NEW, HIGHEST RELIABLE GENERATION OF PWB SURFACE FINISHES FOR LEAD-FREE SOLDERING AND FUTURE APPLICATIONS

Frando van der Pas
Enthone Inc.
Cookson Electronics

Introduction

In order to meet the emerging requirement of eliminating lead from electronics, the printed wiring board (PWB) industry is moving away from hot-air-leveled SnPb solder to alternative final finishes. Although known for short product life cycles and continuous technology changes, the electronics industry has yet to adopt an industry-wide, hot air solder leveling (HASL) alternative. Numerous papers have been published over the years predicting the replacement of HASL with organic solderability preservatives (OSPs), electroless nickel/immersion gold (ENIG) or other metallic immersion technologies such as silver and tin. So far, none of these predictions has yet become reality. HASL is the predominant final finish applied worldwide. However, three main drivers are pushing the electronics industry to consider HASL alternatives: cost, technology and the need for lead-free materials. The need of using lead-free materials has generated tremendous pressure in the electronics industry in the last few years. For PWB surface finishes there are several potential different viable candidates. OSPs and metallic alternatives such as immersion tin and immersion silver have been successfully tested and introduced to replace tin-lead HASL as a final surface finish

HASL alternatives

The use of most well known HASL alternatives, including ENIG, chemical tin, OSPs and the youngest PWB finish immersion silver, seems to be different in each of the world regions. Although in Europe there seems to be a preference for chemical tin as a finish, US fabricators seem to favor immersion silver. In Asia, OSP technology and immersion silver are being used more extensively. The main reason for these regional preferences is OEM/CEM preference and application.

- Immersion silver provides a single surface finish that is, under conditions, wire bondable and has low contact resistance for key contacts and metal-to-metal shielding. Although it is a newer finish, there are clear advantages to this finish, which could replace a great part of the HAL (and even ENIG) market. Although there are historical concerns with silver, such as electromigration and sensitivity to oxidation, the newer generations of immersion silver technologies have largely eliminated such issues.

- OSP has been a market leader for HASL alternatives worldwide and provides a wide process window for the applicator. There are still misconceptions that OSPs can only be used for single thermal profiling and need nitrogen and aggressive soldering materials. Experience and data have shown in the last ten years that the generation of substituted benzimidazoles are fully compatible with no-clean assembly of mixed technology boards and can withstand more than three heat cycles required for this type of assembly. Although nitrogen will help to improve wetting, it is not required. OSPs are the lowest cost surface finish available. Newer generations of more thermally stable materials are specially released for lead-free assembly requirements.

- Immersion tin is already on the market for some time and provides a thicker, uniform metallic coating for improved ICT probe life and lubricity for press fit pins. Although the cost is higher and processing of this finish is more difficult than for example OSPs or silver, it seems there is once again a growing interest due primarily to the lead-free target date of July 2006. Specifically, in Europe the interest in tin as a finish is growing. Concerns on whiskers have been addressed with new additive systems by most of the suppliers of tin chemistries.
- ENIG is a well-established surface finish that has been used for many years. ENIG has demonstrated excellent soldering properties. Cost is relatively high due to the use of precious metals and chemistry basis and also compatibility with solder resists is an issue during fabrication. Another major issue linked with this finish is black pad.

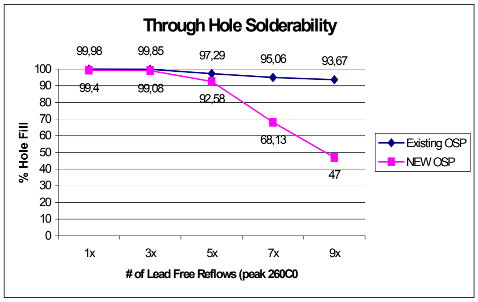
This paper describes in more detail the next generation alternatives on OSP technology and immersion silver. As a combination, both finishes have potential to replace the majority of assemblies in the lead-free future.

