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503–1

TECHNICAL REPORT

Revised: August 23, 2004

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Solderability of Lead–Free Electrodeposits

In This Report:

Abstract

This report gives confidence that matte and bright tin plating (lead free) performs as well as the currently accepted matte and bright tin/lead plating in soldering processes, and that matte and bright tin plating passes industry soldering requirements when processed in a tin/lead *or* tin–based (lead–free) soldering bath.

Introduction

Recent legislative efforts[1] and customer requests have driven the need for lead–free electrodeposits (platings) used in electronic connectors. Using lead–free plating gives a pure tin plate, and such a tin plating scheme has been used as a solderable electrodeposit for many years at Tyco Electronics. However, because tin plating with a matte finish is new to many of our customers and, for the high–reliability user, tin plating with a bright finish is the chosen standard[2], an evaluation was warranted to prove that matte and bright tin plating is capable of being used successfully with existing tin/lead solder processing, making it backwards compatible, and with tin–based solder processing, making it forward compatible.[3]

Three tests are covered in this report. Test 1 and Test 2 used lead–free plated specimens processed in tin/lead solder and lead–free solder. The lead–free solder was composed of tin/silver/copper; however, the results are more broadly applicable to most tin–based lead–free solders. Test 3 used matte and bright tin plated (lead–free) *and* matte and bright tin/lead plated specimens processed in tin/lead and lead–free solder. The bath used as a control finish for the tin/lead plating was Rohm and Haas Solderon—SC for the matte, and BHT90 for the bright. The bath used as a control finish for the tin plating was Tyco Electronics—Bath A for the matte, and Bath D for the bright. All tests were performed in accordance with the test methods and evaluation criteria detailed in IPC/EIA/JEDEC J–STD–J002B.

The solderability tests in this report verify the integrity of the finish (matte or bright) and the ability of the specimen to provide an active surface for soldering. Changing certain aspects such as geometry and base metal impact solderability; however, those effects are insignificant when compared to the effects of changing the finish. The results from these tests are expected to be valid for the majority of solderable components.

Conclusion

- Tin plated specimens wet as well as tin/lead plated specimens.
- The difference of solderability performance between matte tin plated specimens and bright tin plated specimens is indistinguishable.
- In Test 1, specimens were subjected to the solder bath/dip and look test using no steam aging (as plated), resistance to dissolution of metallization test using steam aging after 8 hours and heat aging after 16 hours using the solderability acceptance criteria established by J–STD–J002B. All specimens passed with no less than 95% coverage.
- In Test 2, specimens were subjected to the solder bath/dip and look test using no steam aging (as plated) and heat aging after 16 hours using the solderability acceptance criteria established by J–STD–J002B. All specimens passed with no less than 95% coverage.

NOTE *The specimens used in this test were taken from a three-month production trial to show the consistency and capability of matte tin plating to meet solderability requirements.*

- In Test 3, specimens were subjected to the wetting balance test using the suggested evaluation criteria established by J–STD–J002B. The tin/lead plated specimens wetted faster than the tin plated specimens in the early seconds of the test; however, the tin plated specimens showed a greater wetting force than the tin/lead plated specimens in the latter seconds of the test. Some specimens did not meet the suggested evaluation criteria under Set A (defined in J–STD–J002B); those specimens had dewetting of 1% or less. The differences in forces which caused these specimens to fall under the suggested limits were within the measurement capability of the test device.

Statistically, the bright tin plated specimens showed a better or equivalent solderability performance than the matte tin/lead plated specimens.

Technical Discussion

Test 1

Test Method and Materials

Parameters are provided in Figure 1.

Test Method	Flux	Solder	Solder Pot Temperature
Solder Bath/Dip and Look (Test B) **See Note**	KESTER 145 (25% Solids, Nonactive Rosin)	Tin/Lead (63/37)	240°C
		Lead-Free SAC 405 (95.5% Tin, 4% Silver, 0.5% Copper)	260°C
Resistance to Dissolution of Metallization (Test D) **See Note**	KESTER 145 (25% Solids, Nonactive Rosin)	Tin/Lead (63/37)	260°C
		Lead-Free SAC 405 (95.5% Tin, 4% Silver, 0.5% Copper)	280°C

Note Test for leaded components with established accept/reject criteria.

Figure 1

Conditioning

All specimens were evaluated in each of three conditionings:

1. As plated
2. After 8 hours steam aging
3. After 16 hours heat aging (at 155°C)

Specimen Properties

Quantity: 10

Details are provided in Figure 2.

Base Metal	Plating See Note	Centerline Spacing on Strip
Phosphor Bronze (C51100)	Matte Tin	2 mm (1.54 mm Gap Between Contacts)

Note Plating only over non-press-fit portion of contact. Thickness met drawing specifications.
Bath was Tyco Electronics Bath A.

