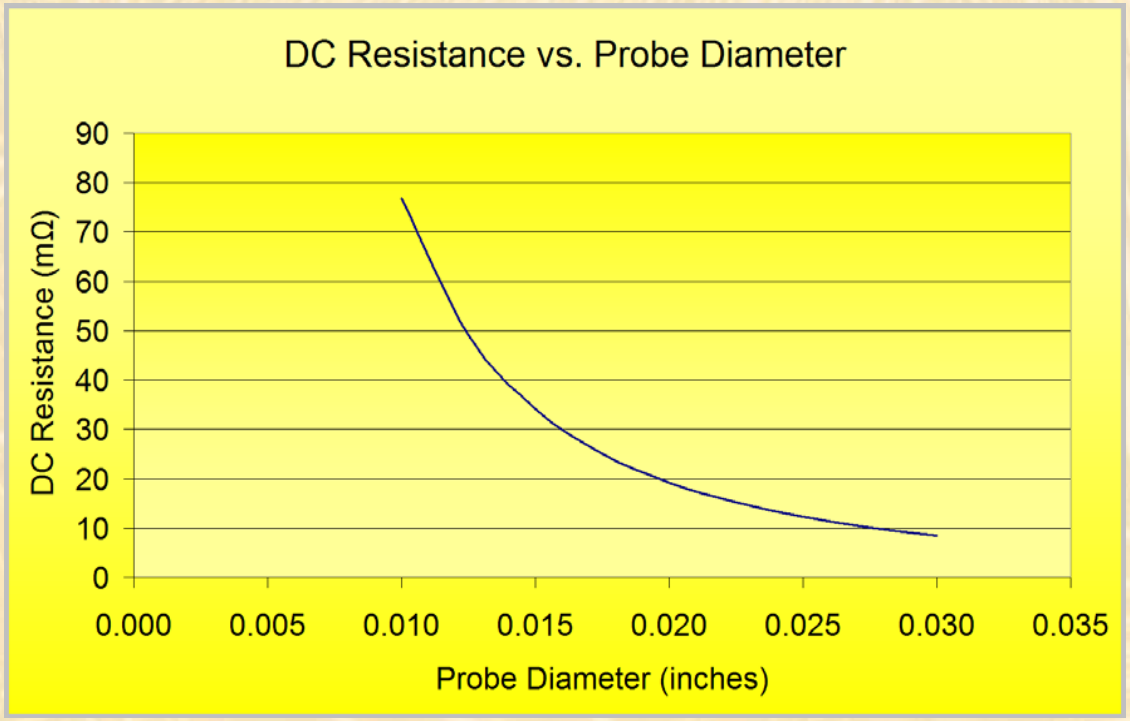




Images courtesy IDI

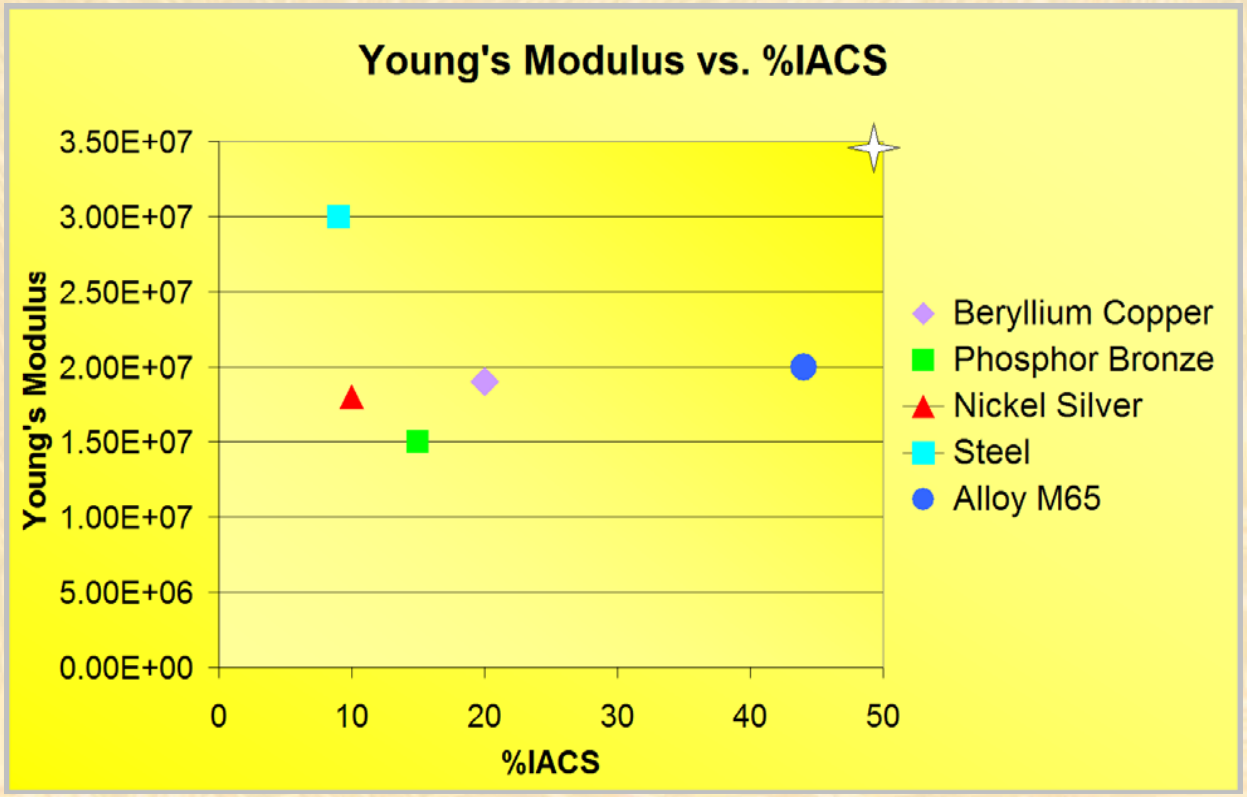
DC Resistance: Construction

- ***Construction***
  - ***Physical size of spring probe affects DC resistance due to bulk resistance effects***



DC Resistance: Construction

- ***Bulk Material Choices:***
  - ***Hardness / Conductivity***

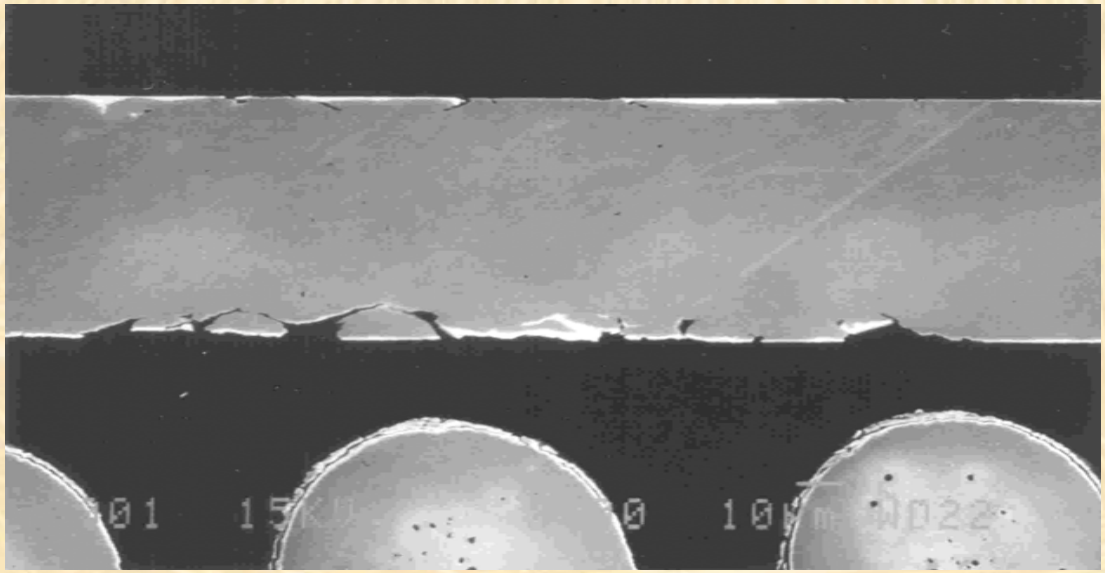


DC Resistance: Construction

- *Manufacturing Techniques*
  - *Pre-Plating: Material choices*
    - *Noble metals*
      - *Rhodium*
      - *Pure Gold*
      - *Hard Gold Hardening Agents*
        - *Copper*
        - *Cobalt*

DC Resistance: Construction

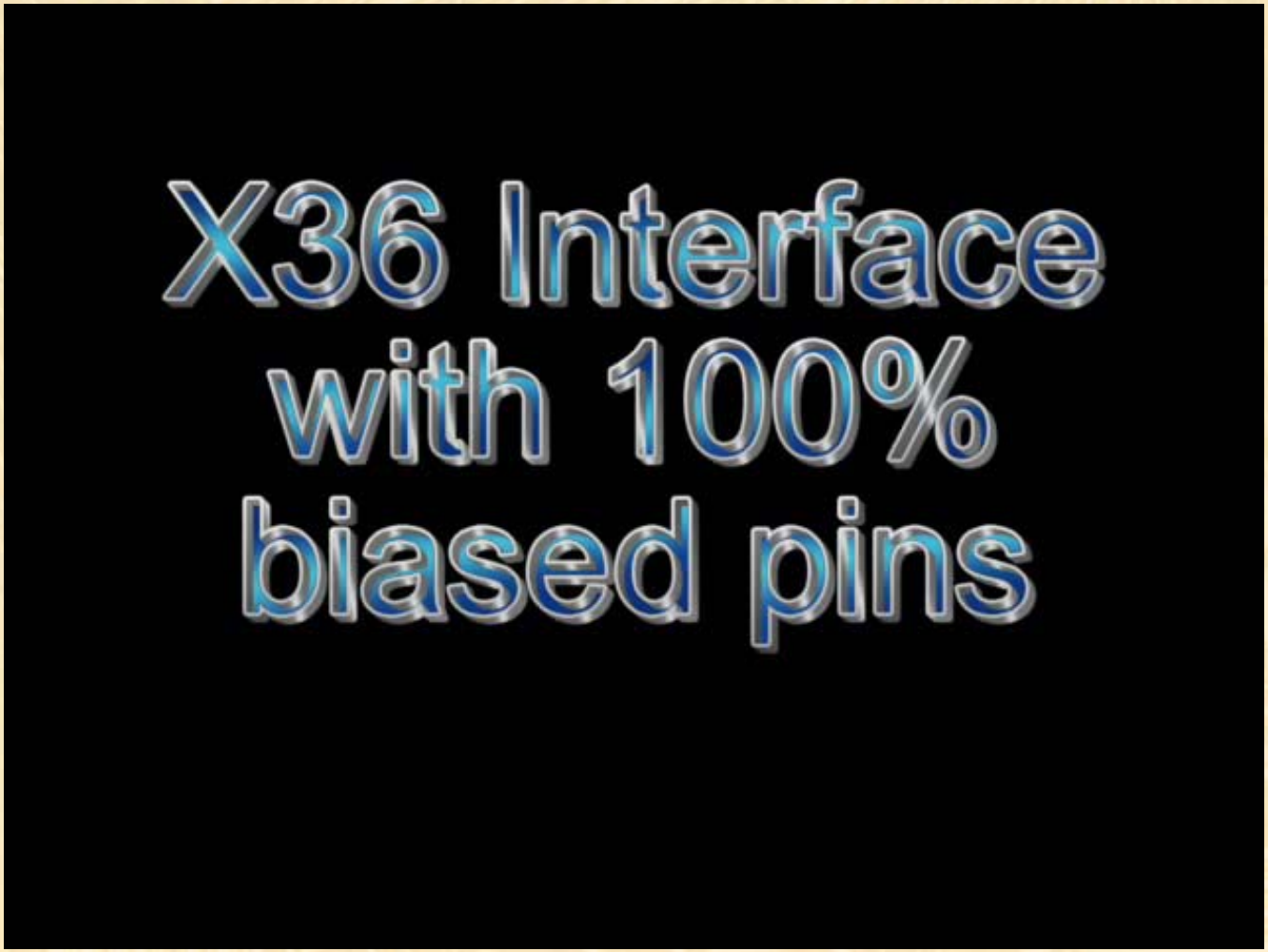
- *Manufacturing Techniques (cont'd)*
  - *Drawing*
    - *Effect of the drawing process on pre-plating / cladding*



