Immersion Silver Surface Finish:
Usage Requirement Test Results
& Production Experience

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Abstract:
Immersion Silver (IAg) as a printed wiring board (PWB) surface finish has been utilized on Lucent Technologies telecommunication circuit pack assemblies since September 1997. Use of this surface finish was initiated due to the need for a flat, solderable surface that provides reliable, high yield solder assembly through multiple thermal excursions. To assess IAg's production suitability and use requirements, a yearlong evaluation program was undertaken in the fall of 1996.

This presentation details the recommended procedures used to assure quality and reliability of surface finishes used on PWBs for telecommunication products and equipment and provides the testing results for IAg. These procedures included:

- Surface insulation resistance (SIR) to check compatibility of fabricated PWBs with surface finish and solder mask (Customer Requirements e.g., Bellcore GR78 and IEC68-2-3) as well as to check compatibility of surface finish with solder mask/assembly processes and materials (Lucent Internal Requirement)
- Electromigration (EM) to check tendency of a fluxed and heat exposed surface finish to migrate
- Solvent Extract Conductivity (SEC) test of PWB fabrication cleanliness
- Solderability to check acceptability and quality for solder assembly
- Solder joint integrity/reliability to insure defect-free use
- Real time determination of shelf life to insure surface finish will perform its intended function throughout storage life

The systematic and careful introduction of IAg surface finish and production experience will be described. In less than 2 years over one-half billion solder interconnections have been made to IAg surface finished PWBs. We enter the new millennium with the knowledge that IAg has met or exceeded all our expectations and has become our surface finish of choice for solder assembly.

INTRODUCTION

Silver migrates! Silver tarnishes! Silver sulfides! Why would anyone use silver? There must be reasons why immersion silver (IAg) is being used as a printed wiring board (PWB) surface finish. This manuscript provides the data one major manufacturer of telecommunications equipment generated to answer those questions. As will be shown, the data confirms that IAg is an acceptable alternative surface finish.

The utilization of Organic Solderability Preservative (OSP) as an alternative to Hot Air Solder Level (HASL) surface finish enabled high yield solder assembly of fine pitch components to electronic circuit packs. However, there are clear limits to its performance, because after one or more reflows, both the wave solder and test processes suffer due to the increased oxidation. When telecommunications circuit pack size and density increased, there was a corresponding increase in the number of assembly soldering defects. Analysis of the soldering defects indicated that many were due to PWB fabrication contamination (e.g., solder mask residue or incomplete stripping of etch resist plating) of copper features. An example of the effect contamination has on solder assembly is shown in Figure 1. If the contaminated boards had been HASL processed, the defects possibly would have been corrected (i.e., contamination "burnt-up") or at least the bare boards discarded by the fabricator before assembly committed expensive components to the circuit pack. Because of the difficulty in detecting surface contamination, board fabricators have made little progress in developing adequate contamination detection or screening processes. Although the HASL process (i.e., immersing boards in molten solder) allows contaminated copper features to be visually detected, the resulting HASL surface finish topography is not acceptable for fine pitch component assembly. The act of a metal sticking to a copper feature gave rise to the search for an alternative metallic surface finish (i.e., if a feature plates, it isn't contaminated and should be solderable). The ability to visually inspect a metallic plated board at fabrication and detect contaminated features is obvious in the photographs presented in Figure 2. These boards were immersion silver (IAg) plated and as the board on the left shows, all features were completely covered. However, there are several features on the board on the right that did not plate with silver. Although the plating, or lack there of, doesn't determine what the contamination is, it certainly enables the boards with contaminated copper to be detected and scrapped or re-plated at fabrication.

The numerous metallic surface finishes available necessitates determining the one most appropriate for use. Ideally, this is simple. Test them all and use the one that works best. In the real world with limited resources it's not that simple. For us, the most cost-effective approach was to leverage resources and participate in consortia activities. The results of the National Center for Manufacturing Sciences (NCMS) PWB Surface Finishes Program indicated that immersion gold over electroless nickel (IAu/ENi) was a viable metallic surface finish alternative to HASL. This NCMS program evaluated most of the alternatives available prior to the program's 1995 completion date. The introduction of IAg as a HASL alternative came too late to be incorporated into the full NCMS evaluation. However, preliminary evaluations suggested it also would be an acceptable alternative to HASL. Subsequent evaluations by the Circuit Card Assembly and Materials Task Force (CCAMTF) reported to consortium members in Spring 1996 and published in 1997[1] confirmed positive soldering results using IAg.

