EXTREME LONG TERM PRINTED CIRCUIT BOARD SURFACE FINISH SOLDERABILITY ASSESSMENT

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Agenda

- Background
- Test Coupons
- Analytical Instrumentation
- Test Results
- Discussion
- Conclusions
- Questions

Figure 4-5 Illustration of Acceptable Solderable Terminal

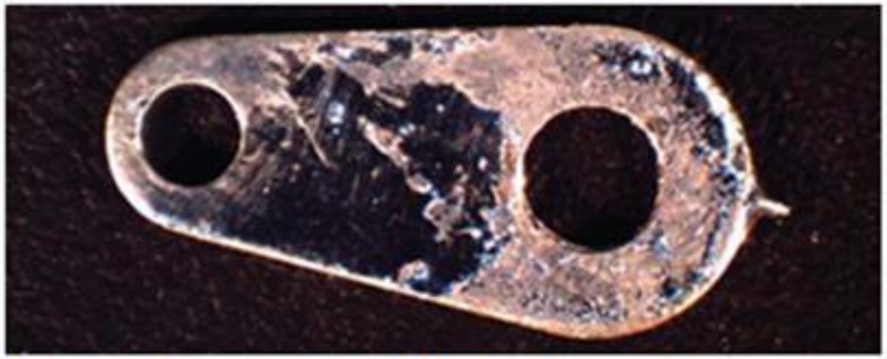


Figure 4-6 Illustration of Unsolderable Terminal

Photo Courtesy of IPC JSTD-002 Specification

Background

- **In 1993 Rockwell Collins introduced an avionics product which incorporated Chip On Board (COB) technology, that used a dual electroplated gold printed circuit board surface finish configuration to satisfy wirebonding and soldering process requirements.**
    - **A gold plating thickness of approximately 30 microinches for solderability and avoidance of gold embrittlement issues was specified on the soldering pads.**
    - **A gold plating thickness of approximately 60 microinches for wirebondability was specified on the bonding pads.**
    - **The dual plating configuration was successful but substantially increased the cost and complexity of the printed circuit board**

- **A 1995-1996, investigation evaluated a number of board surface finishes with the goal of qualifying a replacement surface finish for the dual plating configuration. The replacement surface finish needed to be wirebondable, avoid solder joint integrity issues associated with gold content and have a minimum 12 months shelf life.**

Background

The 1995/96 testing:

- **Solderability testing in accordance with the IPC-JSTD-002 specification**
- **Surface finish oxidation assessment using Sequential Electrochemical Analysis (SERA)**
- **Ball bond/wedge bond wirebondability testing (both Al and Au) in accordance with the MIL-STD-883D, Method 2011.7, test condition C procedures.**

Surface Finishes Evaluated

Surface Finish	Plating Configuration
Electrolytic Gold/Nickel/Copper	Au = 3 μinch increments, Range: 3 - 24 μinches
ENIG Electroless Nickel/Immersion Gold	Au - 2-4 μinch
ENIPIG Electroless Nickel/Immersion Palladium/Immersion Gold	Flash Au, Pd = 3 μinch increments, Range: 3 -24 μinches
Electroless Palladium/Nickel/Copper	Pd = 3 μinch increments, Range: 3 - 24 μinches
Electroless Palladium/Copper	Pd = 3 μinch increments, Range: 3 - 24 μinches
Immersion Silver/Copper	3 μinches
Immersion Bismuth/Copper	3-5 μinches
Note: Nickel thickness (when used) for all samples was 100-200 μinches	

D. Hillman, P. Bratin, M. Pavlov, "Wirebondability and Solderability Of Various Metallic Finishes For Use In Printed Circuit Assembly", SMI Conference Proceedings, 1996

Background

- The 1995/96 testing revealed that ENIPIG and the electroless palladium surface finish combinations met the desired solderability, shelf life and wirebondability goals.
- The ENIPIG surface finish replaced the dual gold plating finish configuration to reduce costs and to improve the overall product integrity.

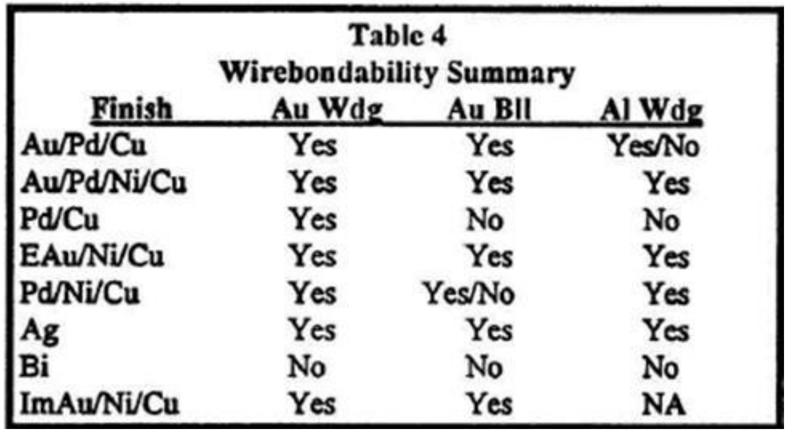


Table 4
Wirebondability Summary

Finish	Au Wdg	Au Bll	Al Wdg
Au/Pd/Cu	Yes	Yes	Yes/No
Au/Pd/Ni/Cu	Yes	Yes	Yes
Pd/Cu	Yes	No	No
EAu/Ni/Cu	Yes	Yes	Yes
Pd/Ni/Cu	Yes	Yes/No	Yes
Ag	Yes	Yes	Yes
Bi	No	No	No
ImAu/Ni/Cu	Yes	Yes	NA

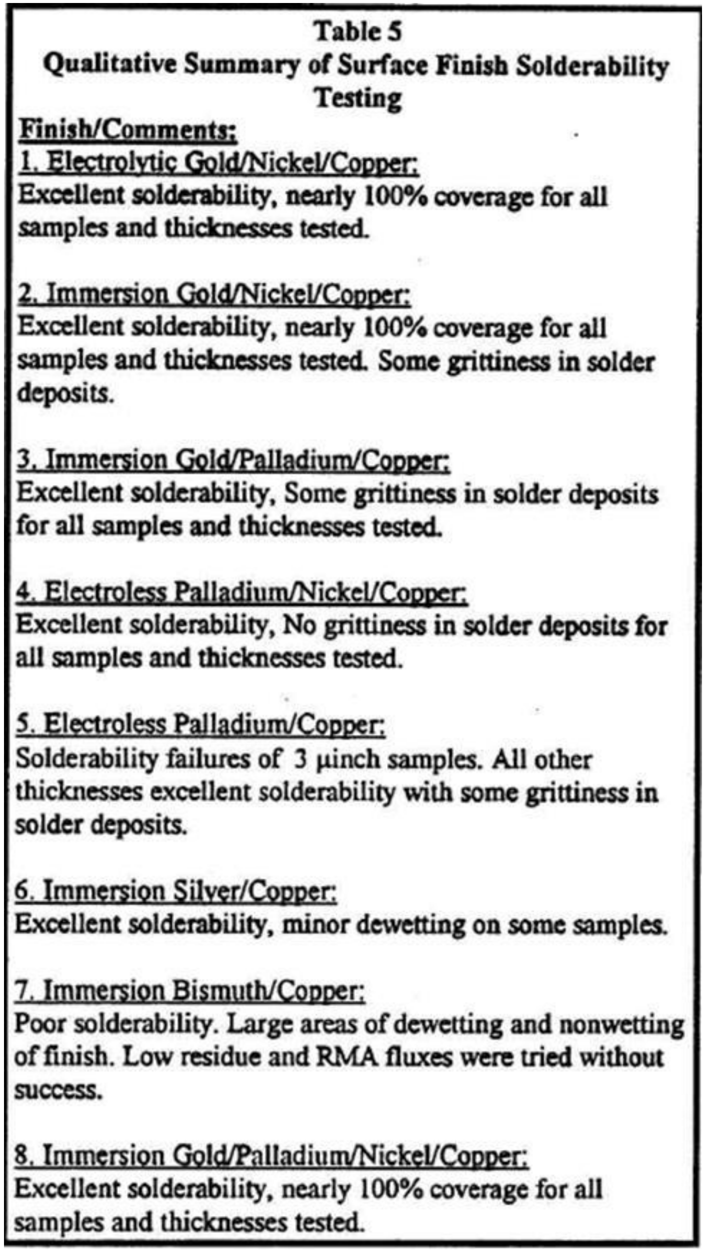


Table 5
Qualitative Summary of Surface Finish Solderability Testing

Finish/Comments:

1. Electrolytic Gold/Nickel/Copper:
Excellent solderability, nearly 100% coverage for all samples and thicknesses tested.

