SAND2006-3238P

Surface Finishes List Paul Vianco (ptvianc@sandia.gov), Sandia National Laboratories, Albuquerque, NM Edition 05/18/06

Surface Finish	Component Thickness (microns)	Circuit Board Thickness (microns)	Solderability	Unprotected Shelf Life (units)	Solderability Retention After Multiple Reflows	Comments	Action	References
63Sn-37Pb, hot dip	2.5 - 13		Excellent	1 years	Excellent	Provides in-situ solderability test. Literature documented shelf life is 1 year.	None	*Soldering Handbook, Third Ed.* , referencing MIL-STD-1276D;
63Sn-37Pb, hot dip (HASL)		2.5 - 13	Excellent	1 years	Excellent	HASL on circuit boards is acceptable for leaded I/Os of pitch > 0.5 mm and for BGAs with > 1mm pitch. The HASL finish must be >1.3 microns for adequate solderability protection. Literature documented shelf life is 1 year.	None	EPI email 9/13/03; K. Banerji and E. Bradley, "Manufacturability and Reliability of Products Assembled with New PCB Finishes," *Proc. Surface Mount Inter.* (1994), p. 584.
63Sn-37Pb, electroplated	7.6 - 23	7.6 - 23	Excellent	1 year	Excellent	Account for thickness fluctuations due to variations in throwing power. Acceptable for ultra-fine pitch (pitch < .5 mm) leaded I/O packages.	None, or improve the shelf life by a fusing treatment	*Soldering Handbook, Third Ed.* , referencing MIL-STD-1276D
63Sn-37Pb, electroplated and fused	2.5 - 13	2.5 - 13	Excellent	1 years	Excellent	The melting temperature of 63Sn-37Pb solder is 183°C. Account for surface tension effects that thin the coating at edges. Literature documented shelf life is 1 year.	None	*Soldering Handbook, Third Ed.* , referencing MIL-STD-1276D

100Sn, hot dip	2.5 - 13	2.5 - 13	Excellent	1 years	Excellent	Provides in-situ solderability test. Literature documented shelf life is 1 year.	None	*Soldering Handbook, Third Ed.* , referencing MIL-STD-1276D
100Sn, electroplated	7.6 - 13	7.6 - 13	Excellent	1 year	Excellent	Account for thickness fluctuations due to variations in throwing power. Potential development of Sn whiskers. Likelihood of whisker formation is significantly reduced by: (1) matte Sn, (2) Ni under layer; and (3) a thick Sn layer. Most companies prohibit bright 100Sn finishes and allows matte 100Sn finishes only under special circumstances.	None, or improve shelf life to 3 years by a fusing treatment	*Soldering Handbook, Third Ed.* , referencing MIL-STD-1276D; C. Xu, et al., "Understanding the Whisker Phenomenon - Mechanisms Study," *Proc. Surface Mount Tech. Inter.* (2001)
100Sn, electroplated and fused	2.5 - 13	2.5 - 13	Excellent	1 years	Excellent	The melting temperature of 100Sn is 232°C. Account for surface tension effects that thin the coating at edges. Literature documented shelf life is 1 year. Reduced liklihood of Sn whisker formation.	None	*Soldering Handbook, Third Ed.* , referencing MIL-STD-1276D
100Sn, immersion		0.4 - 1.8	Excellent	6 months in sealed, dessicant-filled bag; 1 year (per 155C, 4 hour test) for thicknesses > 1.0 micron.	Excellent	Solderability is degraded by humidity: 65C/85% RH results in a two week shelf life. Evidence that immersion Sn is prone to Sn whisker formation. ImSn cannot retain solderability after two reflows; it is less affected by 155C thermal aging.	None	I. Artaki, et al."Solderability Protective Coatings: Immersion Sn vs. Azoles," *Proc. SMI* (1993). D. Ormerod, "Production Application of Flat Solderable Tin Finishes: Some Practicle Considerations," *Proc. Surface Mount Inter.* (2000). D. Xie, et al., "Solderability and Process Integration Studies of Immersion Silver and Tin Surface Finishes," *Proc. Surface Mount Tech. International* , (2002). S. Lamprecht, et al., "Aging Characteristics of Immersion Tin Surface Finishes," *Proc. Surface Mount Tech. Assoc. Inter.* (2002). "155C, 4 hours = 1 year" storage life: P. Bain, et al., *PC Fab* . Feb. 2000, pp. 1 - 9. M. Arra, D. Shangguan, and D. Xie, "Wetting of Fresh and Aged Immersion Tin and Silver Finishes by Sn/Ag/Cu Solder," Proc. APEX 2003, S12-2-1 to 12-2-7.

