Nickel-Palladium-Gold: A Cost Effective, Sn-Whisker-Free Termination Finish

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The work presented here is abstracted from a paper written by myself and Se Chuel Park (sech.park@samsung.com) of Samsung Techwin Co., Ltd as members of the HDP Users Group.

The complete paper is located at:
www.hdpug.org/public/4-papers/2005/2005.htm

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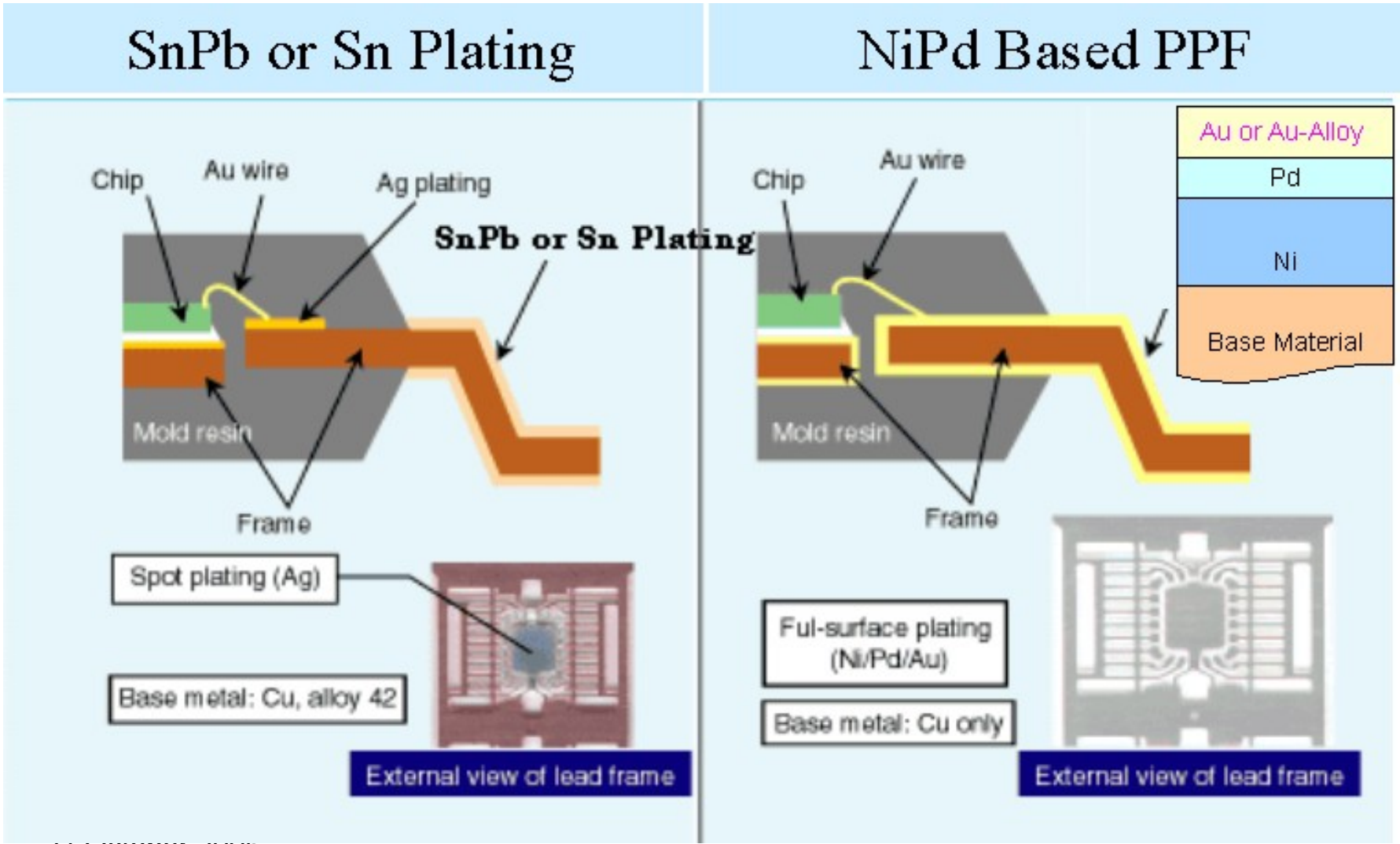
Objectives

- NiPdAu **P**re-**P**lated **F**inishes (PPF's) are economical and effective Pb-free finishes for IC leads.
- No risk of Sn whiskers with NiPdAu PPF.
- Tens of billions IC's are in use with NiPd and NiPdAu PPF finished leads; sold over the past 15 years.
- Cost of the NiPdAu based leadframe finishes has been addressed by reducing the Pd content by ~7X and adding an ultra thin (30~100 angstrom) top layer of Au.
- Solderability performance is equivalent to that of fusible Sn finishes.

Plating Comparison



Some History

- In 1989, Texas Instruments introduced NiPd finished leads, converting >90% of their leaded product to **NiPd** within 2 years.
- The functional finish at that time was 2-layers:
  - **0.075µ (3u”) Pd** over
  - **2µ (80u”) Ni**
  - Pd was ~$120/toz., but ranged up to $1000/toz.
  - Pd is currently at $180-$185/toz.

Sn Whiskers

- Mechanism for Sn whiskers is not still understood – 50+ years of recognition.
- For Sn on Cu; related to stress in Sn layer.
- But, mechanism for Sn movement (stress relief) not well defined.

- Sn whiskers represent an unbounded $ risk to IC manufacturers using matte Sn.

Sn Whiskers

The #1 mitigation technique for whiskering : simply “don’t use tin finish”.