2. Immersion Gold/Nickel/Copper:
Excellent solderability, nearly 100% coverage for all samples and thicknesses tested. Some grittiness in solder deposits.

3. Immersion Gold/Palladium/Copper:
Excellent solderability, Some grittiness in solder deposits for all samples and thicknesses tested.

4. Electroless Palladium/Nickel/Copper:
Excellent solderability, No grittiness in solder deposits for all samples and thicknesses tested.

5. Electroless Palladium/Copper:
Solderability failures of 3 μinch samples. All other thicknesses excellent solderability with some grittiness in solder deposits.

6. Immersion Silver/Copper:
Excellent solderability, minor dewetting on some samples.

7. Immersion Bismuth/Copper:
Poor solderability. Large areas of dewetting and nonwetting of finish. Low residue and RMA fluxes were tried without success.

8. Immersion Gold/Palladium/Nickel/Copper:
Excellent solderability, nearly 100% coverage for all samples and thicknesses tested.

Background

- Spare test specimens with the investigation surface finishes were produced for the study but were not utilized during testing.

- These specimens were placed in non-sealed polyethylene bags, stored in a 21ºC/30%-65% RH environment and promptly forgotten.

- The specimens were re-discovered in 2015 after accumulating 20 years of total storage time.

- These specimens provided an opportunity to investigate extreme long term solderability of a well characterized set of printed circuit board surface finishes.

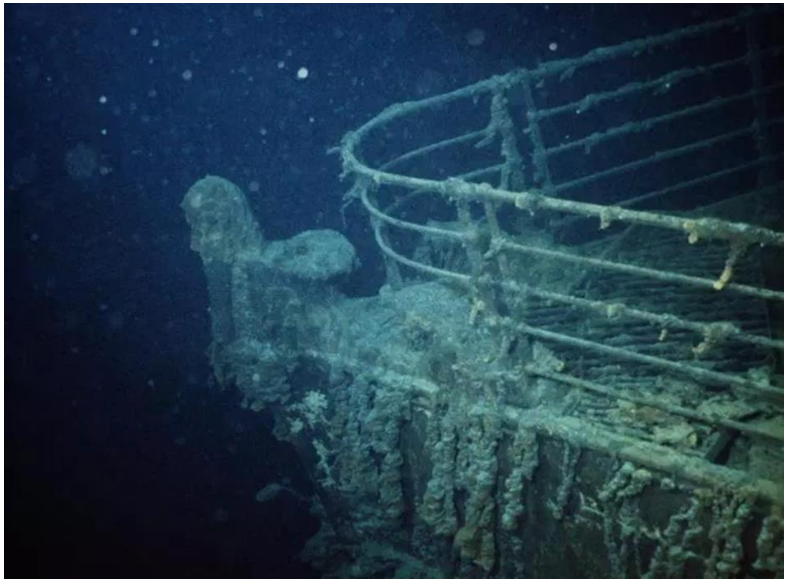
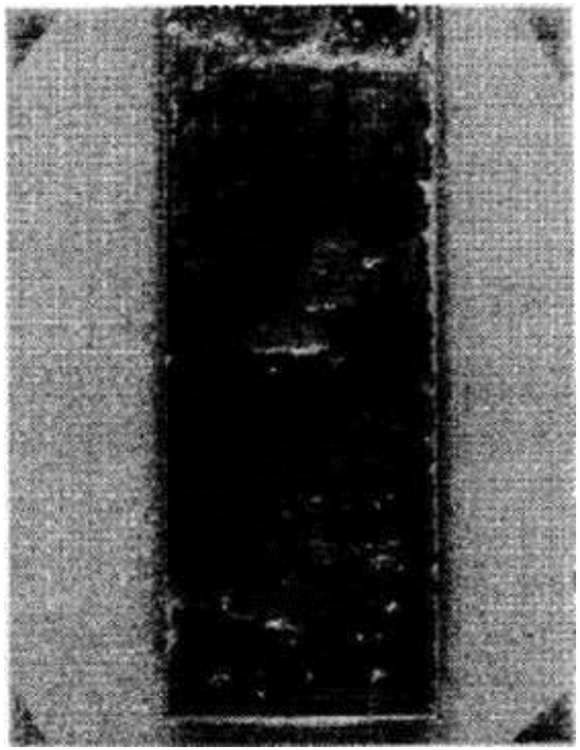


Photo Source: Time Inc. Network

Photo Source: Wikipedia

Test Coupon

- Bismaleimidc-triazine (BT) laminate
- 0.040 inches thick with 0.5 ounce copper outer layers
- Sheared into 3x3 inch squares
- These 3x3 substrates were electroplated with approximately 0.001 inches of copper prior to the application of each specific test surface finish
- The test substrates that contained a nickel layer had approximately 0.0001 - 0.0002 inches of electroless nickel plating deposited
- The 3x3 test substrates were diamond cut into 6 sections approximately 0.5 inches wide after plating for use in the 1995/96 evaluation



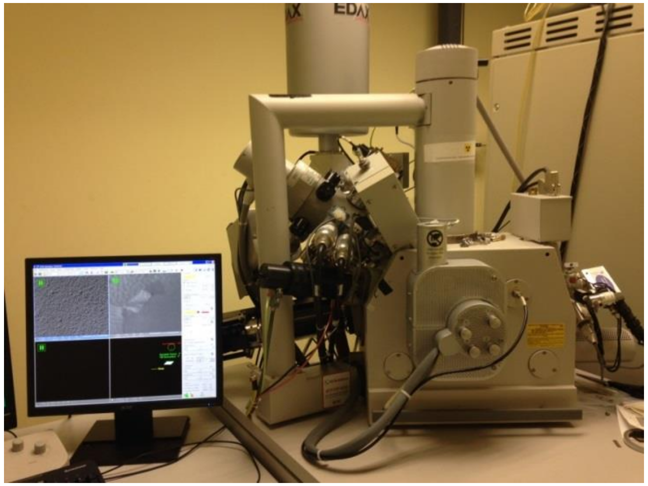
- 3-5 spare specimens of each surface finish were available for this investigation

Analytical Equipment

- **Metronelec ST88 wetting balance**
  - **Protocol per IP CJSTD003C WAM1**
  - **Eutectic SnPb solder**
  - **Test flux # 1.**
  - **Test temperature was 235C**
  - **Dwell time of ten seconds**

- **Focused Ion Beam (FIB) microscopy**
  - **FEI Quanta 200-3D Dual Beam system**
  - **Gallium target ablation source**
  - **Maximum ablation rate of 0.5 microns/minute**
  - **A layer of platinum was vapor deposited onto the test samples prior to FIB analysis to prevent extraneous ablation damage**