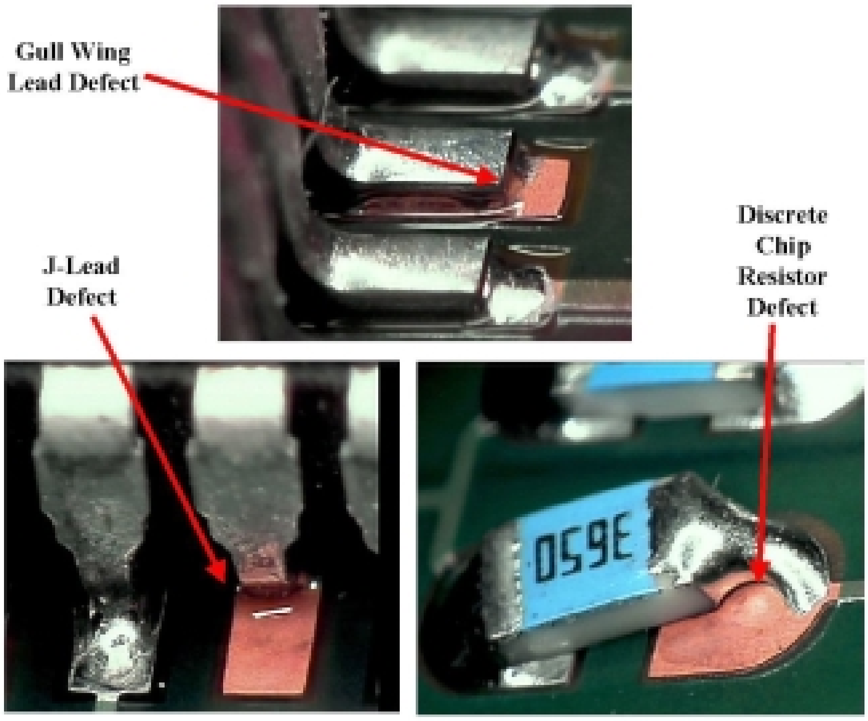
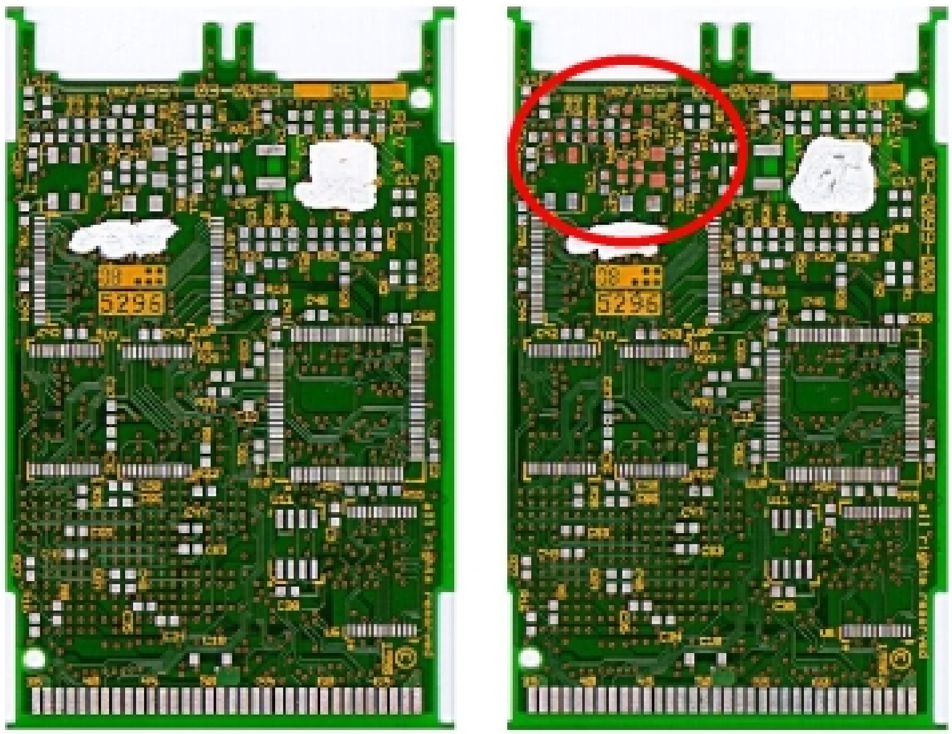


Figure 1. PWB fabrication contamination induced solder assembly defects

As a consequence, a pilot production assembly trial with 25 circuit packs each of IAg and IAu/ENi was conducted in the fall of 1996. Twenty boards of each surface finish were surface mount reflow assembled using a production line for telecommunication transmission equipment circuit packs. Both surface finishes soldered well with no soldering defects detected. Five boards of each surface finish were subjected to temperature/humidity pre-conditioning overnight (i.e., 65°C / 85%RH / 22 hour exposure). The pre-conditioned IAg boards soldered well with no defects. Each of the IAu/ENi boards had several non-wet features. Although the sample size was extremely small, the results were vastly different and, at first, difficult to rationalize. The four microinches of IAg plating couldn't have been a better diffusion barrier than the five microinches of IAu plating. However, these thin surface layers are not intended to act as diffusion barriers. They are sacrificial layers intended to preserve the solderability of the underlying metallic surface. Unlike IAu whose underlying layer is nickel, the underlying layer for IAg is copper. The fluxes used in "leave behind" (i.e., rosin based materials) solder paste do an adequate job of reducing copper oxide but are not effective at reducing nickel oxide. Since the original intention of metallic plating was to detect contaminated copper rather than to make copper more solderable, this initial assembly trial resulted in a decision to move forward with evaluation of IAg.

AVAILABLE IAg DATA AND GAP ANALYSIS

An evaluation team consisting of Bell Laboratories surface finish and soldering experts, manufacturing engineers, and supply chain engineers was organized to collect and evaluate available IAg data. In the spring of 1997 the team was expanded to include a vendor of IAg chemistry and a PWB fabricator whose European division had already installed IAg surface finish plating equipment. This team reviewed the available data and recommended procedures to assess quality and reliability of surface finishes used on PWBs for telecommunication products and equipment.



a). Board with all features plated   b). Board with features that didn't plate

FIGURE 2. Fabrication contamination induced plating defects

Because most solder assembly personnel have, at one time or another during their careers, experienced problems associated with silver plating (i.e., metal migration, oxidation, sulfadation), the team wanted to insure IAg surface finish would meet all requirements and perform well in production and use. The recommended procedures to assess quality and reliability of surface finishes used on printed wiring boards for telecommunication products and equipment are listed in Appendix 1 through 8. These specifications and requirements were not chosen specifically for IAg. They apply to any (i.e., “x”) surface finish. The evaluation team summary of IAg data and gaps in the data as of April 1997 are listed in Table 1. As indicated, the major concern regarding IAg came from past experience with “thick” pure silver plating. Initial evaluation data indicated IAg did not migrate [2]. This data was generated by the vendor of the chemistry and didn’t use the procedures or materials outlined in Appendix 4. Although there were gaps in the SIR data and quantitative solder joint integrity data had not yet been generated, assessment of

TABLE 1. Summary of IAg Data and Gap Analysis (April 1997)