Figure 2

Result

As defined in J–STD–002B, the solderability acceptance criteria is 95% minimum wetting coverage.

Details are provided in Figure 3.

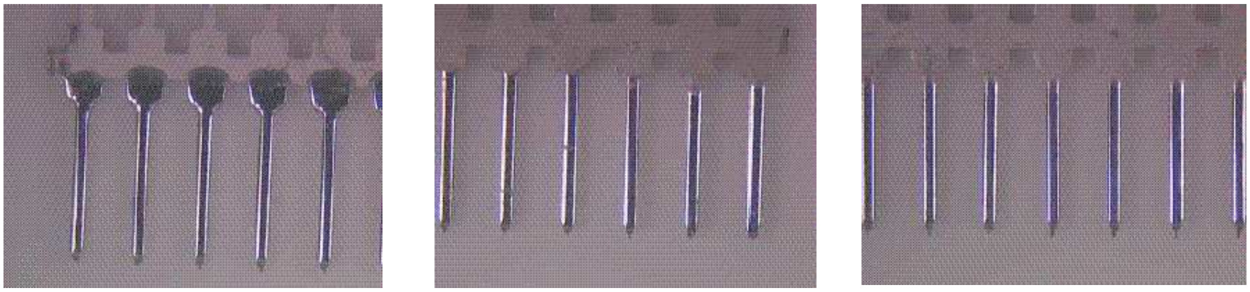
Test Method	Minimum Coverage			Accept/Reject Criteria (95% Minimum)
	As Plated	After 8 Hours Steam Aging	After 16 Hours Heat Aging	
Solder Bath/Dip and Look	≥95%	≥95%	≥95%	Accept
Resistance to Dissolution of Metallization	≥95%	≥95%	≥95%	Accept

Figure 3

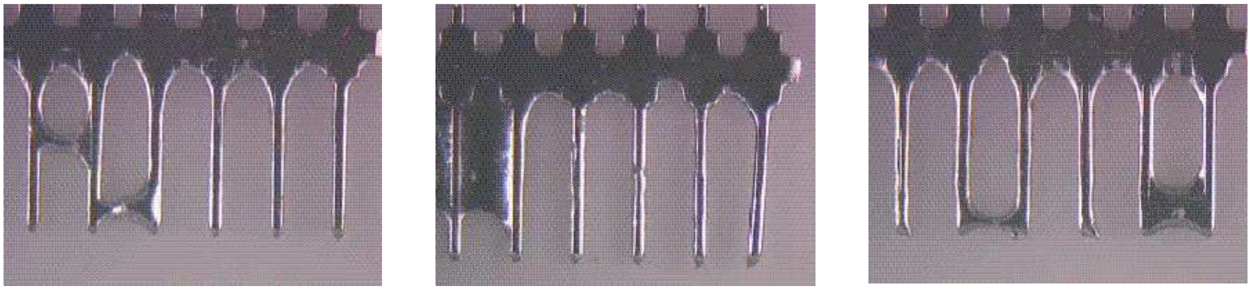
Visual results are provided in Figure 4.

