

# Solderability of Sn/Cu Lead-Free Solder as a HASL Bare Board Final Finish

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## Abstract

Sn/Cu lead-free solder is a good alternative to 63/37 solder for use in HASL processes. Solderability of Sn/Cu surface exceeds that of 63/37 solder, nickel-gold, OSP, silver, and immersion tin both before and after heat induced aging.

## Introduction

There has been a number of final finishes introduced in the past to replace conventional Hot Air Leveling (HASL). These finishes have been introduced as a way of improving surface co-planarity and other defects inherent in the HASL process. The push towards the elimination of lead has only accelerated this process. The problem with many of the alternative finishes is that in many cases these finishes are not as robust as HASL.

The purpose of this paper is to address this by introducing a lead free alloy known as Sn/Cu for the HASL process. Sn/Cu is a unique lead free solder with a nominal composition of 99.3% Sn, 0.6% Cu, 0.1% of other inhibitors and proprietary components. This product is a lead free solder that is gaining greater acceptance in the assembly community as an alternative to the SAC alloy (96.5% Sn, 3.5% Ag and 0.5% Cu) that is also used in the assembly industry.

We decided to focus our efforts on the Sn/Cu alloy because of the reports indicating that 1) Sn/Cu has much less attack on stainless steel solder pots than the SAC alloy and 2) Sn/Cu forms a more stable intermetallic layer and dissolves less copper in the coating process.

The testing reported in this paper includes solderability of various lead-free surface finishes in comparison to standard 63/37 HASL. Solderability tests were conducted after several types of heat aging, to simulate the effects of shelf life, and typical assembly processes. The thicknesses of tin-copper intermetallic layers were also examined for Sn/Cu and 63/37 solders as a measure of the stability of the layers.

## Test Methods

Six surface finishes were evaluated in this test including:

1. Sn/Cu lead-free solder
2. 63/37 solder
3. OSP
4. Electroless nickel – Immersion gold (NiAu)
5. Immersion silver (Ag)
6. Immersion tin (Sn)

The surface finishes were coated onto 3"x3" copper clad FR-4 laminate, 0.059" thick with 0.5/0.5 oz copper foil thicknesses, with the exception of the 63/37 solder finish. The 63/37 solder finish was coated using vertical HASL onto an 18"x24" copper clad FR-4 laminate, 0.059" thick with 0.5/0.5 oz copper foil and then sheared apart into 3"x3" coupons.

Heat aging was done to the coupons using two methods. Dry heat aging for 4 hours at 155C was done in Precision Thelco and Blue M Stabl-Therm laboratory ovens to simulate 1 year of storage on the shelf. The other method of heat aging was reflow cycling through a Vitronics Unitherm SMR-400 oven. The profile used is shown in Figure 1.