Surface Insulation Resistance (SIR) – IAg passed IPC-SF-818 requirements (Alpha Fry Ltd. European regional Development Laboratory report No. PC/97/ADP/002). Although not tested to GR78 requirements the IPC-SF-818 data showed IAg performed as well as the bare copper control. These results indicated that IAg should pass GR78 requirements. The recommendation was that this test be run in parallel to development and pilot production activities.
IEC SIR – IAg had not been tested to IEC requirements. The recommendation was that this test be run in parallel to development and pilot production activities.
Electromigration (EM) – IAg passed Chemistry vendor testing (Alpha Fry Ltd. European Regional Development laboratory Report No. PC/97/ADP/002) as well as IPC-TM-650 Method 2.6.14. It also passed additional electromigration testing, at the request of Xerox, at applied voltages of 5V and 7.5V (Alpha-Fry memorandum 19 February 1996).
Solvent Extract Conductivity (SEC) – IAg passed Bellcore and MIL C 28809B solvent extract conductivity (Alpha Fry Ltd. European regional Development Laboratory Report No. PC/97/ADP/002).
Solderability – IAg passed and exceeded many solderability tests (Circuit Card Assembly and materials task Force July 1996 Evaluation of Alternative Surface Finishes [IPC Wetting Balance Test], Dave Hillman Rockwell Avionics 1996 SMI technical presentation [ANSI/J-STD-003, ITRI/October Project Alternative Metallic Finishes for PWB (IPC Printed Circuits Expo 1997).
Solder Joint Integrity/Reliability – Qualitative assessment by CCAMTF / Rockwell / Lucent indicated IAg produces “acceptable” solder joints. ITRI/October Project found highest pull strength and no significant variation from first thermal process to fifth. Preliminary Lucent Technologies data indicated good solder joint integrity. The recommendation was that quantitative solder joint integrity/reliability evaluation be run in parallel to development and pilot production activities.
Shelf Life – No real time shelf life data exists. Lucent Technologies pilot production trial indicated accelerated aging (65°C / 85%RH / 22 Hours) did not affect assembly quality. ITRI/October Project found IAg survives 5 thermal preconditioning processes. The recommendation was that real time shelf life be run in parallel to development and pilot production activities.
Summary – The major concern regarding IAg came from past experience where pure silver had been shown to migrate. The electromigration tests performed indicate that the commercially available IAg does not migrate. Although there isn’t quantitative solder joint integrity data and gaps in the SIR data (i.e., not tested with the solder mask or Lucent technologies materials and processes), assessment of the remaining data indicated limited scale pilot production evaluations could be conducted in parallel with the IAg surface finish development effort.

the remaining data indicated limited pilot production evaluations could be conducted in parallel with the IAg surface finish evaluations.

SIR Evaluation Results

SIR measurements to check compatibility of fabricated PWBs surface finish and solder mask (Bellcore GR78) results are presented in Table 2. These SIR coupons were processed through a production dual wave soldering facility with spray application of 700 to 1000 μg/sq.in. of a commercial alcohol based succinic acid activated no-clean low solids flux (LSF).

TABLE 2. Average Log SIR Values for Day 4

Solder Mask Surface Finish	Processed Down	Processed Up	Control
Curtain Coat LPI Copper	10.9 (.1)	9.4 (.6)	12.3 (.3)
Curtain Coat LPI Immersion Silver	10.8 (.1)	9.0 (.4)	11.1 (.1)
Electrostatic Spray LPI Copper	9.7 (.1)	8.7 (.4)	10.7 (.2)
Electrostatic Spray LPI Immersion Silver	10.3 (.1)	8.5 (.2)	10.0 (.3)
Note: Numbers in parentheses are standard deviations of the averages.			

Additional SIR measurements to check compatibility of surface finish with solder mask/assembly process results are presented in Table 3. These SIR coupons were processed through a production dual wave soldering facility with spray application of 700 to 1000 μg/sq.in. of a commercial water based VOC-Free no-clean flux. The SIR coupons for IEC requirement testing were also processed using the VOC-Free no-clean flux. The IEC testing results are presented in Table 4.

All of the SIR measurements made on the commercially available IAg surface finish passed the respective SIR requirements. Additional SIR measurements to IEC requirements were made on an IAg surface finish that was being developed during this time period by another chemistry vendor. This developmental IAg surface finish comprised 100 microinches of silver plating with 1 microinch of immersion gold over the IAg plating. The IAu was used to prevent silver migration. Although this extremely “thick” IAg plating passed SIR requirements, it failed electromigration testing. Figure 3 shows silver dendrites formed during electromigration testing of this non-commercialized IAg surface finish.

Electromigration Results

Although the “thick” non-commercialized IAg failed electromigration testing, which isn’t surprising given the quantity of silver plating, the commercially available “thin” IAg passed electromigration testing. The electromigration test results are listed in Table 5. The electromigration coupons showed no sign of corrosion or dendrite formation. The commercially available IAg tested incorporates an organic in the plating process. Its been suggested that this organic may be responsible for preventing electromigration but there is no confirming data. And in fact, one would expect the organic not to be present during electromigration testing (i.e., the organic is probably decomposed during the wave soldering process). The other suggestion is that there isn't enough "free" silver available to migrate. The silver plating thickness on large features averages about 4 microinches.

TABLE 3. Average Log SIR Values for Day 4 and Day 14

Solder Mask Surface Finish	Day 4 (A)	Day 14 (B)	Delta (A-B)
Control: Curtain Coat LPI OSP Copper	10.7 (.3)	10.6 (.3)	0.1
Control: Electrostatic Spray LPI OSP Copper	10.5 (.1)	10.7 (.1)	0.2
Control: Curtain Coat LPI Immersion Silver	10.4 (.1)	10.4 (.1)	0
Control: Electrostatic Spray LPI Immersion Silver	10.2 (.1)	10.5 (.1)	-0.3
Curtain Coat LPI OSP Copper	10.6 (.2)	10.5 (.2)	0.1
Electrostatic Spray LPI OSP Copper	10.2 (.4	10.6 (.20	-0.2
Curtain Coat LPI Immersion Silver	10.5 (.2)	10.5 (.2)	0
Electrostatic Spray LPI Immersion Silver	10.5 (.1)	10.7 (.1)	-0.2
MS-59124 requirement			≤1.0
Note: Numbers in parentheses are standard deviations of the averages.			