Sn Whiskers

"*Any claims for "whisker-free" tin-plating processes, or guaranteed lifetimes without a whisker failure, must be regarded with skepticism at this time.*"

Joe Smetana, Alcatel

ECTC, 2004

JEDEC Std 201

“ENVIRONMENTAL ACCEPTANCE REQUIREMENTS FOR TIN WHISKER SUSCEPTIBILITY OF TIN AND TIN ALLOY SURFACE FINISHES”

- Final Ballot Draft for JESD201 out on 9-1-05

JEDEC Whisker Growth Test Method

JEDEC standard JESD22A121, "Test Method for Measuring Whisker Growth on Tin and Tin Alloy Surface Finishes"

Published May 2005, details a suite of tests that provide:

-- an industry-standard method of measuring and comparing whisker propensity for different plating or finish chemistries and processes

-- a consistent inspection protocol for tin whisker examination

-- a standard reporting format

Some Misconceptions About NiPdAu PPF

- High cost of this plated finish
- Issues in the IC assembly process
  - Plating cracking after lead forming
- Soldering and fillet shape after board mount

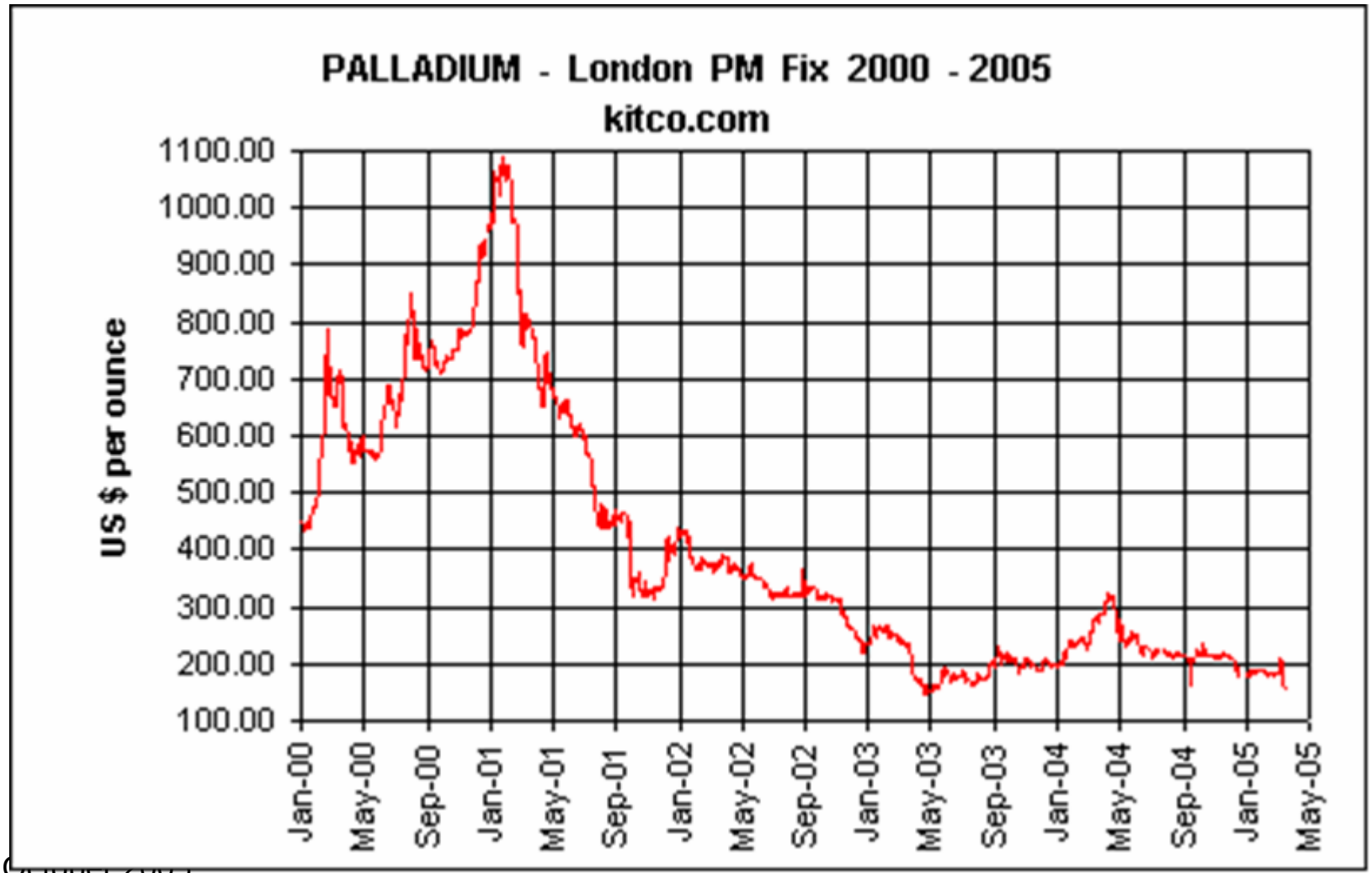
Cost: Lowering Pd Content

Now NiPdAu PPF are 3-layer structures.

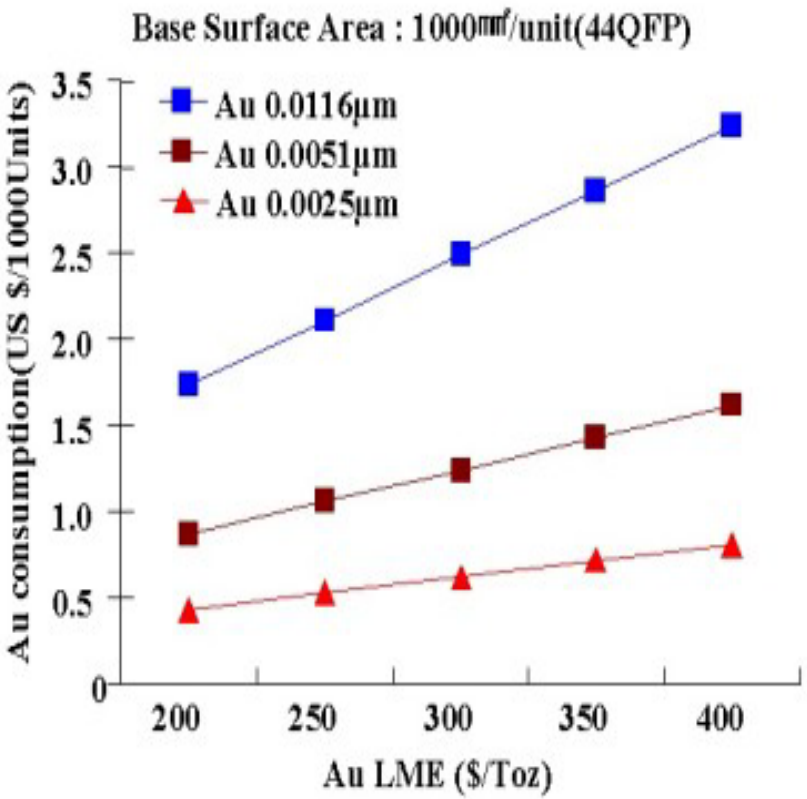
- **Ni** over the base metal, 0.5 - 2 µ
- **Pd** 0.01 - 0.15 µ (2-layer 0.075 – 0.15µ)
- **Au** or Au-alloy, 0.003 – 0.015µ

