Why Electroless Palladium: Study on Impact of Electroless Palladium on Electroless Nickel Deposits

Eric Stafstrom
Technic Inc

Executive Summary: IPC Midwest 2009

Electroless nickel immersion gold (ENIG) has captured the major share of the lead free final finish market globally even though it's not the least expensive. ENIG not only provides a robust metallic coating required for assembly with lead free alloys, but also, an effective barrier to virtually stop copper migration into the attachment surface of the PCB. This provides a true surface with long term, low contact resistance with long shelf life and good solderability. So why make any changes to ENIG? Three reasons;

- Improved window on lead free soldering
- Improved robustness for touch contacts.
- Wire bonding of fine features

Lead Free Soldering: After years of testing, discussions, failures and success, lead free soldering has completed the transition from the lab to production. Lead while bad for the environment, was great for soldering and had a tremendous operating window. When compared to eutectic tin lead, liquidous time and spreadability of lead free alloys is less making the final finish on the PCB more critical. As far as ENIG, imperfections in the ENIG deposit, which were not critical with eutectic tin lead, can become an issue because the operating window on Pb-free soldering processes are tighter.

Soldering actually occurs on the electroless nickel as the immersion gold is dissolved into the solder joint. Oxides or intermetallics on the electroless nickel decrease the solderability of the electroless nickel surface causing poor solder wetting or weak solder joints. The oxides and intermetallics are actually corrosion products from the deposition of immersion gold on the electroless nickel. With eutectic tin lead this was called black pad and as suppliers we have learned to reduce the aggressiveness of the immersion gold by shorter times or chemical changes and to increase the chemical resistance of the electroless nickel by increasing the phosphorus content and selection of stabilizers. Classic black pad was a major issue with eutectic solder, but minor amounts of corrosion products typically soldered fine. Now with reduced wetting from lead free soldering, the amount of corrosion products that can be tolerated is reduced.

These corrosion products can be observed under the immersion gold by stripping the gold and evaluating the surface below. A few things become evident in the location and formation of the corrosion products. They almost always initiate around the electroless nickel grain boundaries and or in areas where the electroless nickel coverage is not complete, like around micro-pits or edges of traces or around pads. When cross-sectioned, if due to imperfections in the electroless nickel deposit, large corrosion spikes can be seen at relatively low power. These areas while extremely small would still solder completely with eutectic tin lead and with most lead free soldering processes. The exception is a lead free process with extremely short liquidious time. This provides less wetting time to penetrate the corrosion products.

Why Electroless Palladium

A Study On Impact Of Electroless Palladium
On Electroless Nickel Deposits

Eric Stafstrom Technic Inc.

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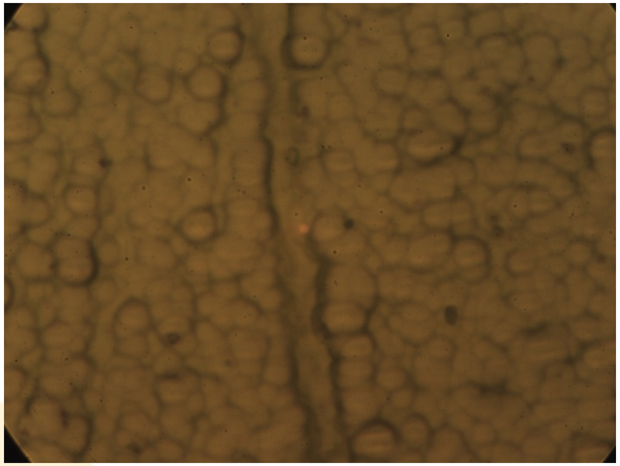
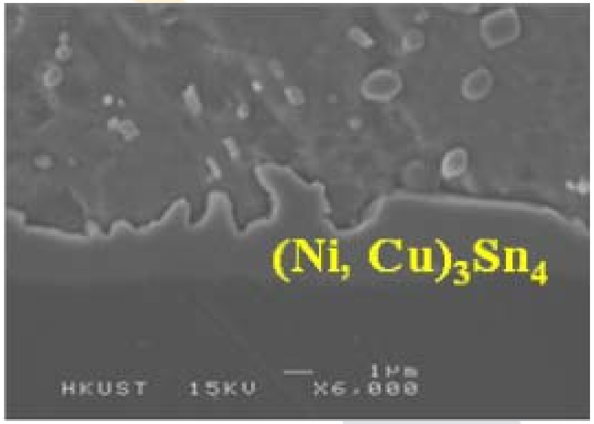
Why ENEPIG



- Benefits
  - Improved solderability
  - Improved solder joint strength
  - Wire bondable
  - Improved Contact resistance
- Theory
  - Complete coating EN surface
  - Different Sn intermetallics on Pd



Impact Of Stabilizer On EN Deposit

- Typical EN deposit nodular in nature no break or “cracks” in deposit
- Choice & Level Of Metal Stabilizer Changes EN Morphology
  - High levels of metal stabilizer creates breaks/fissures in EN surface
  - Specific stabilizers have a 0.5 ppm range in concentration

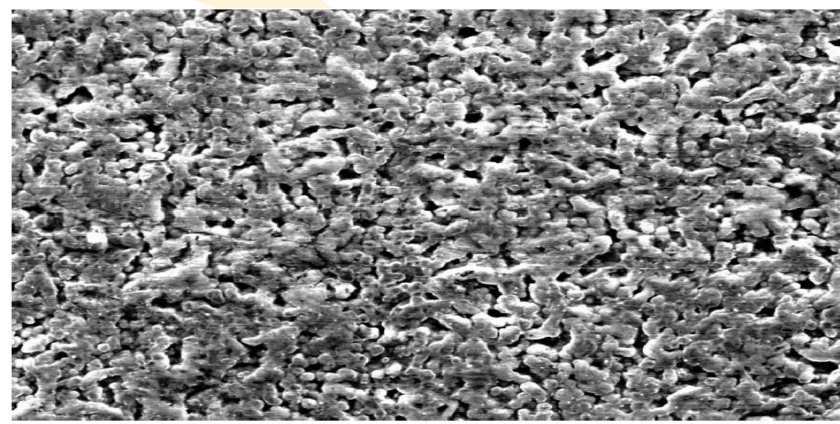


Figure 1. The surface of one of the brighter pads shows a definitely unusual structure. 2,000X

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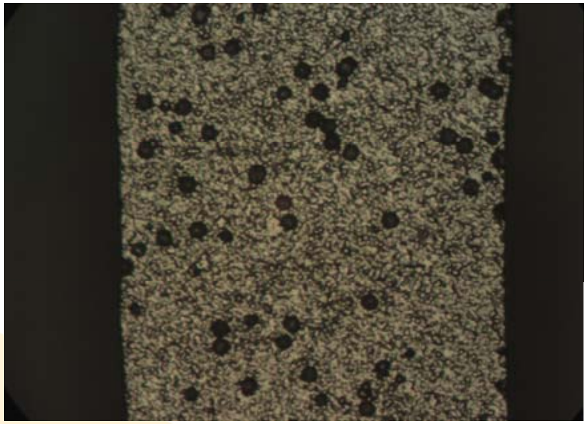
Impact Of Micro-pits On EN Deposit

- Pitting in EN surface
  - Activation & EN Stability
  - Surface Tension of EN solution
- Pitting provides access to Cu to immersion Au
  - Increase immersion Au activity
  - Creates hyper attack on EN
  - Creates dark Ni-oxide making surface difficult to solder



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Impact Of Sulfur Stabilizer On EN Deposit

- Sulfur stabilizer impacts grain boundary
  - Specific compounds makes grain boundary more susceptible to attack
  - Deep corrosion sites into En surface usually visible @ 1000X
  - Dark areas are Ni-oxide and are less solderable