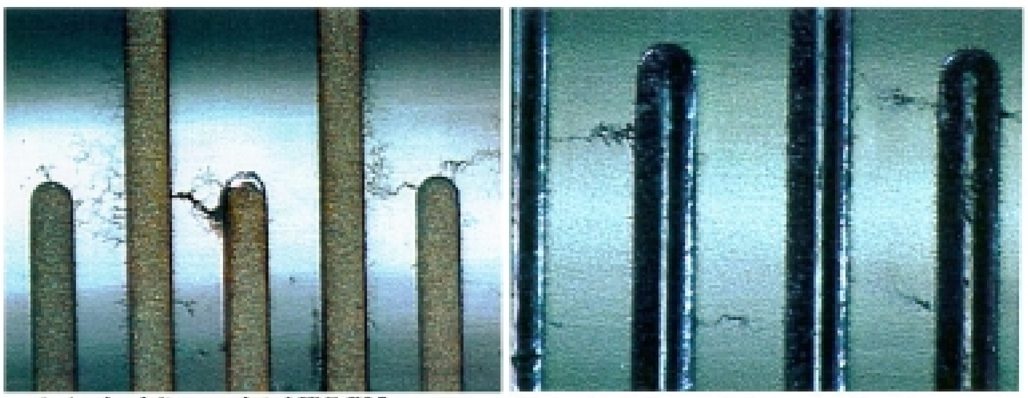
TABLE 4. Average Log SIR for 21 Days 40°C/90%RH + 24 Hour Ambient

Solder Mask Surface Finish	Processed Down	Processed Up	Control
Curtain Coat LPI Copper	8.75	8.65	8.50
Curtain Coat LPI Immersion Silver	8.75	8.75	8.70
Electrostatic Spray LPI Copper	8.90	8.50	8.40
Electrostatic Spray LPI Immersion Silver	8.70	8.95	8.90

It should be noted that X-Ray Fluorescence (XRF) and Auger depth profiling measurements indicate that IAg plates thicker on smaller features than larger features.

TABLE 5. Average Log IR Values for 96 and 500 Hours

	96 Hours	500 Hours	Delta
Copper Control	3.99	3.63	0.36
Copper Process-Down	4.03	3.52	0.51
Copper processed-Up	4.13	3.69	0.44
IAg Control	3.54	3.29	0.25
IAg Processed-Down	3.57	2.96	0.61
IAg Processed-Up	3.77	3.56	0.21
Requirement			≤1.0



a). Ag dendrites on plated IPC-B25 coupons   b). Ag dendrites on plated and soldered coupons

FIGURE 3. Ag Dendrites on Electromigration Tested "Thick" (>100 μinch) IAg

Figure 4 presents a comparison of IAg plating thickness as a function of feature size. The silver thickness on features >50 mil wide was approximately 4 ± 2 microinches. The silver thickness on 12.5 mil wide (i.e., the width of the traces on the IPC B-25) coupons used for electromigration testing was approximately 8 ± 2 microinches. This provides some degree of confidence that electromigration was tested at an IAg plating thickness that would be experienced on fine pitch surface mount features.

Recently, another vendor has commercialized an IAg plating chemistry. Although this newly commercialized IAg chemistry also incorporates an organic, it plates thicker than the earlier commercialized material. Electromigration testing was conducted on two sets of coupons plated with this recently commercialized material. One set was plated with what is referred to as a "nominal" plating thickness and the other at a "thick" plating thickness. The thickness of the "nominal" samples was measured to be 10 ± 2 microinches and the "thick" samples were measured to be 30 ± 4 microinches. Both the "thick" and "nominal" plated samples passed the electromigration test. The electromigration testing results are listed in Table 6. Inspection of the electromigration coupons after testing revealed neither dendrites nor evidence of corrosion on any of the coupons. This newly commercialized IAg ("Normal" and "Thick"), processed using a VOC-Free no-clean flux, passed the Bellcore electromigration test.