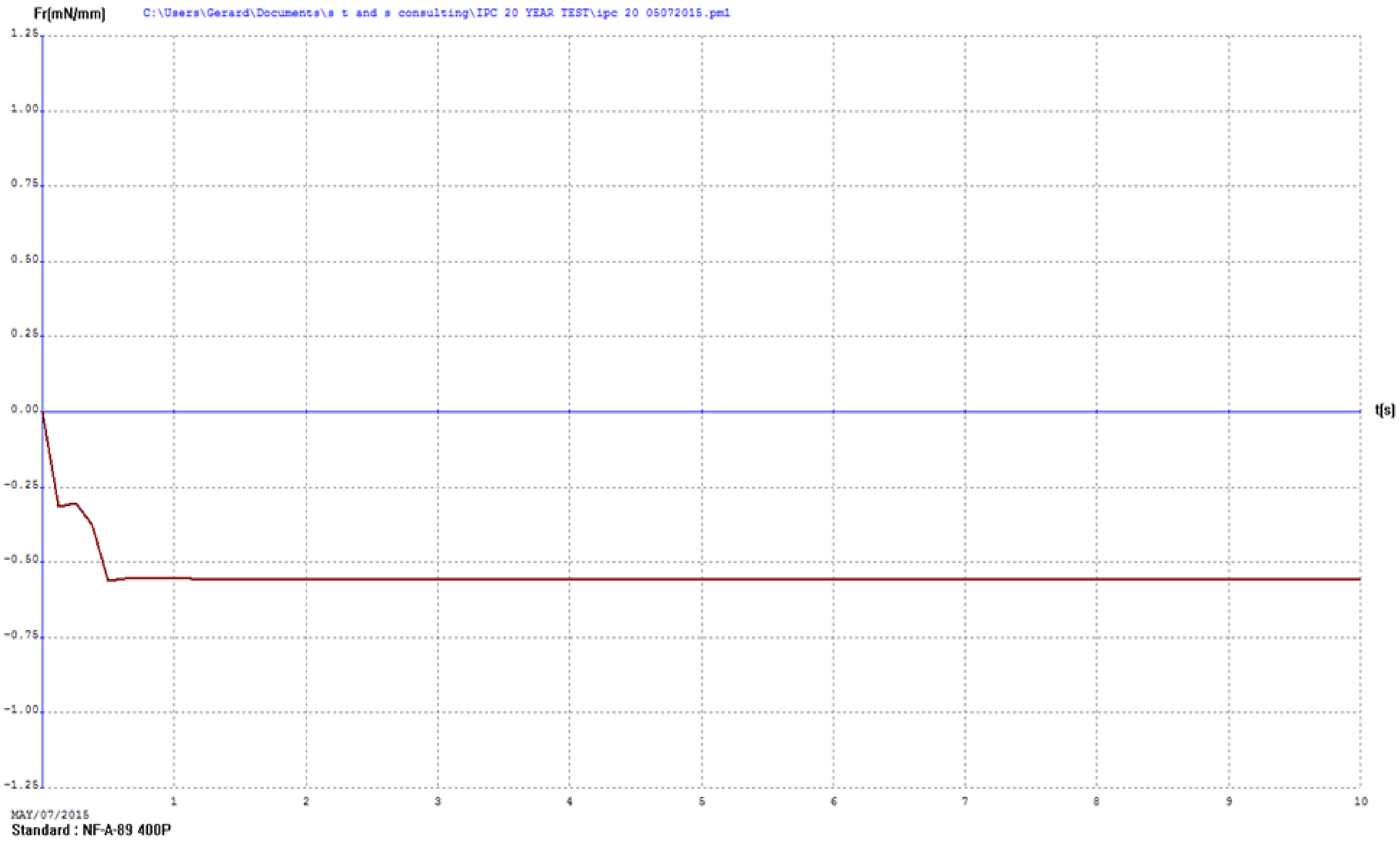
- **Fischer Technologies XDV-SDD X-ray Fluorescence (XRF) system**



FIB System

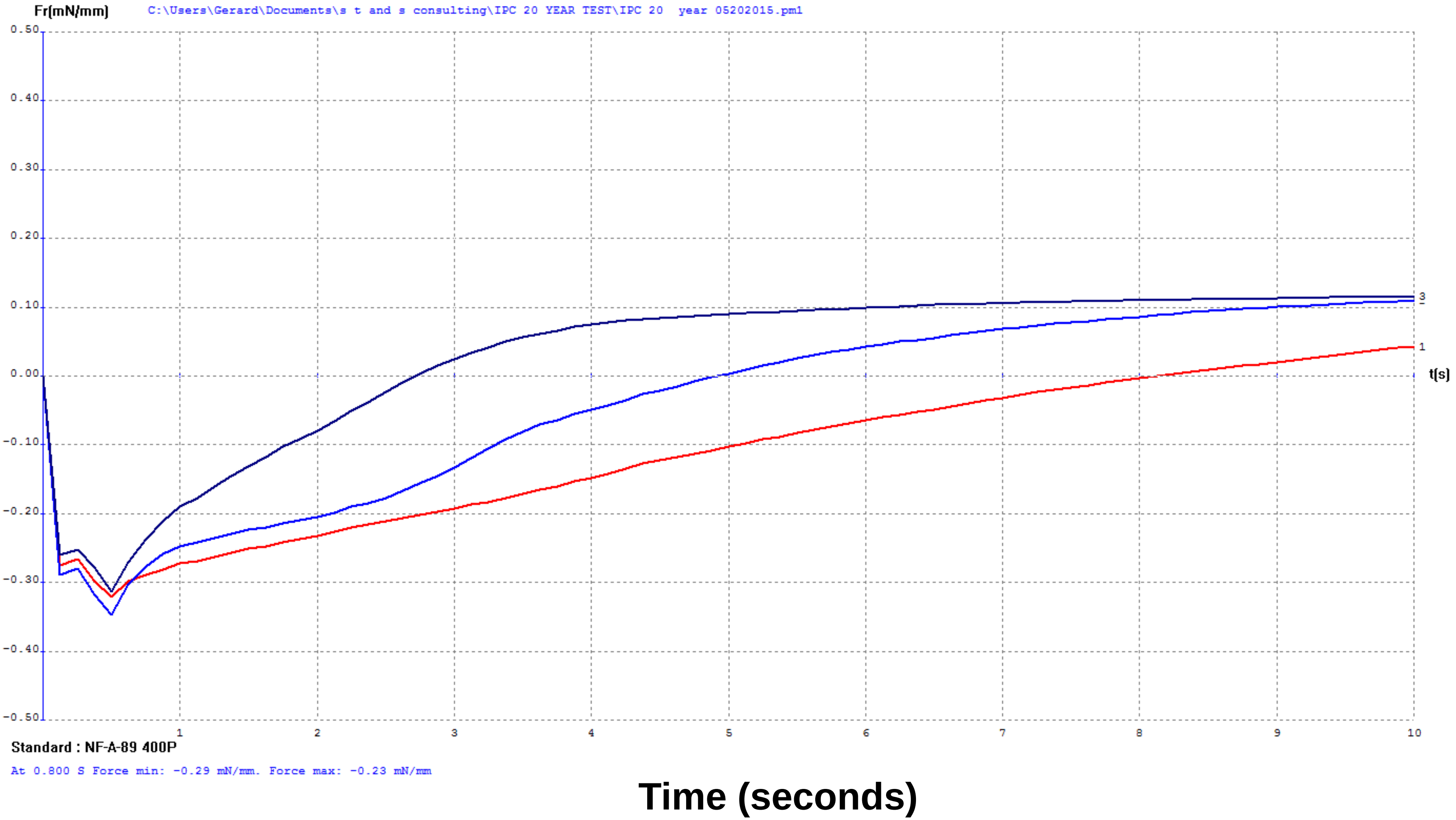
XRF System

Test Results – Immersion Bismuth



Time (seconds)