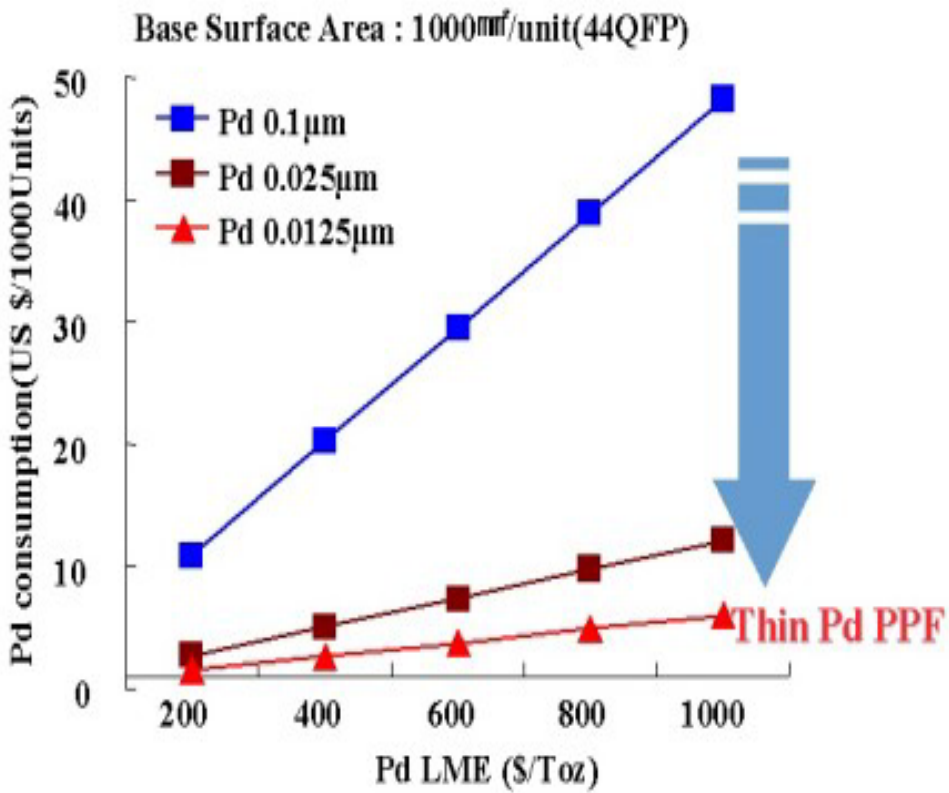
- **Pd** content has been reduced by ~ 7X, added 30 - 150 angstrom of **Au**