DC Resistance: Construction

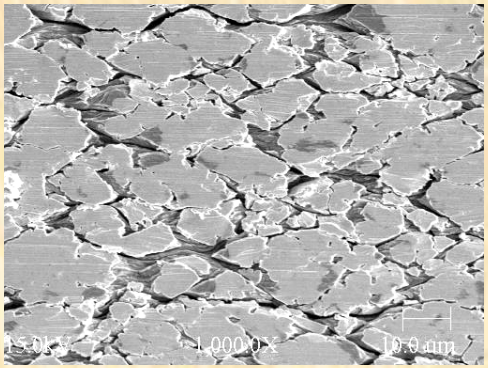
- *Manufacturing Techniques (cont'd)*
  - *Surface treatments*
    - *Plated strip*
      - *Underplating with electroplate Ni to prevent copper diffusion*
    - *Clad strip*
  - *Surface finish*
    - *It can be too rough*
    - *It can be too smooth*

DC Resistance: Construction



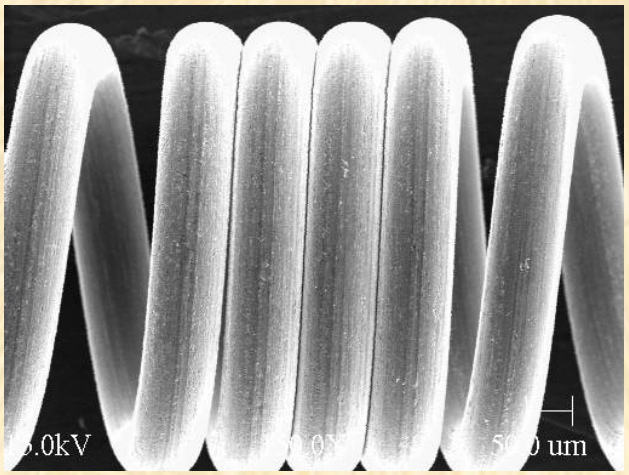
DC Resistance: Construction

- *Manufacturing Techniques (cont'd)*
  - *Post-draw Surface treatments*
    - *After forming, inner surface of barrel can be repaired.*
      - *Electroless / electroplate Nickel*
      - *Electroless / electroplate Gold*
        - *With electroplating processes must be concerned about plating "throw"*



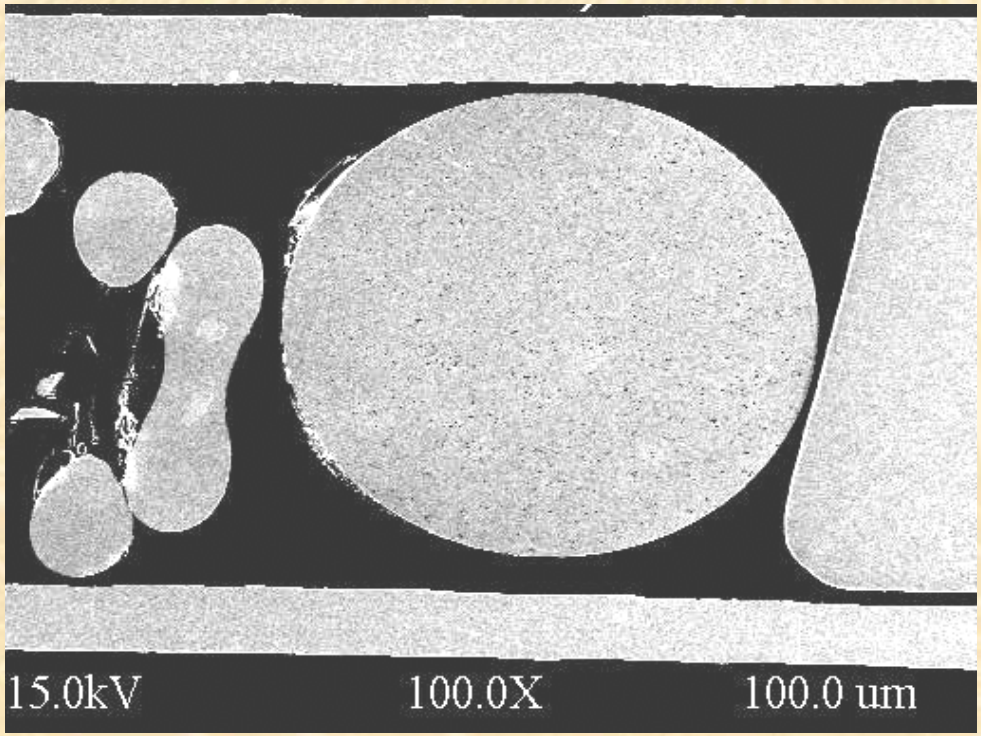
DC Resistance: Construction

- Springs
  - Materials
    - Stainless Steel
    - Music Wire
    - Beryllium Copper
    - Phosphor Bronze
  - Plating (for non-stainless steel springs)
    - Nickel
    - Zinc
    - Gold



DC Resistance: Construction

- *Balls (for ball-bias construction)*
  - *Material: Steel or Stainless Steel*
  - *Plating*
    - *Hard Gold*
    - *Rhodium*

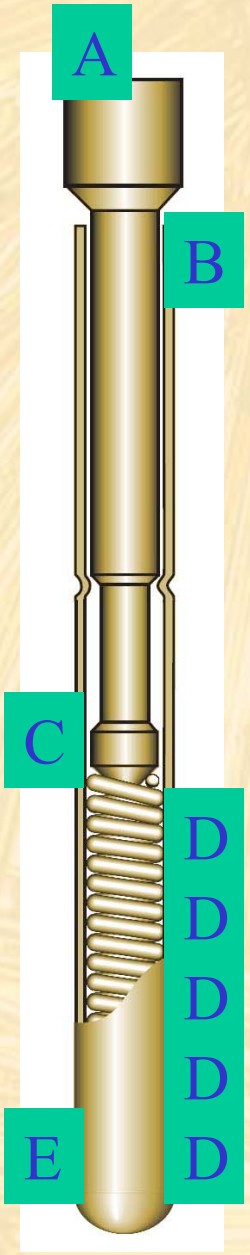


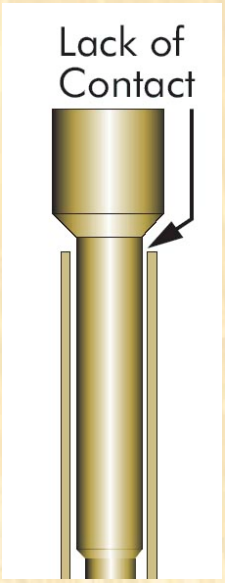
DC Resistance

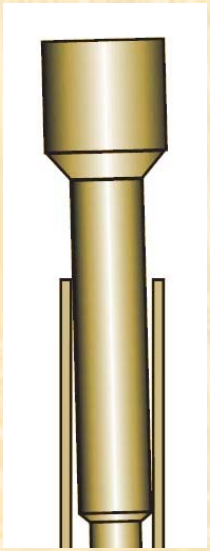
- ***Constriction Resistance***
  - ***Covered extremely well by January Kister's 1998 SWTW presentation: "Intro to Physics of Contact Resistance", which provided a concise distillation of Ragnar Holm's 500-page seminal work "Electric Contacts – Theory and Applications"***

DC Resistance

- Constriction Resistance (cont'd)
  - Where does the contact occur?
    - At the probe tip
    - Within the probe
    - Through the spring?!?
    - At the probe receptacle





