Technical Paper

Solderability of Lead Free Electrodeposits in Tin/Lead Solder

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Introduction

Recent legislative efforts[1] and customer requests have driven the need for development of lead free electrodeposits for electronic connectors. This report reviews solderability qualification experiments performed on these new coatings to demonstrate backwards compatibility of lead free platings with tin/lead reflow solder processes.

The pure tin deposits now in use by Tyco Electronics are fully backward compatible with tin/lead wave solder processes and forward compatible with lead free solder processes.[2] The pure tin coatings have also shown evidence of being fully forward compatible with future lead free solder processes.[3] Experiments reported here use tin/lead solder with tin/lead and lead free surface finishes to compare solderability performance.

Scope

Solderability experiments verify the integrity of the terminal finish and its ability to provide an active surface for soldering. While aspects such as terminal geometry and base metal can impact solderability of individual products, their effects are insignificant when compared to the effects of changing the terminal finish. The testing included in this report was performed on production plated contacts using tin and tin/lead coatings. These contacts were selected to be representative of the plating manufacturing processes used at Tyco Electronics. As such, the results provided below are expected to be valid for the majority of wave solderable and surface mount solderable components.

Test Method

A variety of testing has been performed to look at solderability of these coatings.[2] All testing in this report was performed using a Robotic Process Systems, Inc. wetting beam balance in accordance with the method described in the IPC/JEDEC J-STD-002B[4] specification section 4.3.1 Wetting Balance Test (Test E, leaded Components). General information on the theory behind this type of testing can be found elsewhere.[5] The wetting beam balance testing parameters are shown in Table 1. A key exception in this testing to IPC/JEDEC J-STD-002B was the solder pot temperature used (i.e. 220 °C). This was done to simulate the temperature of a tin/lead solder reflow operation.

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[1] EU directives that apply are ELV (2000/53/EC), RoHS (2002/95/EC) and WEEE (2002/96/EC); these are available at www.tycoelectronics.com/leadfree.
[2] Tyco Electronics Publication 503-1, Solderability of lead free platings, 2004.
[3] Garner, C.M., et al, 2000 Electronics Packaging technology Conference, IEEE, pp 6-9.
[4] IPC/JEDEC J-STD-002B specification – 4.3.1 Test E Wetting Balance Test (leaded components).
[5] 'Soldering in Electronics: A Comprehensive Treatise on Soldering Technology for Surface Mounting and Through-Hole Techniques 2nd edition', R. J. Wassink, R. J. Klein Wassink, Feb. 1997, ISBN 09115024X.

Table 1: Wetting Beam Balance Test Conditions	
Test Parameter	Value
immersion speed:	25.4 mm/s
immersion depth:	3 mm
flux approved for J-STD-002B:	Kester 182 (slightly activated)
number of replicate specimens tested per type:	30
solder:	63/37 Sn/Pb
solder temperature:	220 °C

The wetting beam balance test method, as specified in IPC/JEDEC002B, has three critical measurements for each test: zero cross time (T0), force at 2 seconds (F2) and force at 5 seconds (F5). Zero cross time indicates the speed of wetting, while F2 and F5 quantify the degree of wetting and identify plating that may be susceptible to dewetting.

Materials and Samples:

The samples examined in this work use either bright 93/7 tin/lead or matte tin as the lead free electrodeposit[6]. There were two different Tyco Electronics product part numbers used which were similar in style and dimension. These products were readily available in both tin/lead and lead free plating versions and are representative of many components in the Tyco Electronics catalog.

A nickel underplate, 1.27 – 2.5 μm (50-100 μin) thick, was used with all samples. Both the pure tin and 93/7 Sn Pb electrodeposit thicknesses were in the range of 2.5 – 5 μm (100-200 μin). Table 2 shows the two different sample combinations tested.

Table 2: Two Unique Samples Tested by Wetting Beam Balance		
Sn based deposit metal	Sn deposit type	Base metal
pure tin	matte	nickel over C26000 (CuZn30)
93/7 tin/lead	bright	nickel over C51000 (CuSn5)

Results:

The relevant pass/fail criteria are listed relative to the suggested evaluation limits (as per IPC/JEDEC J-STD-002B specification section 4.3.1 Wetting Balance Test) are:

T_0 - time to zero cross-over (the time it takes for the wetting force to cross-over from a negative to a positive value)
F2 - Wetting Force at 2 seconds (the wetting force 2 seconds into the test)
F5 - Wetting Force at 5 seconds (the wetting force 5 seconds into the test)

[6] The bright tin/lead was deposited using Rohm and Haas Solderon SC and the matte tin plating was created using Tyco Electronics Lead Free plating bath A, as per Tyco Electronics specification 112-65-1.