Pd Price History

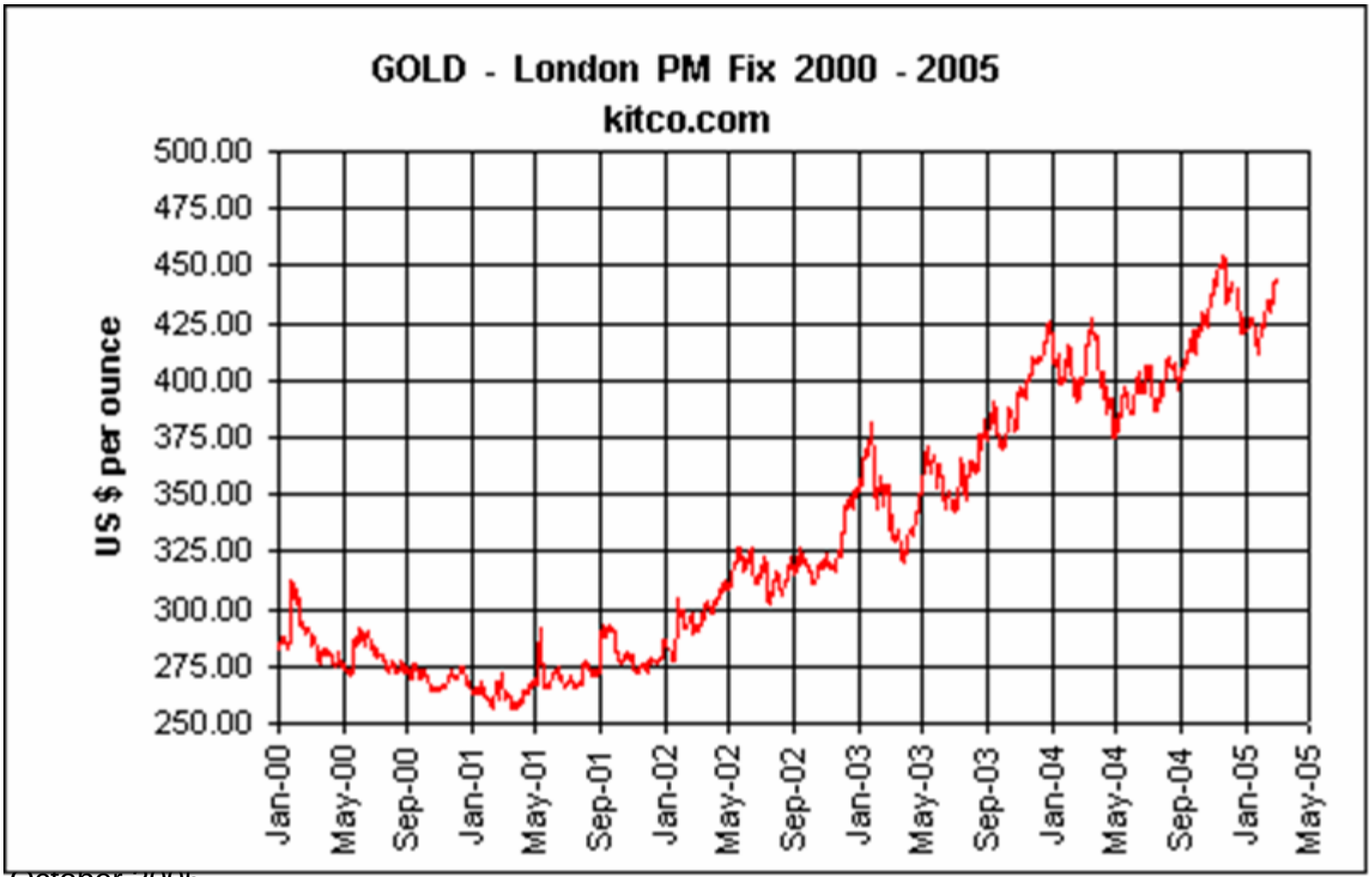


PM Price v. Thickness, Sensitivity

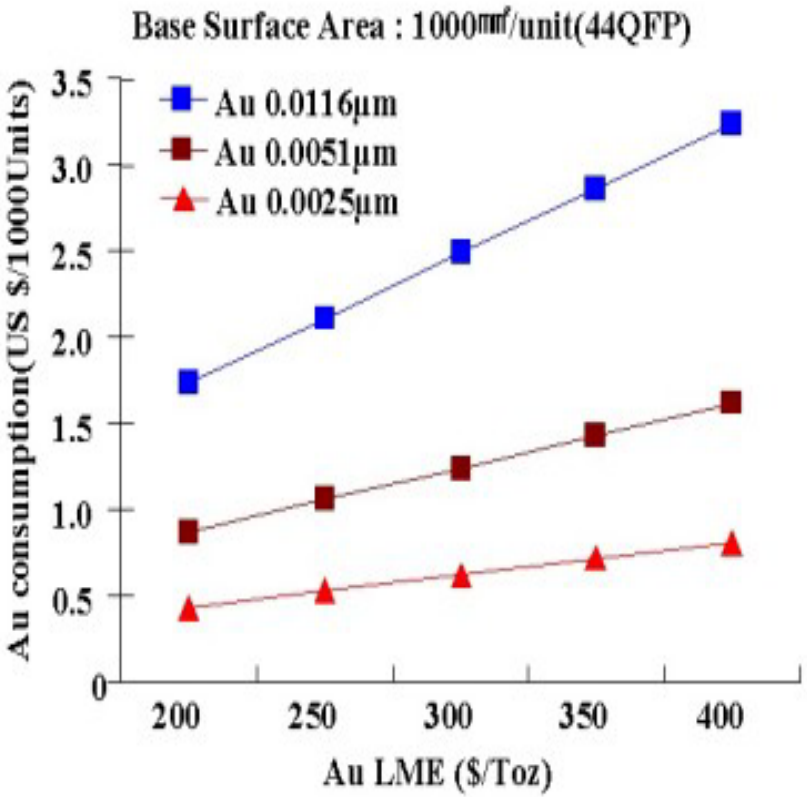


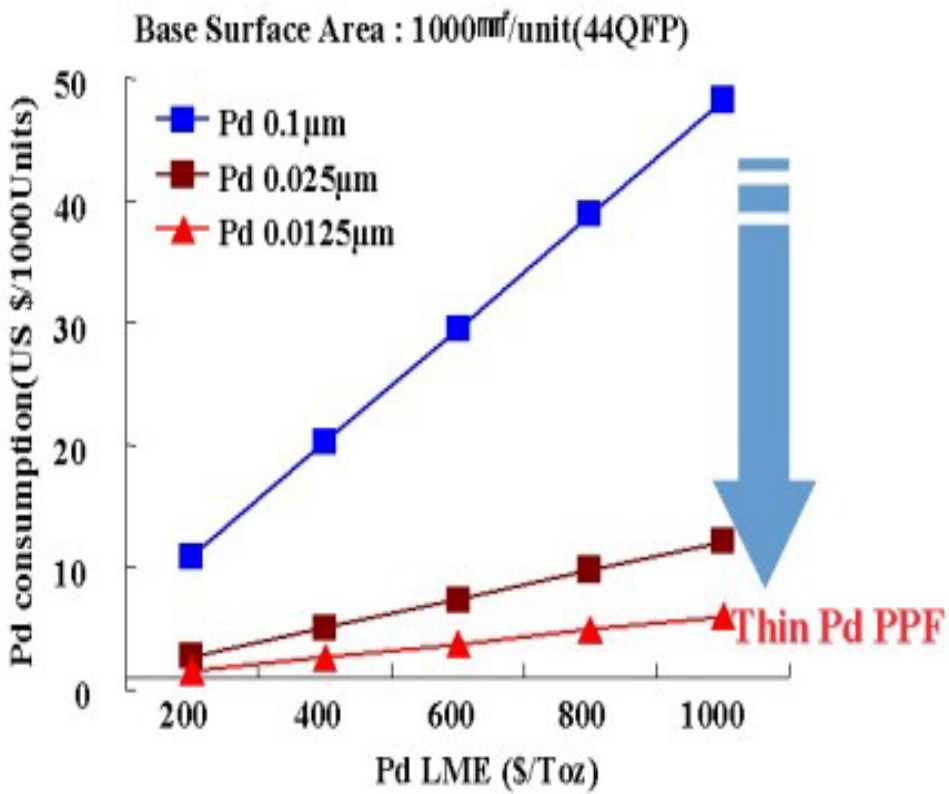


Au Price History



PM Price v. Thickness, Sensitivity





NiPd Based PPF v. Ag Spot

- Cost:
  - NiPdAu finished leadframes may be at a slight premium to Ag spot plated leadframes, but:
    - Do the material content and make some yield and throughput assumptions.
  - NiPdAu leadframe cost must be netted against post mold plate cost that is eliminated
  - Subcon A/T's may not embrace PPF since it eliminates significant value added.