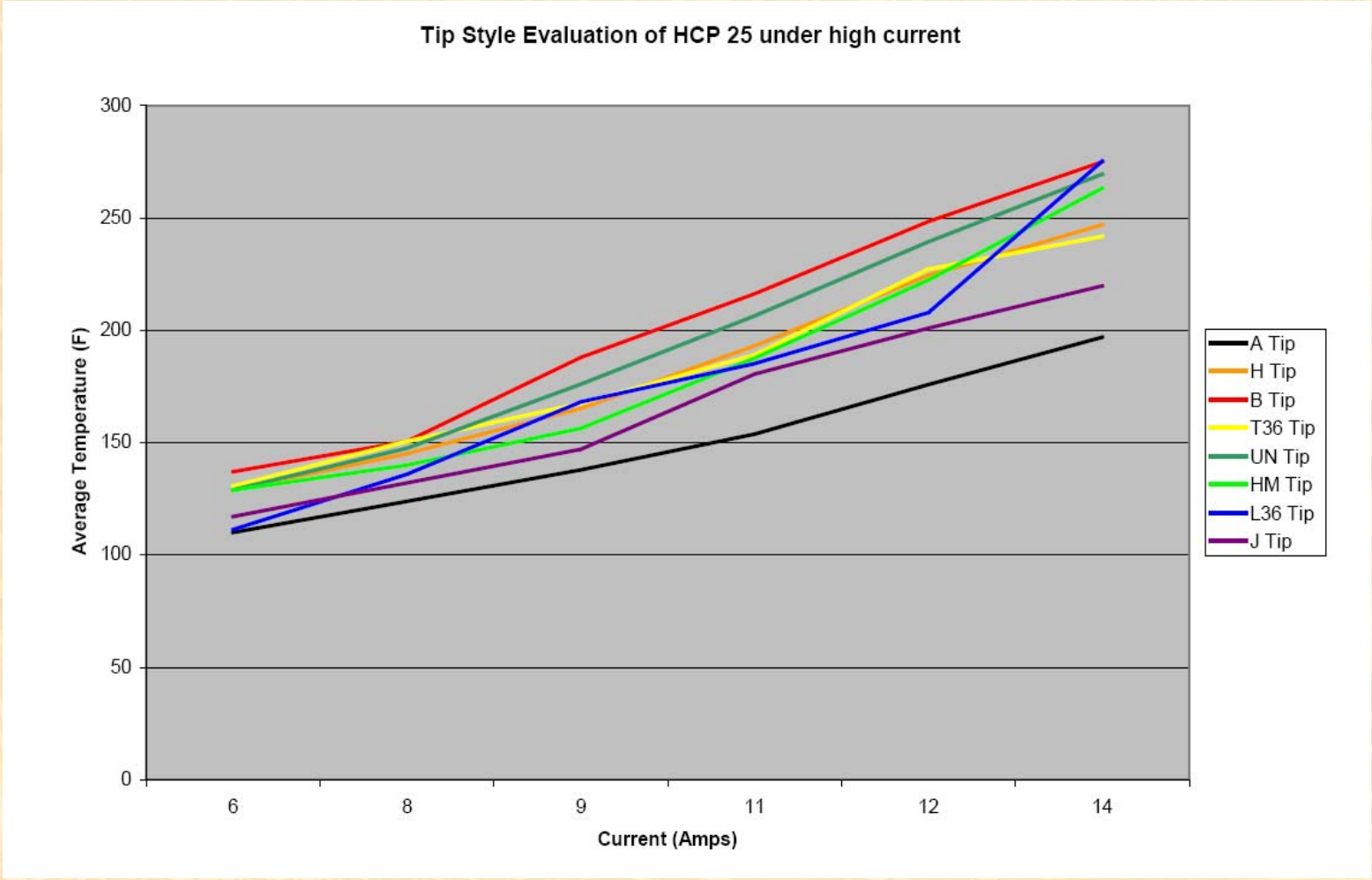


Images courtesy IDI

Current Handling

- *Controlled by many factors*
  - *Constriction resistance(s)*
  - *Bulk resistance of probe plunger and barrel material*
  - *Path for thermal energy away from heated probe*

Current Handling

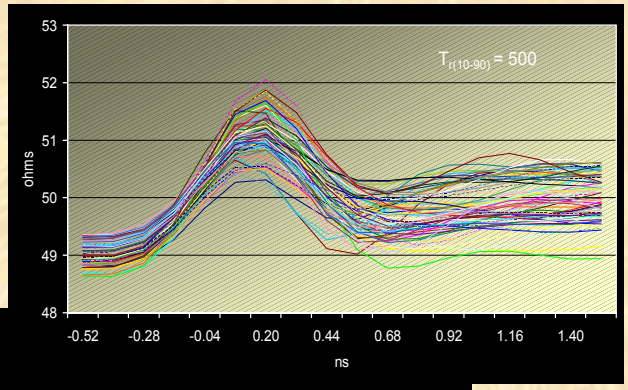


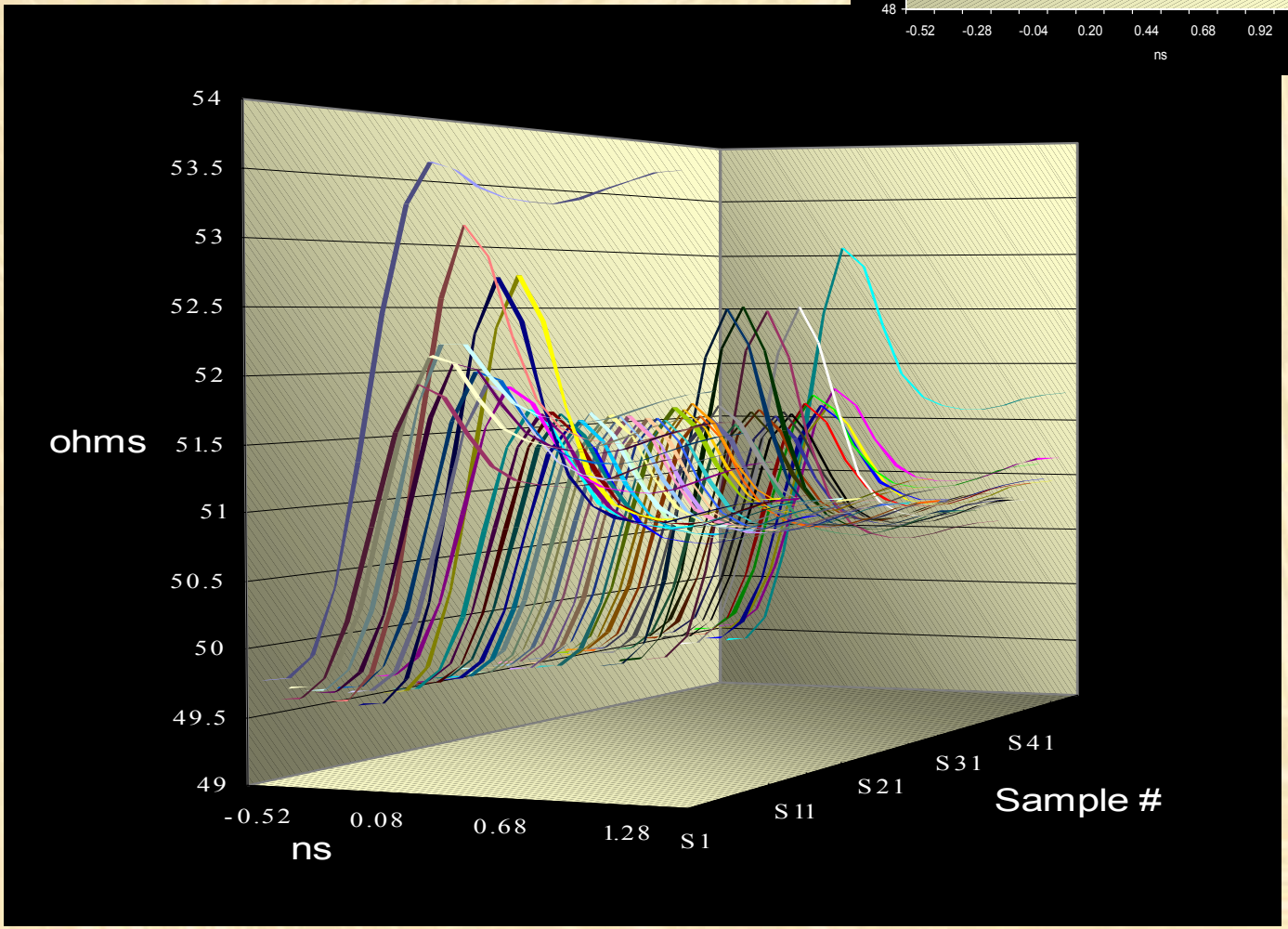
Courtesy of ECT

RF Performance

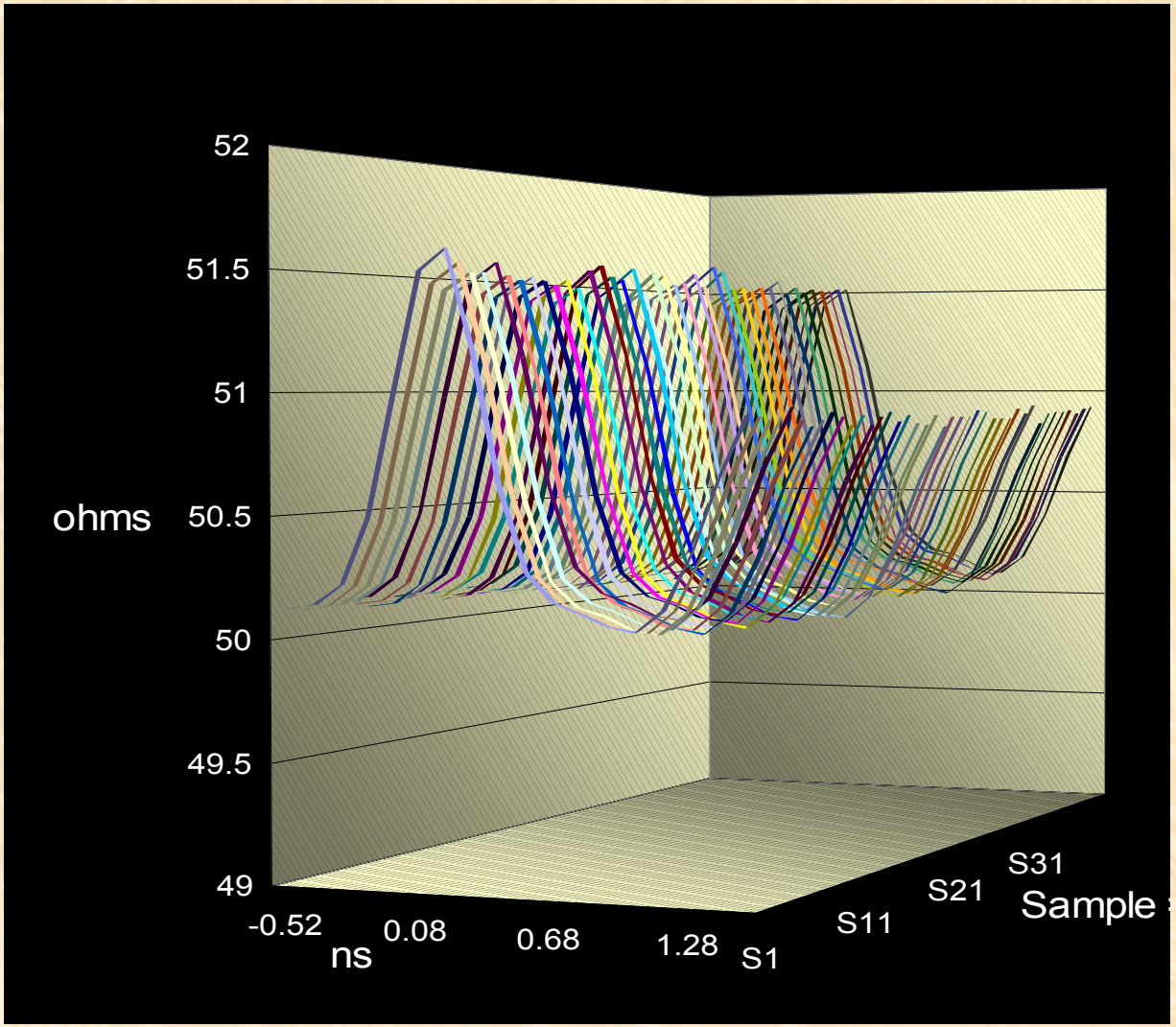
- *2001 paper "Enabling X144 Flash Memory Test" showed that DC Resistance reliability affects RF results*