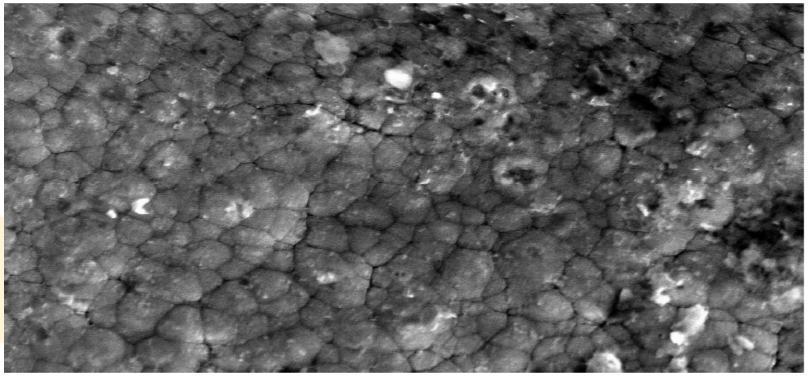
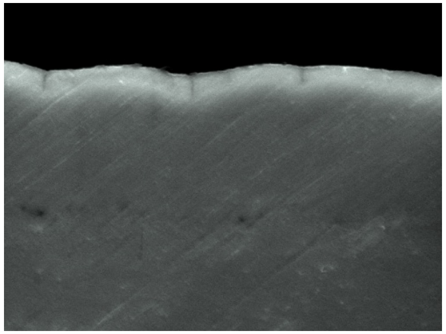
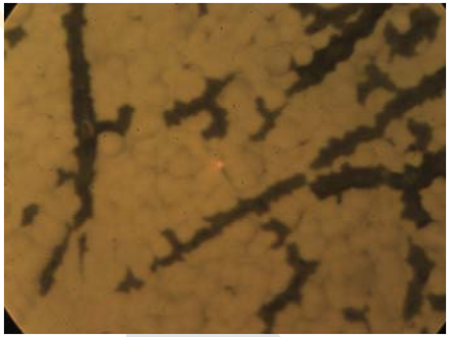


Figure 7. Higher magnification shows a pattern of deeply grooved grain boundaries. 2,000X





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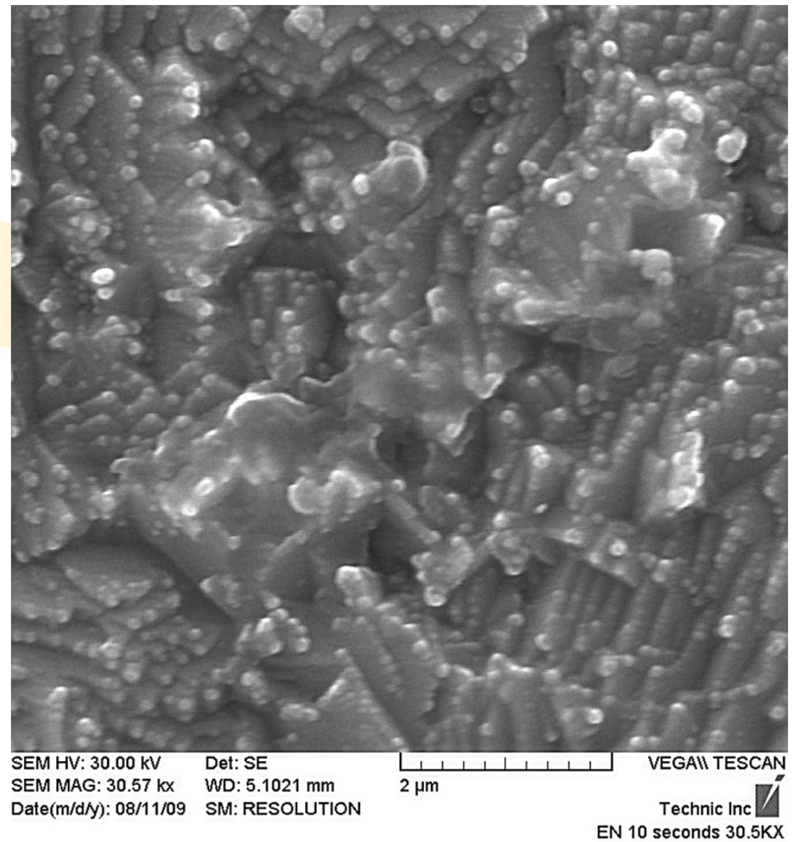
Impact Of Activation On Initiation Of Electroless Nickel

- 10 Seconds Electroless Nickel
- Pd lay down will determine nucleation of electroless nickel
- Grain boundaries (cauliflower Structure) determined by activation



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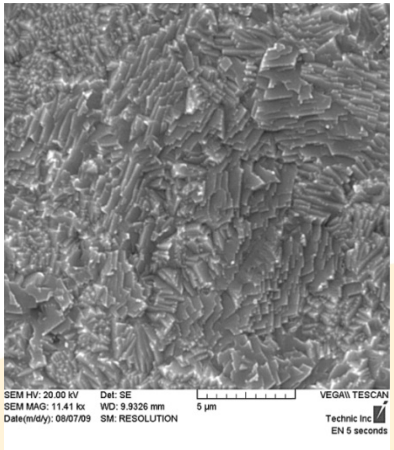
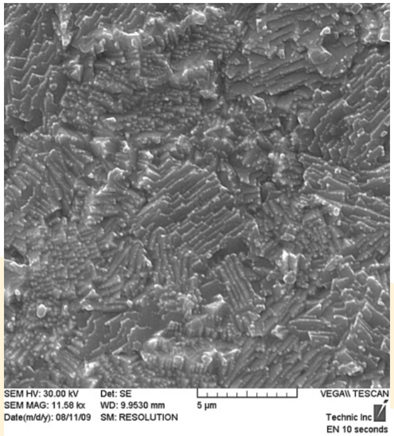
Electroless Nickel Nucleation

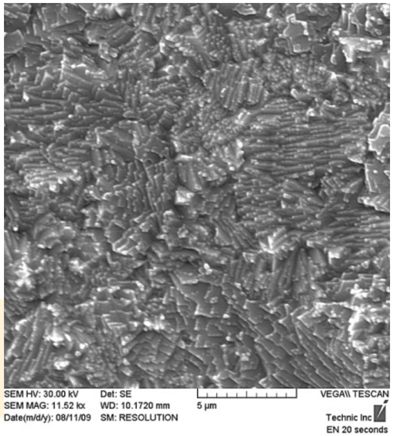
5 Seconds



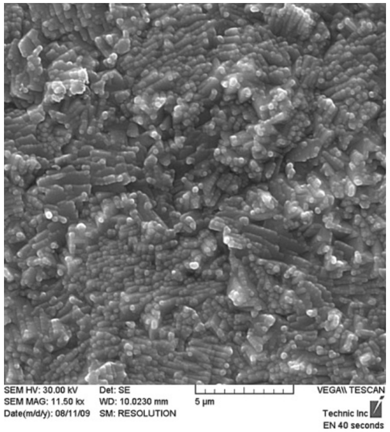
10 Seconds



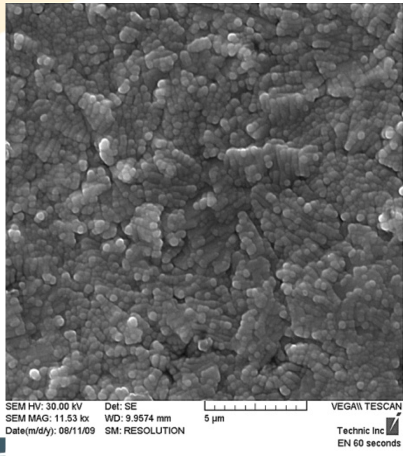
20 Seconds



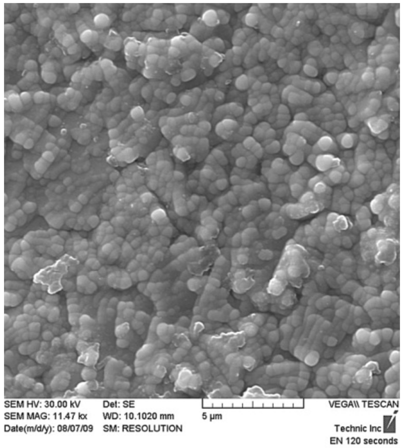
40 Seconds



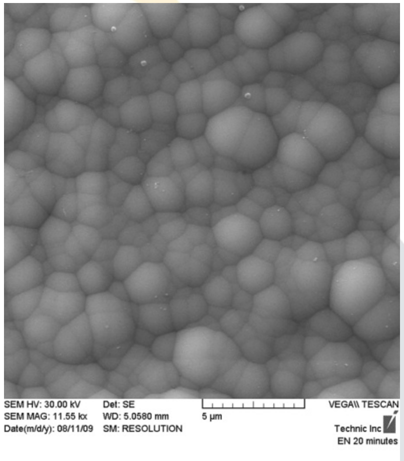
60 Seconds



120 Seconds



20 Minutes



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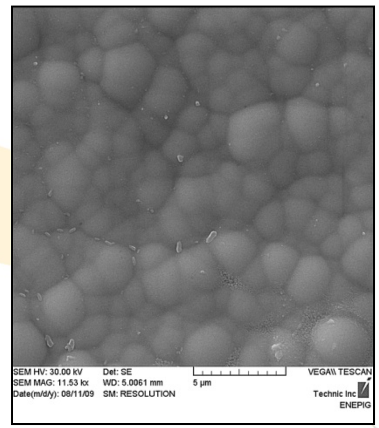
ENIG Process Control Parameters Effecting EN Deposit Integrity