IC assembly process Concerns

- Plating cracking after lead forming
- Wire bond capillary life reduction

Texas Instruments in adopting NiPd based finishes, recognized that any new IC lead finish would have to be a "drop in" replacement for the IC assembly/ test site and the end user.

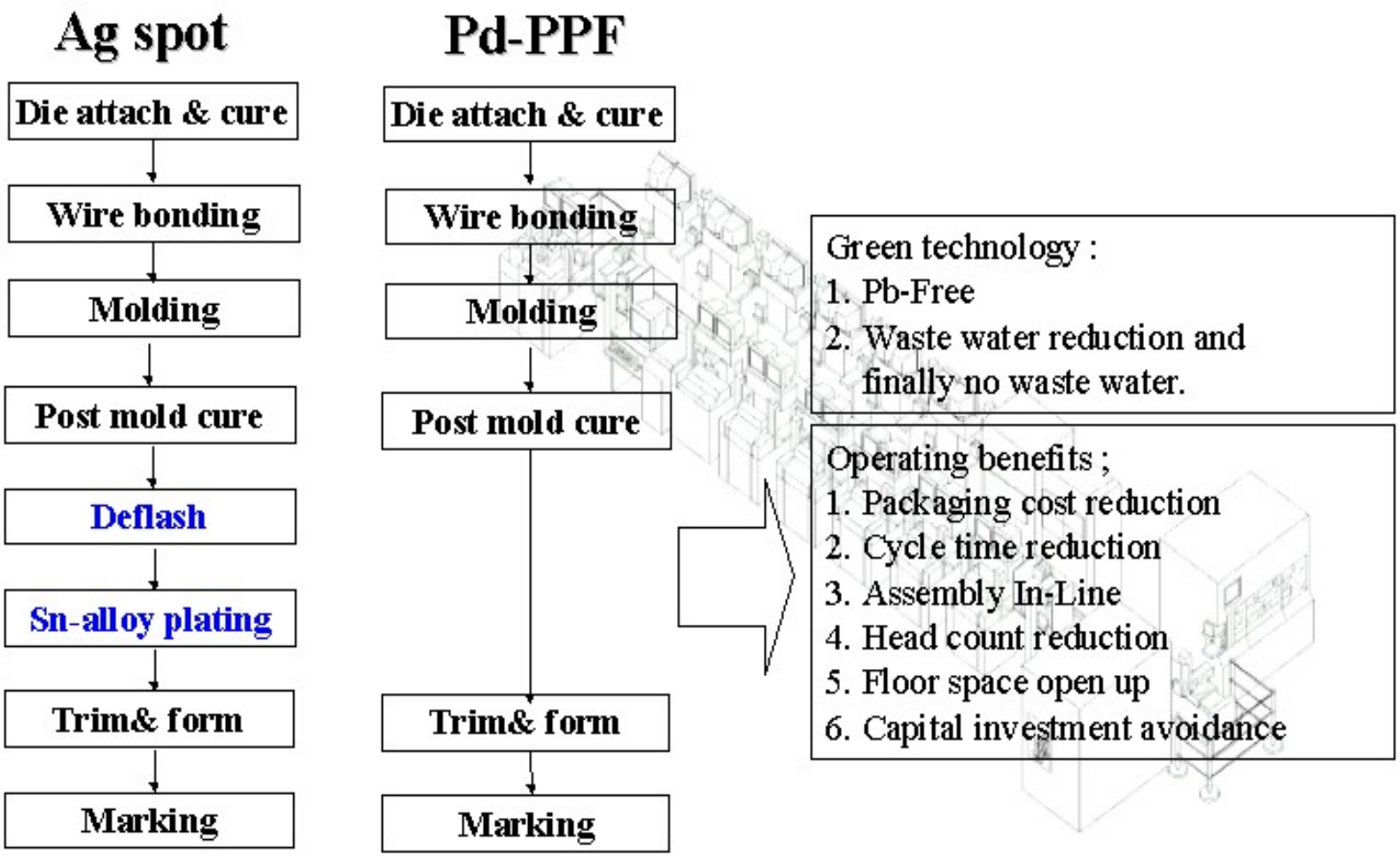
End User Issues

TI Experience:

The introduction of tens of billions of NiPd and NiPdAu finished IC's over a 15-year period has been remarkably transparent to the end users.

What concerns there have been are related to board level solderability. NiPd PPF solder joints "look different".

IC assembly comparison Sn-post plating vs. NiPdAu Pre-plating



Implications of Previous Foil

Solderable finish applied by the leadframe maker.

- Plating control at the leadframe maker essential
  - Pd and Au are very difficult to measure at specified thicknesses.
  - Must be vigilant for handling/contamination.

The good news:

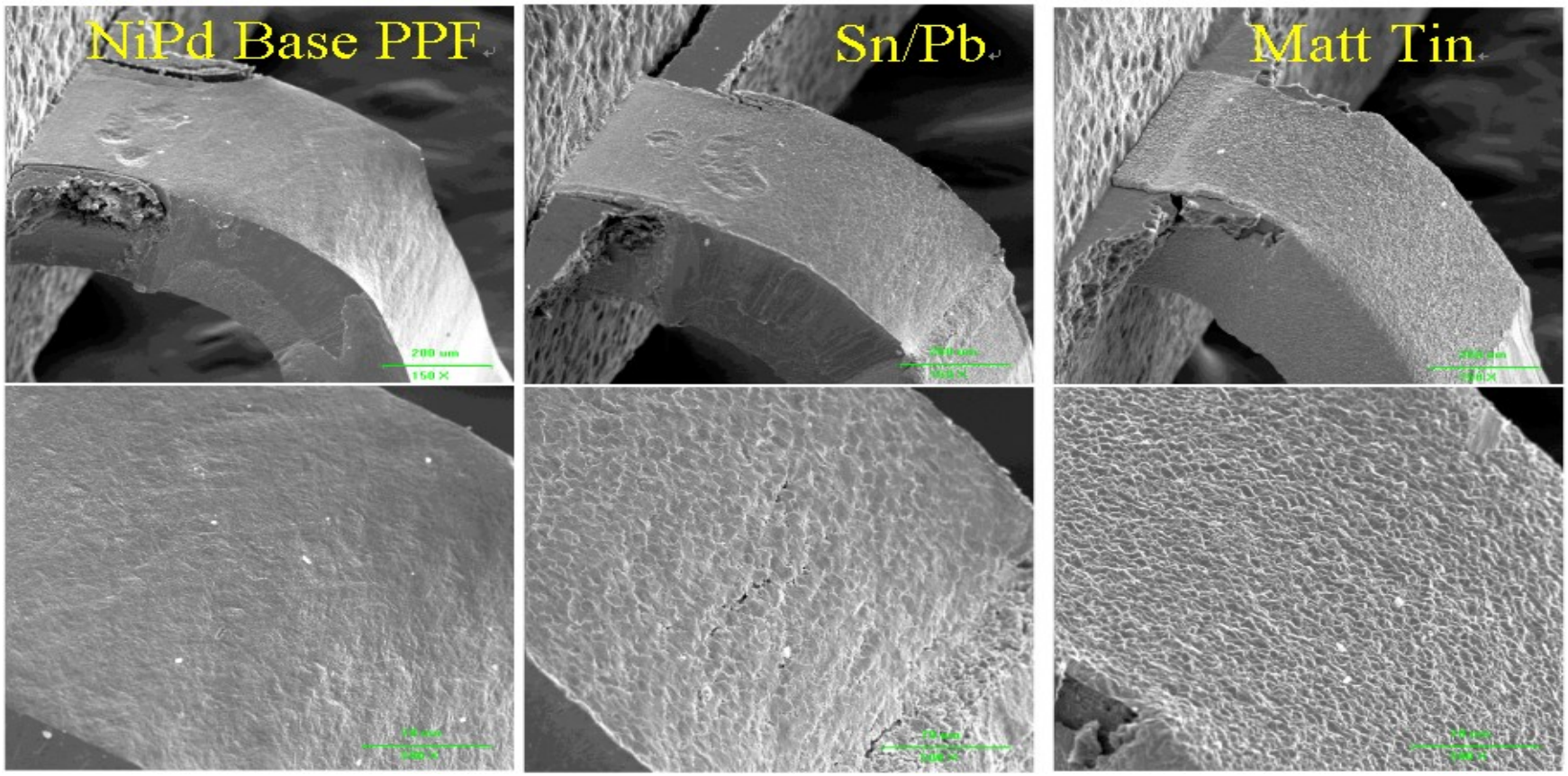
- Fewer defect opportunities in leadframe plating
- Very long shelf life, >8 years
- Resistant to oxidation/tarnish
- Built in fail safe – no Pd = no wire bond.
- NiPdAu PPF eliminates post mold plating costs.

Trim/Form Cracks

- Leadframe Cu alloys can crack (yield) during forming.
- Crack propagates through Ni barrier layer create micro-cracks at the surface.
- Pd and Au cracking are unobservable - these metals are so thin.
- Ductile Ni that “stretches” over the Cu cracks and forming tool optimization minimize cracks.
- Trim/Form tooling optimization is key = experience.

- Bonus – because NiPdAu is relatively hard and thin, virtually no flaking, burring, slivers seen at T/F.

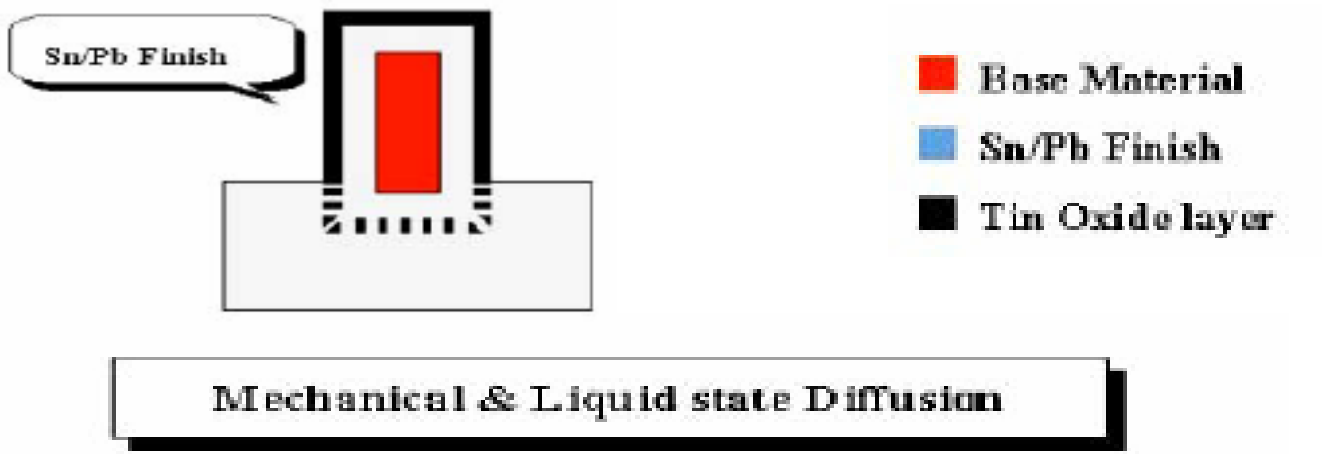
Trim/Form Cracking
Lead Shoulder (14-l SOP)