RF Performance





RF Performance



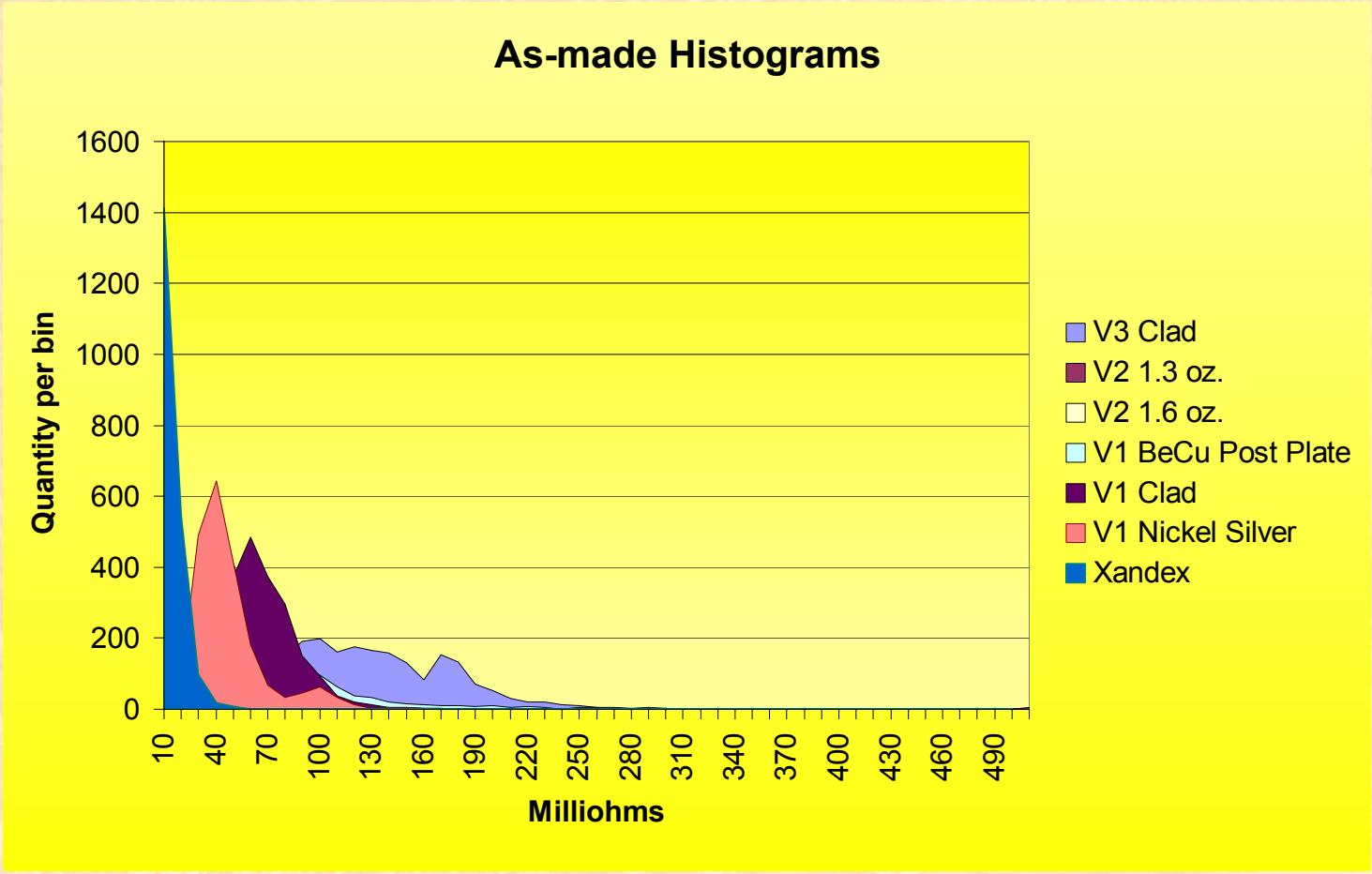
Functional Compliance – Will it Work?

- *Verification*
  - *DC Resistance Testing*
  - *Materials Analysis*
  - *Force Testing*

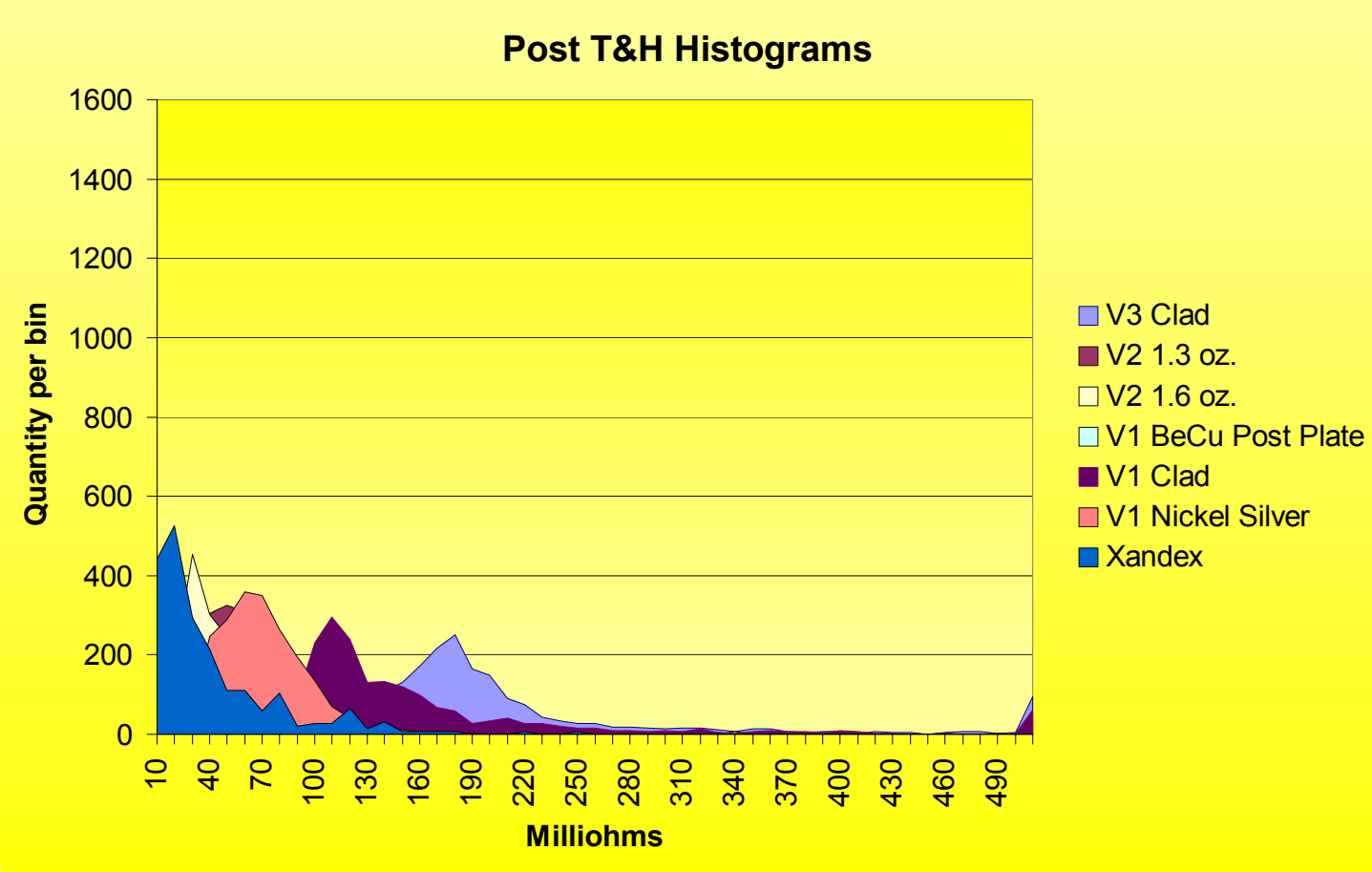
Functional Compliance

- *DC Resistance Testing*
  - *Before & After Temperature & Humidity challenge*
    - *Start up effect*
    - *Effect of surface treatment on post T&H results*
  - *Testing one-at-a-time vs. as-a-group*

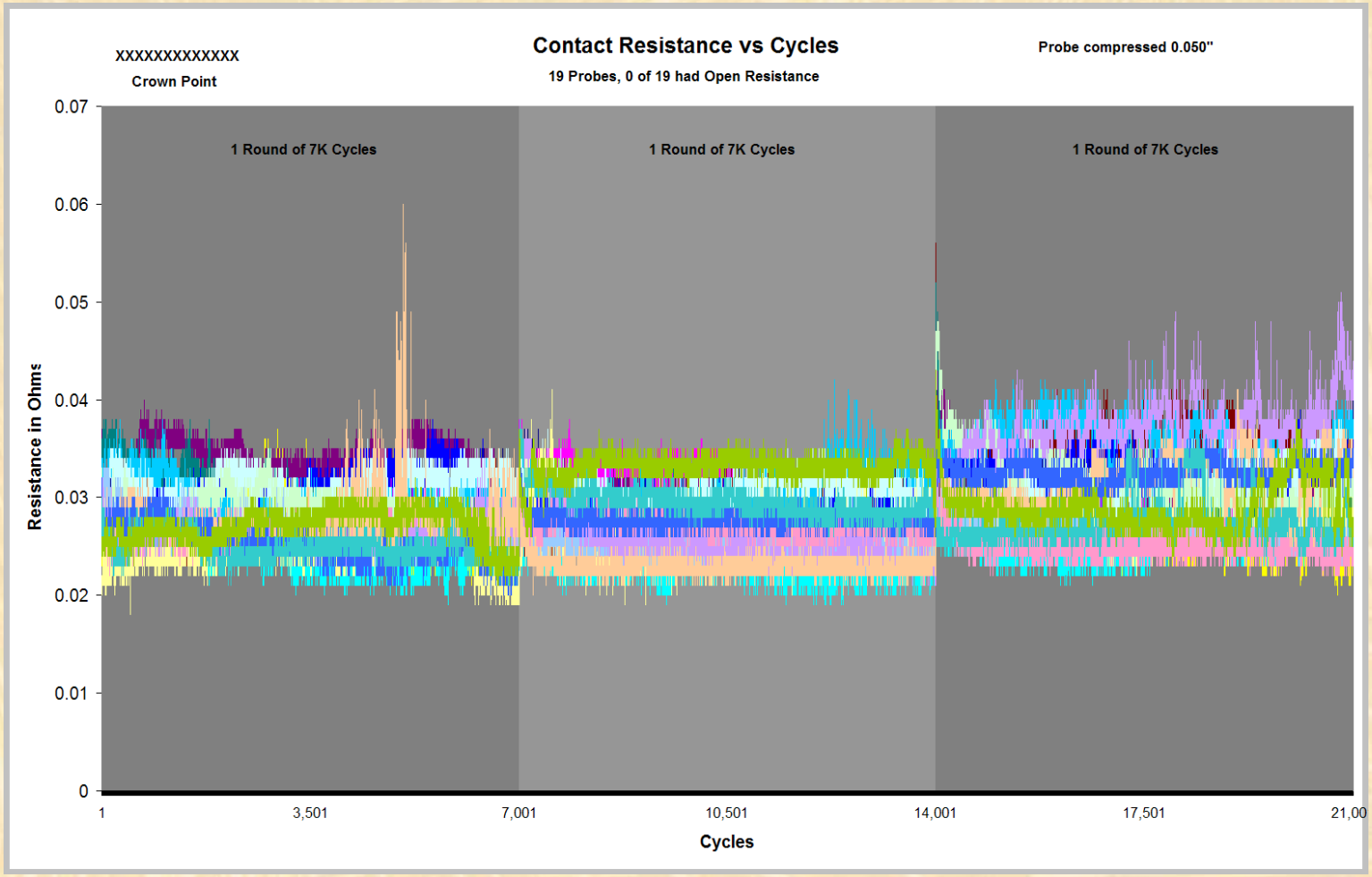
Functional Compliance
DC Resistance Testing