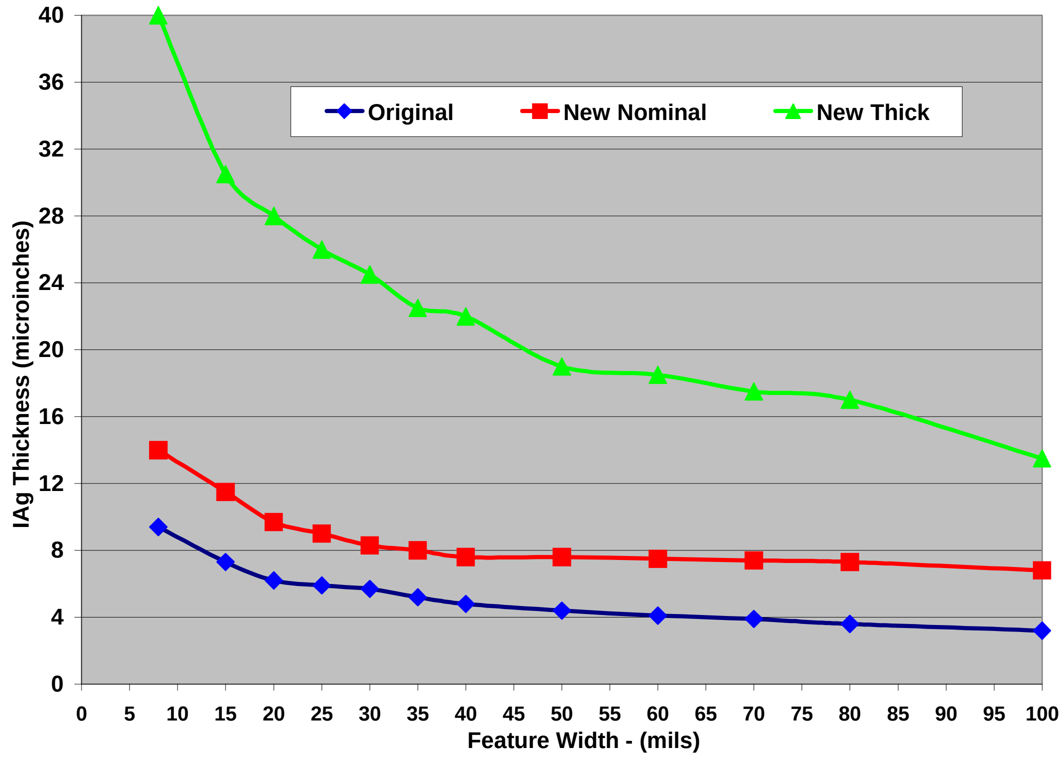


FIGURE 4. Comparison of IAg Thickness to Feature Size

TABLE 6. Average Log SIR at 65°C/85%RH

Samples	After 6 Hr / 0 V (A)	After 96 Hr / 0 V + 500 Hr / 10V (B)	Change in SIR (A – B)
Bare Copper Control	11.1 (.2)	11.2 (.1)	-0.1
Nominal IAg Processed-Down	11.5 (.1)	11.4 (.1)	0.1
Thick IAg Processed Down	10.9 (.7)	11.3 (.3)	-0.4
Nominal IAg Processed-Up	9.7 (.2)	10.5 (.8)	-0.8
Thick IAg Processed-Up	9.9 (.1)	11.1 (.1)	-1.2
Bellcore requirement			≤ 1.0
Note: Numbers in parentheses are standard deviations of the average			

Solvent Extract Conductivity (SEC) Results

The temperature of the IAg plating chemistry is considerably lower than HASL processing temperature. Also, the IAg plating process doesn't use any water-soluble fusing fluids like those used in HASL that degrade board cleanliness. Because of these conditions IAg plated boards always passed SEC testing.

Solderability Results

There are many solderability tests available which can and have been employed to test the solderability of IAg plated boards. Everyone who published results of IAg solderability (i.e., NCMS, Alpha Metals [3], CCAMTF [1, 4], Rockwell [5], Texas Instruments [6], Ford Motor Company [7], ITRI/October Project [8], Viasystems [9], MacDermid [10]) has reported excellent solderability. As indicated earlier, our experience with "as-plated" and temperature/humidity pre-conditioned IAg on telecommunications circuit packs have confirmed its good solderability.

Solder Joint Integrity/Reliability Results

Figure 5 presents pull strength data for SOIC gull wing leads comparing the integrity of solder joints made to IAg and OSP coated copper surface finished boards. As you can see, there is no discernable difference in the pull strength values. Ten cycles of liquid (-40°C) to liquid (+125°C) thermal shock did not deteriorate the solder joint integrity. The pull strength testing was performed with SnPb plated component leads as well as PdNi plated component leads. Of more importance than the pull strength values, Figure 5 also shows the mode of failure (MOF). The solder joints, including those made to IAg surface finish, failed cohesively (i.e., ductile failures) in the bulk solder near the solder/lead interface and did not fracture at the board surface finish.

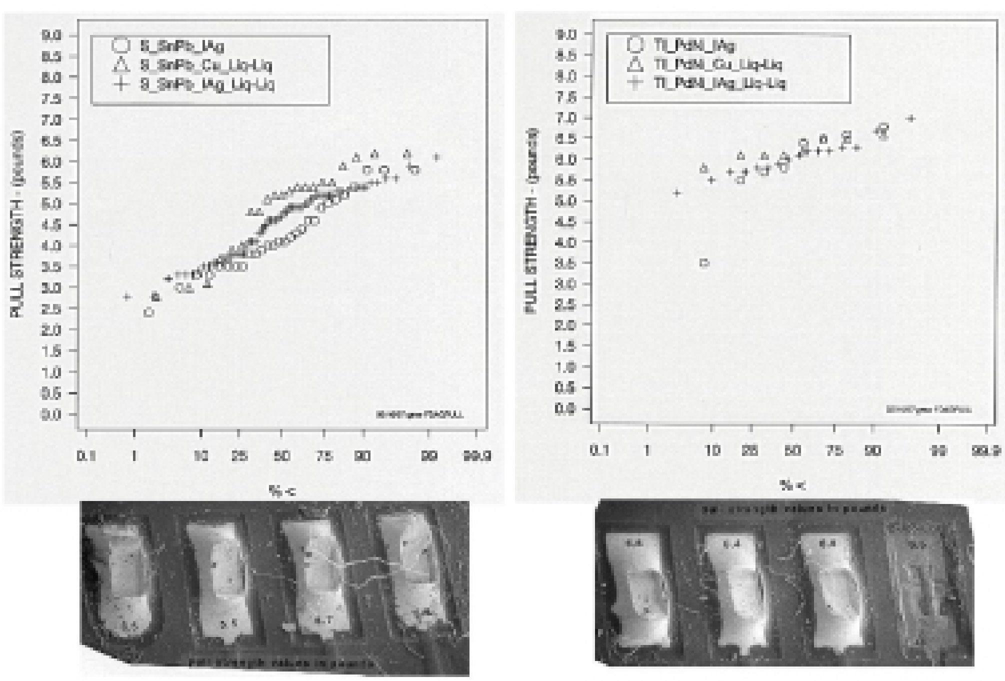


FIGURE 5. PULL STRENGTH FREQUENCY DISTRIBUTIONS AND MOF

After surface mount reflow soldering with SnPb solder paste it is difficult to determine differences between IAg and OSP, or for that matter between IAg and HASL. After reflow soldering the SnPb solder is interconnected to copper by a copper-tin intermetallic for all three surface finishes. Therefore, one would expect there to be insignificant difference in solder joint integrity/reliability. A SEM comparison of gull wing lead solder joint to IAg and OSP pads along with EDX analysis of the IAg joint is presented in Figure 6.

