NiPd Finishes for Pb-Free Leaded Components

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Leadframe Finish Attributes

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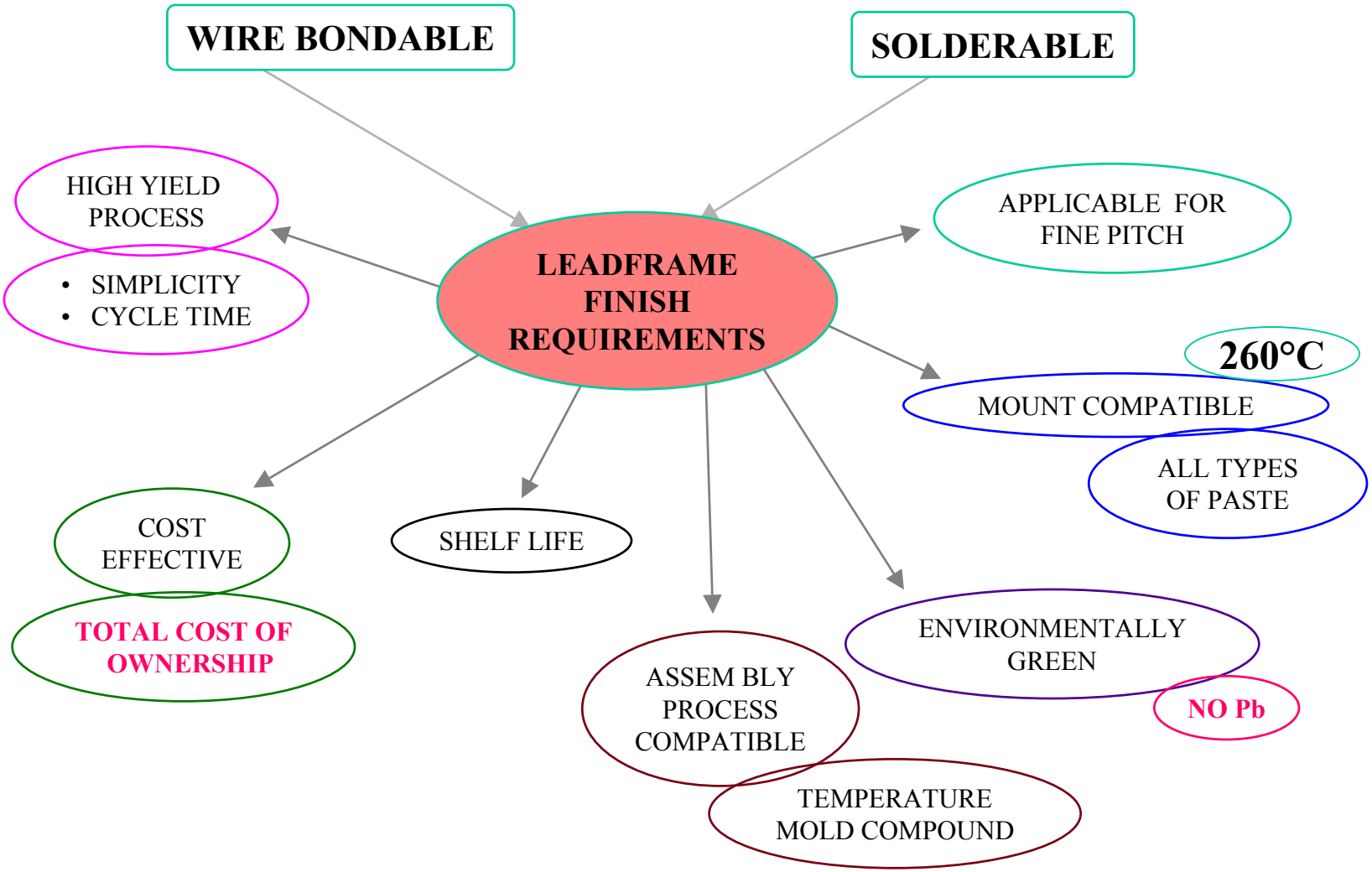
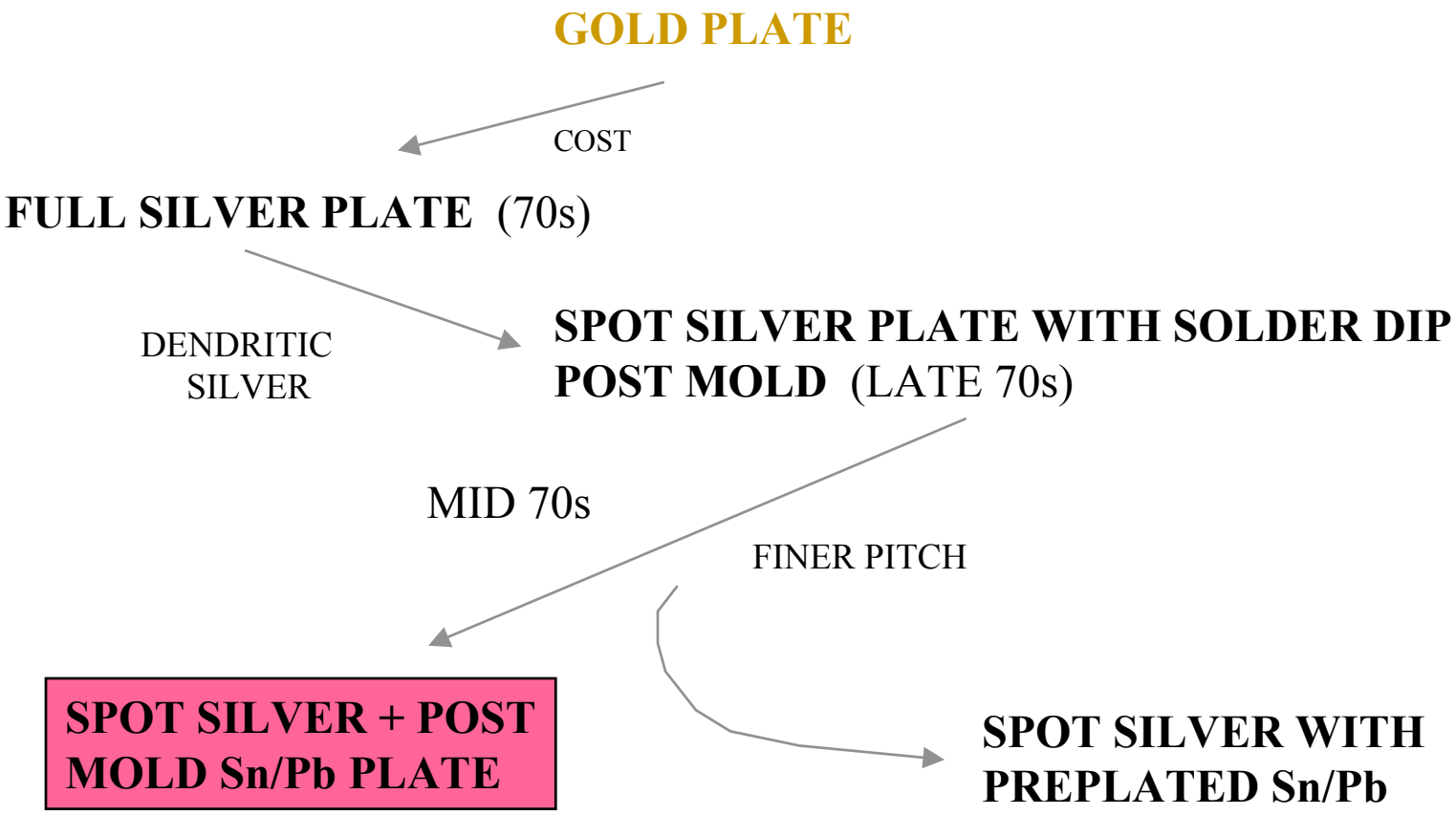