Test Results – Immersion Silver



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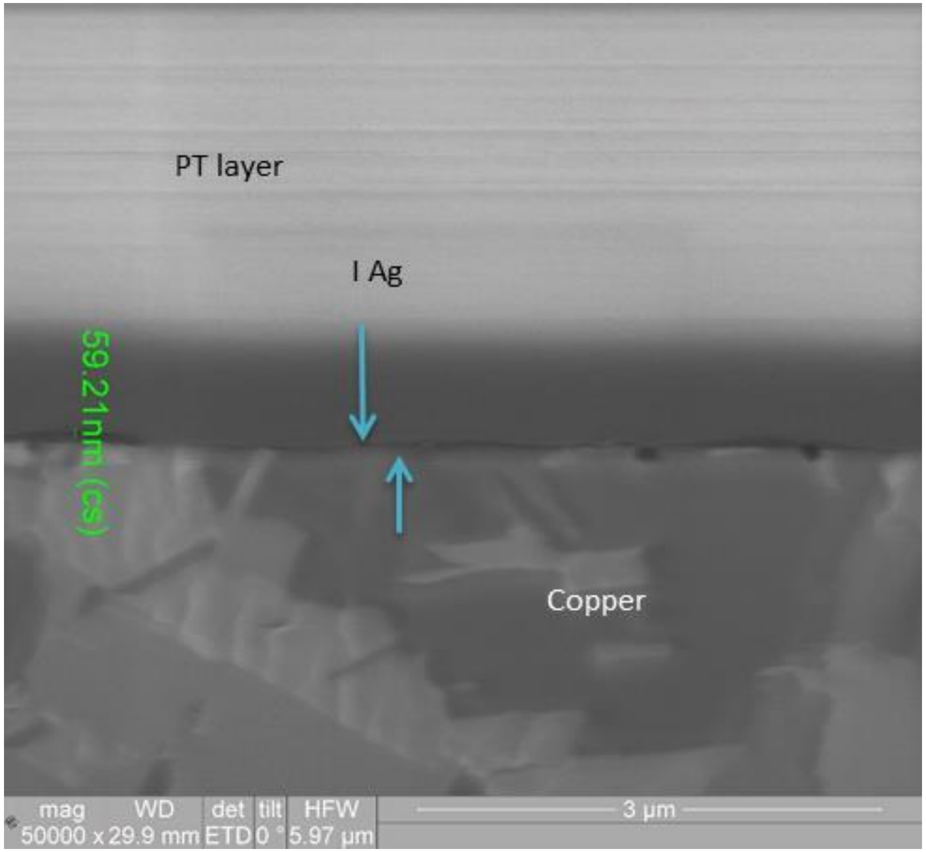
Standard : NF-A-89 400P

At 0.800 S Force min: -0.29 mN/mm. Force max: -0.23 mN/mm

Test Results – Immersion Silver

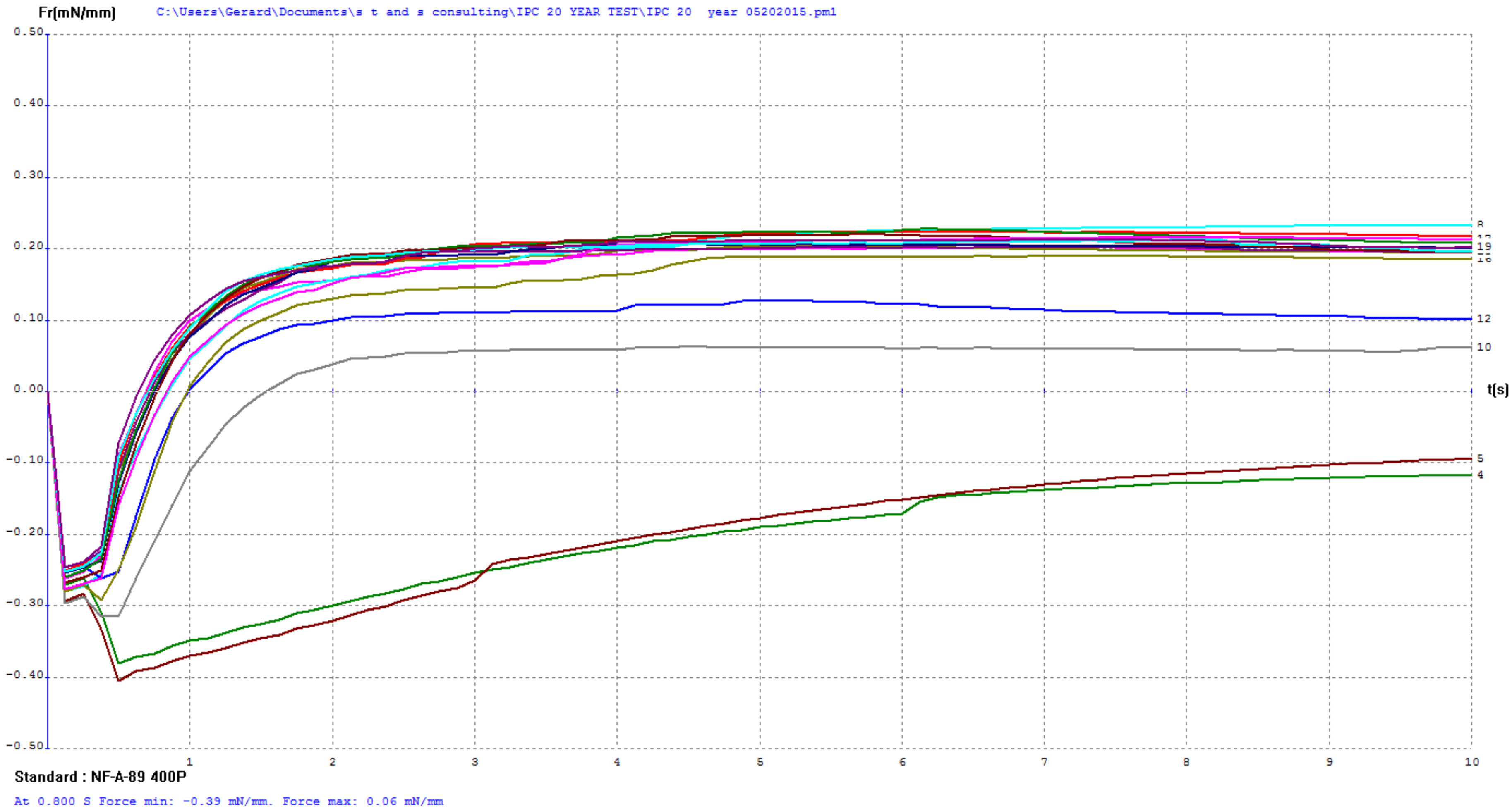
- **Since current immersion silver surface finishes are typically 8-16 microinches thick, it was speculated that the original 3 microinch layer was consumed by oxidation and/or diffusion after 20 years of storage**

- **XRF assessment measured 1.2 microinches of immersion silver while FIB assessment measured the immersion silver deposit closer to 2.4 microinches in thickness**