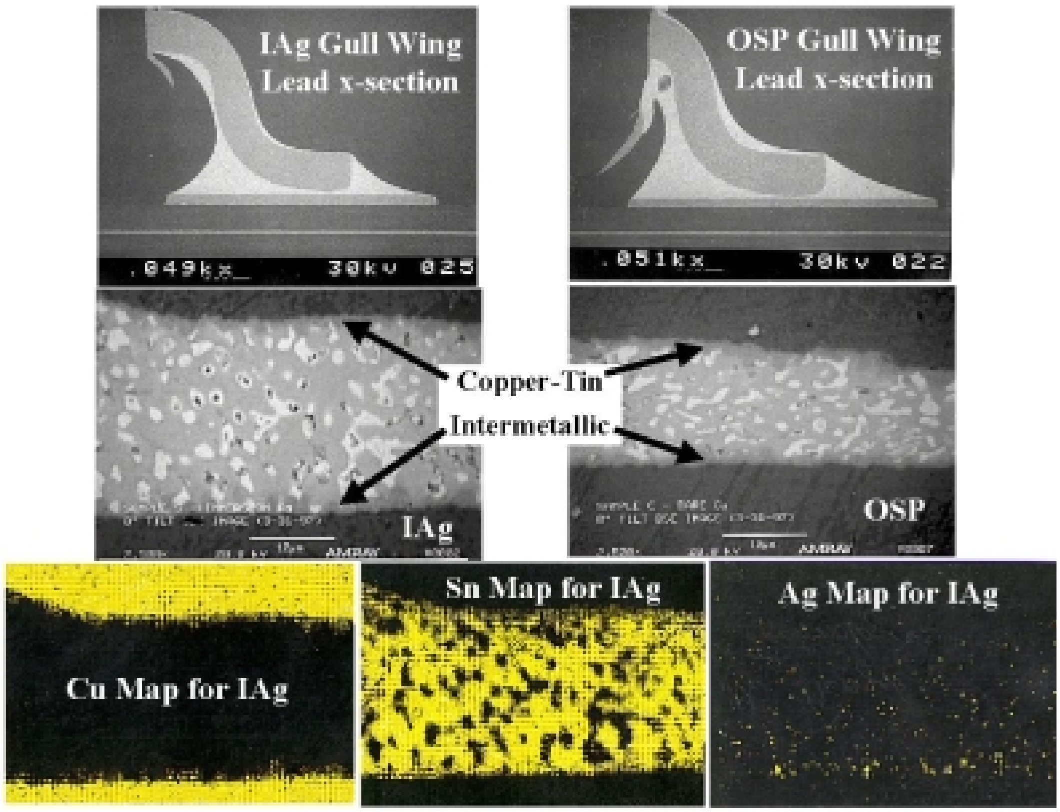


FIGURE 6. SEM/EDX Comparison of IAg and OSP Solder Joints

Shelf Life Results

Shelf life solderability evaluations were conducted using coupons with 130 – 35 mil diameter PTHs. Coupons were stored in ambient manufacturing environments in a New England and Midwest manufacturing plant as well as in the Bell Laboratories Engineering Research Center in New Jersey. The coupons stored at the two manufacturing plants were solder drag tested using 245°C, Sn60/Pb40 solder and a 25% solids water white rosin (WWR) flux. Drag testing was accomplished on coupons that were stored for 1 month and 3 month intervals. Drag test solderability measurements were supposed to be made at 6 and 9 months. However, the captive board shop doing the drag testing was sold during this time period and the coupons were not tested. As indicated earlier, solderability testing of IAg has always indicated good solderability. For completeness, it was decided to solderability drag test the coupons which were stored in the New Jersey location. These coupons had been exposed to the laboratory environment for 22 months. During the workweek the laboratory environment averages about 27°C and 50%RH. On weekends the temperature and humidity rise considerably during the summer months. The drag testing solderability results for the shelf life coupons are presented in Figure 7. All of the coupons were equally solderable during the first three months of storage. It should be noted that half of the 22 month aged coupons were subjected to a forced convection reflow in an air environment before being solderability tested. Although the 22 month aged coupons were not as solderable as the ones aged for only 3 months, the IAg solderability performance was not statistically different than the HASL coupons. The reflowed coupons were equally as solderable as the non-reflowed 22-month aged coupons. It should also be noted that the IAg, Nude-copper, and HASL coupons performed considerably better than the OSP coated copper.

The positive results of all the IAg testing encouraged the evaluation team to recommend moving forward with pilot production implementation.