Leadframe Finish Attributes

LEADFRAME FINISH HISTORY



1988/1989 **Pd/ Ni INTRODUCTION**

2001-2002 **NiPdAu CONVERSION**

Structure for NiPd finish

Palladium (0.075 µ min.)

Nickel (1.0 µ min.)

Palladium/Nickel Strike

Nickel Strike

Copper Base Metal

Structure for NiPdAu Finish

Gold (30 – 150 angstroms)

Palladium (0.02 μ min.)

[1/3 Pd content of NiPd system]

Nickel (.5 μ min.)

Copper Base Metal

Pre-Plated (PPF) v. Post-Mold (PMF) Finish

What is the significance of NiPd and NiPdAu?

These are pre-plated finishes (PPF).

The solderable finish is applied at the leadframe maker, not in a post mold finishing (PMF) operation.

NiPd is a departure from the Ag spot plating, and has implications beyond simply the wire bonding and soldering mechanism differences.

NiPd Finishes for Pb-Free Leaded Components

Wire Bonding - is done to the Ni surface. The wire goes through the thin Pd (up to 0.25μ) and makes a NiAu intermetallic. Whereas in Ag spot plated leadframes, wire bonding is done to the Ag surface, a relatively thick, soft substrate.

The differences in wire bonding mechanics have implications for capillary design and bonding parameters.

NiPd Finishes for Pb-Free Leaded Components

Soldering - the Au dissolves rapidly into the solder paste, as does the Pd. The solder joint is made to the Ni.