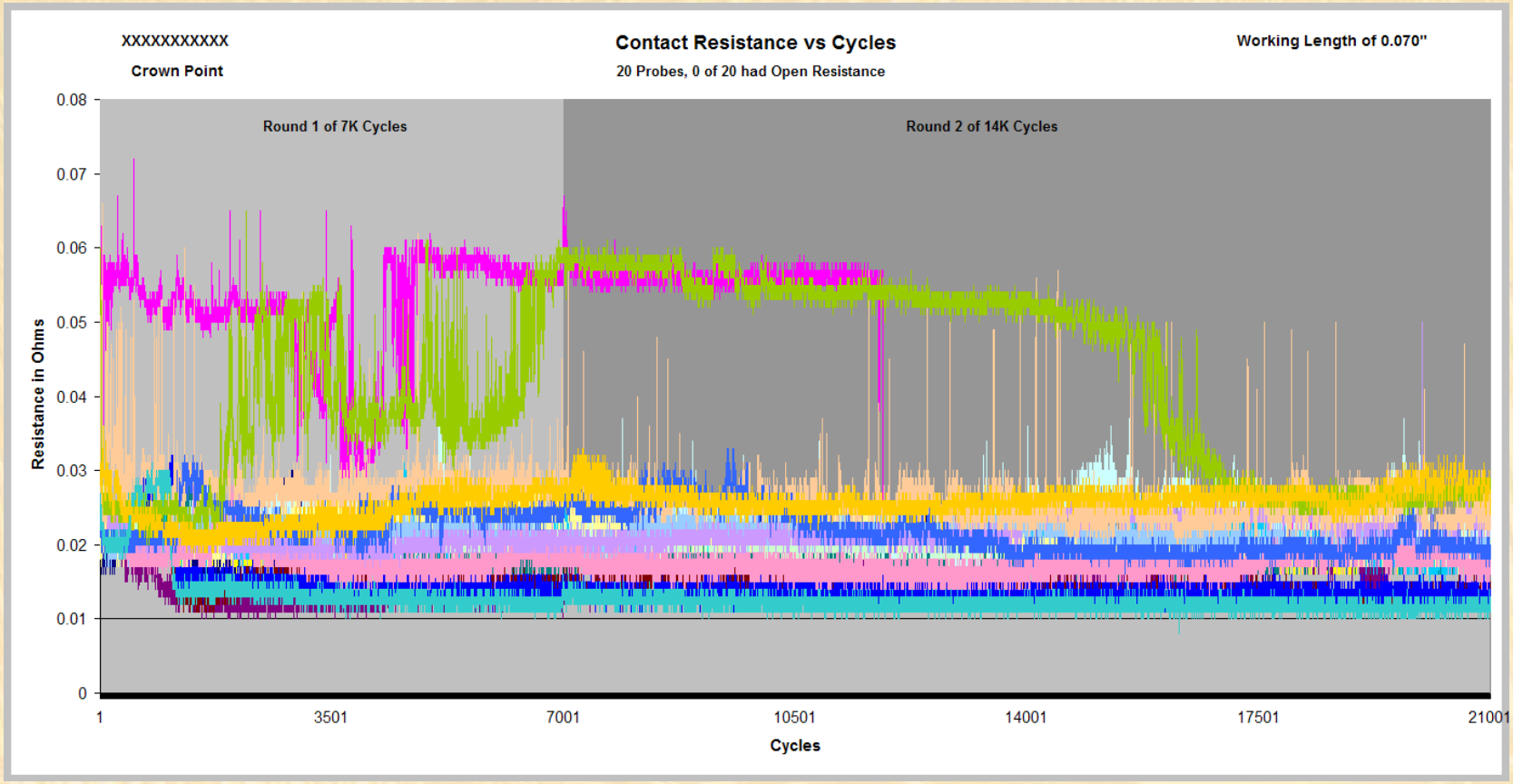
Functional Compliance
DC Resistance Testing



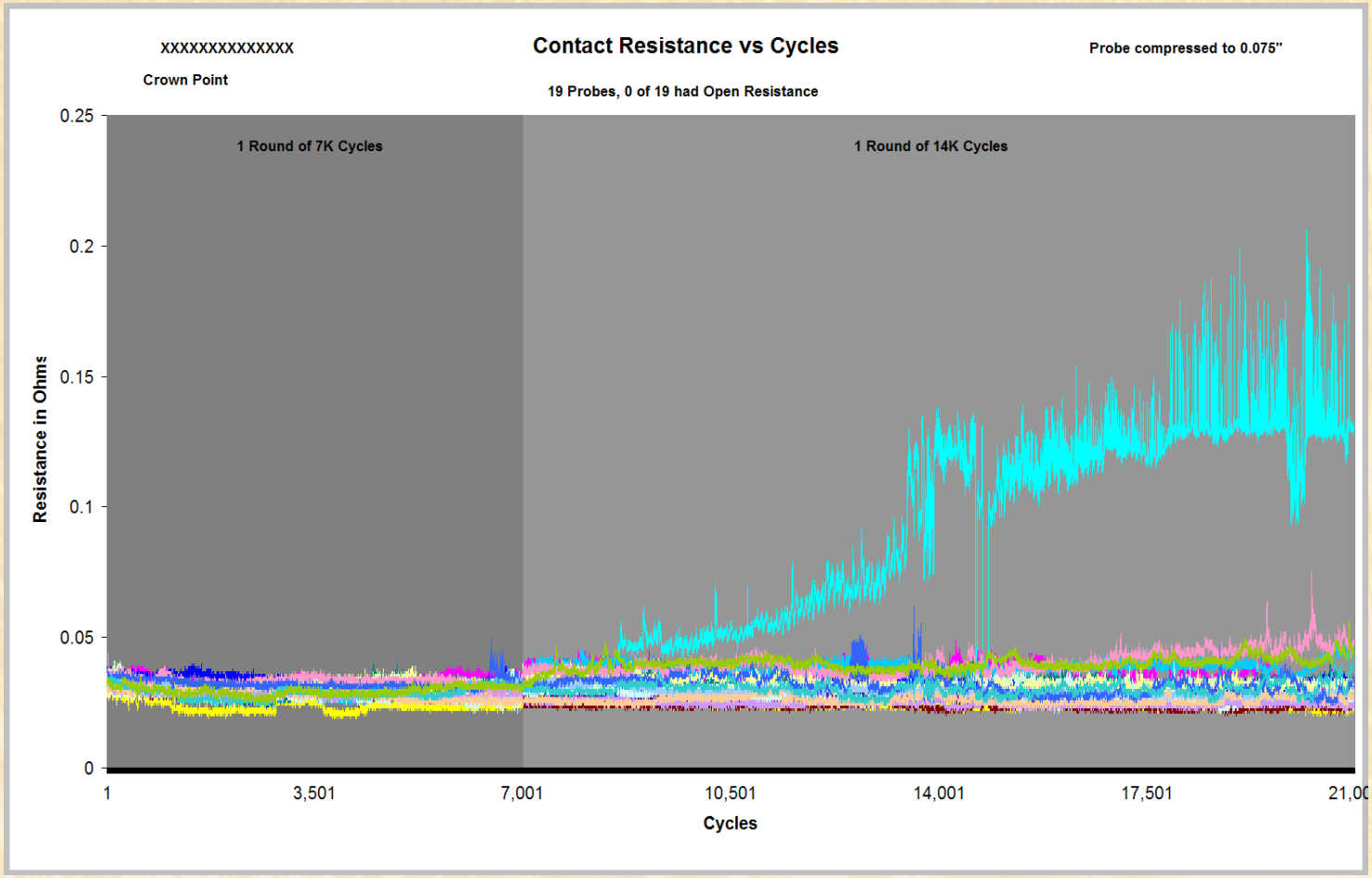
Functional Compliance
DC Resistance Testing – Good