The suggested evaluation criteria[7] for **F2** (and indirectly **F5**) is '50% of the Maximum Theoretical Wetting Force' (50%MTWF) and is calculated as follows (as per IPC/JEDEC J-STD-002B):

$$50\%MTWF = (\mathbf{t})(P)(\cos\alpha) - (\mathbf{d})(\mathbf{g})(V)$$

where:

t = surface tension of the solder = 0.4 joules/m^2
P = specimen/solder surface periphery in mm
α = optimal wetting angle = 0°
d = density of the solder @ 220 °C = 8001 kg/m^3
g = gravitational constant = 9.8 m/s^2
V = volume of immersed specimen at the maximum immersion depth

P [mm] and V [m^3] and are calculated from the geometry of the base part being tested. The calculated base part 50%MTWF values for the specimens used in this study are 177 μN/mm for the pure tin samples and 170 μN/mm for the 93/7 tin/lead samples.

The wetting beam balance test data are presented in Figures 1 and 2 for the matte tin and bright tin/lead deposits, respectively.

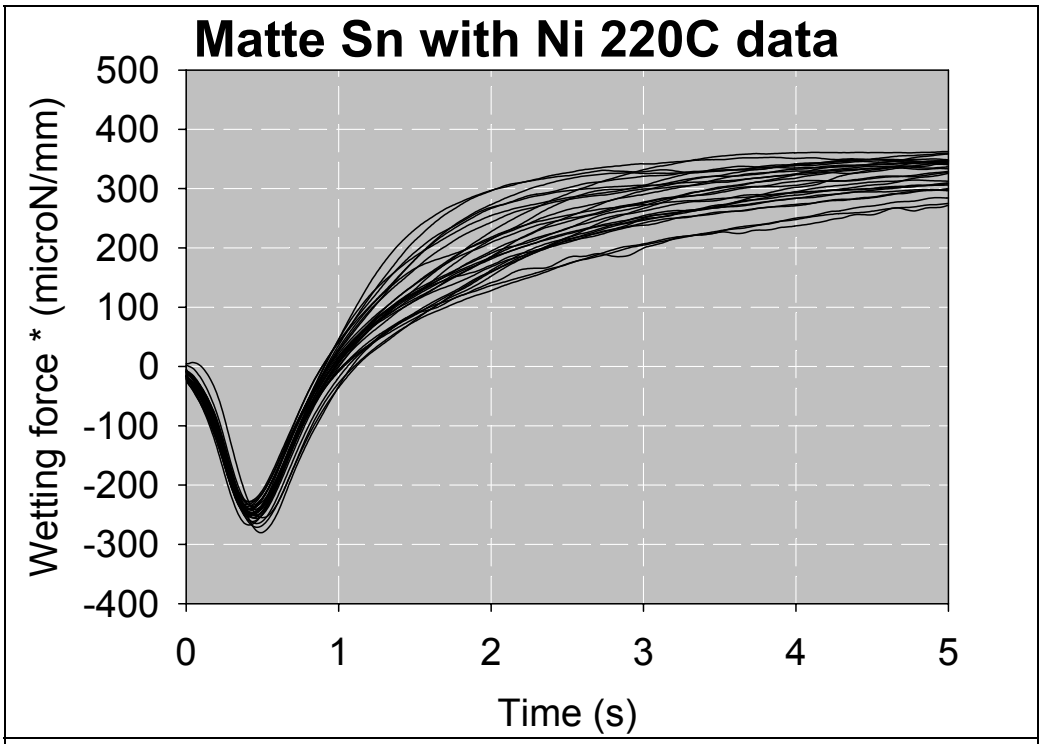

Figure 1. Collection of wetting beam balance curves for matte pure tin plating over nickel submerged in tin/lead solder at 220 °C.