- Electroless Nickel Bath:
  - Measurable: pH, temp, Ni, Hypo, Ortho
  - Qualitative: metal & sulfur stabilizer, complexant, solution flow, wetter level
- Activation
  - Measurable: Pd, acid, temp, etch rate, oxidizer in micro etch, contaminates
  - Qualitative: Rinse water, agitation, racking,
- Part Design
  - Galvanic effect
  - Solder mask
  - Dimensions & types of features

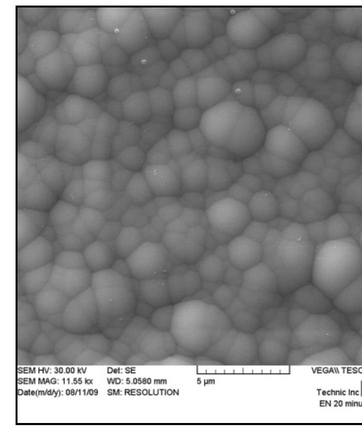
ENEPIG Mechanism For Improved Performance

- Like Immersion Au Electroless Pd Initiates First On Ni Grain Boundaries
- Immersion Au is Chemically Designed to Corrode EN Creating By Products
- Potential Difference Between Au & Pd Much Lower making Immersion Au Less Aggressive on Pd
- Electroless Pd “Seals” EN Defects Limiting The Attack Of Immersion Gold

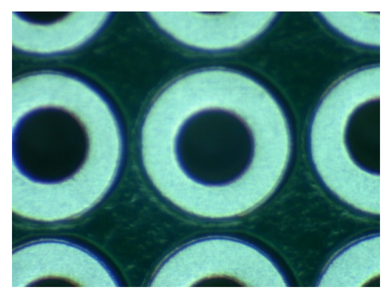
ENEPIG
(10 micro inches Pd)



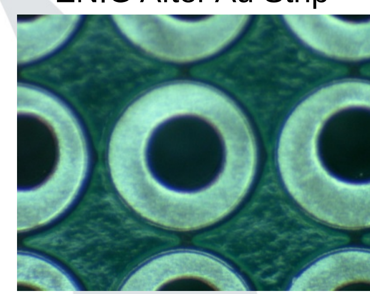
Typical ENIG Deposit



ENEPIG After Au Strip



ENIG After Au Strip



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Study To Compare ENEPIG To ENIG

- Quantify Amount of Pd For Different Applications
- Evaluate Solderability
- Measure Contact Resistance
- Impact of Pd on Wire Bonding

ENEPIG Wetting Balance Results

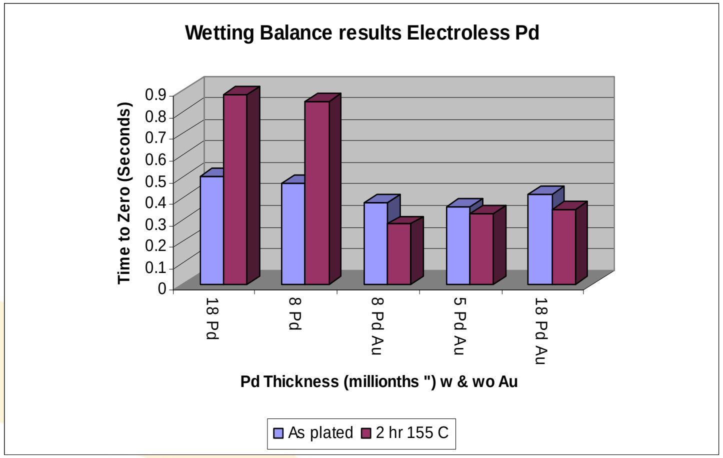
Wetting Balance Parameters:

SAC; 260°C; 5 sec. dwell time;

non activated type R flux

Test Vehicle:

Olin 151 lead frame with & without 2 hour 155 ºC Bake



	Time to 0 (sec)	Max Force (uN/mm)	Time To Max (sec)
AS Coated ENEP	0.50	1.21	5
1 Hour 155C Bake ENEP	0.88	1.76	5
AS Coated ENEPIG	0.38	0.90	3.2
1 Hour 155C Bake ENEPIG	0.28	0.7	5

ENEPIG As Coated

ENEPIG 2 Hour 155 C

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Impact Pd Thickness Wetting Balance Test: ENIG Vs ENEPIG

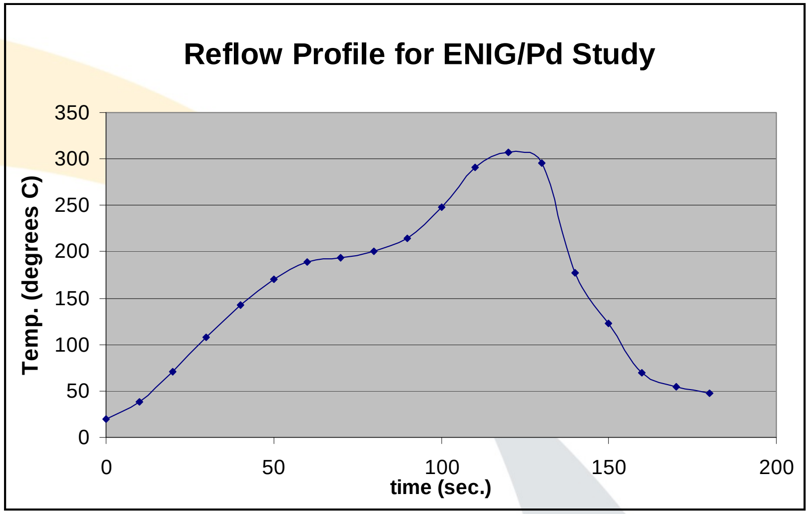
Wetting Balance Parameters: SAC; 260°C; 5 sec. dwell time; non activated type R flux

Test Vehicle:

Olin 151 lead frame

As plated, 3 SMT Reflows with & without 2 hour 155 ºC Bake

ENIG vs ENEPIG with 6 Thickness of El Pd



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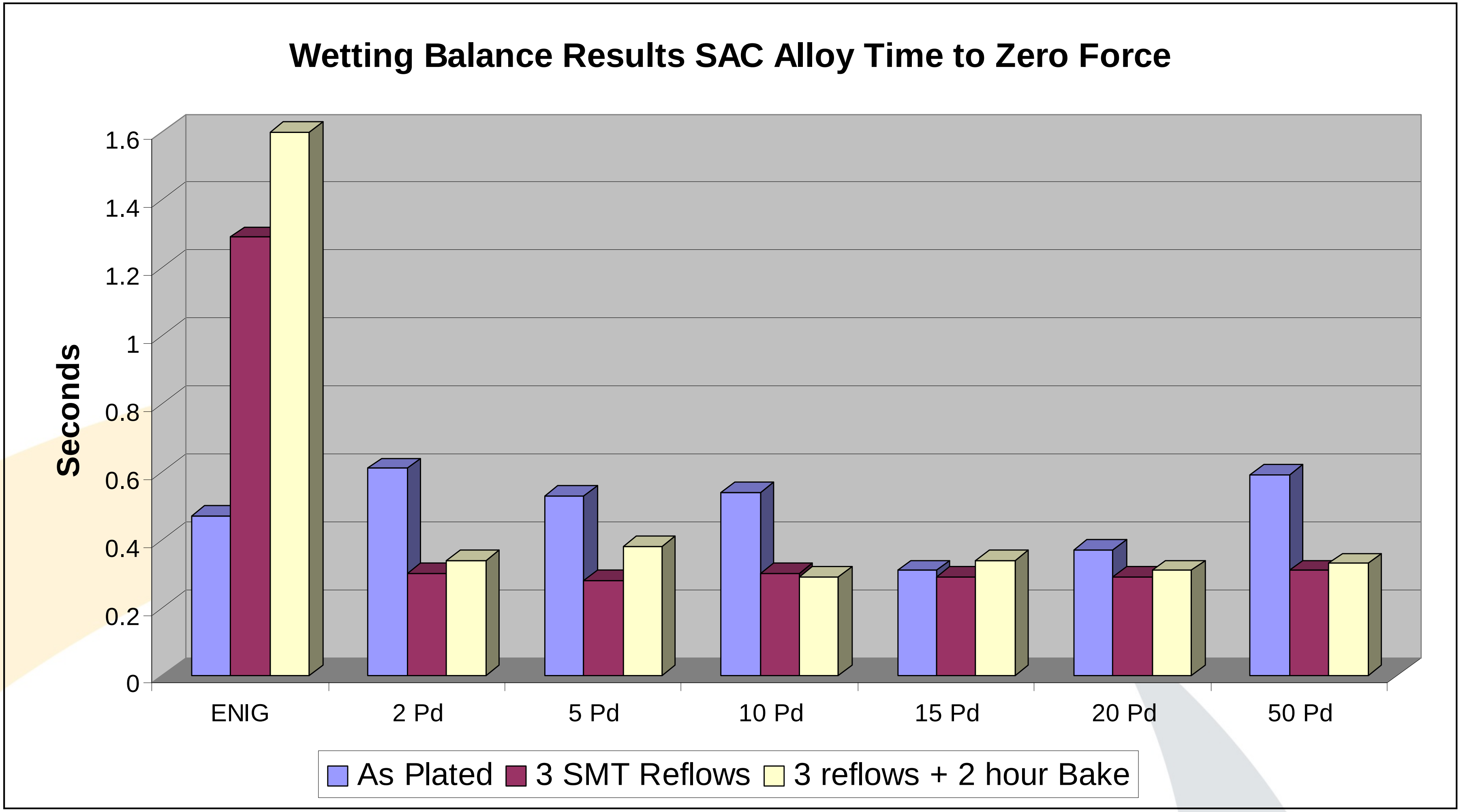
Wetting Balance Results ENIG vs ENEPIG After 3 SMT Reflows