METAL	RATE µ/SEC (215C)	RATE µ/SEC (250C)
Ni	*< 0.0005*	*0.005*
Pd	*0.0175*	*0.07*
Cu	*0.08*	*0.1325*
Au	*1.675*	*4.175*

Sn or SnPb finishes are fusible coatings, they *melt* during reflow.

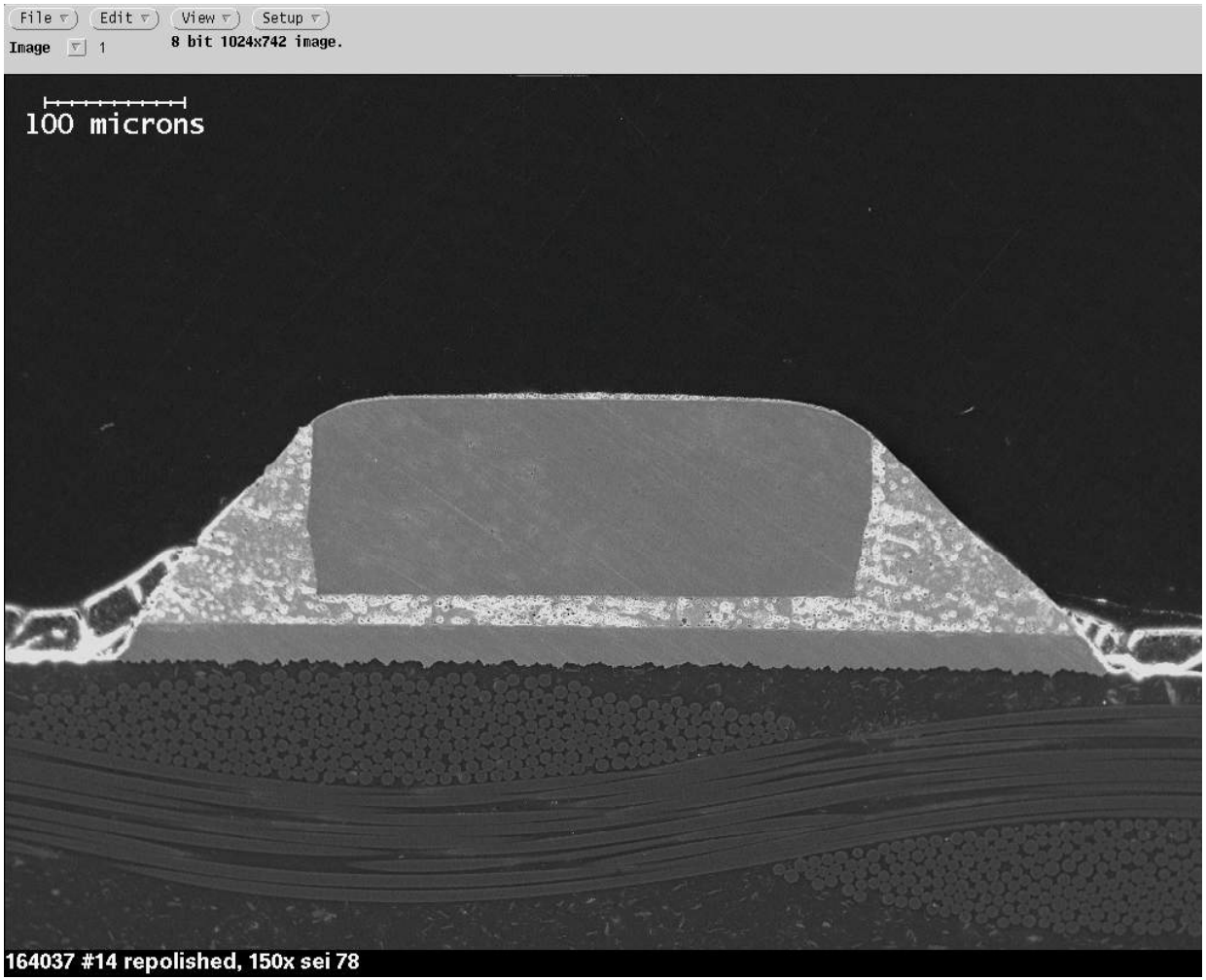
This explains some results seen with steam aging.

Soldering

Solder joints to NiPd or NiPdAu finished leads look different than solder joints to solder finished leads.