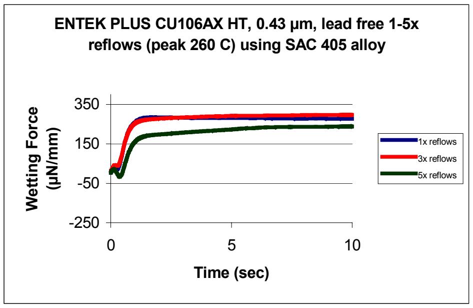
Lead-free

The assembly industry is currently evaluating lead-free soldering alternatives. While certain alloys seem to be the choice of specific OEMs, an industry-wide alloy containing tin, silver copper seems to be preferred. However, all the alloys being used require higher reflow temperatures and yield slower wetting speeds. Paste suppliers have engineered specific flux and paste chemistries to improve the wetting of these new alloys. ENTEK® PLUS OSPs and AlphaSTAR™ immersion silver meet all WEEE requirements for lead-free surface finishes. Independent of the surface finish, the alloy type and the temperature of the solder determine the greatest influence on solderability. Initial studies indicate that the higher reflow temperatures do not affect the solderability or bond strength of OSP and immersion silver. The higher melting temperatures apparently help penetration of the OSP and wetting of the tin and silver surface even with double-sided reflow. Immersion silver has received a great deal of interest in recent years as the alternative final finish of choice to HASL for many OEMs in the telecommunications, computer, automotive and consumer electronics industries. As the popularity of immersion silver has grown, a number of proprietary plating formulations have emerged from the supplier base since the original immersion silver process was introduced to the industry.

New OSPs for lead-free

OSP processes provide a temporary layer to clean and protect the copper surface from oxidation. During soldering, the organic coating is penetrated, dissolved and chemically broken down by the flux or solder paste flux vehicle and heat of the soldering process. Past experience has provided an understanding of how soldering occurs on an OSP. In general non-thermal cycled OSPs have good wetting properties, almost independent on materials or processes used but thermal cycling results in additional cross linking of the coating making it slightly more chemical resistant and less penetrable by weak organic acids used in standard flux formulations. The profiles used in lead free soldering and subsequently the higher temperatures involved will affect this phenomenon. Therefore, a new generation of OSPs has been developed and released to withstand higher temperatures and make no clean flux penetration easier, thus resulting in improved solderability. ENTEK® PLUS CU-106A(X) HT is the industry's next generation OSP that has been specially formulated to meet the stringent demands of today's most complex PWB lead-free assembly processes. Based on the existing and patented ENTEK PLUS CU-106A technology, this latest innovation has been modified to provide a more thermally stable (i.e. higher temperature = "HT") coating without sacrificing the OSP's well established record of reliability. Compared to existing technologies this new generation of OSPs has the ability to withstand by far more than three lead-free thermal cycles without significant solderability degradation. This has been confirmed with wetting balance and solderability testing as well as production experience. Furthermore, this coating is fully compatible with mixed metal finishes technologies such as ENIG/OSP assemblies.

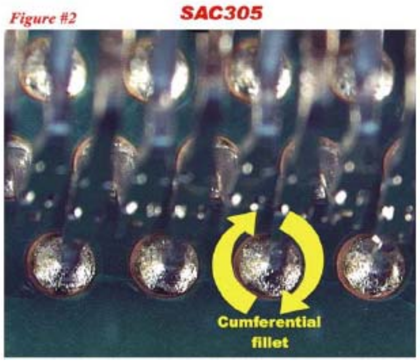




All data gathered using OSPs indicate that lead-free thermal processing (with elevated temperatures) does reduce the OSP wetting properties (i.e. larger wetting angle). However, the wetting angles for the lead-free alloys are still well below 90 degrees and consequently should be suitable for lead-free processing. When using the new OSP for lead-free, Many factors should be considered before implementation. Before choosing a supplier, one should consider the amount of thermal processing the parts will be exposed to, the kind of flux or paste that will be used, thermal profiles used, nitrogen or air, etc. All of these factors can then be used to determine the OSP type or supplier as well as the required OSP thickness for that particular process.