Functional Compliance
DC Resistance Testing – Weird

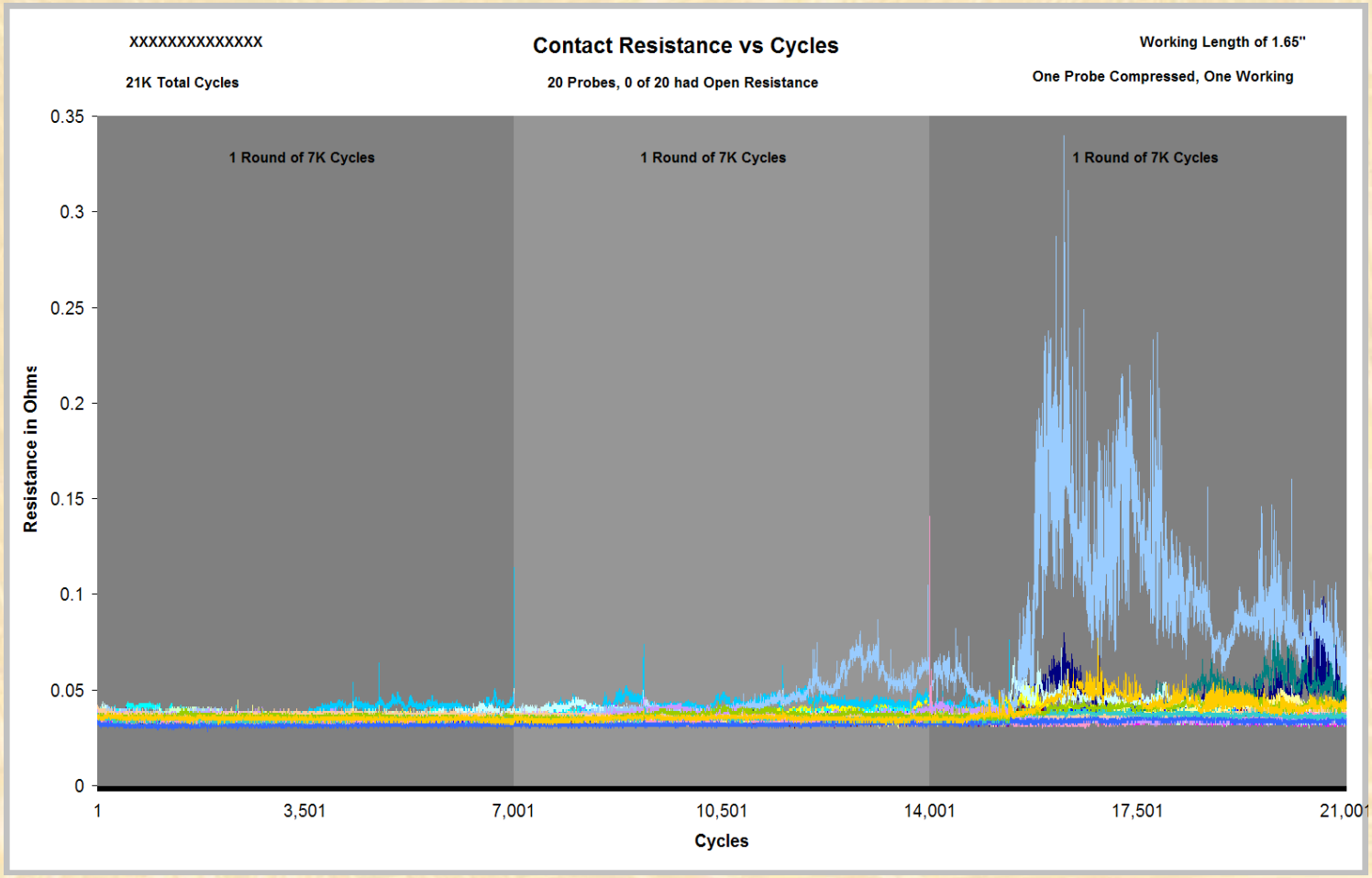


Functional Compliance
DC Resistance Testing – Bad



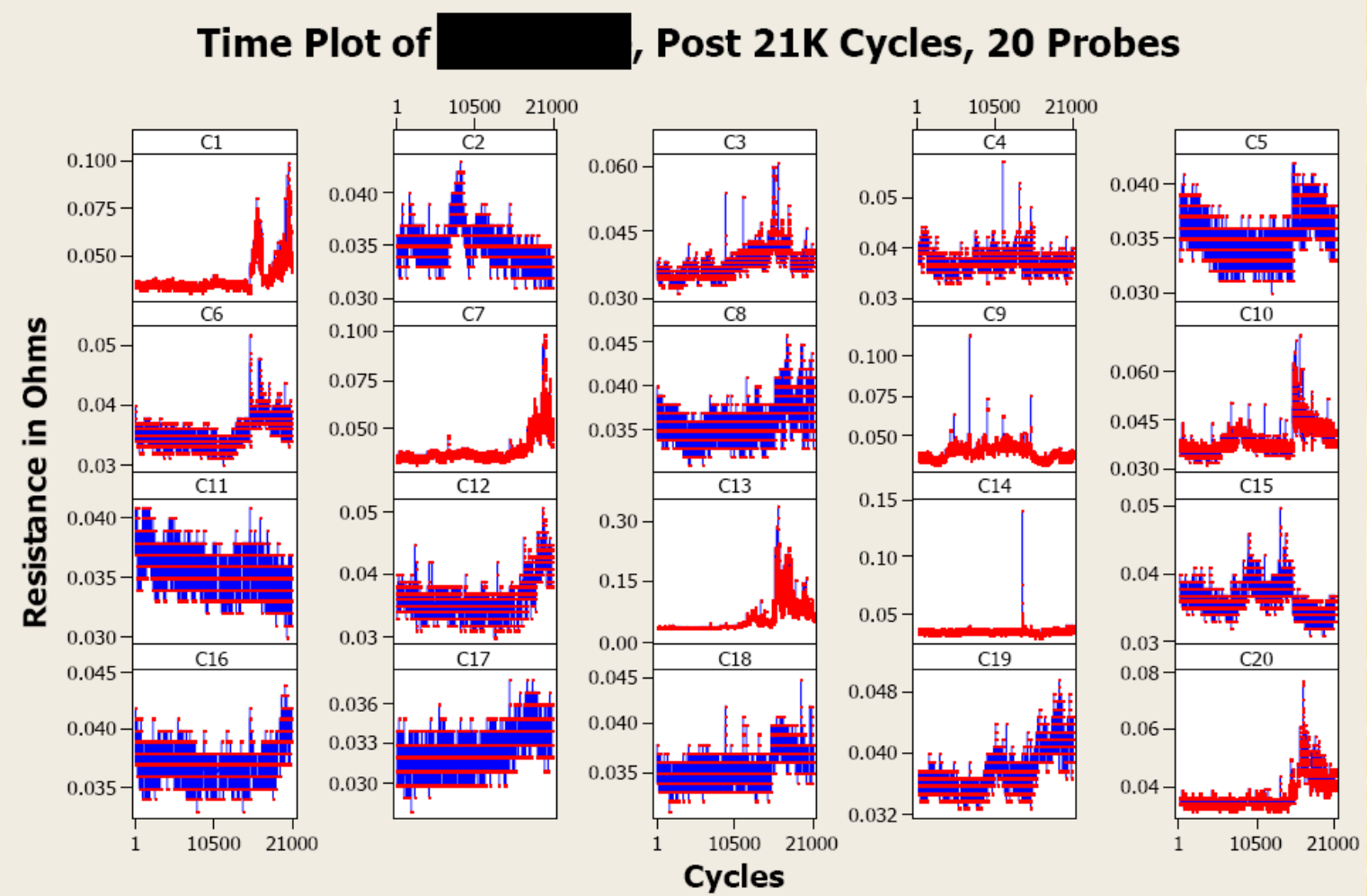
Functional Compliance

DC Resistance Testing – Start Up Effect



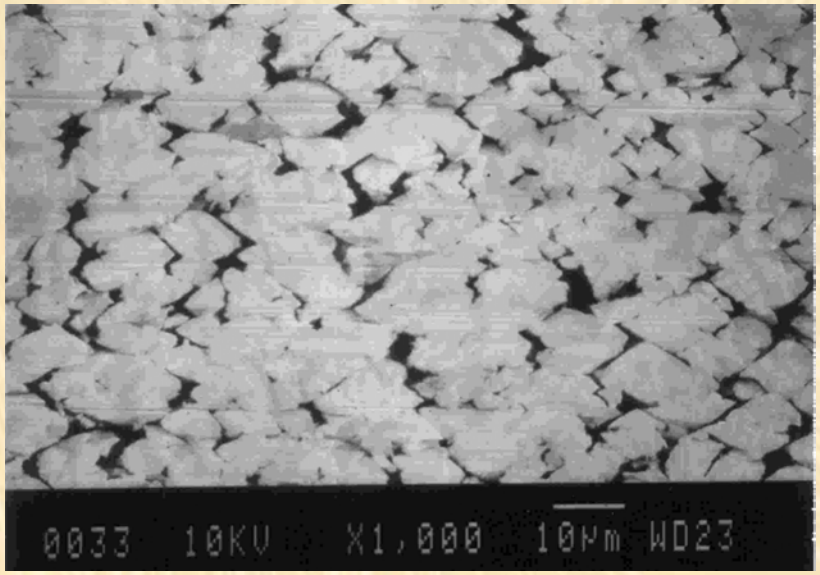
Functional Compliance