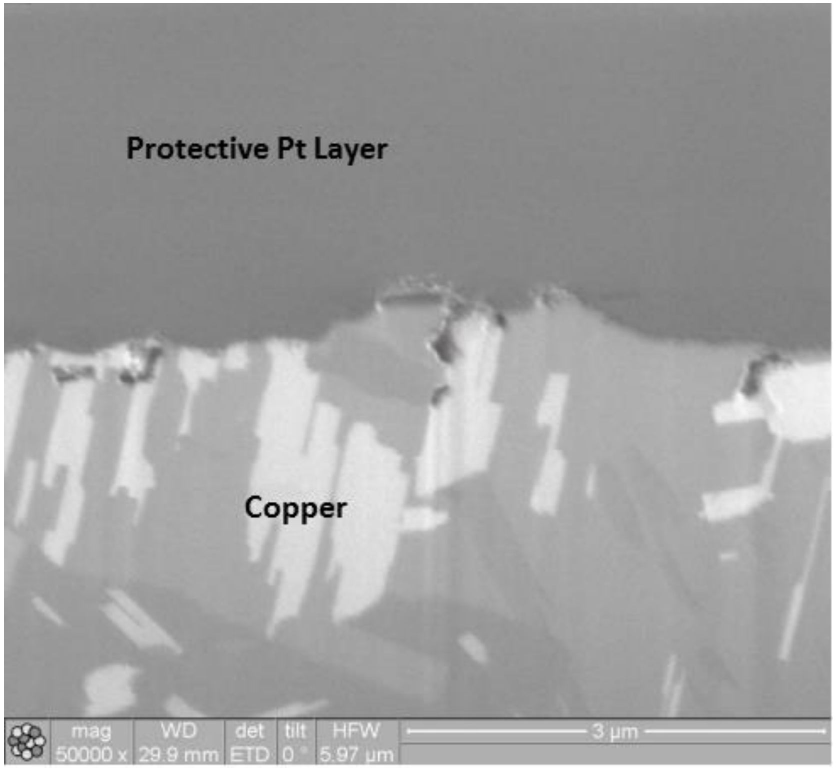
FIB Image of the Immersion Silver Deposit (50000X Magnification)

Test Results – Electroless Pd/Cu



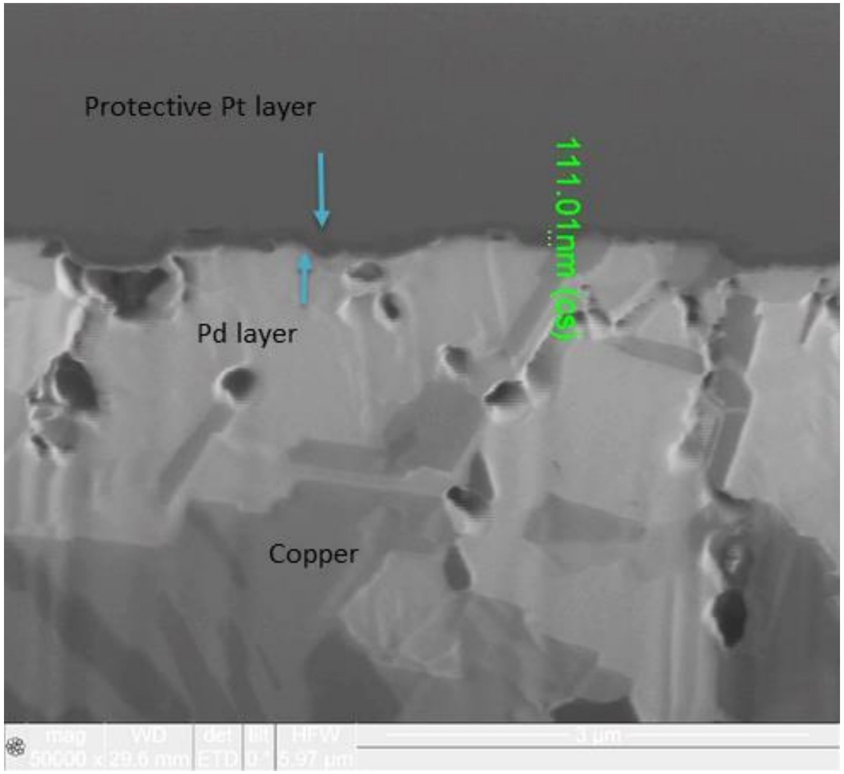
Time (seconds)

Test Results – Electroless Pd/Cu



FIB Image of the Nominal 3 Microinch Electroless Palladium Deposit (50000X Magnification)

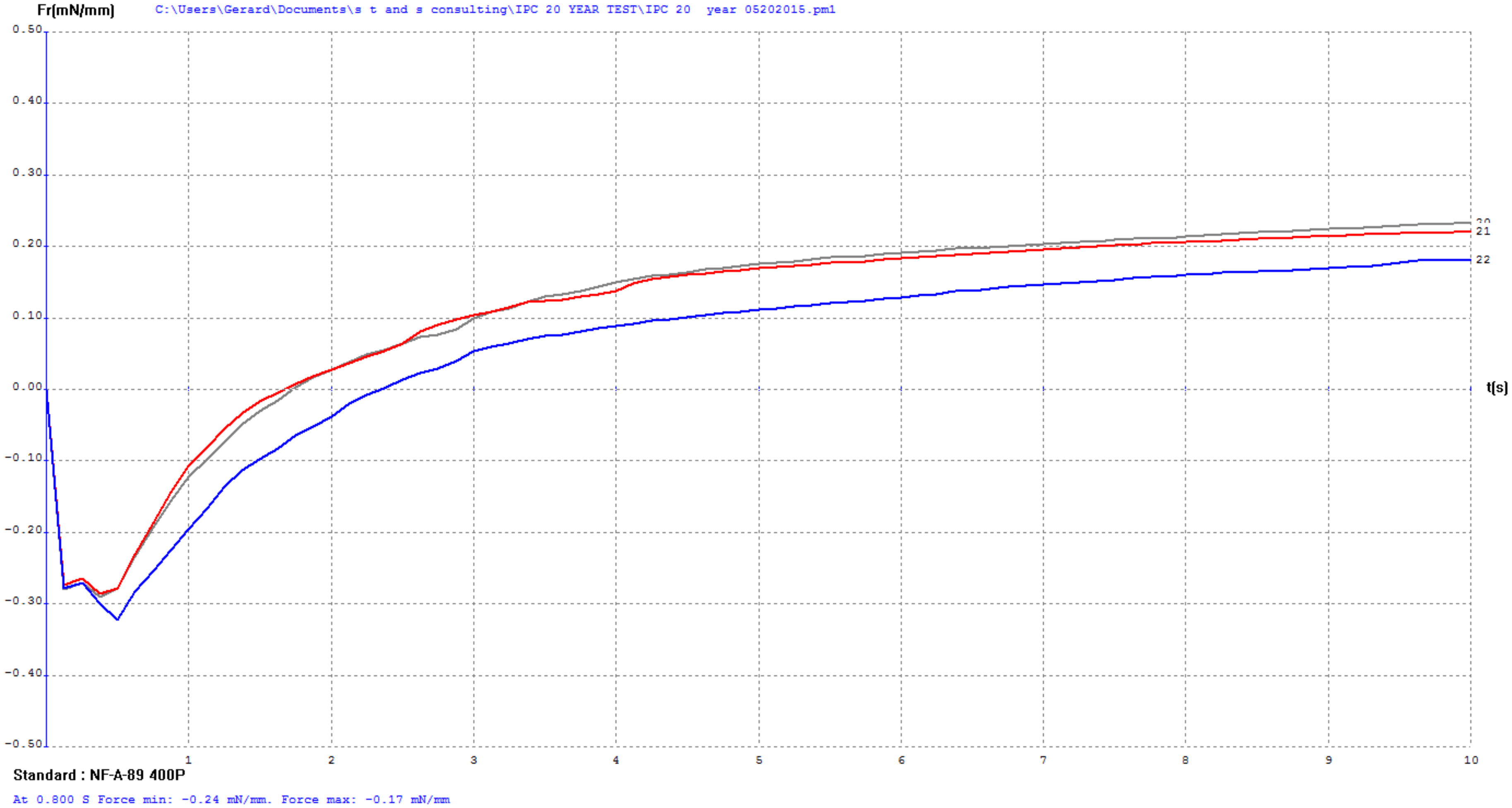
XRF assessment found no evidence of electroless palladium but FIB assessment measured the electroless palladium deposit at 0-0.3 microinches in thickness