Figure #1

Figure #2



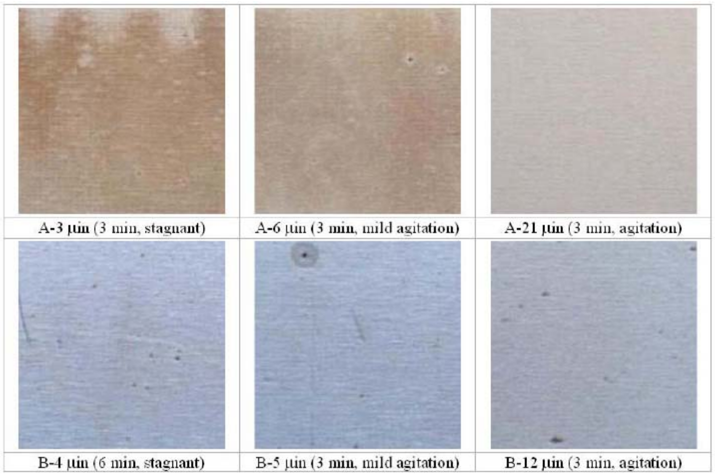
Source CE Analytics ; Both through-hole connections exhibited good solder filet and circumferential wetting present on secondary source side of the solder joint coated with OSP. The SACX0307 exhibited a slightly better circumferential wetting

New immersion silver for improved performance

Immersion silver is becoming of greater interest for many OEMs in the telecommunications, computer, automotive and consumer electronics industries as a lead free alternative to HASL. As the interest in immersion silver has grown, a number of proprietary plating processes have originated from the supplier base since the first immersion silver process was introduced some eight years ago. There have been numerous studies exploring the capabilities and advantages of the immersion silver plating processes currently available in the marketplace. One distinction among the various chemistries available has been “thick” versus “thin” immersion silver coatings. Fundamental differences in the surface preparation and plating processes influence the performance of the various immersion silver coatings, thus resulting in different performance characteristics that are independent of the silver thickness as measured. Earlier papers show that, at a given silver thickness, the tarnish resistance is different for silver coatings plated from two different processes. Because the deposit characteristics vary from process to process, the silver thickness requirements to ensure reliable performance at assembly should not be applied generically to all immersion silver processes, but should be considered individually. A commercial process (Process X) known for fast deposition and thick silver was used as a benchmark for the newly developed process (Process A). The tarnish resistance was evaluated by several tests, including the humidity test of 85°C/85% relative humidity (RH) and a hydrogen sulfide test.

Process X

Process A

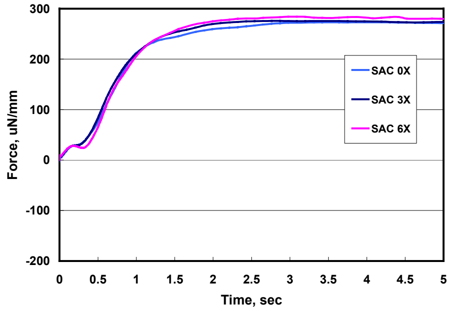


A-3 µin (3 min, stagnant) | A-6 µin (3 min, mild agitation) | A-21 µin (3 min, agitation)

B-4 µin (6 min, stagnant) | B-5 µin (3 min, mild agitation) | B-12 µin (3 min, agitation)

Exposed to 85º/85%RH for 24 hours process X shows significant tarnish, especially at thickness <6 microinches

Additionally, results for lead-free soldering with this new immersion silver have proven to be compatible with different lead-free alloys, even after multiple heat cycles. The resistance to tarnish will help to achieve good results during the assembly of this final finish.



AlphaSTAR™ immersion silver solderability with SAC 305 alloy after 5 lead-free reflow profiles (peak 260 C).

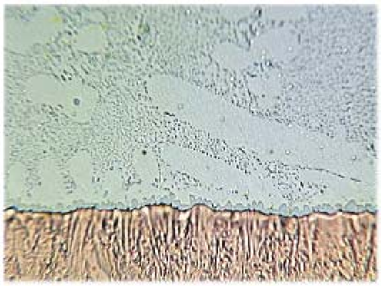
Finally, it has been demonstrated that the control of thickness and the deposition rate of the immersion silver, thus type of process chemistry, plays a role in the reduction of galvanic attack.

Solder joint reliability

Both OSP and silver provide an optimum surface for printing with all types of solder paste. The paste is placed directly on the surface finish, providing direct contact of the flux and wet the PWB surface. The stencil forms an effective gasket for depositing a perfect solder paste print, eliminating the smear and bridging issues of HASL. The result is high first-pass assembly yields with these alternatives. Differences in solder wetting are dependent on the PWB finish, design and application.