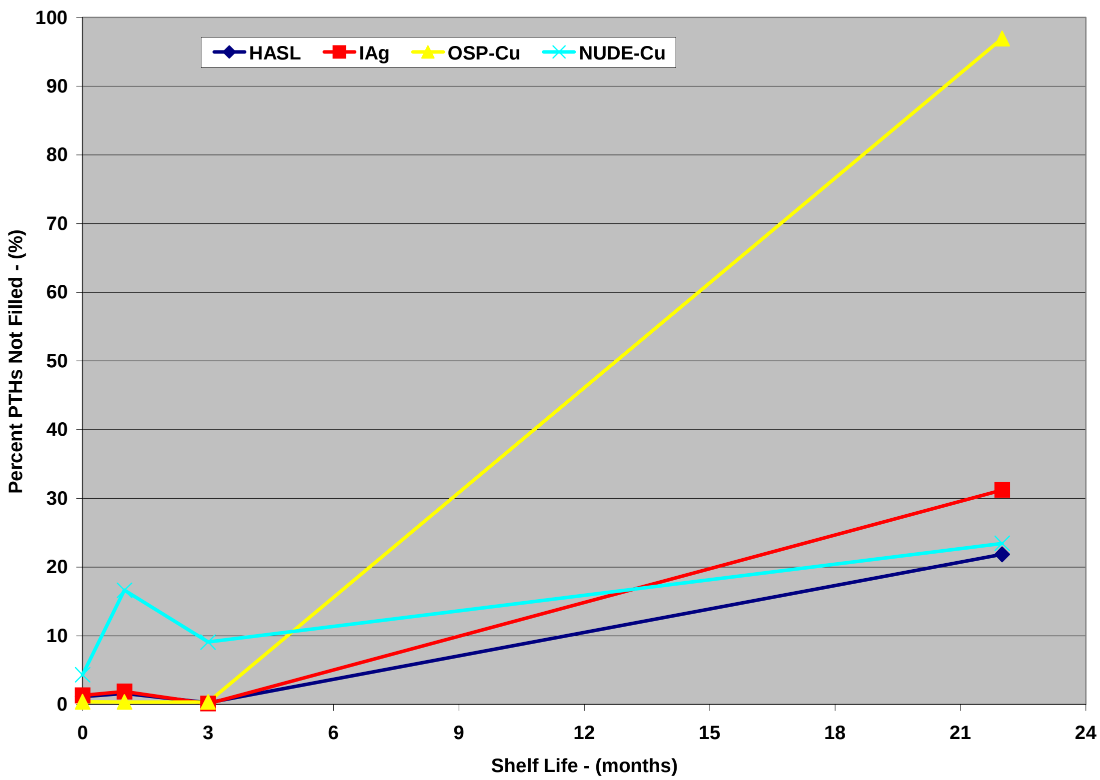


FIGURE 7. Solder Drag Test Results for 130 PTH Coupons

Pilot Production Implementation and Ramp-up

The introduction of immersion silver surface finished boards into product was approached cautiously. This was a result of concerns about the historical problems associated with silver migration, and the finish's lack of presence in the industry. During the summer of 1997, our board vendor contracted to have one code finished with immersion silver. This was done in parallel with the final electromigration testing. To insure that electromigration would not be a product issue, a circuit pack code was selected that allowed complete coverage of all exposed metal surfaces with solder during reflow and wave soldering. There was no exposed silver on this code after circuit pack assembly (i.e., the silver dissolved into the solder). This allowed for accrual of production experience while other testing was ongoing. The product was carefully followed through the assembly process and met all expectations. It printed similar to an OSP board, yet had the hole fill and testing characteristics of HASL product.

Since reliability testing revealed no concerns, cutover of fourteen additional circuit pack codes was requested the first quarter of 1998. The approach was to continue low volume production until our board vendor had capability to apply the IAg surface finish at their facility. Up to this point in time our PWB vendor contracted out the IAg surface finish. All of the boards were processed through circuit pack assembly and testing without issue. The IAg surface finish proved to be a drop-in replacement for circuit pack assembly. No processes were changed to accommodate the new surface finish. In October of 1998, our board vendor's new in-line IAg plating process was inspected. After sampling plated boards it was deemed operational, and the final phases of the implementation began. Three separate circuit pack builds utilizing boards plated in the new facility were evaluated. This was to insure our board vendor's process stability. These were again monitored throughout the assembly process with no issues found. In February 1999, our board vendor was given a ramp-up schedule for telecommunication transmission circuit packs. In March 1999, a second factory producing switching equipment requested cutover of a significant number of product codes. As of the beginning of June 2000, over 300 active codes have been cutover. Over 500,000 boards with the IAg surface finish have been fabricated and assembled at three manufacturing locations and one contract manufacturer location. Only a single processing issue has arisen during this ramp-up. On two lots of product, the coating was thinner than the minimum specification. This was evident by a copper hued appearance to the plated surface features. The board vendor was informed, and has instituted tighter plating and inspection process controls to prevent reoccurrence. The indicted product was monitored through assembly and even these suspect boards processed well (i.e., soldered and tested without incident). We can't over emphasize that we are not using IAg as a solderable surface, we are using it as a visual inspection to know that the underlying copper was "clean" when plated with IAg and hence should be solderable.

Conclusions

The immersion silver surface finish provides a level of circuit pack assembly "processability" that exceeds both HASL and OSP. It has the flat topography on surface mount pads essential to optimal printing. It also has the hole fill and testability features similar to a HASL board. Finally, if there are residues or contaminants on the features to be soldered, it can easily be identified visually, unlike OSP boards, before expensive components are placed. Immersion silver has met or exceeded all our expectations and is our surface finish of choice. We are now receiving boards with IAg surface finish from six vendors. We enter the new millennium with the knowledge that IAg has met or exceeded all our expectations and has become our surface finish of choice for solder assembly.

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APPENDIX 1. SURFACE INSULATION RESISTANCE (SIR)
to check compatibility of fabricated PWB with surface finish and solder mask (Bellcore GR78)

"X" = surface finish being evaluated

Coupons:	25 / 50 mil lines / spaces solder mask striped pattern
Test Condition:	35^{o} C / 85% RH / No Bias / 96 hours
Number of coupons:	3 per sample group
Solder Mask:	Type being used for product **IAg was tested using an electrostatic sprayed and flow coated LPI solder mask**
Soldering Process:	Type being used for production **IAg was tested using a dual wave, 6.5 ft./min., 450^{o}F**
Flux:	Type being used on product **IAg was tested using a spray application (700 – 1000 µg/sq.in.) of an alcohol based, succinic acid activated no-clean low solids flux**

SAMPLE GROUP	SURFACE FINISH	SIDE FLUXED	SIDE WAVE SOLDERED	SIR REQUIREMENT
PWB Fabrication Control	Bare Cu	None	None	$= 1 \times 10^{10}\ \Omega$
Surface Finish Control	OSP	None	None	$= 3 \times 10^{9}\ \Omega$
Surface Finish Control	"X"	None	None	$= 3 \times 10^{9}\ \Omega$

APPENDIX 2. SURFACE INSULATION RESISTANCE (SIR)
to check compatibility of surface finish with solder mask/assembly process
(Lucent Technologies MS-59124 Classification and Usage Requirements of Soldering Fluxes)

Coupons:	25 / 50 mil lines / spaces solder mask striped pattern
Test Condition:	65^{o} C / 85% RH / 50V Bias / 14 days with SIR measured daily
Number of coupons:	3 per sample group
Solder Mask:	Type being used for product **IAg was tested using an electrostatic sprayed and flow coated LPI solder mask**
Soldering Process:	Type being used for production **IAg was tested using a dual wave, 6.5 ft./min., 450^{o}F**
Flux:	Type being used on product **IAg was tested using a spray application (700 – 1000 µg/sq.in.) of water based VOC-Free no-clean flux**

SAMPLE GROUP	SURFACE FINISH	ASSEMBLY PROCESS
PWB / Solder Mask / Surface Finish Control	OSP	None
PWB / Solder Mask / Surface Finish Control	"X"	None
PWB / Solder Mask / Surface Finish / Process	OSP	Actual Assembly Process
PWB / Solder Mask / Surface Finish / Process	"X"	Actual Assembly Process

Qualification Acceptance Requirements

Passing behavior is:

- an average SIR which does not drop more than a factor of 10 from day 4 to 14
- no dead shorts on any of the test coupons
- no dendrite growth covering more than 20% of the spaces between conductors, and
- no signs of corrosion at 1X visual exam.