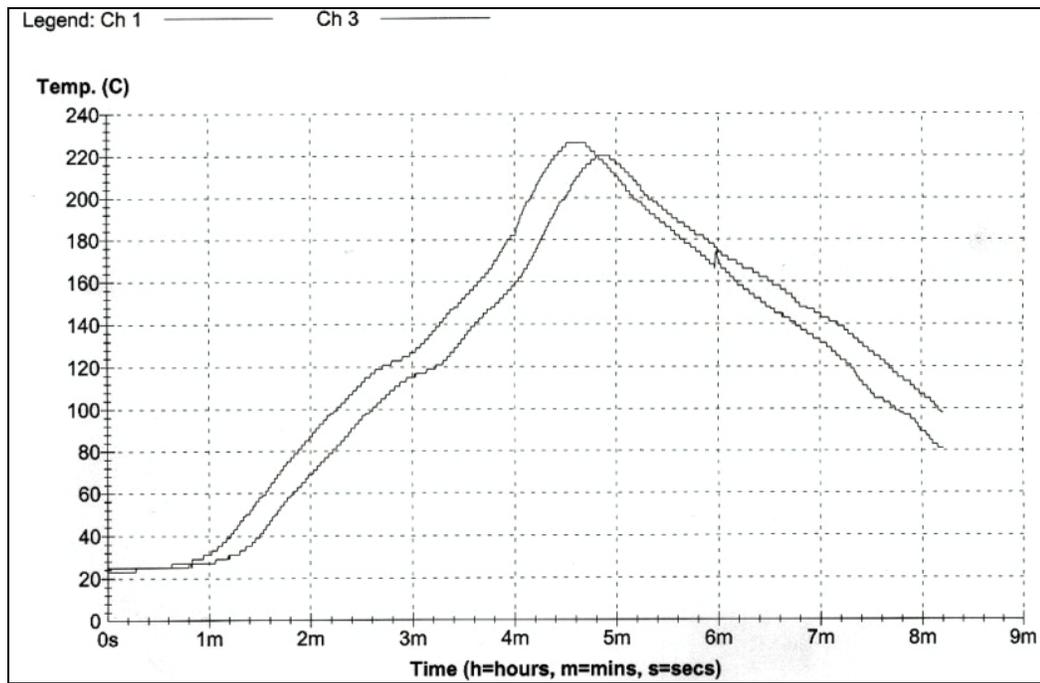


Figure 1 – Reflow Oven Profile

Each surface finish was subjected to eight types of heat aging. The heat aging types were as follows:

1. Fresh (no aging)
2. 1 Reflow cycle (RC)
3. 2 RC
4. 3 RC
5. 4hr/155C
6. 4/155 and 1 RC
7. 4/155 and 2 RC
8. 4/155 and 3 RC

After heat aging, thickness measurements were taken on Sn/Cu and 63/37 solder using Sequential Electrochemical Reduction Analysis (SERA). This was done in an effort to understand what effect heat aging has on the copper-tin intermetallic layers in these finishes.

Solderability testing was done using a standard no-clean 63/37 solder paste (Florida CirTech NC 650). The paste was screened through a stainless steel stencil onto the test coupons and the coupons were reflowed using the profile depicted in Figure 1.

The solderability test pattern was designed to give bridging of surface mount pads as an indication of good wetting. The test pattern had 4 rows of 25 surface mount pads in each. The pads were rectangular shaped, 1.6 mm x 0.8 mm, with rounded corners. The spacing from pad to pad became successively larger from 0.80 mm to 3.20 mm down the row of the pad. This pattern is depicted in Figure 2.

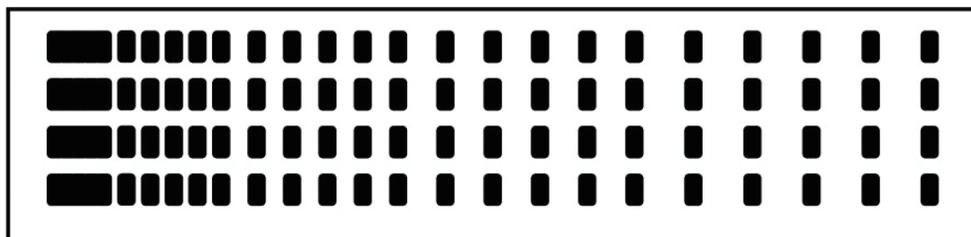


Figure 2 – Solderability Test Pattern

After reflow, the test coupons were evaluated for solderability by measuring the spread of the solder down each row. Solder spread was measured by counting the number of pads that bridged together. The maximum number of pads that could bridge together was 25 in a row. An average value of the number of bridged pads per row was taken from multiple runs of each coupon type. The average solderability values were turned into percentages for ease of comparison. The maximum solderability percentage is 100%. An overall solderability average for each finish was calculated

## Results and Discussion

Thickness measurement results are shown in Table 1.

All thicknesses in Table 1 are in microns. In the case of 63/37 solder, the Sn column actually represents the Sn/Pb alloy thickness. The variation in thicknesses in the Sn/Cu and 63/37 solder finishes was expected due to the HASL method used to coat the coupons.