[7] From IPC/JEDEC J-STD-002B

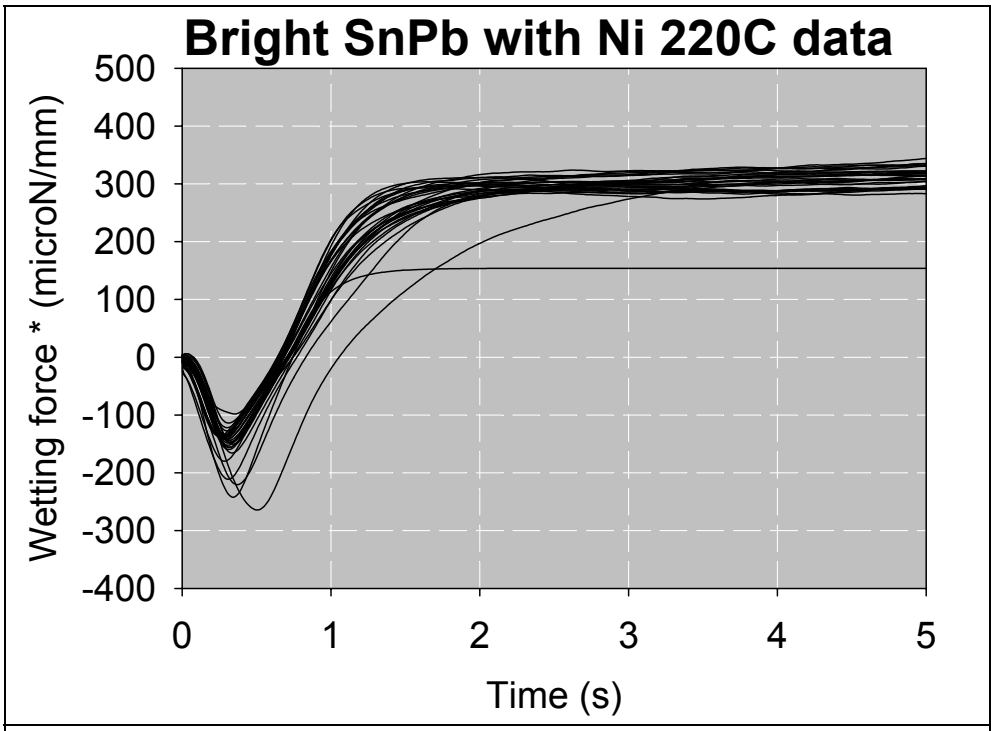

Figure 2. Collection of wetting beam balance curves for bright 93/7 tin/lead plating over nickel submerged in tin/lead solder at 220 °C.

Discussion:

When comparing the solderability performance of the pure tin vs. 93/7 tin/lead deposits:

T_0:
The 93/7 tin/lead deposits wet faster (0.69 seconds, σ=0.08) than the pure tin deposits (0.96 seconds, σ=0.06). One of the 93/7 tin/lead samples had a zero cross time greater than one second, while 7 of the pure tin samples had a zero cross time greater than 1 second. All of the samples had a zero cross time of less than 2 seconds.

F2:
The wetting force of the 93/7 tin/lead deposits at 2 seconds (285 uN/mm, σ=32) is larger than the wetting force of pure tin deposits (203 uN/mm, σ=49). One of the 93/7 tin/lead samples had a force at 2 seconds less than 50% of the MTWF, while 9 of the pure tin samples had a force at 2 seconds less than 50% of the MTWF. All of the samples had a positive wetting force at 2 seconds.

F5:
The wetting force of the pure tin deposits at 5 seconds (326 uN/mm, σ=26) is larger than the wetting force of 93/7 tin/lead deposits (306 uN/mm, σ=33). All of the pure tin samples had a wetting force at 5 seconds that was greater than the wetting force at 2 seconds. 2 of the 93/7 tin/lead samples had a wetting force at 5 seconds lower than the wetting force at 2 seconds. This reduction in wetting force is small, less than 3% of the total wetting force and does not indicate significant dewetting of the solder.

In summary, the 93/7 tin/lead deposits initially wet faster. However, as the test proceeds, the pure tin deposits exhibit a greater wetting force than the 93/7 tin/lead deposits.

Conclusions:

1) Pure tin plated components show excellent solderability and are backwards compatible with tin/lead solder processes.

2) 93/7 tin/lead deposits initially wet faster than pure tin. However, as the test proceeds, the pure tin deposits exhibit a greater wetting force than the 93/7 tin/lead deposits.

Additional information on our lead free products can be found on our website:
http://www.tycoelectronics.com/leadfree