- Evaluation Of Wetting Balance
  - Time to 0, 2/3 force, max force, Time to max force
  - Shape of the curve
- ENIG: 1.29 Sec time to 0 & 2.51 sec time to 2/3
- ENEPIG: 0.3 & 0.7 seconds

ENIG Wetting Balance 3 SMT reflows

ENEPIG (2 PD) Wetting Balance
3 SMT reflows



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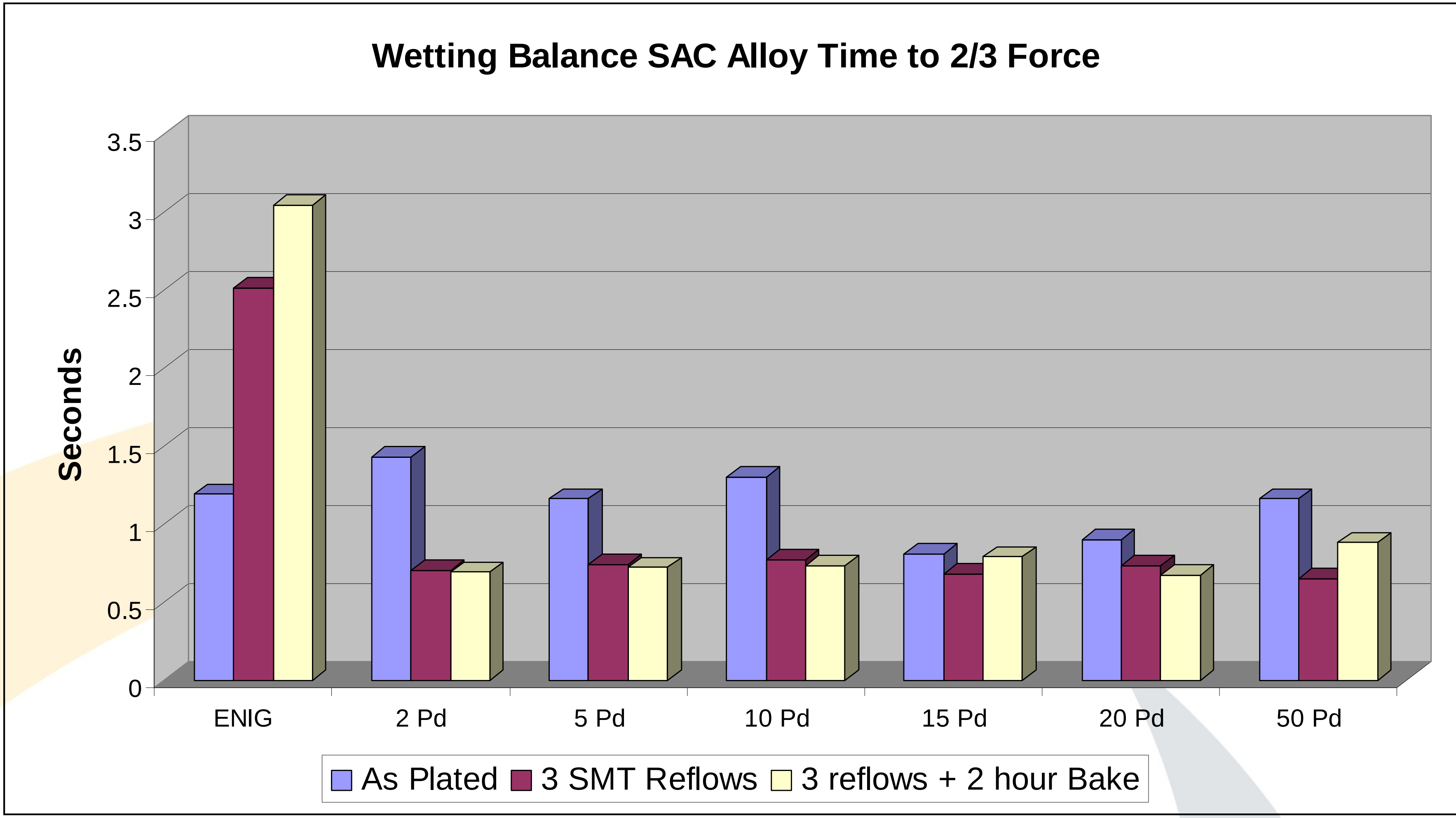
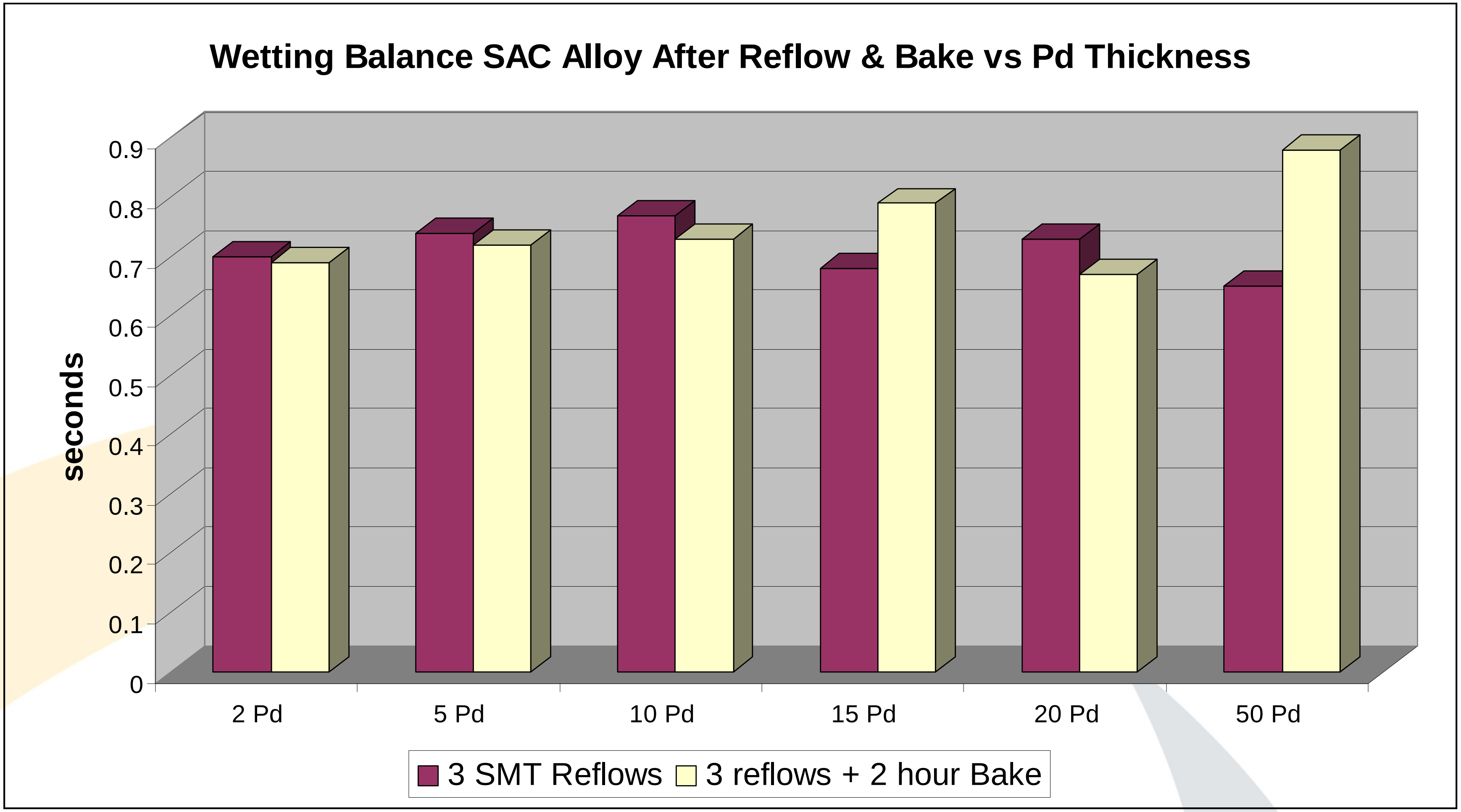