Ni, electroplated Au, electroplated	Ni: 1.3 - 3.8 Au: 1.3 - 2.5	Ni: 1.3 - 3.8 Au: 1.3 - 2.5	Excellent	3 years	Excellent	Electroplated Au coatings of thicknesses, x, in the range of 0.2 < x < 1.3 microns offer a reduced protection of Ni solderability. Literature documented shelf life is 1 year. Honeywell experience is a 4 year shelf life. However, a 3 year life will be established for uniformity of follow-on sample solderability test procedures.	WR product requires the removal of **ALL** Au coatings having a thickness of greater than 0.2 microns from component I/O's, using a hot Sn-Pb dip process. A minumum of 2 immersions is required; 3 immersions are recommended for smaller leads.	*Soldering Handbook, Third Ed.* , referencing MIL-STD-1276D; Presentation by R. Davidson, Honeywell DSES, Albuqureque, NM 12/9/03
Ni, electroplated; Au, electroplated "flash"		Ni: 1.3 - 3.8 Au: 0.25 - 0.76	Excellent	3 months	Satsifactory	Electroplated coatings, when used as etch resist, can leave heavily undercut Cu pads/traces. The board layout should compensate for Cu undercutting to prevent Ni slivers from breaking off of the pads. The thin, Au "flash" offers very poor, long-term protection against Ni oxidation. However, Au need not be removed by hot solder dip procedure.	This range of Au thicknesses still presents a reliability concern unless the Au is removed prior to soldering, due to the potential for Au embrittlement, particularly of smaller, surface mount solder joints. Also, thin Au coatings offer less protection of Ni solderability in both storage as well as for multiple reflow processes.	*Lockheed Martin procedure discussed per* EPI emails: 9/13/03, 10/3/003
Ni, electroless Au, electroless	Ni: 1.3 - 3.0 Au: 0.5 - 2.0	Ni: 1.3 - 3.0 Au: 0.5 - 2.0	Excellent	1 year: Au<1.3 3 years: Au> 1.3	Excellent	The P content of the electroless Ni layer can vary from 5 - 11%; the low P content (6%) is preferred.	This range of Au thicknesses presents a significant reliability concern unless removed prior to soldering, due to the potential for Au embrittlement, particularly of smaller, surface mount solder joints.	P. Vianco, *Circuit World* **25** (1998) pp. 6-24, referencing MIL-STD-1276D
Ni, electroless Au, immersion (ENIG)		Ni: 1.3 - 3.0 Au: 0.05 - 0.2	Excellent	1 year	Excellent	The P content of the electroless Ni layer can vary from 5 - 11%; the low P content (6%) is preferred to avoid embrittlement. High P content appears to eliminate "black pad". The Au layer is sufficiently thin that it is not necessary to remove by hot solder dipping process. Exposure to 65C/85% RH for 7 weeks degraded solderability. There remains the "Black Pad" issue with ENIG.	The immersion Au layer is sufficiently dense to provide a solderability shelf life of 1 year. **CAUTION:** Although the layer is suffiently thin that it need not be removed by hot solder dipping, reports have been made that Au migrates back to the interface, forms a (Au, Ni)-Sn IMC layer that embrittles that interface. The embrittlement has been observed in mechanical bending of PWAs with BGAs and after thermal shock (-55C/125C, liquid-to-liquid, 250 cycles).	P. Vianco, *Circuit World* **25** (1998) pp. 6-24, referencing J. Coderre, et al., *Proc. IPC Expo* March 1997, p. s16-6-1. I. Artaki, et al., "Printed Wiring Board Surface Finishes: Evaluation of Electroless Noble Metal Coatings," Proc. Surface Mount Inter. (1995) p. 891. R. Jay and A. Kwong, "Dealing with the "Black Pad Defect" - A Failure Analyst's Perspective," *Proc. Surface Mount Inter.* (2001) . P. Backus and S. Lamprecht, "High Phosphorous ENIG- Highest Resistance Against Corrosive Environment," Proc. APEX 2003, p. S12-3-1 to S12-3-5.