APPENDIX 3. SURFACE INSULATION RESISTANCE (SIR)
for International (IEC) Requirements

Reference:	Section 6.5 JNL-100-06118
Coupons:	25/50 mil lines/spaces solder mask striped pattern
Test Condition:	IEC68-2-3 40^{o} C / 90% RH / 100 VDC Bias / 21 days
Measurement Times:	Before test, 1,2,4,7,10, 21 days, 1 hour after recovery and 24 hours after recovery. Measurements before test as well as recovery measurements to be made at room temperature ambient conditions
Test Requirements:	SIR = 1.9 x 10^{9} Ω Requirements Before test and Recovery: = 6.4 x 10^{9} Ω
Solder Mask:	Type being used for product **IAg was tested using an electrostatic sprayed and flow coated LPI solder mask**
Soldering Process:	Type being used for production **IAg was tested using a dual wave, 6.5 ft./min., 450^{o}F**
Flux:	Type being used on product **IAg was tested using a spray application (700 – 1000 μg/sq.in.) of water based VOC-Free no-clean flux**

APPENDIX 4. ELECTROMIGRATION (EM)
to check tendency of fluxed and heat exposed surface finish to migrate (Bellcore GR78 procedures)

Coupons: IPC B-25 B or E 12.5 mil lines / 12.5 mil space pattern
Test Condition: 85 ^{O}C /85% RH / 10 VDC Bias / 96 hours and 500 hours
Number of coupons: 3 per sample group
Soldering Process: Type being used for production
IAg was tested using a dual wave, 6.5 ft./min., 450^{o}F
Flux: Type being used on product
IAg was tested using a spray application (700 – 1000 µg/sq.in.) of water based VOC-Free no-clean flux

SAMPLE GROUP	SURFACE FINISH	SIDE FLUXED	SIDE WAVE SOLDERED	SIR REQUIREMENT
"E" Top Side Contamination Control	Bare Cu	Comb	Back (comb up)	$SIR_{500\ hrs} > 0.1 \times SIR_{96\ hrs}$
"E_x" Top Side Contamination	"X"	Comb	Back (comb up)	$SIR_{500\ hrs} > 0.1 \times SIR_{96\ hrs}$
"F" Assembly Process Control	Bare Cu	Comb	Comb (down)	$SIR_{500\ hrs} > 0.1 \times SIR_{96\ hrs}$
"F_x" Assembly Process	"X"	Comb	Comb (down)	$SIR_{500\ hrs} > 0.1 \times SIR_{96\ hrs}$

APPENDIX 5. SOLVENT EXTRACT CONDUCTIVITY (SEC)
test of PWB fabrication cleanliness (Bellcore / NSI)

Test Vehicle: Production code PWB
Test Conditions: 75% Isopropyl Alcohol / 25% Deionized Water
Requirements: $\leq 1 \mu g/cm^2$

APPENDIX 6. SOLDERABILITY TEST (Bellcore / IEC / IPC)

Edge Dip Test:	Test of surface metallization and surface mount pads performed in accordance with ANSI/J-STD-003 Test A
Solder Float Test:	Test of plated through-holes performed in accordance with ANSI/J-STD-003 Test C
Rotary or Edge Dip:	IEC tests use 235^{o}C solder and 0.5% halide RMA flux while Bellcore/IPC tests use 245^{o}C solder and WWR flux
Preconditioning:	At discretion of Physical Designer/Customer. Level 1: 35^{o}C / 85% RH for 24 hours (OSP) Level 2: 65^{o}C / 85% RH for 8 days (Consumer Products) Level 3: 65^{o}C / 85% RH for 21 days (Transmission product un-controlled environment) Level 4: 40^{o}C / 92% RH for 10 days plus 105^{o}C for 1-2 hours (IEC) Level 5: 125^{o}C for 1 hour (NCMS) Level 6: 8 hour 93^{o}C Steam Age (IPC intended for SnPb finishes only)

APPENDIX 7. SOLDER JOINT INTEGRITY / RELIABILITY TEST

Test Vehicle:	PWB with 50 mil pitch SOIC (12 to 20 I/Os) surface mount sites	
Solder Paste:	No-Clean Leave-behind 60Sn/40Pb, 63Sn/37Pb, or 62Sn/36Pb/2Ag RMA paste	
Reflow Process:	Forced convection air or nitrogen furnace capable of exposing test vehicles to 220±10^{o}C peak and 60±45 second above 183^{o}C	
Test Method:	Mechanical pull test of individual gull wing leads at about 0.006 in./sec.	
Test Conditions:	Leads pulled in “as assembled” condition and after preconditioning	
Preconditioning:	Liquid (-40^{o}C) to Liquid (+125^{o}C) thermal shock	
Requirements:	Integrity:	Survive 10 Liquid-Liquid cycles
	Reliability:	Survive 100 Liquid-Liquid cycles
	“Survive”:	Defined as results for surface finish being tested performing as well as (i.e., no statistical difference in pull strength) joints made to control surface finish (HASL or OSP).

APPENDIX 8. REAL TIME DETERMINATION OF SHELF LIFE

Test Vehicle:	0.032 inch thick DSR PWB with 2400 PTHs (1/3-13 mil drill, 1/3-22 mil drill, and 1/3-35 mil drill)
Storage Locations:	Manufacturing Locations
Number of TVs:	32 at each location
Test Method:	NCMS Simulated Assembly Wave Solder Test Method or equivalent
Testing Interval:	4 boards removed first month each quarter thereafter and tested
Shelf Life:	Determined as testing interval before defect level decreases 10%