FIB Image of the Nominal 6 Microinch Electroless Palladium Deposit (50000X Magnification)

XRF measurement was 5.6 microinches and the FIB measurement was 4-6 microinches for electroless palladium

Test Results – ENIG



Standard : NF-A-89 400P

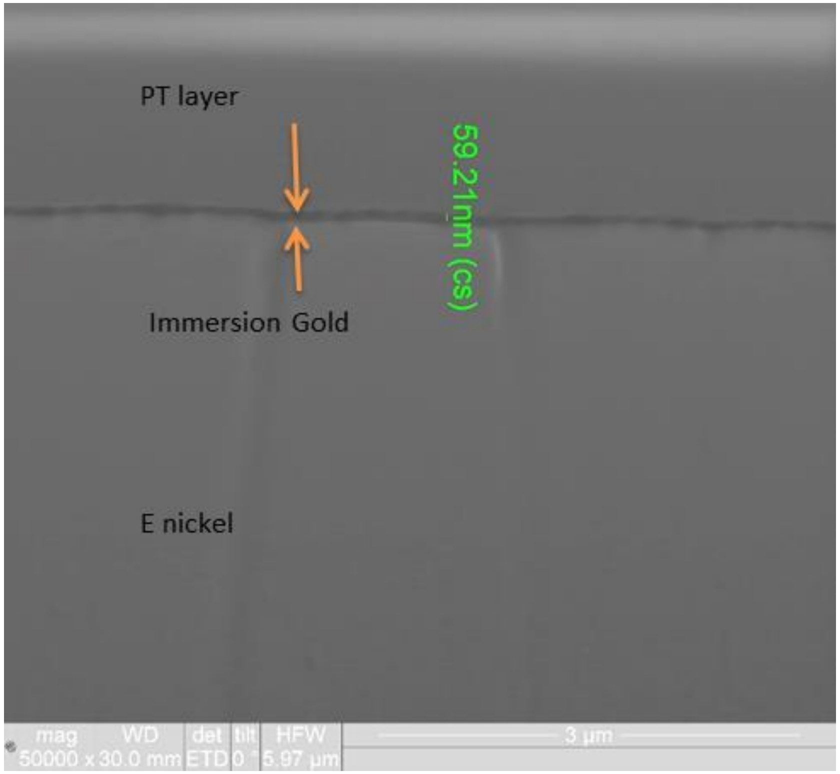
At 0.800 S Force min: -0.24 mN/mm. Force max: -0.17 mN/mm

Time (seconds)

Test Results – ENIG

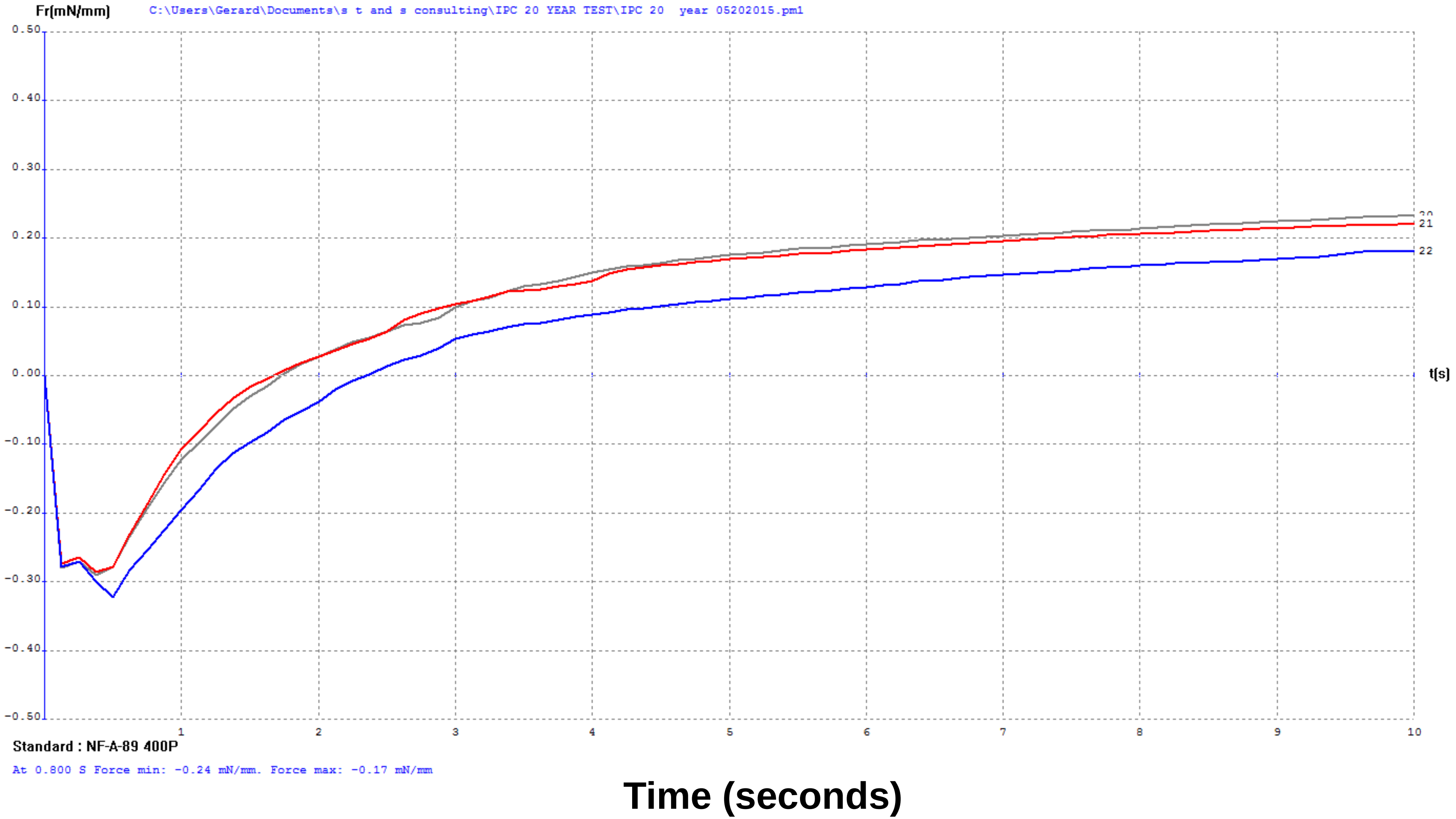
- **XRF assessment measured the immersion gold deposit at 4.9 microinches and the electroless nickel at 406 microinches**

- **FIB assessment measured the immersion gold deposit at 2.4 microinches and the electroless nickel at 400 microinches**