Ni, electroplated Pd, electroplated	Ni strike: 0.1 Ni/Pd: 0.01 Ni: 1.2 Pd: 0.1		Good	1 year	Satisfactory	The "Texas Instruments" Ni-Pd finish. There can be an embrittlement issue with Pd in Sn-Pb solder, similar to that of Au, but at levels of 1-2 wt.% concentraton. Texas Instruments has implemented a Au flash over the Pd layer to improve solderability shelf life. Honeywell DSES uses the Texas Instruments finish WITH AU FLASH on its leaded components (see below). The solderabilty of Ni/Pd finishes is rapidly degraded in 85C/85%RH environments. Solder joint strength degrades with Ni/Pd finishes on both the component lead and PWB pad due to Pd embrittlement. Palladium plating baths are less damaging to laminates than are Au baths.	(1) Steam aging and solderability tests should be used to assess shelf life of the finish. (2) If solderability is poor at the time of testing, or that steam aging shows a shelf life of < 1 year, and the parts will be stored for times > 1 year (e.g., LOPB), then the leads should be hot solder dipped at the time of receival. (3) If the solderability is good, the steam aging indicates a 1 year shelf life, and parts are to be used within that year, no action is required. If the parts are to be stored for times > 1 year, then solderability testing with steam aging should be performed on a sample lot to re-establish the next 1 year shelf life.	P. Vianco, *Circuit World* **25** (1998) pp. 6-24, referencing D. Finley, et al., *Proc. Surface Mount International,* 1995, p. 341. D. Finley, et al., "Assessment of Nickel-Palladium Finished Components for Surface Mount Assembly Applications," *Proc. Surface Mount Inter.* (1995), p. 941.
Ni, electroless Pd, electroless		*(Ni/Pd "strike":0.01 µm)* Ni: 1.3 - 3.0 Pd: 0.1 - 0.5	Good	1 year	Satisfactory	The Pd thickness may need to be reduced to 0.35 µm if Pd is also used on the component I/O to prevent solder joint embrittlement. Preference is for 6% P content in the Ni and Pd coatings. These finishes impart a brittle failure to the interconnection in both three-point bending loads and in thermal shock (-55C/125C, liquid-to-liquid, 250 cycles). The solderabilty of Ni/Pd finishes is rapidly degraded in 85C/85%RH environments. Palladium layer closer to 0.5 µm is required for wire bonding.	(1) Steam aging and solderability tests should be used to assess shelf life of the finish. (2) If solderability is poor at the time of testing, or that steam aging shows a shelf life of < 1 year, and the parts will be stored for times > 1 year (e.g., LOPB), then the leads should be hot solder dipped at the time of receival. (3) If the solderability is good, the steam aging indicates a 1 year shelf life, and parts are to be used within that year, no action is required. If the parts are to be stored for times > 1 year, then solderability testing with steam aging should be performed on a sample lot to re-establish the next 1 year shelf life.	P. Vianco, *Circuit World* **25** (1998) pp. 6-24, referencing D. Finley, et al., *Proc. Surface Mount International,* 1995, p. 341. K. Banerji and E. Bradley, "Manufacturability and Reliability of Products Assembled with New PCB Finishes," Proc. Surface Mount Inter. (1994), p. 584.
Ni, electroplated Pd, electroplated Au, electroplated		Ni: 5.1 Pd: 0.1 Au: 0.1	Excellent	3 years	Excellent	Honywell DSES recommendation for PCBs. Honeywell prefers that the Pd layer remain less than 0.1 µm and a 0.1 µm Au layer cover the Pd.	None	Presentation by R. Davidson, Honeywell DSES, Albuqureque, NM 12/9/03