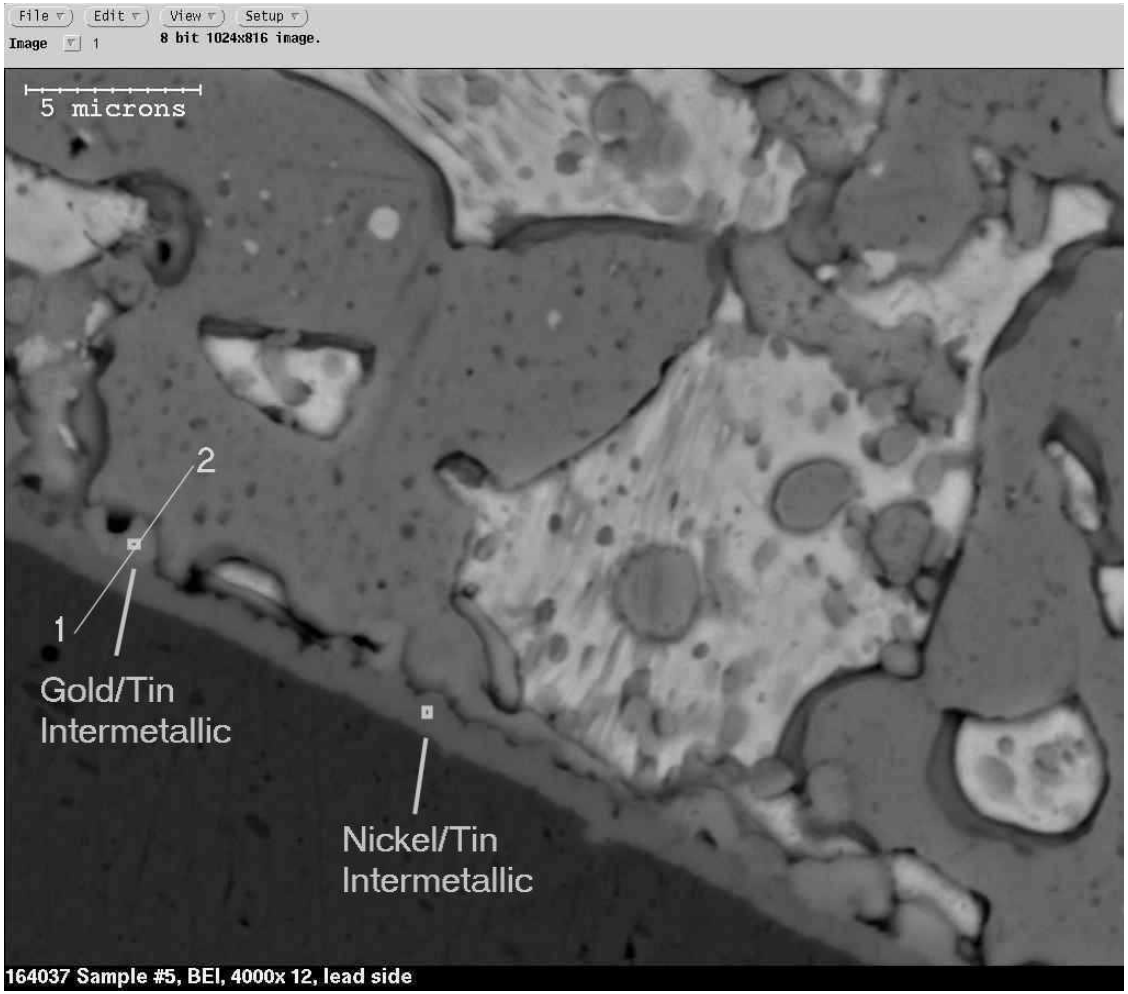
- The only solder brought to the joint is in the paste.
- This allows control of volume of solder by the board assembly house.
- Early on there were issues with machine vision recognizing good solder joints - this has been fixed.
- Studies with SnAgCu and SnBi show compatibility.