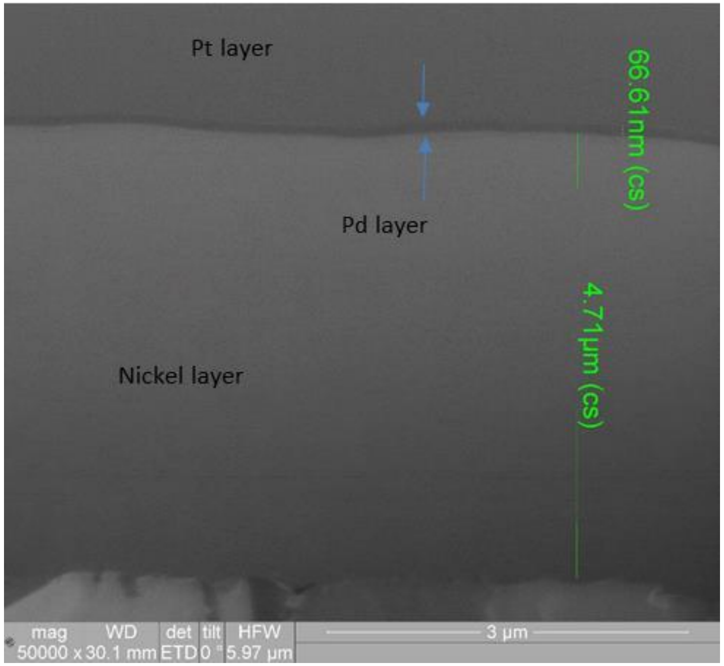


FIB Image of the ENIG Deposit (50000X Magnification)

Test Results – Electroless Pd/Electroless Ni/Cu

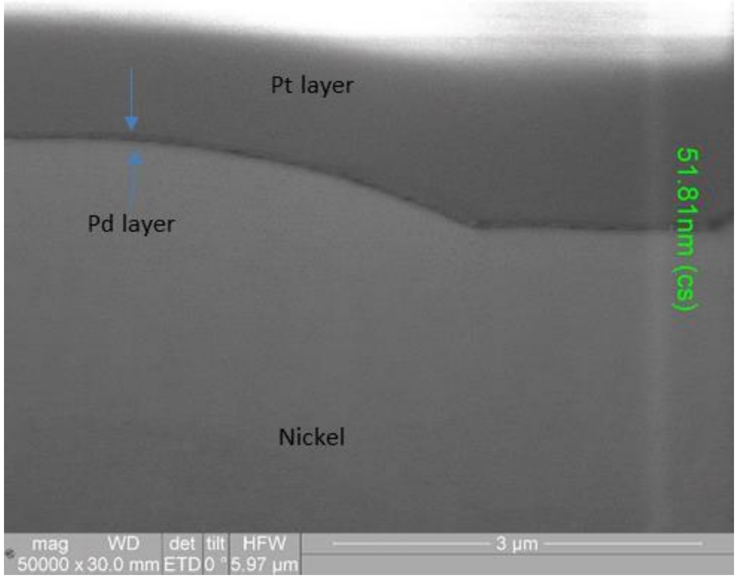


Test Results – Electroless Pd/Electroless Ni/Cu



FIB Image of the 3 microinch Electroless Nickel/Electroless Palladium Deposit (50000X Magnification)

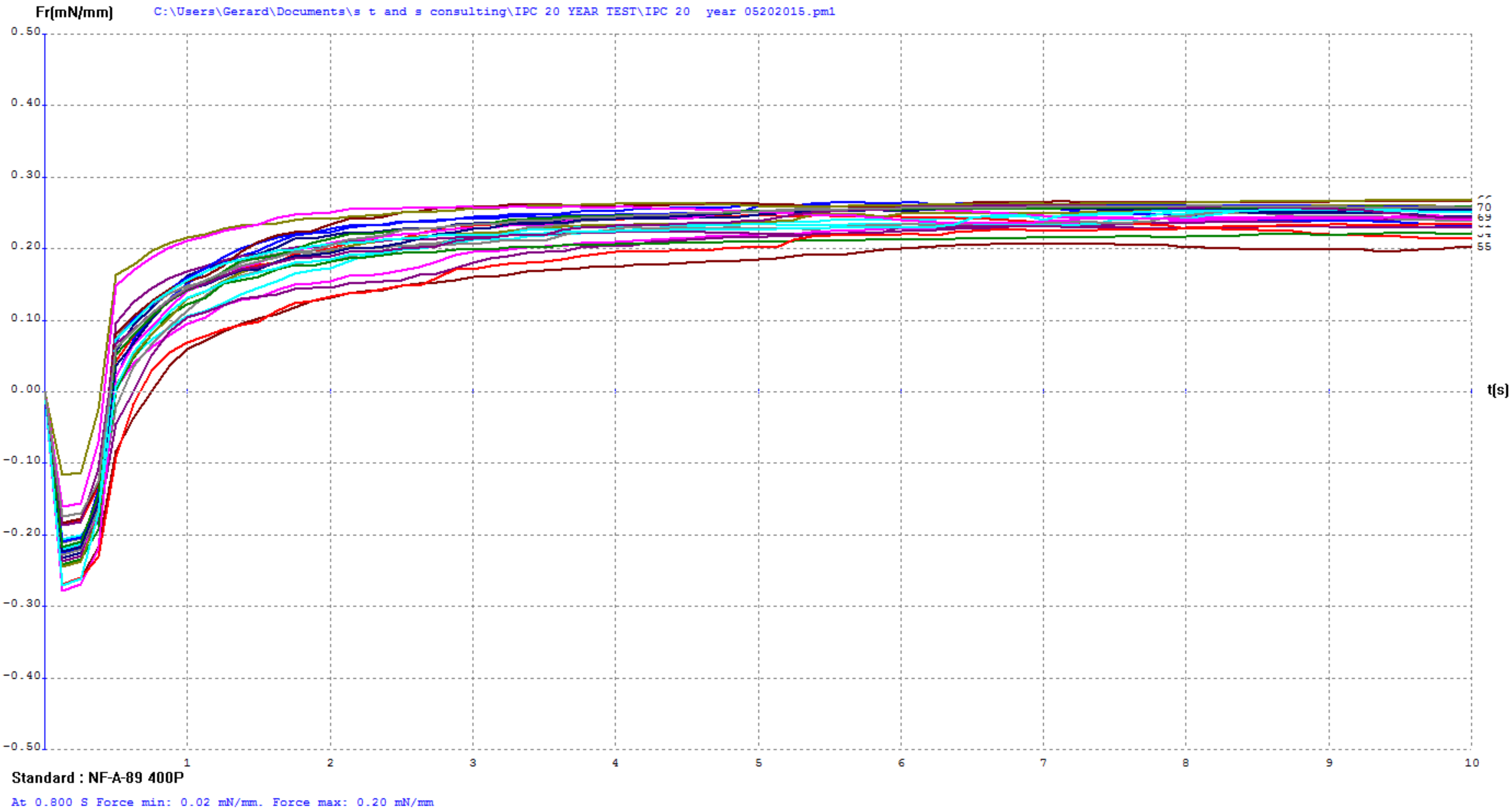
XRF: electroless palladium at 5.11 microinches and the electroless nickel at 180 microinches
FIB: electroless palladium deposit at 2.6 microinches and the electroless nickel at 188 microinches



FIB Image of the 6 microinch Electroless Nickel/Electroless Palladium Deposit (50000X Magnification)

XRF: 5.95 microinches for the electroless palladium and 298 microinches for the electroless nickel
FIB: 2.1 microinches for the electroless palladium and 312 microinches for the electroless nickel

