The Performance and Attributes of the Immersion Silver Solderability Finish

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ABSTRACT

The evolution of fine pitch SMT devices and BGAs has placed additional demands upon the solderability finishes for PCBs. The requirements include solderability, reliability, planarity and the incremental cost of the finish. Because of the planarity issue, the present solderability finish of choice, HASL, is unsuitable for these applications. Immersion silver, however, is compatible with all of these concerns. In particular, immersion silver is a noble metal which forms a planar surface for component attachment while being economically attractive. A paramount issue with silver in electronic applications is the fear of silver migration. The discussion below addresses this issue and shows, in this case, silver migration is not a concern. Attention is also given to the fabrication process, assembly performance, solder joint reliability and shelf life. Applications such as chip on board are also discussed.

INTRODUCTION

The clear direction of the PCB industry is to higher interconnect density. In the past the worth of a PCB was judged by layer count and size. The principle index of value is rapidly becoming interconnect density. As seen in Figure 1 with the advent of micro ball grid arrays and similar chip scale packages, the interconnect density of PCB is growing in a log – linear fashion.

The surface finishes, such as HASL, used in the past are becoming inadequate. The principal issue is planarity. Typically the HASL coating forms a meniscus which may approach a mil in thickness at the apex, but well below 100 micro inches at the end of the pad. The degree of variation is inversely proportional too the size of the feature. This effect degrades assembly yields to the point that many facilities will not accept HASL finishes on boards with features below a twenty mil pitch.

A new generation of noble metal surface finishes has been developed to address this need. A comparison is made in Table I. Of particular interest is the immersion silver coating.* The immersion silver coating is approximately five micro inches thick and therefore, essentially flat. It is cost effective, simple to apply and compatible with most PCB materials. A barrier undercoating such as nickel is unnecessary. The coating has been the subject of numerous assembly studies both in North America and Europe. The solderability results have been comparable to HASL while at the same time showing considerable improvement in such areas as component placement. Finally, numerous metallic migration and SIR studies have been performed verifying that the immersion silver is a robust and reliable coating.

THE IMMERSION SILVER COATING AND PROCESS

The immersion silver coating is depicted in Figure 2. The coating consist of a layer of silver approximately four to five micro inches thick with a thin inhibitor layer superimposed. The inhibitor layer is essentially an OSP. The coating is applied by an immersion process which exchanges copper from the base metal for silver in the silver nitrate bath. A particular benefit of immersion processes is the self terminating feature; that is the process terminates when the coating completely covers the base material. As a result, the plating thickness is consistent and easily controlled.

The process consists of four baths, a precleaner, then a micro etch followed by the conditioner and finally the plating bath. The baths do not use any objectionable chemicals.

* Alpha Metals, Inc., Jersey City, NJ. Viasystems has made this coating available in Europe for over two years and has recently installed the process in it's facility in Richmond, Virginia.

RELIABILITY TEST

Silver coatings have been a concern to the electronics industry for sometime due to the perception of silver migration. Consequently, a considerable amount of work has been carried out to determine the likelihood of this coating migrating**.** Testing, conducted by an independent laboratory, of the immersion silver coating has met or exceeded IPC electromigration tests requiring seven days exposure to THB environment of 85^0 C, 90%RH and 10 volts DC for seven days. Coupons coated with immersion silver have also undergone SIR testing using the parameters of IPC - S F - 818. The typical resistance values after exposure to this environment for 90 days was between 2 and 3×10^{10} Ω. Bare copper coupons used as controls ranged slightly less than the immersion silver coupons.

SOLDERABILITY TEST

Solderability test on immersion silver coupons have been reported in Reference (1). Through hole coupons with the immersion silver coating were compared to others with HASL, and a OSP coating. The comparisons were made using steam aging as the stress (see below). The immersion silver coating is seen to compare very well with the HASL coating.

SOLDERABILITY COATING	HOLE FILL NO STRESS	HOLE FILL AFTER ONE HOUR STEAM AGING
IMMERSION SILVER	99.97%	99.90
HASL	100%	99.97
THICK OSP	93.57%	92.62

SOLDER JOINT QUALITY

The strength of solder joints formed on immersion silver coated SMT lands has been investigated by Wenger (2). The results are shown in Figure 3. These joints are formed on 50 mil pitch SMT pads. The quality of the pads was investigated by a tensile test which stressed the joints to rupture. Several conclusions can be drawn from Figure 3. First, the rupture strength of the joints consistently exceeds 1.0 pounds which is within the range generally attributed to a joint formed on a HASL surface. More important, however, is the fact that the rupture always occurs at the lead interface and never at the pad/board interface. This indicates that the bond at the pad is superior to that formed at the lead.