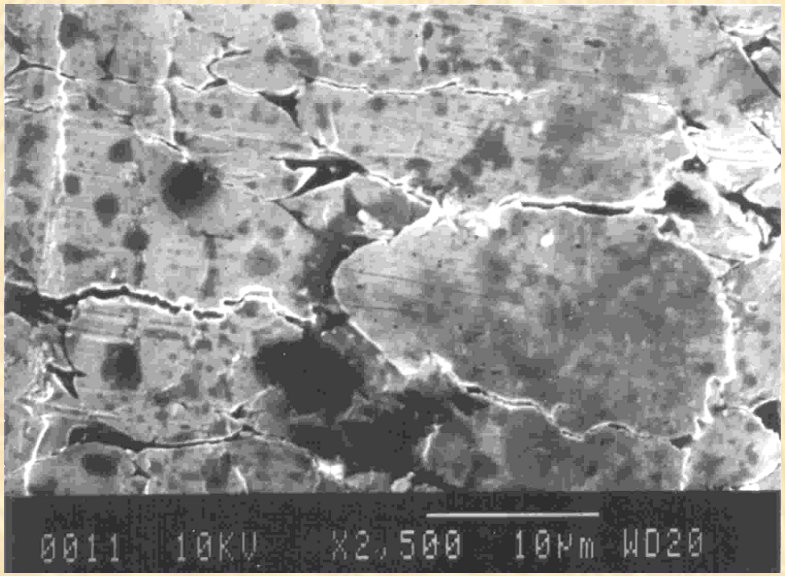
DC Resistance Testing



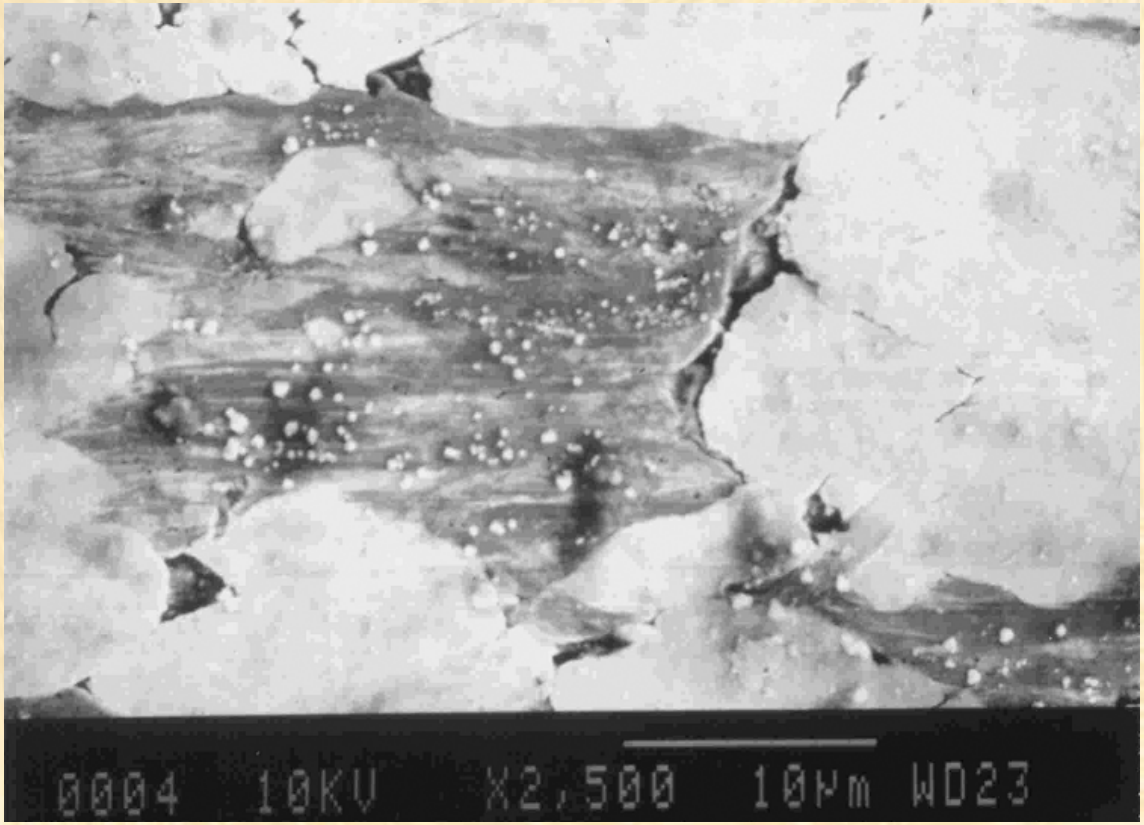
Functional Compliance
Force Testing

Functional Compliance
Materials Analysis

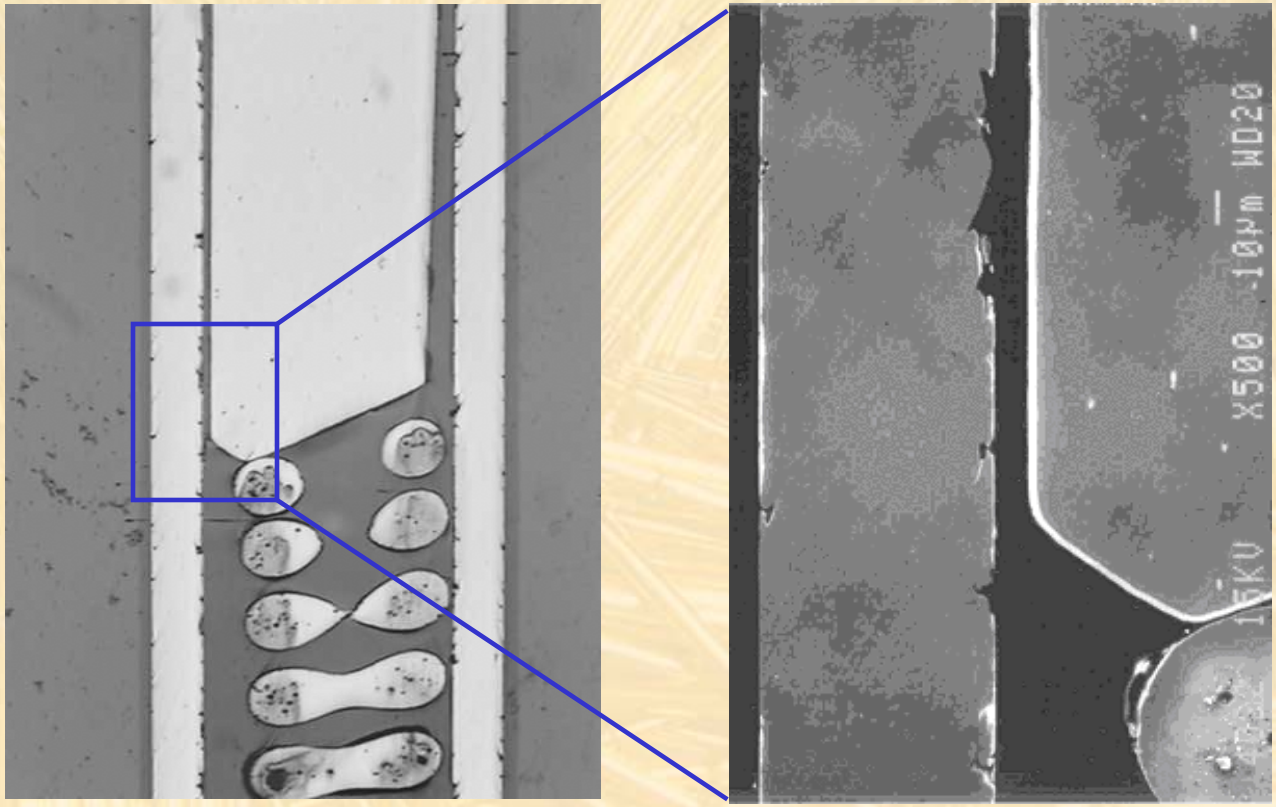




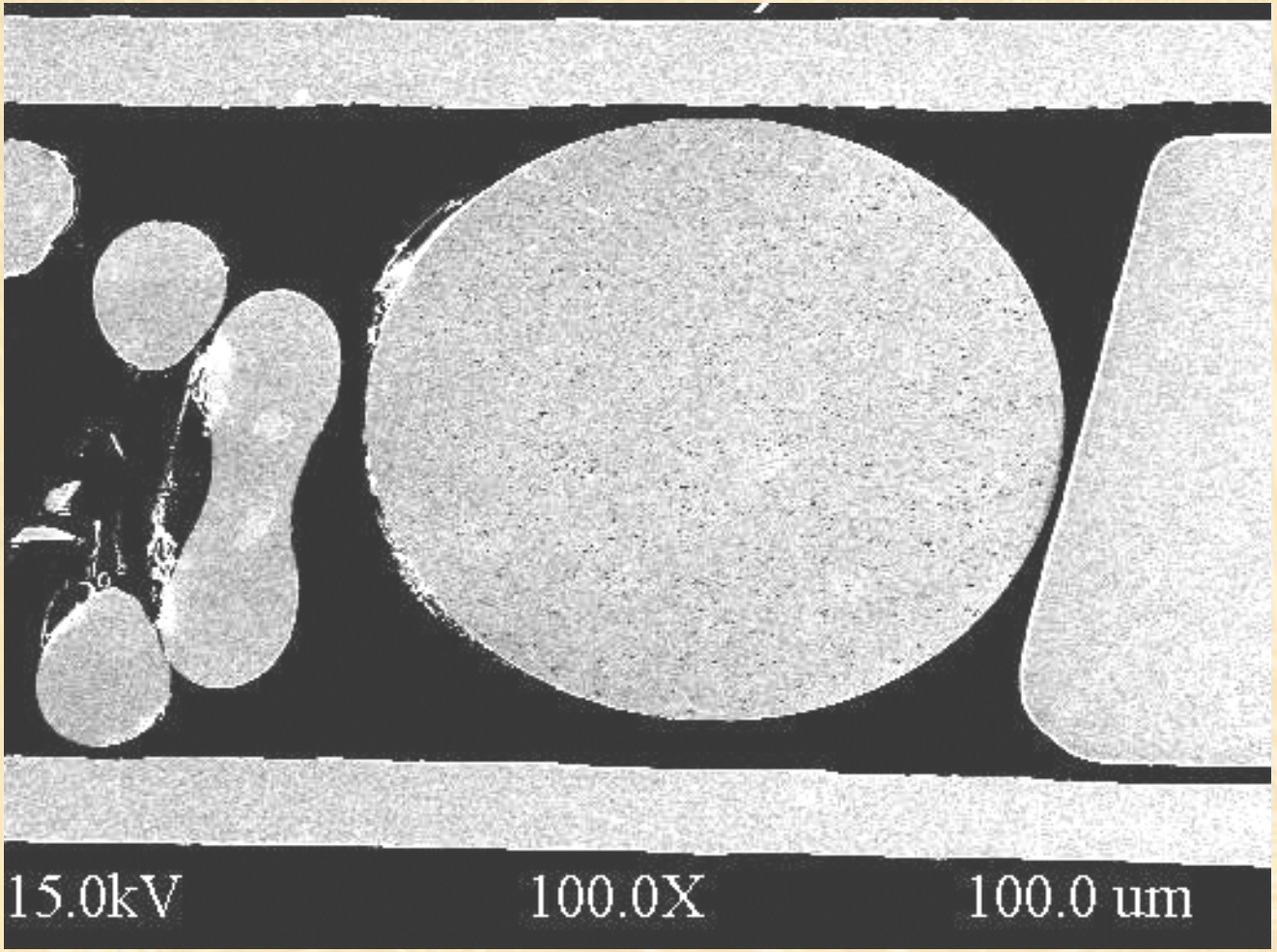
Functional Compliance
Materials Analysis