Cross Section of Solder Joint



4000X, Lead Side

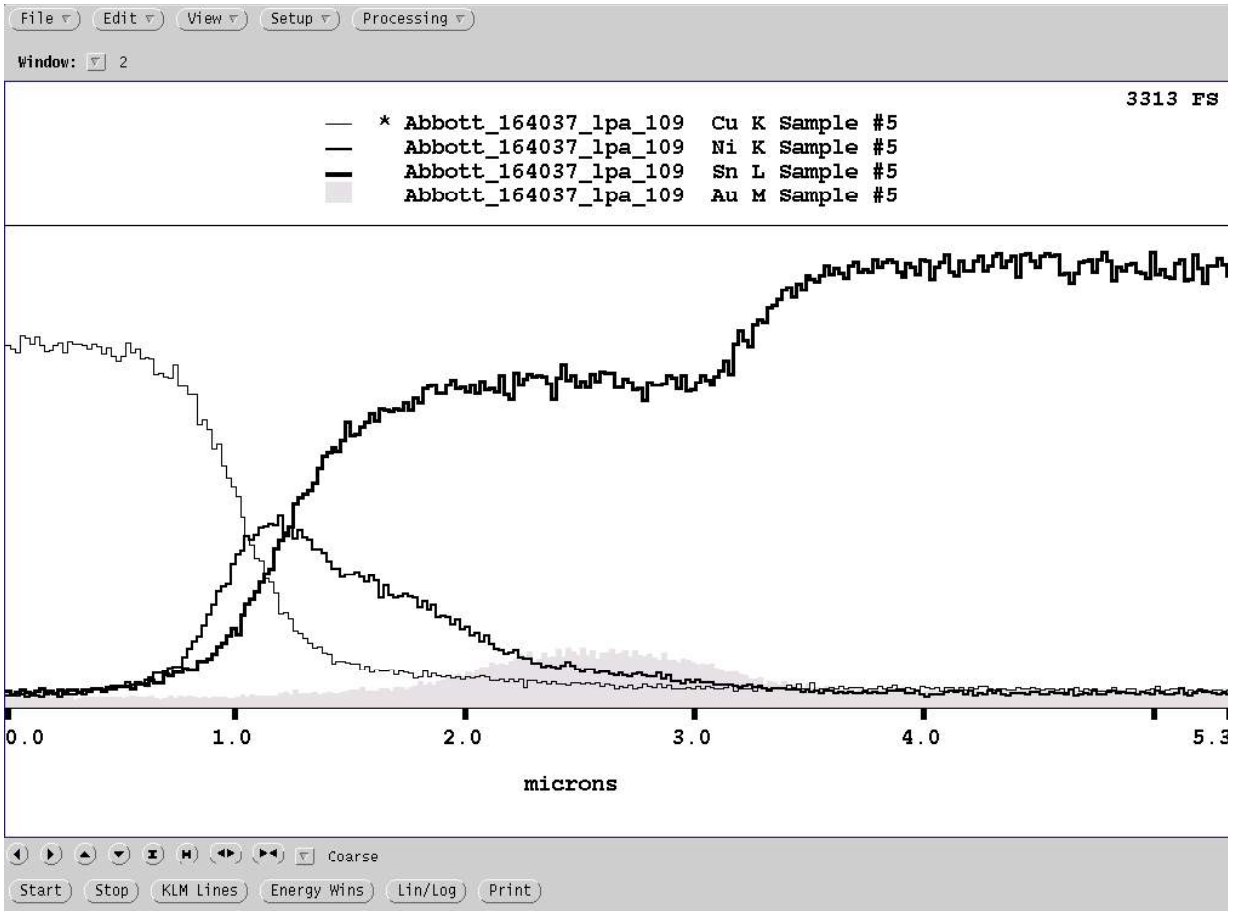
NiPdAu + NiAu PWB



Spectra of Cu, Ni, Au and Sn

(from points 1 to 2)

NiPdAu + NiAu PWB



Mold Compound Adhesion

Mold compound adhesion to Ni substrates and Ag surfaces has historically been an issue.

Our experience has been that the thin layer of Pd over the Ni surface enhances mold compound adhesion - with specific mold compounds.

The advent of 260°C reflow, associated with Pb-free processing, poses a challenge.

Economics

There are 3 main areas of economic concern:

1. Cost of post mold plating/cost of ownership.
2. Cost of Pd and Au - precious metals
3. (Subcontract) Assembly/test house - vested in PMF.

COST OF OWNERSHIP

ELIMINATION OF POST MOLD Sn/Pb PLATING

ELIMINATED COSTS

	SPACE	EQUIPMENT	PERSONNEL	UTILITIES	WATER	EXHAUST	INVENTORY	CONSUMABLES	
PLATING	?	?	?	?	?	?	?	?	?
PROCESS WATER	?	?	?	?	?		?		
WASTE TREATMENT	?	?	?	?	?	?	?	?	
QUALITY CONTROL	?	?	?	?		?		?	
CHEMICAL STORAGE	?		?	?		?	?		

YIELD RELATED COSTS:

- No solder flake/burrs @ t/f
- Improved lead planarity
- No chemical exposure or thermal shock to assembled device
- Less mechanical damage

DISPOSAL COSTS ELIMINATED

- WASTE TREAT SLUDGE
- SPENT PLATING LINE BATHS
- Pb CONTAMINATED TRIM SCRAP

OTHER COSTS

- PERMITTING -- WASTE TREATMENT
  CHEMICAL STORAGE
- REDUCES CYCLE TIME/LOWERS INVENTORY OF ASSEMBLED DEVICES

Assembly/Test Advantages

- **CONFORMAL COATING MINIMIZES HANDLING TRANSPORT JAMS and VERY THIN COATING (LESS ABSOLUTE VARIABILITY THAN Sn/Pb) PLATE GIVES BETTER GULL WING LEAD PLANARITY**
- **NO Pb IN MANUFACTURING PROCESS AND PRODUCT**
- **TRIM SCRAP VALUE: THIS MUST BE NETTED AGAINST LEADFRAME COST AS WELL AS COSTS FOR DISPOSAL OF Pb CONTAMINATED SCRAP.**
- **NO DENDRITIC Ag GROWTH AND NO Sn WHISKER POTENTIAL**