Thermal cycling studies of solder joints formed on immersion silver coated pads have been carried out by Guy (3) and compared to HASL solder joints. The test vehicle used a variety of SMT devices including chip carriers, QFPs (some with 20 mil pitch leads) and 1.5mm BGA packages. The temperature extremes were -55^0 C and 125^0 C. The dwell time was half and hour. Failures were detected only in the leads of the chip carriers. Weibull distribution fits were made to the data and presented below; the two distributions are essentially the same.

Weibull Parameter	Immersion Silver	HASL
Scale Factor	145.02	157
Shape Factor	4.3	3.09
Median	133.17	139.42

ASSEMBLY TRIALS

Prior to starting production, Viasystems performed several assembly trials at customer sites. In all cases the designs selected required three soldering operations. HASL coated boards were used as controls. Both mixed technology and two sided reflow boards were used in these studies. The components involved were 20 mil pitch QFPs, SMT discretes and connectors which are assembled in a third soldering operation. Over fifty boards of each surface finish were used in each of these studies. The trials were carried out in a typical assembly operation using no clean fluxes.

In all cases, the immersion silver coated boards performed as well as the HASL boards. There were no defects observed in either population after the first two assembly operations. In the third assembly operation, connector assembly, a substantial improvement was noted in the immersion silver coated boards. The codes used in these evaluations have now been converted to immersion silver.

WIRE BONDING

Wire bonding on an immersion silver surface has been investigated by David Hillman Reference 4. Hillman compared bonding suitability of numerous noble metal finishes including: electrolytic gold over nickel, immersion gold over nickel, immersion palladium over nickel. The bonding operations investigated were: aluminum wire wedge bonding, gold wedge bonding and gold ball bonding. Hillman found the pull strengths for gold wedge bonding, gold ball bonding and aluminum wire bonding were respectively: 6, 5.5 and 7.5 grams which compared favorably with the other surface finishes used in the study.

CONTACT PERFORMANCE

The characteristics of a gold contact have been investigated by Evans and Davison (5) The study compared an immersion silver contact to several other materials, such as: HASL and immersion gold. The applied load was 300 grams and the bias was 5 volts. The results are presented below.

CONTACT RESISTANCE, OHMS

CONTACT MATERIAL	INITIAL VALUE	AFTER $25X10^4$ CYCLES	AFTER $50X10^4$ CYCLES	AFTER $75X10^4$ CYCLES	AFTER 10^6 CYCLES
HASL TO CARBON	43.5	37.9	33.2	32.5	35.6
IMMERSION SILVER TO CARBON	33.2	22.7	23.5	33.2	28.4
IMMERSION SILVER TO IMMERSION SILVER	38.3	37.5	37.1	42.2	41.5
IMMERSION SILVER AGED 10 DAYS @ 40^0C, 92%RH	36.1	40.8	31.4	29.1	42.6
IMMERSION GOLD TO IMMERSION GOLD	38.1	32.3	34.5	36.2	33.9

As shown in the table, the variation in resistance of the immersion silver contact is small even when the contact was exposed to accelerated conditions. Also the immersion silver contact is seen to compare well with immersion gold. While this evidence is not conclusive, it does strongly suggest that immersion silver is a suitable material for both static and repetitive contacts.

SUMMARY

The information collected above shows that immersion silver is a suitable solderability finish for PCBs, in particular boards that use fine SMT surfaces. The reliability issues which have been raised are groundless. Immersion silver may also be a suitable finish for wire bonding and electrical contacts.

REFERENCES

(1) Beigle, S., ”Alternate Metal Finishes for Wire Bond and Soldering Applications”, SMI, 1996