Wetting Balance SAC Alloy Time to 2/3 Force
Seconds
0
0.5
1
1.5
2
2.5
3
3.5
ENIG
2 Pd
5 Pd
10 Pd
15 Pd
20 Pd
50 Pd
As Plated
3 SMT Reflows
3 reflows + 2 hour Bake



Wetting Balance SAC Alloy After Reflow & Bake vs Pd Thickness
seconds
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
2 Pd
5 Pd
10 Pd
15 Pd
20 Pd
50 Pd
3 SMT Reflows
3 reflows + 2 hour Bake

Wetting Balance Results
ENIG vs ENEPIG

- When aged, with SAC 305, solder wetting on ENEPIG is improved over ENIG
- Very thin Pd deposit necessary to improve SAC wetting
- All wetting very good on ENEPIG so impact of increase Pd thickness can not be seen
- Future Work:
  - Evaluation of intermetallic
  - Evaluation of other alloys

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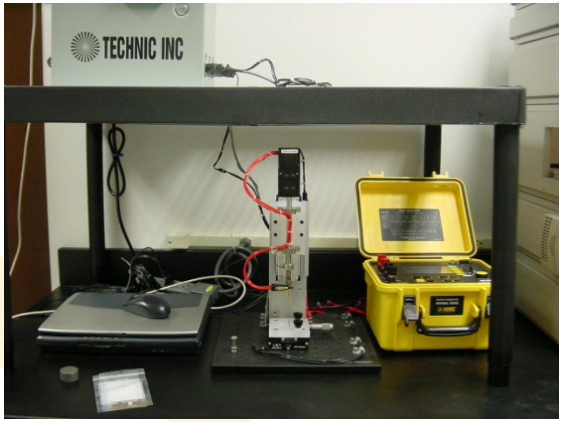
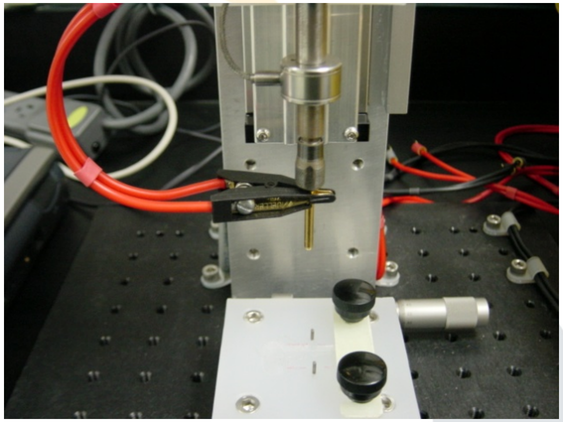
Device To Measure Contact Resistance

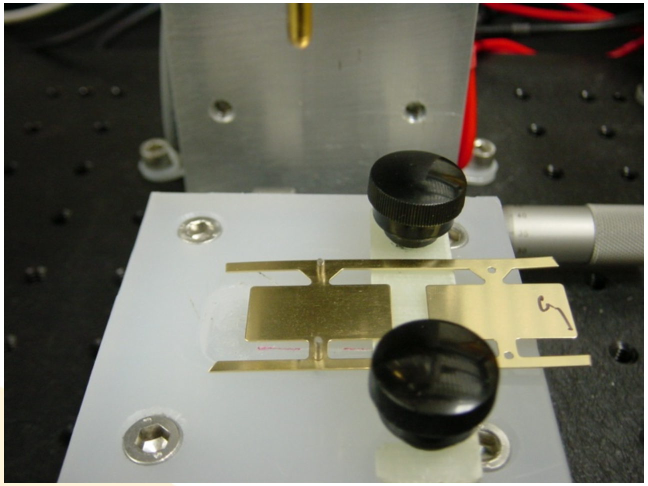
- Modified 4 point Contact Resistance
  - Load cell to control probe force
  - Round probe plated with Au
- Flat Connector Stock As Test Vehicle
- Computer Control Actuation & Data Collection

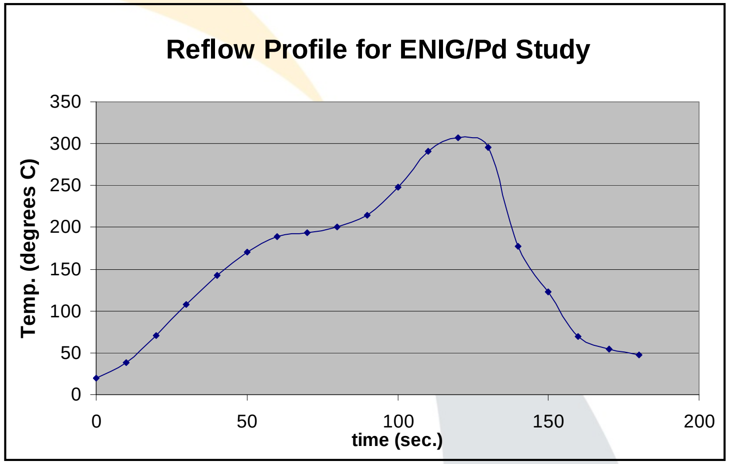




Contact Resistance Test: ENIG vs ENEPIG

- Test Vehicle: Flat Copper Plated Connector Stock
- Test Conditions:
  - Three finishes ENEG, ENIG, ENEPIG
  - 6 Thicknesses of electroless Pd
  - 6 Probe Forces
  - Aging
    - 3 Pd free SMT reflows
    - 3 SMT reflows & 8 hours steam