- **COMPATIBLE WITH EXISTING ASSEMBLY PROCESS, NOT LIMITED BY Sn/Pb EUTECTIC MELTING POINT.**
- **PARTICULARLY APPLICABLE TO FINE PITCH PACKAGES. UNIFORM SOLDER JOINTS. ONLY SOLDER BROUGHT TO THE JOINT IS THAT WHICH IS SCREENED ON THE BOARD**
- **NO Ag TO Sn/Pb SPOT TOLERANCE STACK-UP**

Summary of Key Advantages

IC USER

- CONTROLLED SOLDER FILLETS
- NO LEAD (Pb)
- IMPROVED LEAD PLANARITY
- NO Sn WHISKERS

ASSEMBLY SITE

- COMPATIBLE WITH EXISTING PROCESS
- ELIMINATE POST MOLD Sn/Pb or Sn
- NO LEAD (Pb)
- IMPROVE TRIM/FORM OPERATION
- CYCLE TIME
- LOWER COST OF OWNERSHIP

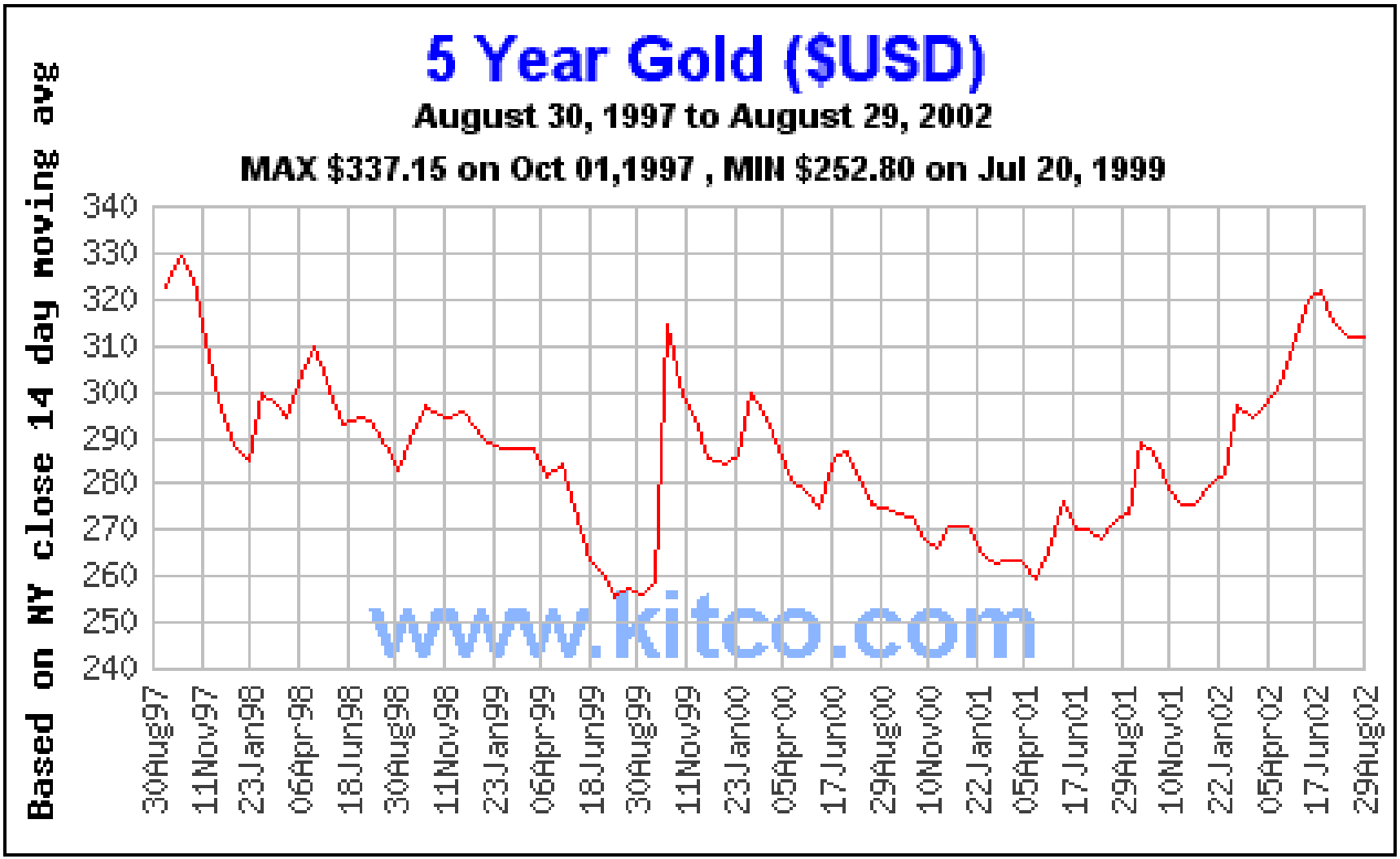
L/F MANUFACTURER

- NO LEAD (Pb)
- NO FREE CYANIDE
- FAST CYCLE TIME
- NO TOOLING
- NO SPOT LOCATION
- BETTER YIELDS
- PRODUCTIVITY
- LOW CAPITAL INVESTMENT