Several studies have demonstrated that soldering directly to the copper surface with OSPs provides the strongest solder joints. Solder joint strength becomes critical when smaller pad sizes are utilized with area array chip packages. When properly deposited, the gold on an ENIG surface is pure and will provide a fast wetting speed for soldering. However, when ENIG is used, the solder joint is formed on a nickel barrier layer, not directly on the PWB's copper surface. A major concern found in the last years and still today is the black pad phenomenon with the assembly of BGAs, resulting in non-adherence of the solder balls onto the PWB surface.

SnAgCu on OSP: Good wetting, dense interface, intermetallics: 1.5-2.5 um



Although many mechanisms and chemical solutions are provided, this is still a major issue with ENIG application. In combination with the high cost of this finish, there are also expectations that ENIG will be (partly) disappearing and replaced by one of the other alternative finishes such as OSPs or immersion silver. The mobile industry has already switched over a few years ago to a mixed finish board whereas the OSP is being used to secure a strong solder joint and the ENIG finish is solely used for touch pad contacts.

Summary

The use of alternatives will not only increase but will replace HASL as the final finish of choice. The problem with alternatives today is the number of choices and the amount of data that has been presented. Alternatives like OSPs, and immersion silver all provide lead-free, highly solderable, flat, coplanar surfaces that, under production conditions, provide significant improvement in first-pass assembly yields. Matching each coating's benefits to assembly requirements and PWB design can differentiate both HASL alternatives.

Immersion silver is still a relatively new technology when compared to OSP and ENIG. However, over the last years, extensive testing and high volume production have proven the reliability of this process. The solder wetting characteristics make this coating more adaptable to an existing no-clean wave soldering process. This surface finish is a potential alternative for most applications, including shielding, aluminum wire bonding, key contacts and soldering. The latest generation silver addresses issues on chemical stability, tarnishing and galvanic etching which were observed with earlier immersion silver chemistries. Since lead-free solder joints appearance are naturally rough on all final finishes, new industry workmanship inspection standards need and are being developed.

References

OSP Characterization in Flip Chip Ball Grid Array Packaging
Li Ann Wetz and Keri Kirschenbaum, Motorola, SPS, Tempe, AZ.;
Presented at IPC SMEMA Council - APEX 2001

Unraveling the Final Finishing Mystery
Eric Stafstrom, Enthone W. Haven CT, paper Circuits Assembly Nov. 2000

The Chemistry and Properties of a Newly Developed Immersion Silver Coating for PWB Yung-Herng Yau, Chonglun Fan, Chen Xu, Anthony Fiore, Karl Wengenroth and Joe Abys
Cookson Electronics PWB Materials and Chemistry, West Haven, IPC Printed Circuits Expo
SMEMA Council APEX- Designers Summit 2004

Lead-free Soldering of Organic Solderability Preservatives
By F.A.M. van der Pas and K.H. Wandner, Enthone GmbH, Europe
PCE – 1st Quarter 2001

Internal Document, Cookson electronics ENTEK® PLUS CU-106A(X) HT and AlphaSTAR immersion silver - 2005

ZVEI Series of Publications ProTechnik Manuals for electrical industrial production
Lead-free soldering: Materials, Components, Processes Technological Assessment of the Change-Over Scenario ©1999-2000 Zentralverband Elektrotechnik- und Elektronikindustrie e.V.
Department Research, Human Resources Development, Production Engineering

Next Generation Organic Solderability Preservatives (OSP) for Lead-free Soldering and Mixed Metal Finish PWBs and BGA Substrates , Koji Saeki , Shikoku Chemicals Corporation Chiba Japan Michael Carano Electrochemicals, Inc. Maple Plain, MN, Presented at IPC Printed Circuits Expo SMEMA Council APEX - Designers Summit 2004

NPL/ITRI report, April 1999; “lead free soldering; an analysis of the current status of lead free soldering”

OSP Characterization in Flip Chip Ball Grid Array Packaging, Li Ann Wetz and Keri Kirschenbaum, Motorola, SPS, Tempe, AZ, Presented at IPC SMEMA Council APEXSM 2001

™ AlphaSTAR is a trademark of Enthone Inc.
® ENTEK is a registered trademark of Enthone Inc.