Ni, electroplated Pd, electroplated Au, immersion	Ni: 1.3 - 3.8 Pd: 0.1 - 0.5 Au: 0.05 - 0.2		Excellent	1 year,	Excellent	*General component lead finish.* The immersion Au layer improves the solderability of this coating.	None. The immersion Au layer is sufficiently dense to provide a solderability shelf life of 1 year. **CAUTION:** Although the layer is suffiently thin that it need not be removed by hot solder dipping, reports have been made that Au migrates back to the interface, forms a (Au, Ni)-Sn IMC layer that embrittles that interface. The embrittlement has been observed in mechanical bending of PWAs with BGAs and after thermal shock (-55C/125C, liquid-to-liquid, 250 cycles).	P. Vianco, *Circuit World* **25** (1998) pp. 6-24, referencing D. Finley, et al., *Proc. Surface Mount International,* 1995, p. 341.
Pd, electroless		Pd: 0.15 - 0.51 Preferred: >0.2	Good	1 year	Poor	As an electroless deposit, the Pd layer tyicially contains 6% P. Thinner layers are preferred for soldering; thicker layers are required for wire bonding. In general, this is a poor choice due to solderability degradation from Cu diffusion and/or Pd oxidation. Preferred to use >0.2 µm Pd or use either a Nik barrier at the Pd/Cu interface or a Au overplate of the Pd. Interface voids have been observed with Pd finishes.	(1) Steam aging and solderability tests should be used to assess shelf life of the finish. (2) If solderability is poor at the time of testing, or that steam aging shows a shelf life of < 1 year, and the parts will be stored for times > 1 year (e.g., LOPB), then the leads should be hot solder dipped at the time of receival. (3) If the solderability is good, the steam aging indicates a 1 year shelf life, and parts are to be used within that year, no action is required. If the parts are to be stored for times > 1 year, then solderability testing with steam aging should be performed on a sample lot to re-establish the next 1 year shelf life.	P. Vianco, *Circuit World* **25** (1998) pp. 6-24, referencing R. Johnson, et al., *Proc. Surface Mount Inter.* , 1998, p. 681 and G. Milad, *Proc. Surface Mount Inter.* , 1996, p. 794. U. Ray, et al., "Assessment of Circuit Board Surface Finishes for Electronic Asseembly of Lead-Free Solders," *Proc. Surface Mount Inter.* (1996) p. 656.

Ag, electroplated	Ag: 3.8 - 8.9	Ag: 3.8 - 8.9	Good	6 months	Satisfactory	Silver oxidizes and tarnishes (Ag-S), resulting in a loss of solderability. Shelf life is an estimate, only. Suitable for Al wire bonding. Pure Ag is prone to the formation of electromigration filaments under moisture and an applied voltage. As well, Ag coatings are susceptible to the formation of Ag-S dendrites.	None, although conformal coatings may inhibit the growth of Ag filaments (electromigration) and Ag-S dendrites.	*Soldering Handbook, Third Ed.* , referencing MIL-STD-1276D
Ag, immersion		Ag: 0.10 - 0.25 Min.: 0.075; Max.: 0.50	Good	1 year	Good	Silver oxidizes and tarnishes (Ag-S), resulting in a loss of solderability. Shelf life is an estimate, only. Sutable for Al wire bonding. Immersion Ag is not prone to electromigration due to the layer being thin and it contains organic additives. As well, Ag coatings are susceptible to the formation of Ag-S dendrites. The solderability is not strongly affected by humidity (85/85). It degrades with 155C, 6 hours and 12 hours exposures. The terminonolgy "thin" and "thick" immersion Ag coatings is used in IPC-4553. These qualifiers refer to thicknesses of 0.07 - 0.12 microns and 0.2 - 0.3 microns, respectively.	None. The thin layer (<0.2 microns) is rapidly dissolved into the solder. However, the thicker the coating, the more time that is required for its dissolution so that solderability testing will show a slight degradation. Standard electromigration testing (high humidity) show no degradation. Filaments form in condenced water conditions to a greater extent that is observed with Au/Ni. Susceptibility to solderability degradation in mixed, flowing gas (corrosive environment: SO2, Cl2, NO2, and H2S; 85C, 85% RH; 96 and 168 hours) was the same as ENIG.	P. Vianco, *Circuit World* **25** (1998) pp. 6-24, referencing F. Houghton, et al., *Proc. IPC Expo* March 1997, p. s16-4-1. IPC-4553, "Specifcation for Immersion Silver Plating for Printed Circuit Boards," Apr. 2003. D. Cullen, "New Generation Metallic Solderability Preservatives: Immersion Silver Performance Results," *Proc. Surface Mount Inter.* (1999). R. Gordon, et al, "Evaluation of Immersion Silver Finish for Automotive Electronics," *Proc. Surface Mount Inter.* (2000). S. Chada and E. Bradley, "Investigation of Immersion Silver PCB Finishes for Portable Product Applications," *Proc. Surface Mount Inter.* (2001). D. Xie, et al., "Solderability and Process Integration Studies of Immersion Silver and Tin Surface Finishes," *Proc. Surface Mount Tech. International* , (2002). M. Arra, D. Shangguan, and D. Xie, "Wetting of Fresh and Aged Immersion Tin and Silver Finishes by Sn/Ag/Cu Solder," *Proc. APEX 2003* , S12-2-1 to 12-2-7.