**Table 1 – SERA Thickness Measurements**

Finish	Ageing	Sn ( $\mu\text{m}$ )	$\text{Cu}_6\text{Sn}_5$ ( $\mu\text{m}$ )	$\text{Cu}_3\text{Sn}$ ( $\mu\text{m}$ )
Sn/Cu	Fresh	1.678	0.843	0.406
	1R	1.683	0.940	0.379
	2R	1.108	1.013	0.346
	3R	1.530	0.870	0.416
	4/155	1.784	0.860	0.257
63/37	4/155 1R	0.922	0.950	0.242
	4/155 2R	1.316	0.914	0.286
	4/155 3R	1.085	0.851	0.311
	Fresh	1.525	0.471	0.139
	1R	0.871	0.474	0.000
63/37	2R	1.145	0.476	0.093
	3R	0.334	0.437	0.106
	4/155	0.501	0.576	0.054
	4/155 1R	0.519	0.620	0.000
	4/155 2R	0.130	1.142	0.000
	4/155 3R	0.389	0.741	0.000

There was an increase in  $\text{Cu}_6\text{Sn}_5$  thickness for 63/37 solder caused by 4 hr / 155C aging which was not seen for the Sn/Cu alloy. This is an indication that the Sn/Cu alloy intermetallic layers are more stable than 63/37 solder intermetallic layers.

Solderability test results are shown in Table 2.

Higher solderability percentages indicate better finish performance. The overall solderability average for each finish is highlighted.

Sn/Cu and immersion tin showed the best overall solderability. Both Sn/Cu and immersion tin show a significant decrease in solderability after 4 hour / 155C aging. Electroless Ni – Immersion Au was the least affected by 4 hour / 155C aging. Immersion silver showed the worst solderability of all finishes.

Selected solderability data was plotted in Figures 3 and 4 to illustrate the differences in the various finishes with heat aging.

**Table 2 – Solderability Test Results**

<b>Finish</b>	<b>Aging</b>	<b>Solderability %</b>
<b>Sn/Cu</b>	Fresh	80
	1RC	84
	2RC	68
	3RC	56
	4/155	32
	4/155 1RC	36
	4/155 2RC	48
	4/155 3RC	44
	<b>Average</b>	<b>56</b>
	<b>Imm. Sn</b>	Fresh
1RC		76
2RC		80
3RC		88
4/155		28
4/155 1RC		20
4/155 2RC		24
4/155 3RC		24
<b>Average</b>		<b>52</b>
<b>NiAu</b>		Fresh
	1RC	44
	2RC	40
	3RC	40
	4/155	52
	4/155 1RC	56
	4/155 2RC	44
	4/155 3RC	40
	<b>Average</b>	<b>46</b>
	<b>63/37</b>	Fresh
1RC		32
2RC		32
3RC		28
4/155		44
4/155 1RC		32
4/155 2RC		24
4/155 3RC		28
<b>Average</b>		<b>32</b>
<b>OSP</b>		Fresh
	1RC	28
	2RC	28
	3RC	24
	4/155	36
	4/155 1RC	36
	4/155 2RC	28
	4/155 3RC	24
	<b>Average</b>	<b>29</b>
	<b>Ag</b>	Fresh
1RC		24
2RC		24
3RC		20
4/155		24
4/155 1RC		20
4/155 2RC		16
4/155 3RC		16
<b>Average</b>		<b>22</b>