Solderability

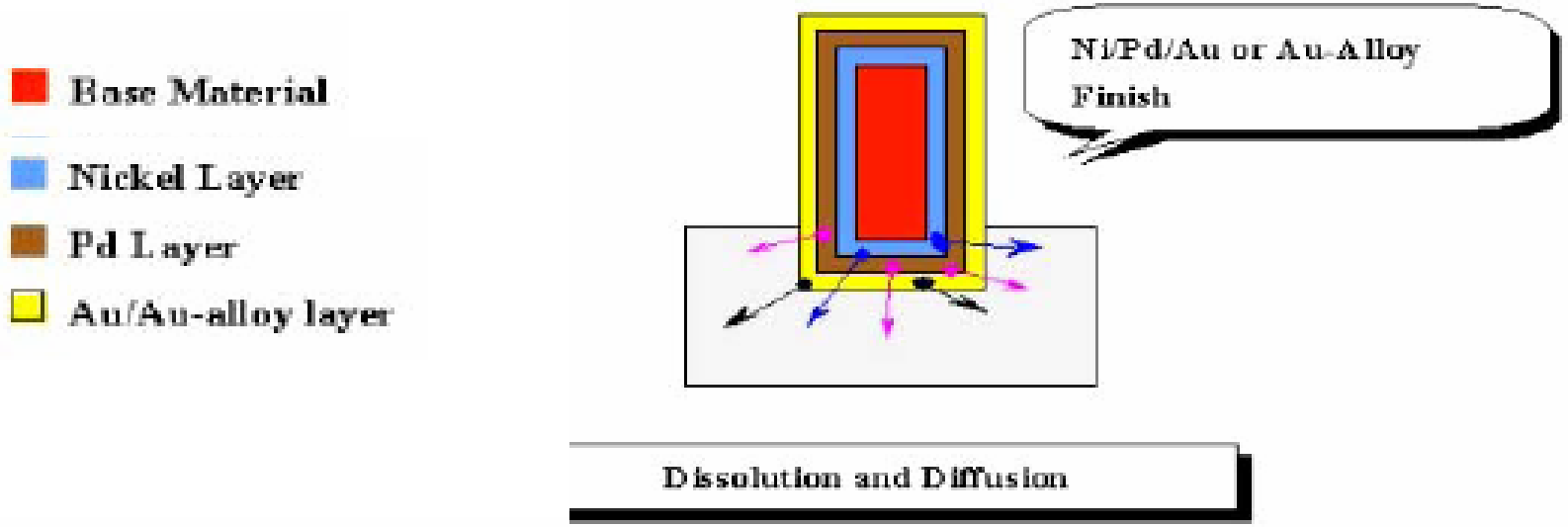
- In NiPdAu PPF's, the Pd and Au layers protect the Ni from oxidation.
- The Ni is the functional layer.
- Pd and Au are sacrificial coatings.
- Solderability speed depends on how fast Pd and Au dissolve into the molten solder.
- NiPdAu PPF's pass the JEDEC standard (J-STD-002B) for non-fusible coatings.

Sn/Pb or Matte Sn Soldering



- Tin oxide layer is broken by expansion of molten under-layer at melting point
- Sn/Pb layer is exposed through cracking of oxide layer and makes an oxide free surface
- Take place a soldering (mechanically mixed oxide free Sn/Pb layer with molten solder and Tin oxide dissolves in molten solder)
- Solder joint is SnCu intermetallics.

NiPd PPF Soldering Mechanism



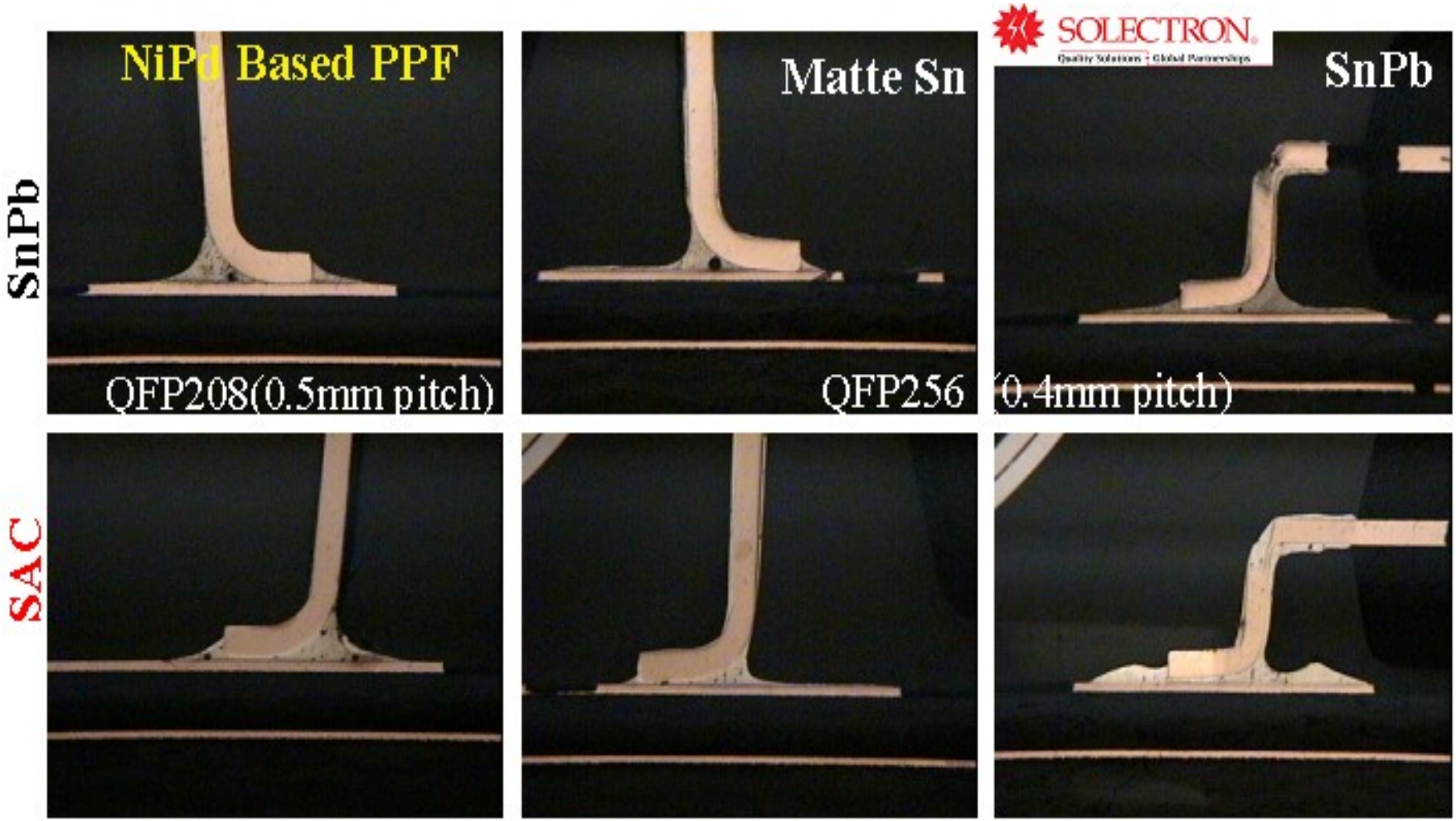
- Au and Pd dissolve in molten solder.
- Solder joint is SnNi inter-metallic. Pd and Au are dispersed in the bulk solder of the joint.
- It is a simple dissolution of Pd into the molten solder.
- The higher the temperature the faster the soldering.
- SAC solder with higher melting points make Pd based finishes wet quicker, i.e. dissolve faster
- The solder joint is made to the Ni. The Pd is a sacrificial layer.