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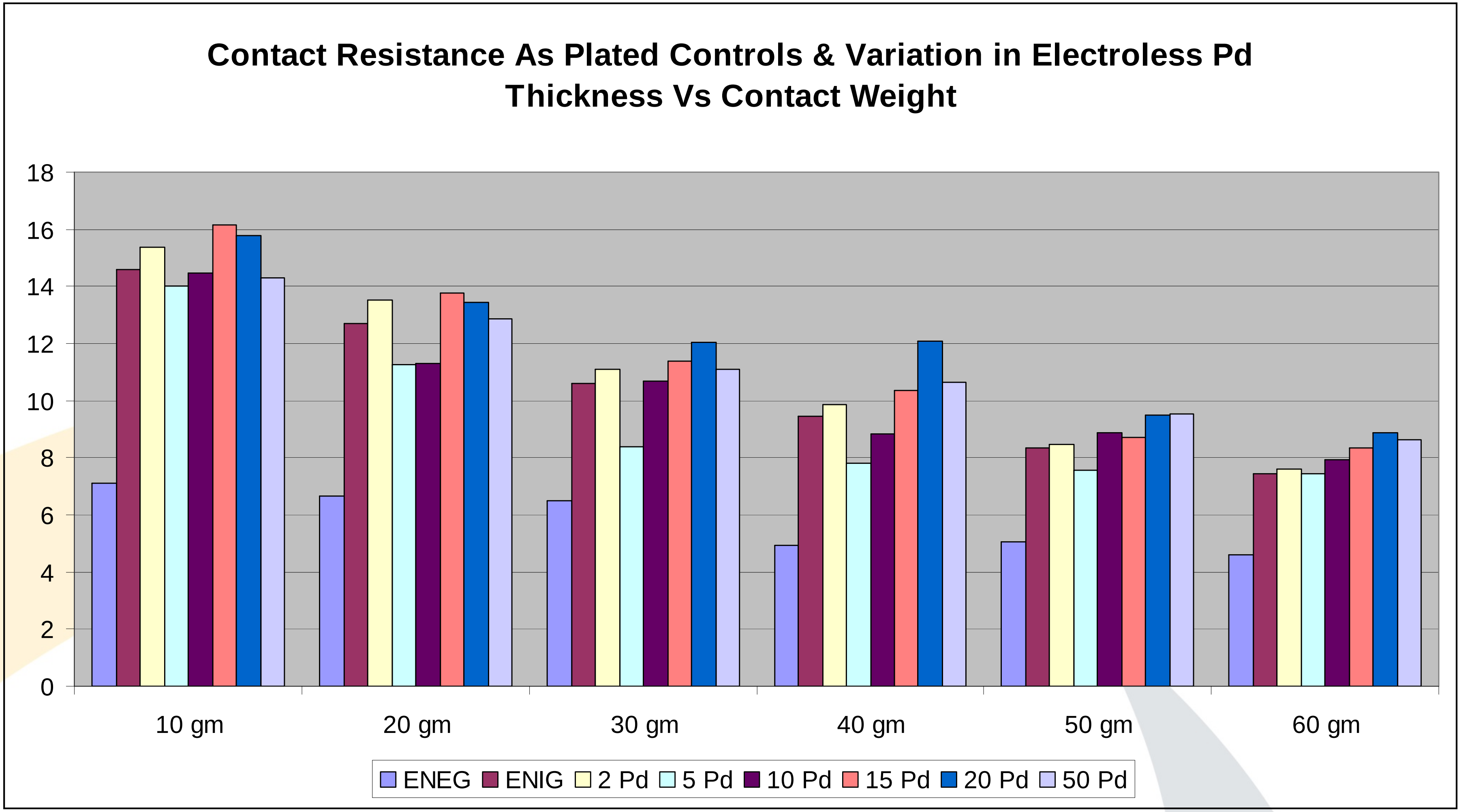
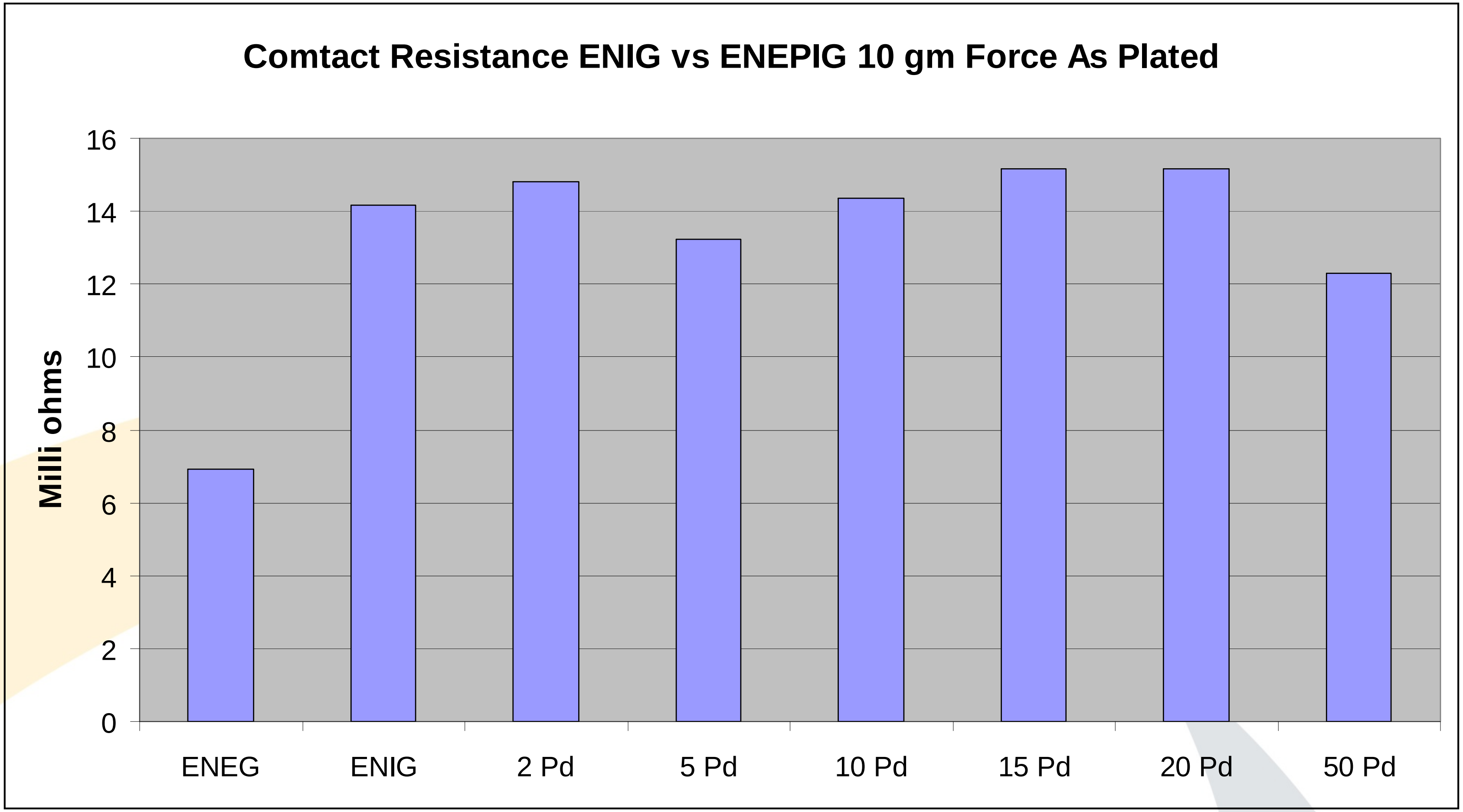
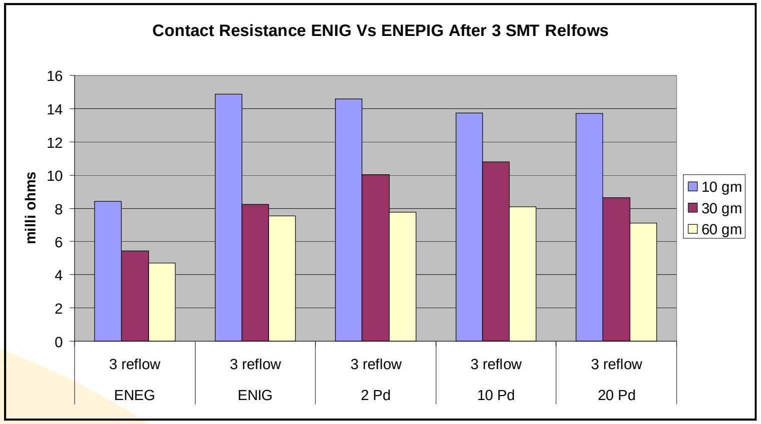
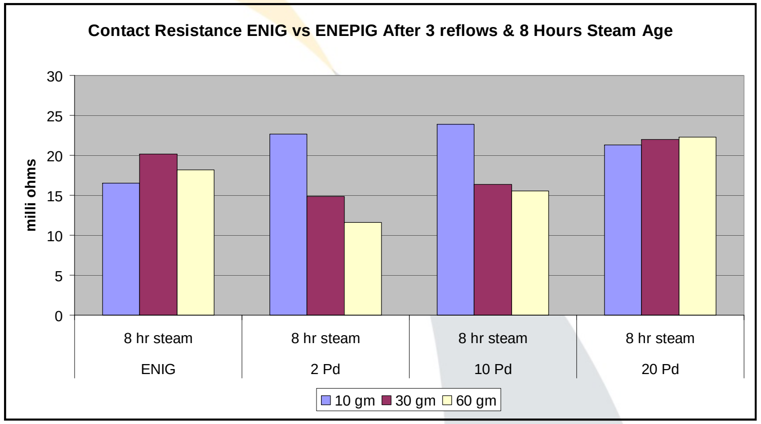