Functional Compliance
Materials Analysis

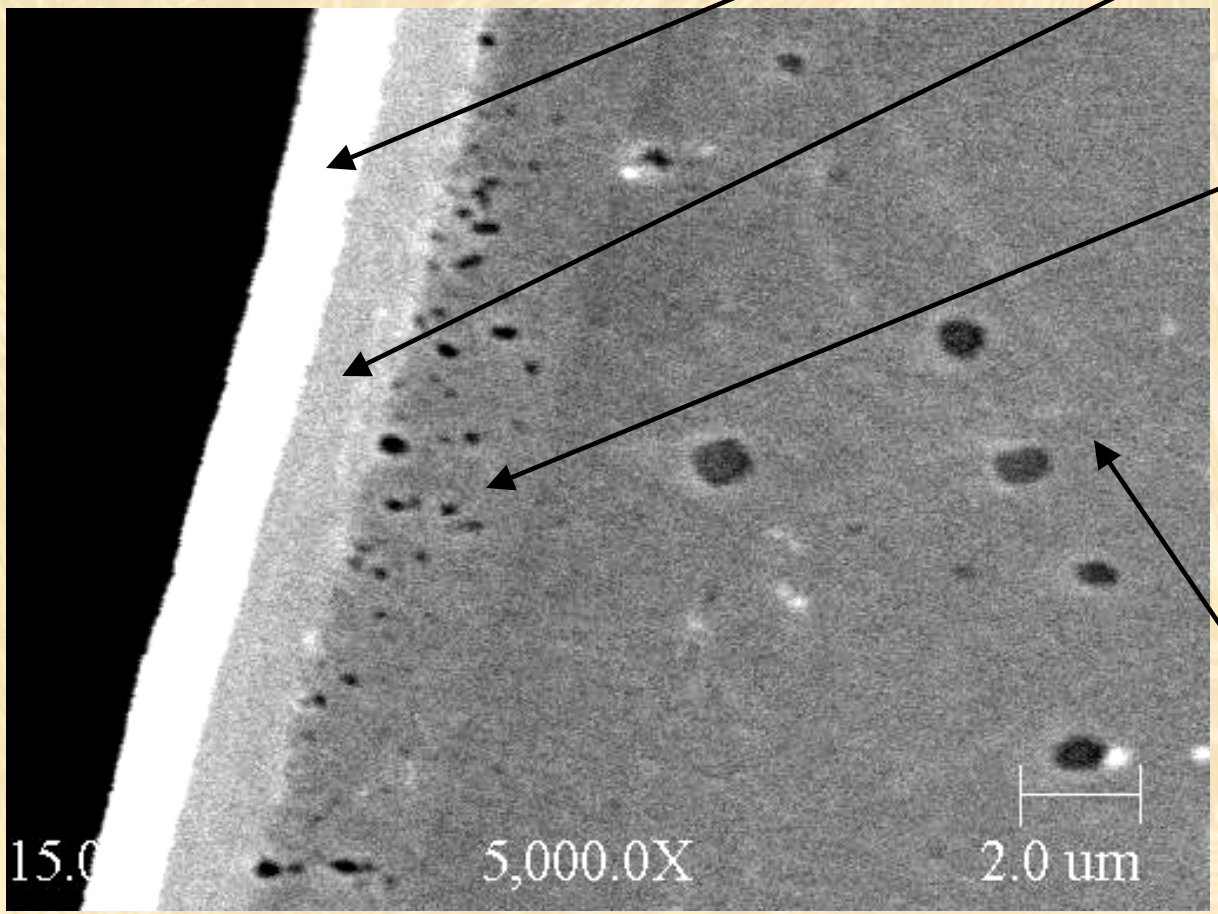


Functional Compliance
Materials Analysis



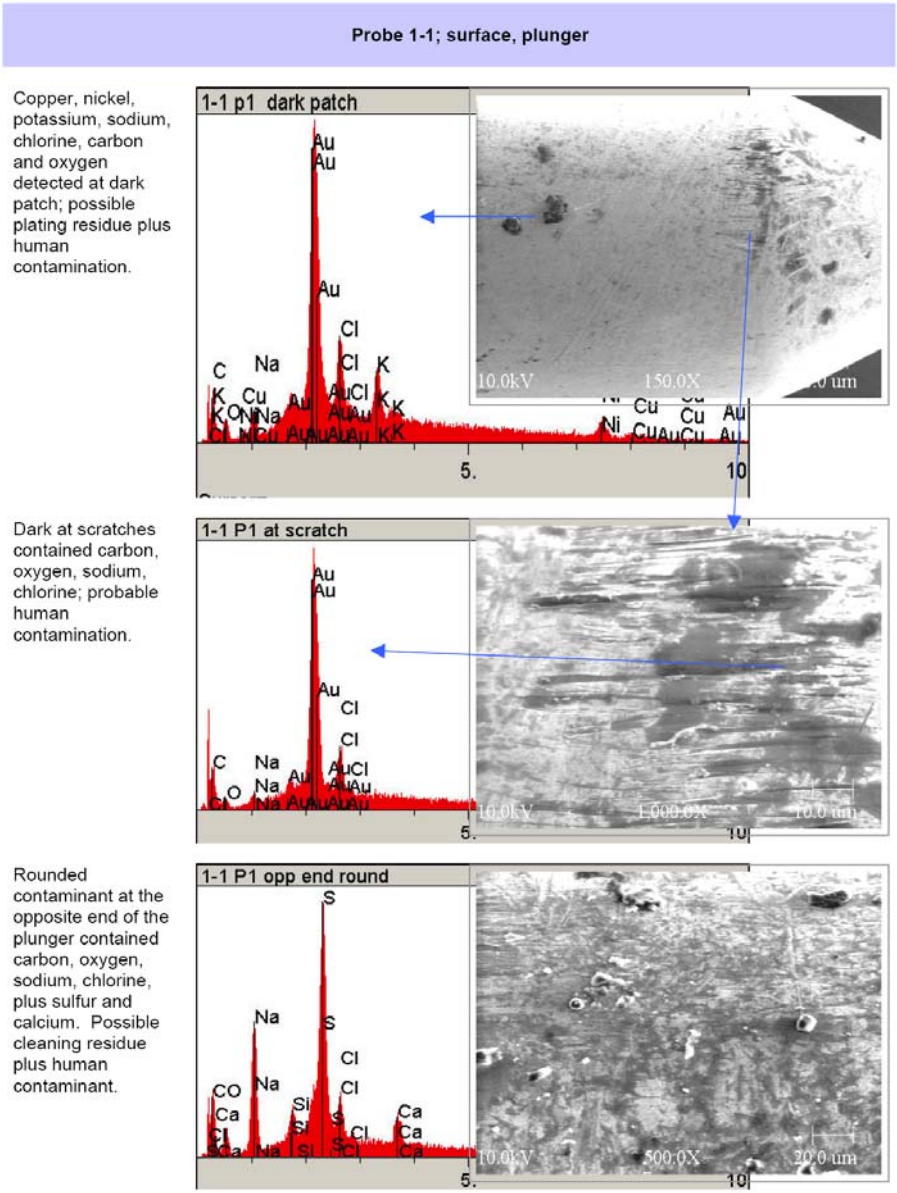
Functional Compliance

Materials Analysis



Functional Compliance

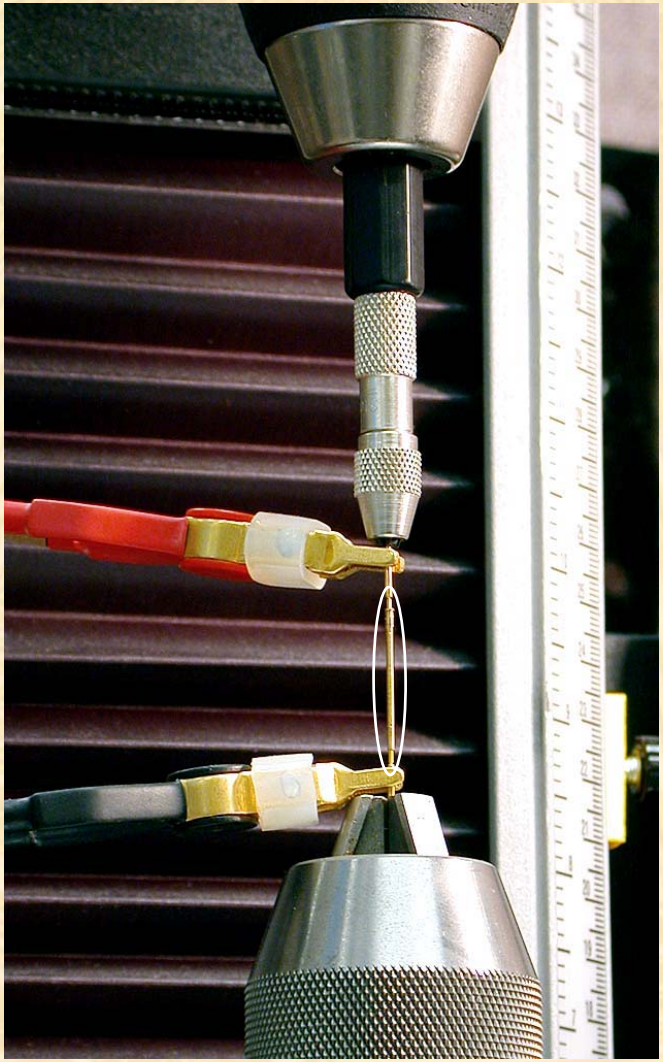
Materials Analysis



Functional Compliance

DC Resistance & Force Testing

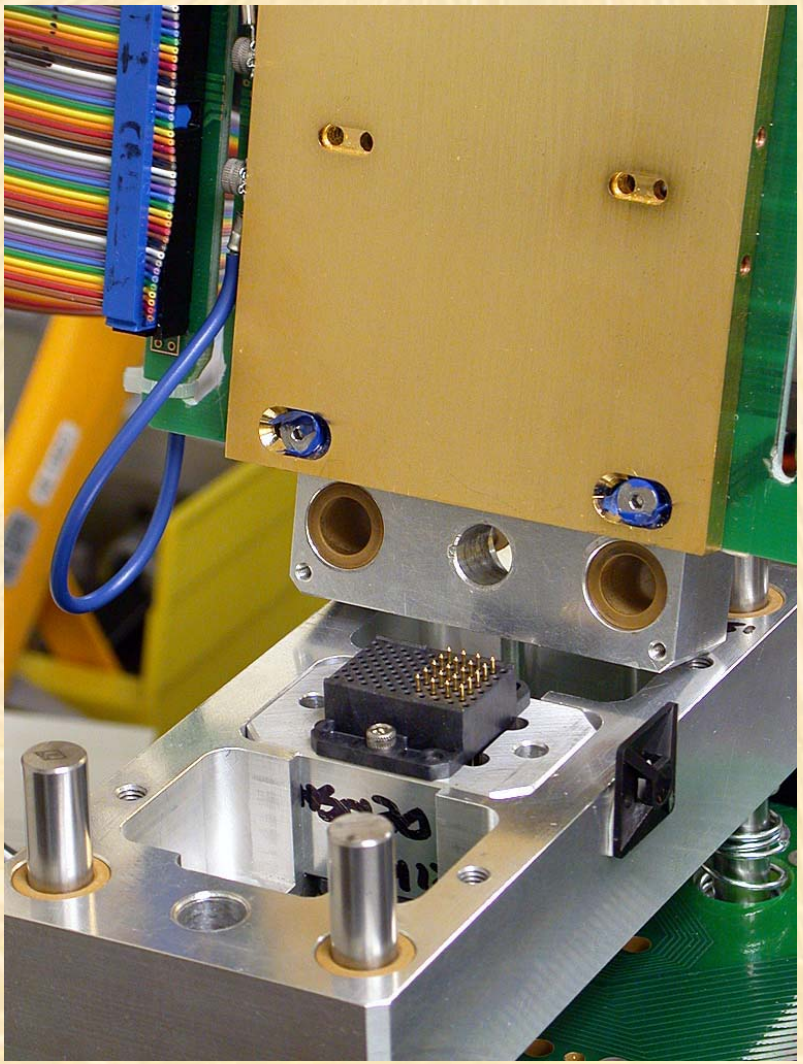
- *Testing one at a time*



Functional Compliance

DC Resistance Testing

- *Testing as a group*



To summarize:

Spring probes are deceptively simple-appearing structures with complex behaviors that extensive amounts of scientific inquiry has yet to fully characterize

When they work, they're wonderful things

When they don't, they'll drive you insane