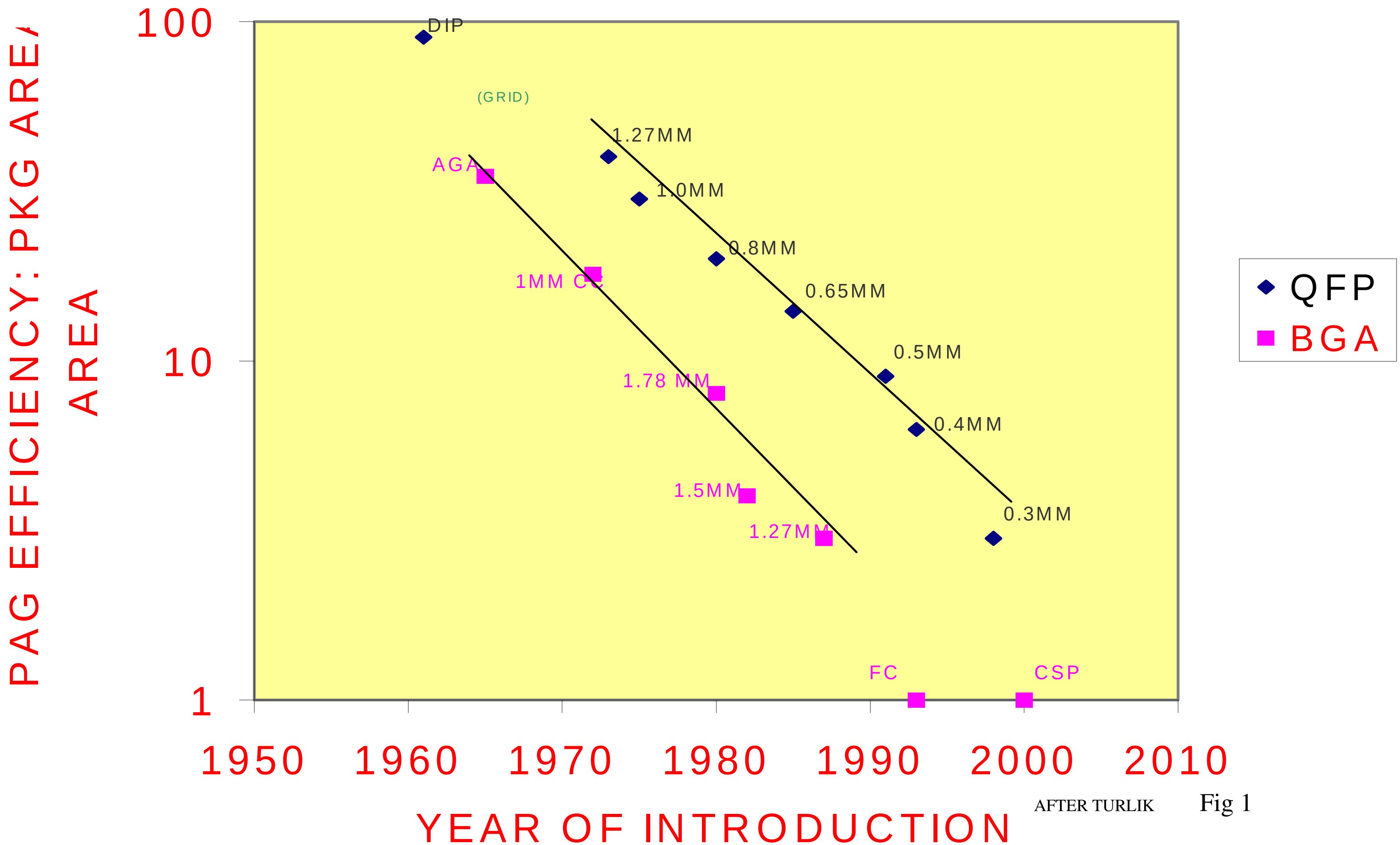
(2) Wenger, G. M. Private Communication

(3) Guy, J. T. “Solder Joint Reliability of Alternative Surface Finishes”, Electronics Manufacturing Productivity Facility, Indianapolis, IN

(4) Hillman, D. , et al, “Wire Bondability and Solderability of Various Metallic Finishes for Use in Printed Circuit Assemblies”, SMI, 1995

(5) Evans, R. B. and Davison,B.G. “Key Patting Testing of PCBs”, IRD Report 95/82, October 30,1995

EVOLUTION OF PACKAGING EFFICIENT



AFTER TURLIK

Fig 1

BGA SOLDERABILITY OPTIONS

ATTRIBUTE	HASL	IMIDAZOLE (OSP)	IMMERSION SILVER	IMMERSION GOLD
COST	MODERATE	ECONOMICAL	REASONABLE	VARIES WITH VENDOR
SOLDERABILITY	SUPERIOR	EXCELLENT	EXCELLENT	VARIES WITH VENDOR
SHELF LIFE	1 YR.	1 YR.	TBD >6 MO	1 YR.
PLANARITY	POOR	EXCELLENT	EXCELLENT	EXCELLENT
COB COMPATABILITY	NO	NO	YET TO BE DETERMINE	WEDGE BONDABLE

TABLE 1

IMMERSION SILVER - CHEMICAL THEORY

Organic inhibitor.