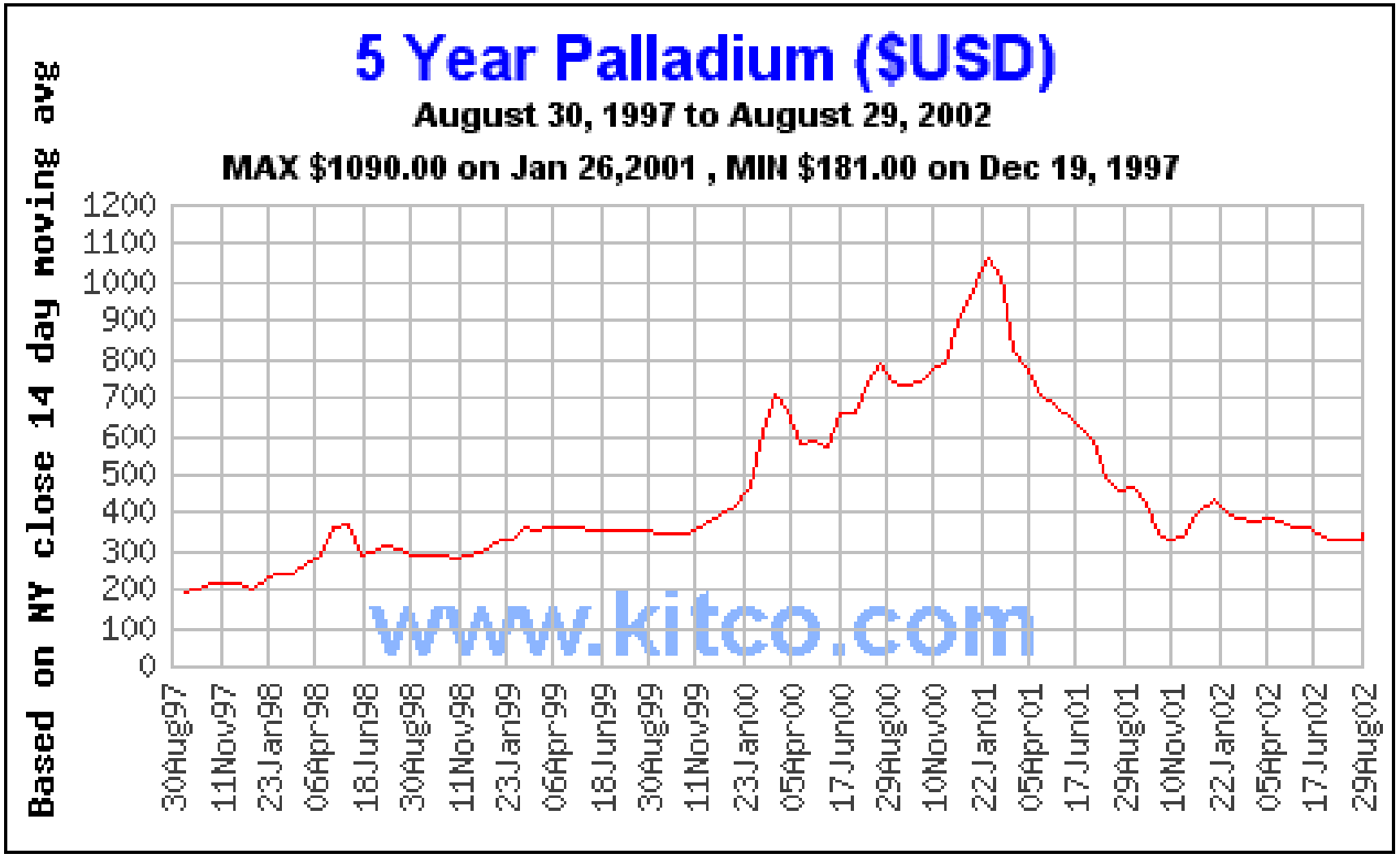
Pd and Au

- Au is a widely traded metal. Cost is ~ $300/t.oz with a density of 19.32 g/cm3.
- Pd is less widely traded. Cost is ~ $330/t.oz. with a density of 12.16 g/cm3.
- Au is widely used in industry, jewelry, dentistry, bullion.
- Pd - major user is/was automotive catalysts.