Organic solderability preservative (OSP)	0.002 - 0.005	Good	1 year	Poor	Current formulations are for Cu underlying metal. Nitrogen atmosphere is preferred. Although restricted in the number of reflow cycles to which it is exposed, OSPs can assuredly retain adequate solderability after long-term exposure to temperatures <60C and likely, so, if T<100C. Not affected by high humidity. If exposed to isopropyl alchohol or terpene cleaners prior to soldering, the latter process must be performed as soon as possible. Solderability retention is 4 - 8 mos on through-hole due to weak knee degradation. Current OSP technologies can tolerate up to 8 hours exposure at 125C; however, solderability degrades at 150C.	None	P. Vianco, *Circuit World* **25** (1998) pp. 6-24, referencing S. Crum, *Elec. Pack. and Production* , June 1996, p. 40. K. Banerji and E. Bradley, "Manufacturability and Reliability of Products Assembled with New PCB Finishes," *Proc. Surface Mount Inter.* (1994), p.584. J. Parker, "Shelf Life and Durability Testing of OSP Coated Printed Wiring Baords, *Proc. Surface Mount Inter.* (1995), p. 907. C. Chung, et al, "OSP Development for Flip Chip Ball Grid Array Packages," *Proc. APEX 2000* .
Bi, immersion	Bi: 0.10 - 0.20	Poor	6 months		Heavy surface oxide inhibits solderability.	Avoid use.	D. Hillman, et al., "Wirebondability and Solderability of Varous Metallic Finishes for Use in Printed Circuit Assembly," *Proc. Surface Mount Inter.* (1996), p. 687.

SOLDERABILITY ASSESSMENT FOR LONG-TERM STORAGE COMPONENTS: Sandia Surface Finishes PRT recommendation: Product having a surface finish with an **X year** shelf life in the above table, where X<3 years, will have its solderability tested every **X years** per the above procedures.

DISPOSITION OF GOLD COATINGS: Electroplated and electroless protective Au finishes shall be removed by hot solder dipping procedures prior to PWA assemby. A minimum of 2 (two) immersions into molten Sn-Pb solder (250C) are required. (Immersion Au is not required to be removed. However, it may be prudent to assure joint ductility by long-term, isothermal aging experiments.) The hot solder dipping procedure can be eliminated if empirical data demonstrates an absense of solder joint embrittlement.

Electroplated Au coatings that are thinner than 1.3 microns are acceptable, provided that solderability tests, including steam aging procedures, demonstrate that a desired shelf life requirement can be met.

100Sn finishes: Bright 100Sn finishes are NOT ALLOWED on any component, substrate, or sub-assembly for JTA or WR hardware Matte 100Sn finishes are NOT allowed on any component, substrate, or sub-assembly for JTA or WR hardware, unless it is demonstrated that the 100Sn finish, or any compositional variation, thereof, will not generate Sn whiskers per the recommended NEMI test procedure as described in the document entitled: "Sn Whisker Mitigation Strategy for the Nuclear Weapons Complex" that generated by the Surface Finishes PRT.