Solderability

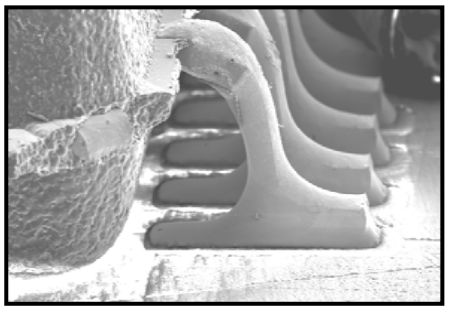
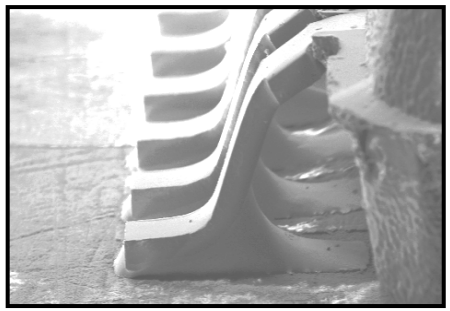
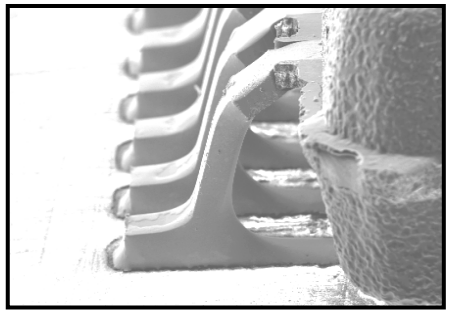
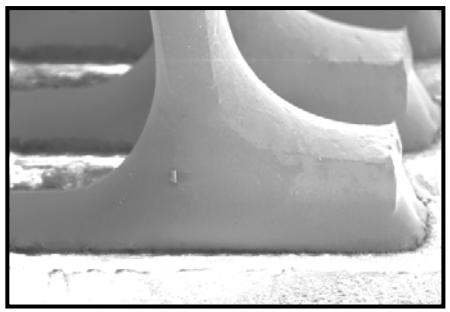
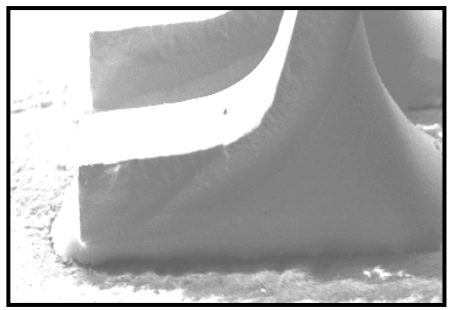
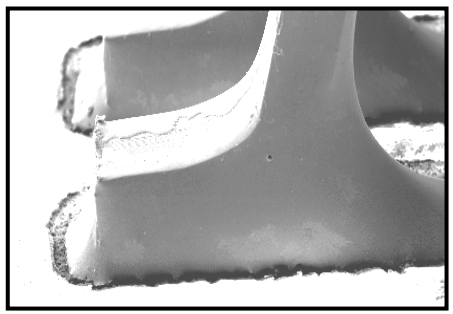
- Some end users do steam age preconditioning.
- Steam aging is an accelerated aging method developed for Sn based, fusible coatings.
- For non-fusible coatings, care must be taken to prevent surface contamination that can act as a solder mask and prevent solder wetting the PdAu.

- Since Pd and Au are noble metals, properly done steam aging will have no effect on solderability.

Solder Fillet shape



Solder Joint Comparison

Sn / Pb	NiPd	NiPdAu
		
		

Recommendations for Further Work

- MSL performance of NiPdAu leadframe finishes (and for all leadframe finishes) is an area of concern.
- It is a complex problem requiring the collaboration of leadframe suppliers, die attach adhesive and mold compound manufacturers.
- MSL improvement with NiPdAu is “easier” because of NiPdAu’s remarkable consistency compared to Ag spot plated leadframes.

Variability in Cu Surface

- Cu strike
- Anti-immersion treatments in Ag spot plating
- Ag immersion on Cu
- Anti-tarnish/anti-resin bleedout treatments for Cu
- Cu oxide thickness depends on Cu alloy, Ag plating, die attach and wire bond thermal history and chemical history.

- With NiPdAu – top surface is Au or Pd/Au.

Conclusions

- NiPd based PPF's are economical and effective Pb-free finishes for IC leads (terminations).
- There is no risk of Sn whiskers with NiPd PPF.
- There are tens of billions IC's in use with NiPd based PPF finished leads that have been sold over the past 15 years.
- The key issue, cost of the NiPdAu finished leadframes has been addressed by reducing the Pd content by ~7X and adding an ultra thin (30~100 angstrom) top layer of Au.

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