Test Results – ENIPIG

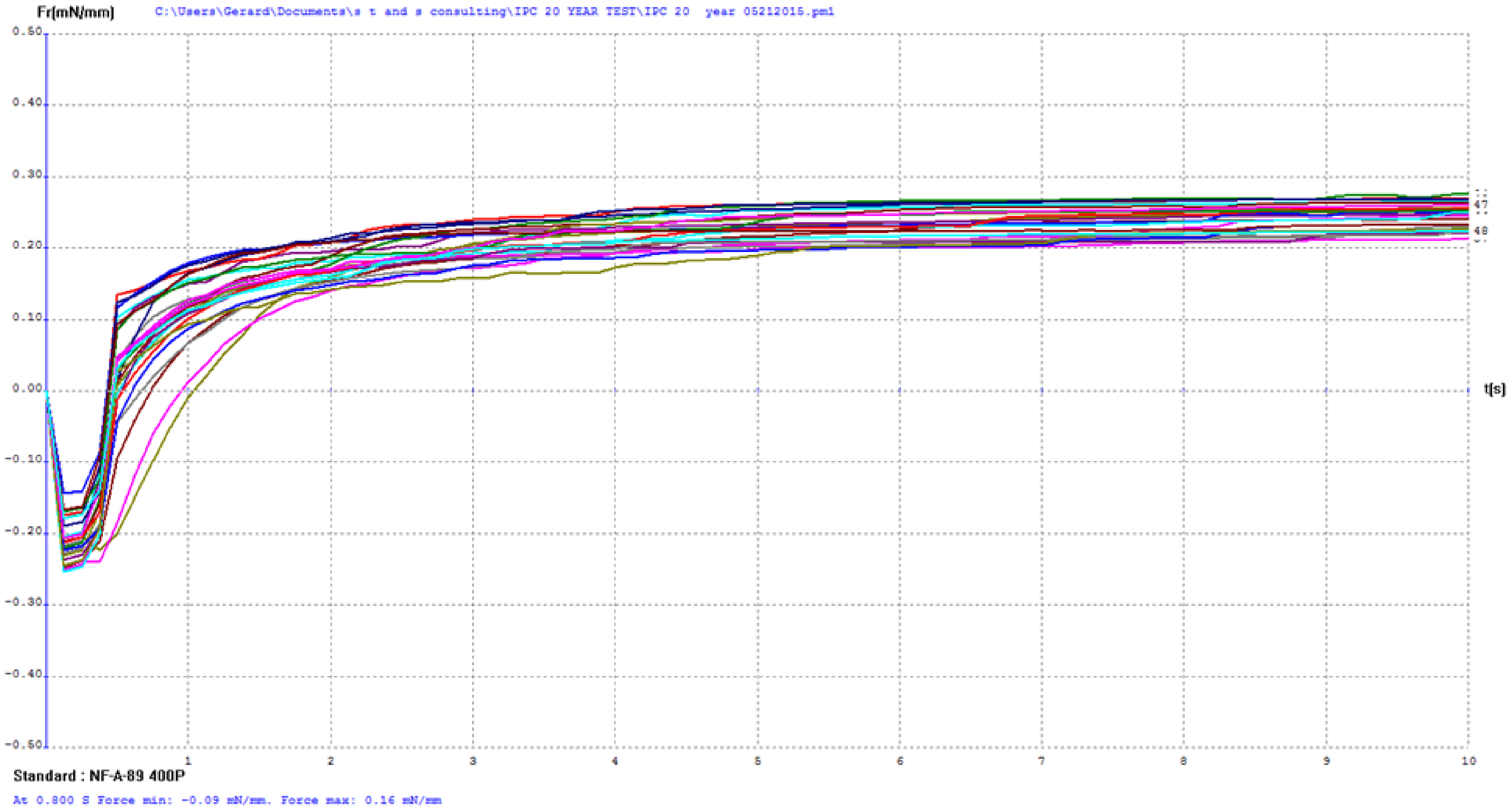


Standard : NF-A-89 400P

At 0.800 S Force min: 0.02 mN/mm. Force max: 0.20 mN/mm

Time (seconds)

Test Results – Electrolytic Au/Electroless Ni



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Standard : NF-A-89 400P

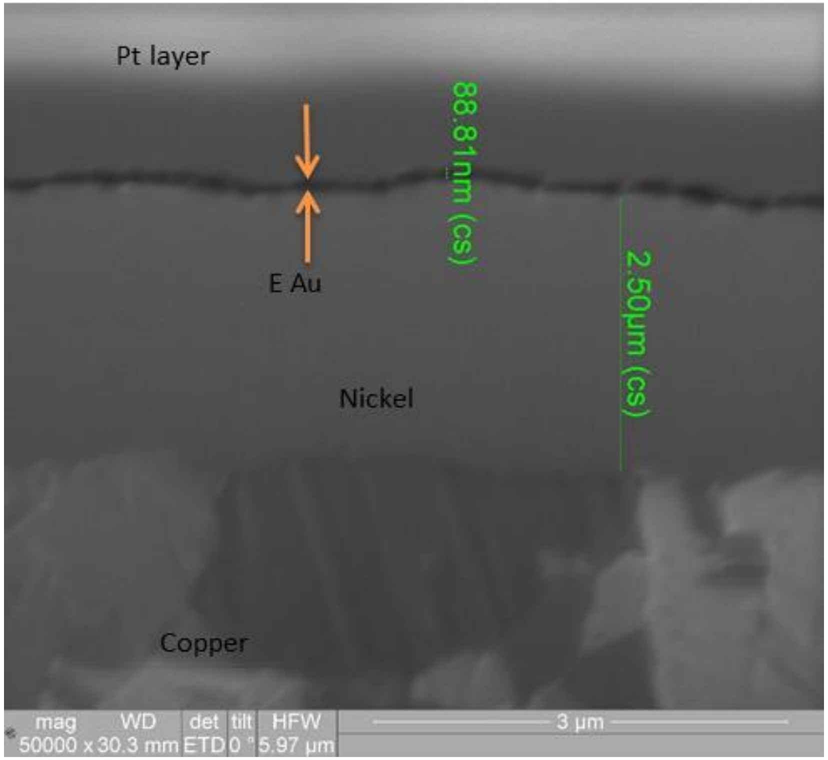
At 0.800 S Force min: -0.09 mN/mm. Force max: 0.16 mN/mm

Time (seconds)

Test Results – Electrolytic Au/Electroless Ni

- XRF assessment measured 5.8 microinches of electrolytic gold and 92 microinches of electroless nickel

- The FIB assessment measured 3.6 microinches of electrolytic gold and 100 microinches of electroless nickel



FIB Image of the Electroless Nickel/Electrolytic Gold Deposit (50000X Magnification)

Discussion

- **Test results confirmed the primary driving mechanisms for loss of solderability: oxidation and diffusion. FIB and XRF assessment showed that the 3 microinch surface finish coupons were significantly degraded after 20 years of storage. The ability of different plating metallurgies and plating combinations to reduce surface finish oxidation and diffusion mechanisms were generally successful.**

- **The thin immersion silver surface finish did surprising well despite its thinness. The IPC-4553 specification requires a significantly thicker plating to avoid the impact of storage and solder processing. The study testing results re-affirm the validity of the specification position/data covering the current immersion silver plating thickness requirements.**

- **The importance of having a nickel plating barrier to reduce the impact of diffusion was demonstrated. Nickel plating prevented the adverse effects of the copper diffusion on a number of the surface finishes.**

Discussion

- **The importance of having immersion gold plating over the palladium plating to reduce the impact of surface oxidation/interface reactions was demonstrated. The immersion gold plating reduced the oxidation of the underlying surface finish and improved the solderability results.**

- **A storage condition of 21ºC/30%-65% RH in non-sealed polyethylene bags is not a particularly harsh environment, but is representative of many board storage environments used in industry today. The study test results are not representative of more severe board storage environments, but the results do demonstrate that properly processed, controlled surface finishes can have extremely long storage lives under specific conditions.**

Conclusion

- The study test results show that a variety of printed circuit board finishes subjected to a storage condition of 21ºC/30%-65% RH in non-sealed polyethylene bags maintained acceptable industry solderability test results after 20 years.

Acknowledgements

- Hank Lajoie and Lisa Gamza of MacDermid Enthone Electronic Solutions for outstanding Focused Ion Beam (FIB) microscopy/XRF analysis

- Ross Wilcoxon, Rockwell Collins, for his scathing review of the manuscript

Questions ???