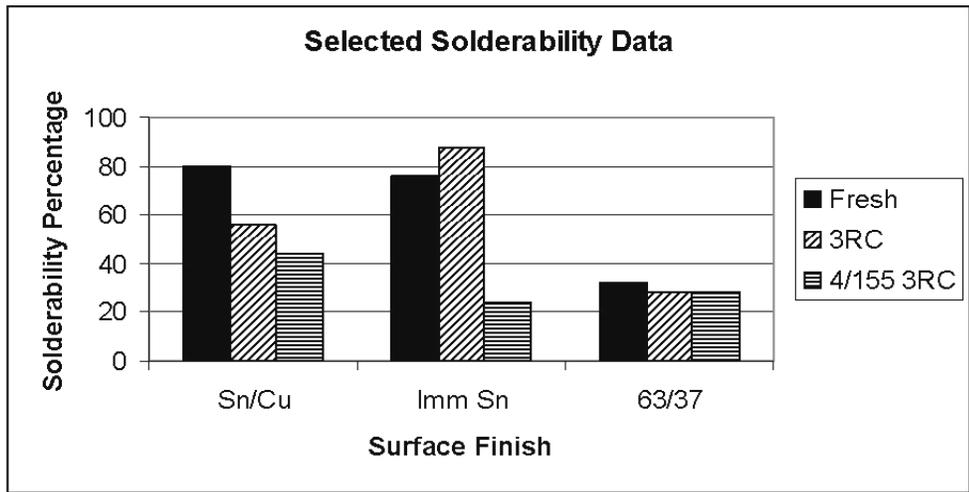


Figure 3 – Solderability Data for Sn/Cu, Immersion Sn, and 63/37 solder finishes

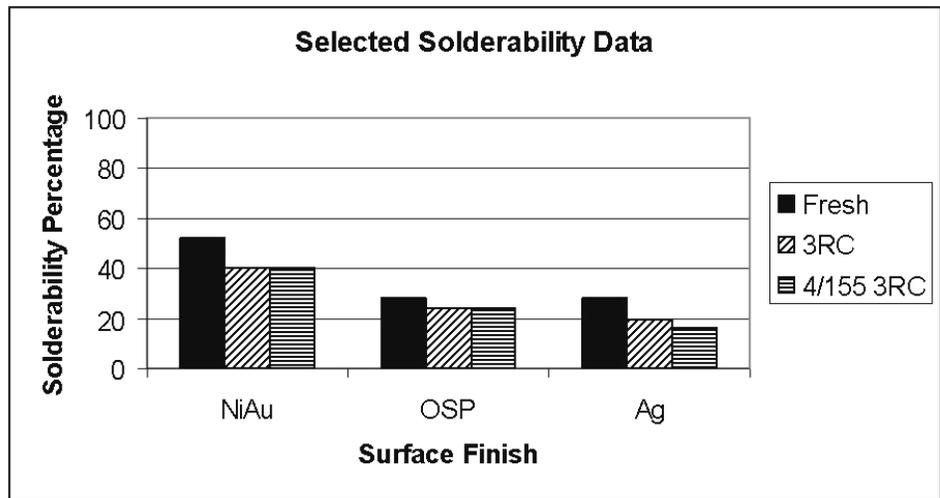


Figure 4 – Solderability Data for NiAu, OSP, and Immersion Silver finishes

There is a trend in reduction of solderability with heat aging for each finish. The solderability of immersion tin appeared to improve with reflow heat cycling. This may be due to thermal annealing of the immersion tin surface, and requires further investigation. Sn/Cu lead-free solder performed better than all finishes, even after 4 hour / 155C and 3 reflow cycle heat aging.

### Conclusions

Sn/Cu lead-free solder appears to be a viable replacement for 63/37 solder in HASL applications. The Sn/Cu alloy shows improved solderability and a better resistance to heat aging than the other finishes tested. The intermetallic layers of Sn/Cu alloy appear to be stable through heat aging.

The next phase of this project will consist of running Sn/Cu solder on circuit boards of various complexity to investigate the applicability of this alloy for high complexity patterns. Wetting balance testing is also planned for the next phase.

### Acknowledgements

We appreciated the assistance of Colin Longworth at DKL Metals for coating our boards with the Sn/Cu lead-free solder.

The Sn/Cu alloy used for this testing was manufactured by Nihon Superior under the name SN100C.