- Hinders oxidation of the silver.
- Hydrophobic surface.
- Simultaneous deposition.

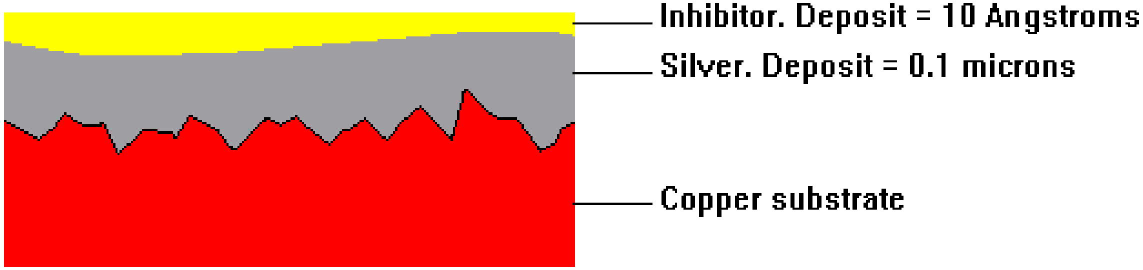
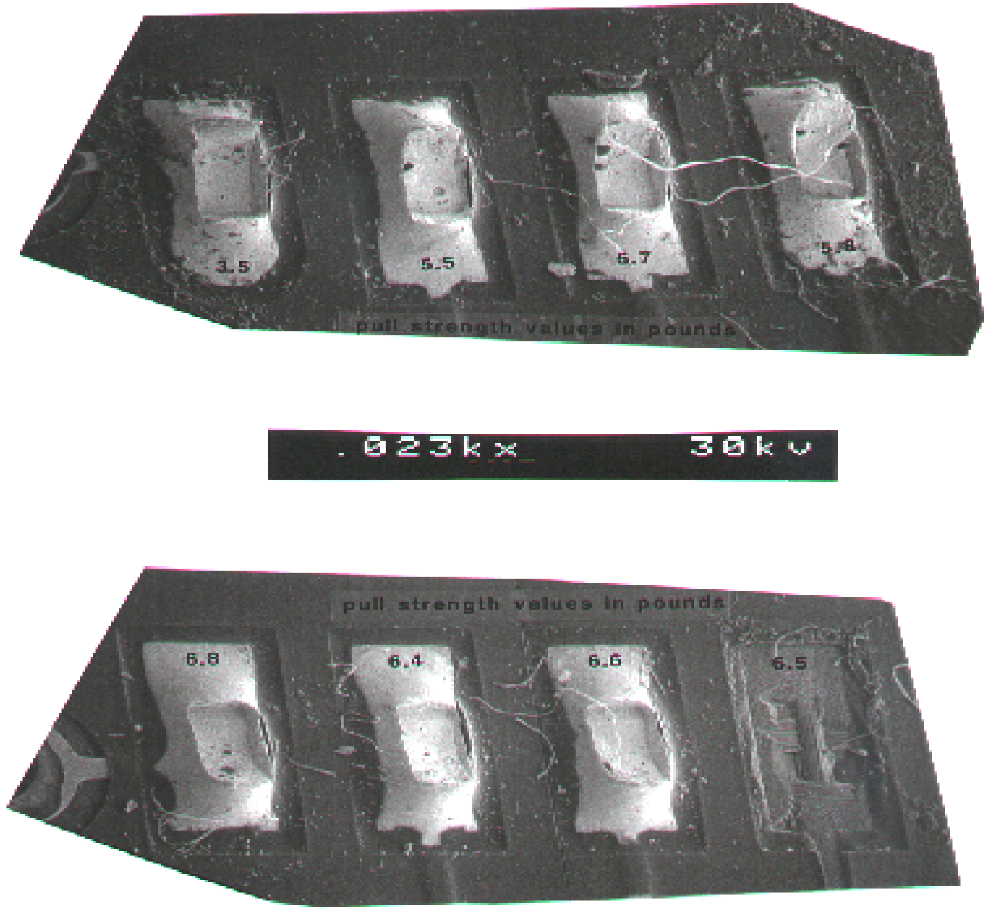


Fig 2

IMMERSION SILVER



PULL TEST EVALUATIONS ON TI 8 I/O SOIC PACKAGE
WITH PdNi PLATED GULL WING LEADS
SURFACE MOUNT REFLOW SOLDERED TO IMMERSION SILVER PWB

Fig 3