Contact Resistance As Plated Controls & Variation in Electroless Pd
Thickness Vs Contact Weight
18
16
14
12
10
8
6
4
2
0
10 gm
20 gm
30 gm
40 gm
50 gm
60 gm
ENEG
ENIG
2 Pd
5 Pd
10 Pd
15 Pd
20 Pd
50 Pd


Comtact Resistance ENIG vs ENEPIG 10 gm Force As Plated
Milli ohms
16
14
12
10
8
6
4
2
0
ENEG
ENIG
2 Pd
5 Pd
10 Pd
15 Pd
20 Pd
50 Pd

Contact Resistance Test After Aging

- ENEG Always Lowest Resistance
- ENIG vs ENEPIG Similar as Plated
- General Trend of Thicker Pd Yield Lower Contact Resistance
- Issues With Gold Thickness on Pd
  - Lower thickness on thicker Pd samples
  - Gold deposit bigger impact on contact resistance





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ENIG vs ENEPIG Gold Wire Bond Strength

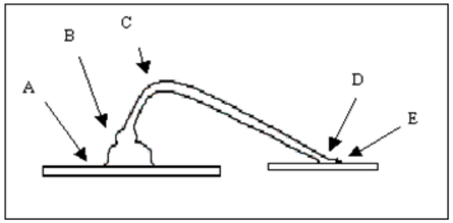
Test Parameters:

- Bonder: AB356 Automatic Gold Wire Ball Bonder
- Wire: 99.99% Gold , Size=1 mil, T.S.=10-15 gm
- Capillary: GAISER Tool Company (1572-17-437GM-20D)

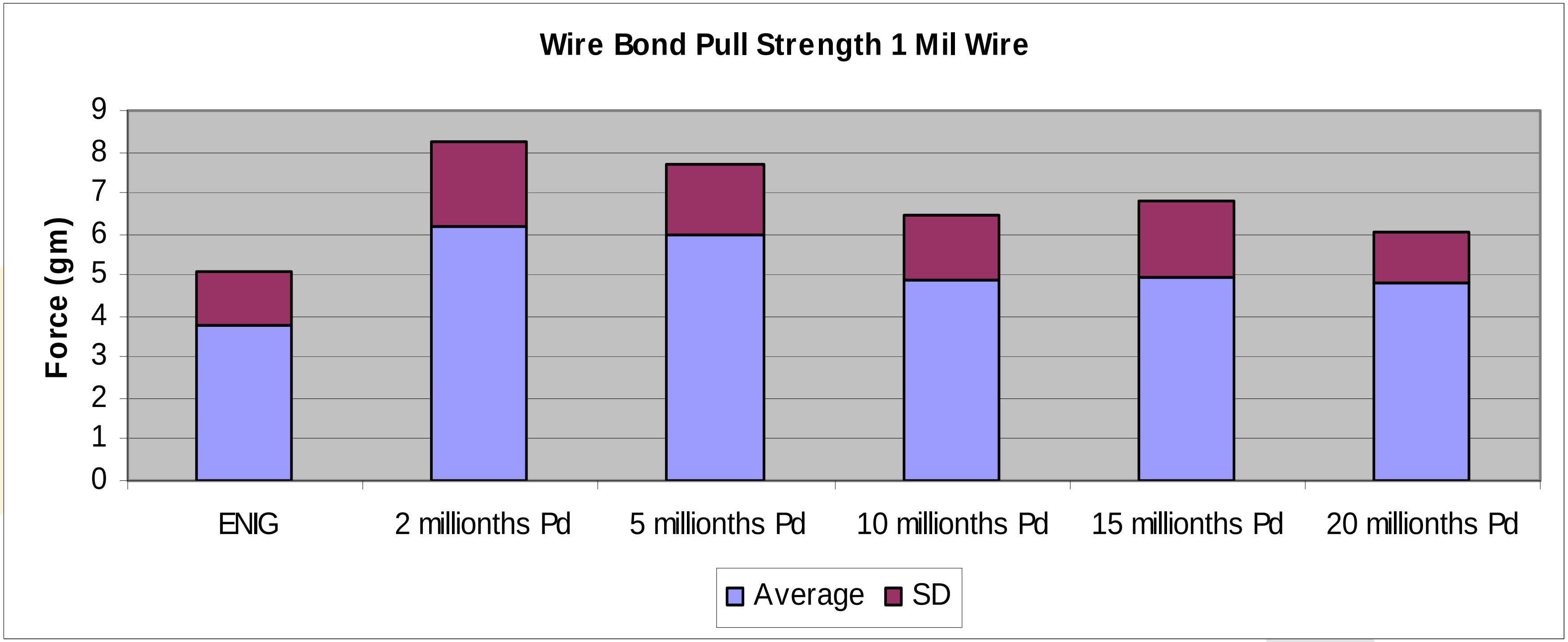
Results

- 5-6 gm Ave pull 1mil Au wire
- ENIG Substantially Lower

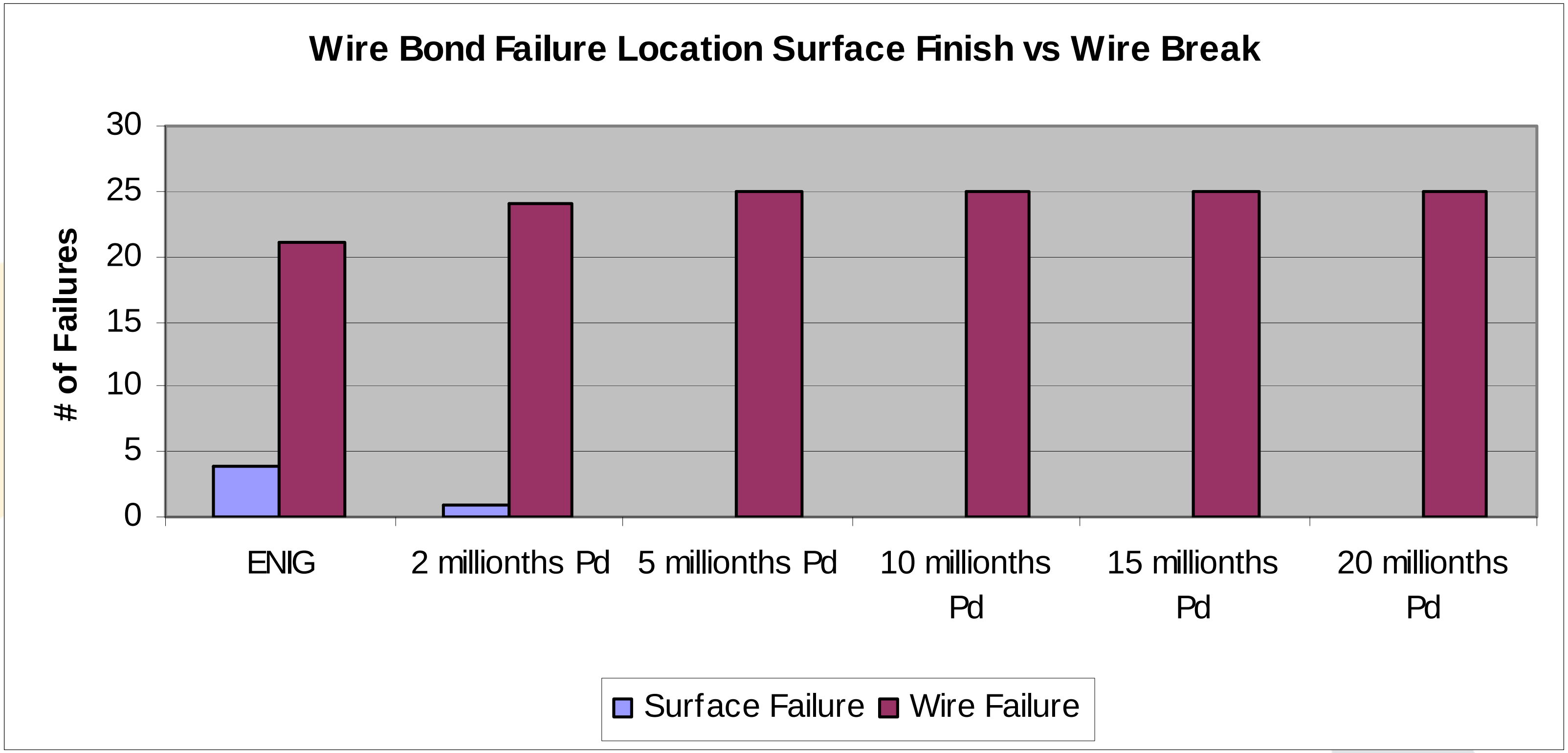
	ENIG		2 microinches Pd		5 Microinches Pd		10 microinches Pd		15 microinches Pd		20 microinches Pd	
Wire#	grams	code	grams	code	grams	code	grams	code	grams	code	grams	code
1	6	A	4.8	B	6.5	B	5.1	B	3.1	D	4.2	B
2	4.5	B	3.2	B	5.5	B	4.2	B	6.3	B	3.5	B
3	2.5	D	6	D	6.5	B	5.5	B	5.2	B	4.2	B
4	2	D	3.8	B	7.8	B	4.3	B	5.1	D	3	B
5	2	D	4.2	B	9.6	B	4	B	5.6	B	7	B
6	3.4	B	2.9	B	5.8	B	4.2	B	7.5	B	5.5	B
7	3.5	B	6.5	B	4.8	B	4.8	B	2.6	B	2.9	D
8	3.5	B	6.9	B	10.1	B	4	B	7.9	B	4.8	D
9	5	B	7.2	D	5.4	B	2	D	6.8	D	3.8	B
10	3.2	B	8.5	D	4.1	B	4.1	B	6.4	B	4.5	B
11	3.8	B	7.4	B	5.5	B	3.1	B	3.2	D	5.2	B
12	2.8	A	5.8	B	6.2	B	6.2	B	10.2	B	4.9	B
13	4.9	B	4.3	B	4	B	7.2	B	5.3	B	6.5	B
14	2.9	B	6.7	B	5.2	B	3.1	B	3.9	B	4	B
15	4.6	B	3.8	B	5.4	B	6	B	4.2	B	6.8	B
16	5.9	A	3.5	B	7.1	B	6.2	B	3.7	B	5.2	B
17	6.2	B	9.9	D	4.8	D	4	B	4.2	B	3.5	B
18	2	D	4	B	5.2	B	3.8	B	2.8	B	3.8	B
19	2.5	D	7.3	B	4.1	B	5	B	4.5	B	5.5	B
20	3.5	D	7.7	B	4.2	B	4.2	B	5.2	D	3	B
21	3.5	B	7.9	B	8.5	D	4	B	2.6	D	4.1	D
22	4.2	B	7	B	3.8	B	4.5	B	6	B	5.2	B
23	3.1	B	9	A	7	B	8.4	B	4.1	B	6.1	D
24	5.1	B	8.9	B	4.2	B	6.3	B	4.2	B	6.4	B
25	4.7	A	8	B	7.5	B	8.3	B	2.5	B	6.2	D
Av	3.812		6.208		5.952		4.9		4.924		4.792	
SD	1.25376766		2.05059341		1.73400308		1.55509914		1.88553264		1.238588	