  Major producers of Pd: Russia, S. Africa
- Electronics is <10% of annual usage; Semiconductors is <5% of the electronics usage.



Courtesy Kitco - http://www.kitco.com/market/



Courtesy Kitco - http://www.kitco.com/market/

Pd Supply & Demand

'000 oz	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Supply										
South Africa	1,260	1,395	1,500	1,600	1,690	1,810	1,820	1,870	1,860	2,010
Russia	2,100	2,400	3,300	4,200	5,600	4,800	5,800	5,400	5,200	4,340
North America	450	415	410	470	455	545	660	630	635	850
Others	70	70	70	70	95	95	120	160	105	120
Total Supply	**3,880**	**4,280**	**5,280**	**6,340**	**7,840**	**7,250**	**8,400**	**8,060**	**7,800**	**7,320**
Demand by Application										
Autocatalyst gross	490	705	975	1,800	2,360	3,200	4,890	5,880	5,640	5,110
recovery	-95	-100	-105	-110	-145	-160	-175	-195	-230	-290
Chemical *	205	190	185	210	240	240	230	240	255	235
Dental	1,195	1,210	1,265	1,290	1,320	1,350	1,230	1,110	820	670
Electrical	**1,830**	**2,015**	**2,230**	**2,620**	**2,020**	**2,550**	**2,075**	**1,990**	**2,160**	**700**
Jewelry	205	210	205	200	215	260	235	235	255	240
Other	60	35	115	110	140	140	115	110	60	65
Total Demand	**3,890**	**4,265**	**4,870**	**6,120**	**6,150**	**7,580**	**8,600**	**9,370**	**8,960**	**6,730**
Movements in stocks	**-10**	**-15**	410	220	1,690	**-330**	**-200**	**-1,310**	**-1,160**	590
	3,880	**4,280**	**5,280**	**6,340**	**7,840**	**7,250**	**8,400**	**8,060**	**7,800**	**7,320**

After Johnson Matthey http://www.platinum.matthey.com/data/pd_92-02.pdf

What If...

the entire semiconductor industry converted to Pd based leadframe finishes?

- Our calculations show that the usage would be in the range of 5-10% of the Pd supply.
- And as the shift from PDIPs to SO's to Leadless packages continues, this will offset volume increases in units.
- And the "entire semiconductor industry" won't convert to NiPdAu or NiPd.

Subcontract Assembly Interest

1. Subcons major value added is in post mold plating.
2. Large investment in machines, people, space, support equipment.
3. Theirs is a material intensive business - leadframes, gold wire, mold compound, die attach material.
4. Sn or Sn/Pb plating is one area where they add considerable value.

THEIR DILEMMA

If a subcon goes to any PPF, then the value added is transferred to the leadframe maker - since the leadframes cost more.
The subcon then has lower revenue over which to spread the cost of the expensive equipment he has bought to do PMF.

Gold Embrittlement

Adding gold to the solder joint raises the issue of embrittlement of the joint by the gold. The following are conclusions from an applications noted located at:
http://focus.ti.com/docs/apps/catalog/resources/appnoteabstract.jhtml?abstractName=szza031

? Theoretical Au content of the solder joints that would result from using the components and PWB's in the study is < 3 wt.% level cited by Glazer as the maximum Au content for fine pitch surface mount devices.

? Theoretical calculations of Au content demonstrate that the contribution of the Au from the lead is dwarfed by the contribution from the PWB.

? Lead pull data showed that Au embrittlement had not occurred, even after 1000 thermal cycles.

? Statistical analysis of the lead pull data pointed to the Au on the PWB as the prime contributor to lead pull force lowering in this study (though still acceptable by industry standards).

Gold Embrittlement

? The metallographic data showed that:

1. The solder joint is made to the Ni surface of the component lead.
2. There is no Cu migration through the Ni barrier layer of the lead.
3. In a system with no Au on the PWB and with a standard Au thickness on the lead, there is no Au detectable in the bulk of the solder joint.
4. The Au from the PWB can migrate across the solder joint and appear at the lead/solder interface in the case of the NiPd finished lead.
5. At very high Au thickness' on PWB and leads, but that give Au concentrations <3 wt.%, acicular SnAu intermetallics do form. These do not appear to be sufficient to affect pull strength.

? The risk of Au embrittlement caused by NiPdAu component lead finish is essentially nil.

Conclusions

- Pd based lead finishes have been commercialized for >12 years. This is not a “new” technology.
- Given a close to 100% conversion at the A/T site, the economics work.
- There are concerns about the supply/demand of Pd.
- There are no whisker or solderability issues.
- Pd finishes are compatible with Pb-free solders (SnAgCu, SnBi).