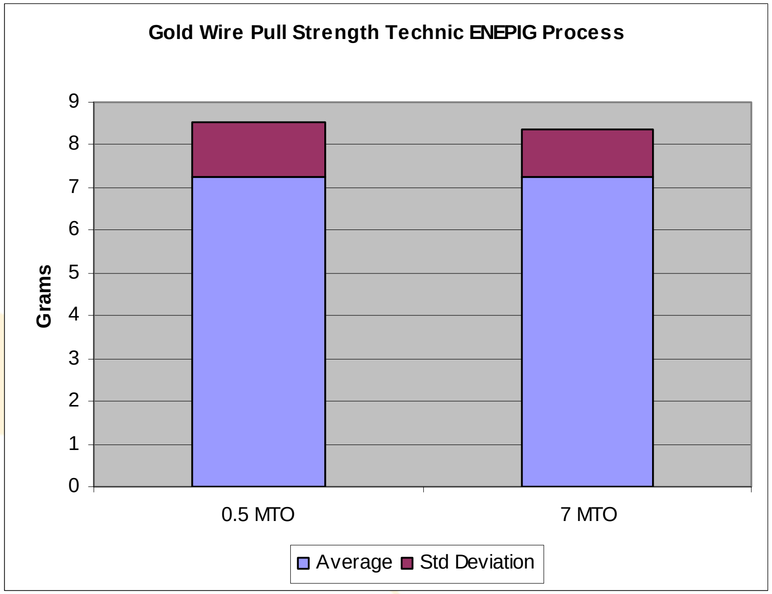
Wire Bond Pull Strength ENIG vs ENEPIG Average & Standard Deviation



Location Au Wire Bond Failure ENIG vs ENEPIG



Gold Wiring Bonding To Electroless Pd/Immersion Gold



MTO Electroless Pd Bonding Test

Test Parameters:

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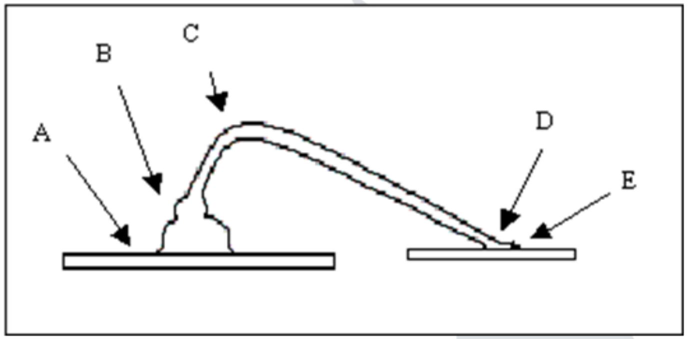
- Wire: 99.99% Gold , Size=1 mil, T.S.=10-15 gm
- Capillary: GAISER Tool Company (1572-17-437GM-20D)



Test Results:

- 2 breaks of 50 samples at “A” or “E” locations
- Ave pull acceptable in all thickness
- Pull strength goes up with higher Pd thickness.

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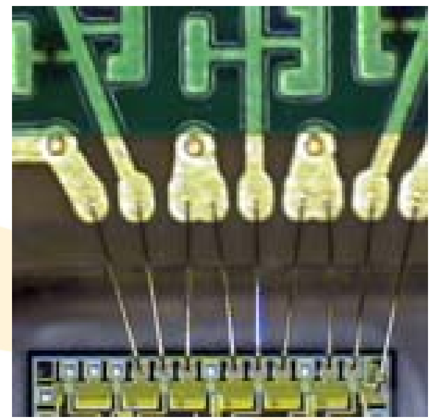
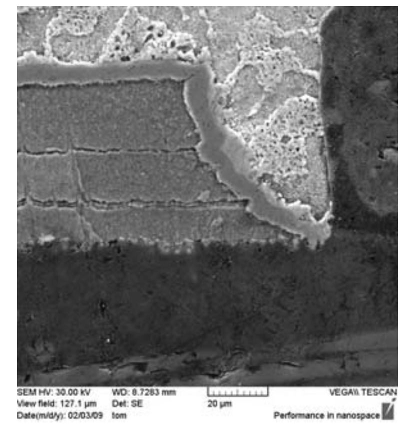
Au Wire Bond Results

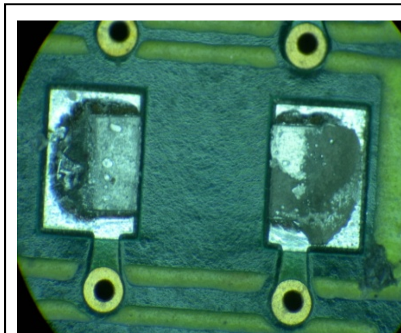
- Acceptable wire bond with over 5 micro inches of Pd.
- Au thickness plays a role in wire bonding even to thick Pd
- Future Work
  - Test 0.8 mil Au wire
  - Au thickness on electroless Pd
  - Evaluate Au wire/Pd interface & impact of aging on bond strength

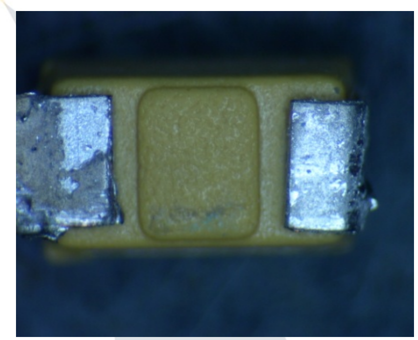
Why Electroless Palladium

- Improve Process Window For Lead Free Solderer
  - Wider window on EN
  - Protection of EN
  - Intermetallic
- Encapsulated wire bonding of fine features
- Low contact resistance but more Au dependent









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Mr. Ben Mikulis: Advanced Microelectronics Inc

For wire bonding

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Thank You For Your Attention

Questions?