Solder Bath/Dip and Look Test

Tin/Lead Solder

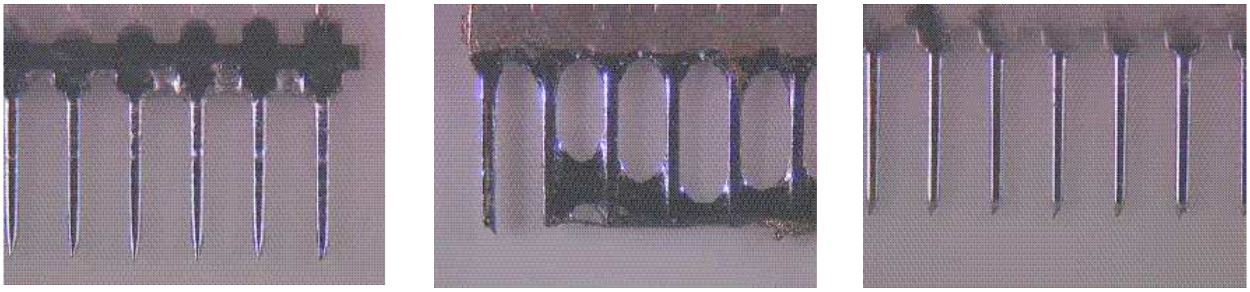

As Plated After 8 Hours Steam Aging After 16 Hours Heat Aging

Lead-Free Solder


As Plated After 8 Hours Steam Aging After 16 Hours Heat Aging

Resistance to Dissolution of Metallization Test

Tin/Lead Solder


As Plated After 8 Hours Steam Aging After 16 Hours Heat Aging

Lead-Free Solder

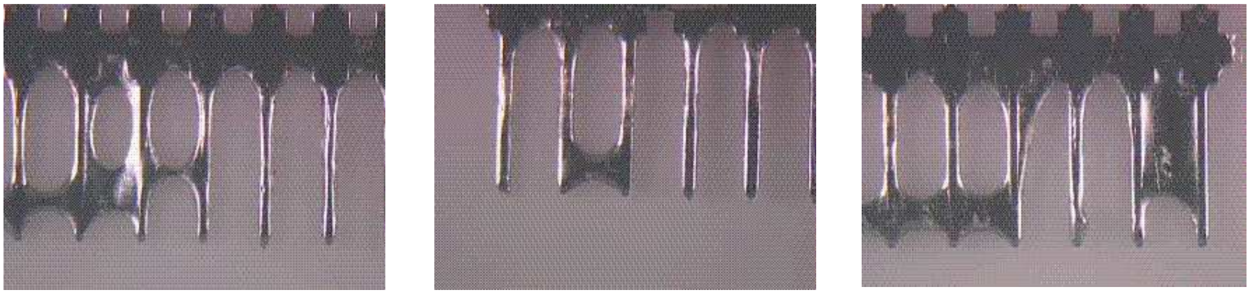

As Plated After 8 Hours Steam Aging After 16 Hours Heat Aging

Figure 4

Test 2

Test Method and Materials

Parameters are provided in Figure 5.

Test Method	Flux	Solder	Solder Pot Temperature
Solder Bath/Dip and Look (Test B) **See Note**	KESTER 145 (25% Solids, Nonactive Rosin)	Tin/Lead (63/37)	245°C

Note Test for leaded components with established accept/reject criteria.

Figure 5

Conditioning

All specimens were evaluated in each of two conditionings:

1. As plated
2. After 16 hours heat aging (at 155°C)

Specimen Properties

Quantity: 175

156 different contact part numbers taken from 6 different manufacturing production plating lines over a 3–month period

Details are provided in Figure 6.

Base Metal See Note 1	Centerline Spacing on Strip	Plating See Note 2
Copper/Tin/Phosphorus	2.54	Matte Tin
510, Phosphor Bronze 5% A	4.00	
Carbon Steel	—	
Copper/Nickel/Silicon	5.08	
301 Stainless Steel	4.00	
Cartridge Brass 70%	2.54	
519, Phosphor Bronze	2.54	
Copper Magnesium	2.54	
194, High Copper 100-265	2.54	
274, Yellow Brass 63%	2.54	

Note 1 Represents a sampling of all base metals. Multiple specimens were used for each base metal.

Note 2 Thickness met drawing specifications.
Bath was Tyco Electronics Bath A.

Figure 6

Result

As defined in J–STD–002B, the solderability acceptance criteria is 95% minimum wetting coverage.

Details are provided in Figure 7.

Minimum Coverage		Accept/Reject Criteria (95% Minimum)
As Plated	After 16 Hours Heat Aging	
≥95%	≥95%	Accept

Figure 7

Test 3

Test Method

Parameters are provided in Figure 8.

Test Method	Immersion		Flux	Solder	Solder Pot Temperature
	Speed	Depth			
Wetting Balance (Test E) **See Note**	25.4 mm Per Second	3 mm	KESTER 182 (Mildly Active Rosin)	Tin/Lead (63/37)	245°C
				Lead-Free SAC 405 (95.5% Tin, 4% Silver, 0.5% Copper)	260°C

Note Test for leaded components without established accept/reject criteria. The suggested evaluation criteria established by J-STD-J002B was used (three critical measurements were taken for this test).

Figure 8

NOTE *General information on the theory behind this type of test method can be found in Soldering in Electronics: A Comprehensive Treatise on Soldering Technology for Surface Mounting and Through-Hole Techniques (Second Edition, Feb. 1997, ISBN 09115024) by R. J. Wassink and R. J. Klein.*

Specimen Properties

Quantity: 120

4 groups (each with a unique plating) of 30 replicate contacts

Details are provided in Figure 9.

Base Metal		Plating	
Type	Thickness	Type	Thickness
Cartridge Brass (C26000, CuZn30)	1.27-2.54 mm	Matte Tin **See Note 1**	2.5-5.0 mm
Phosphor Bronze (C51100, CuSn4)		Bright Tin **See Note 1**	
Phosphor Bronze (C51100, CuSn4)		Matte Tin/Lead (93/7) **See Note 2**	
Phosphor Bronze (C51100, CuSn4)		Bright Tin/Lead (93/7) **See Note 2**	

Note 1 Bath was Tyco Electronics—Bath A for the matte, and Bath D for the bright.

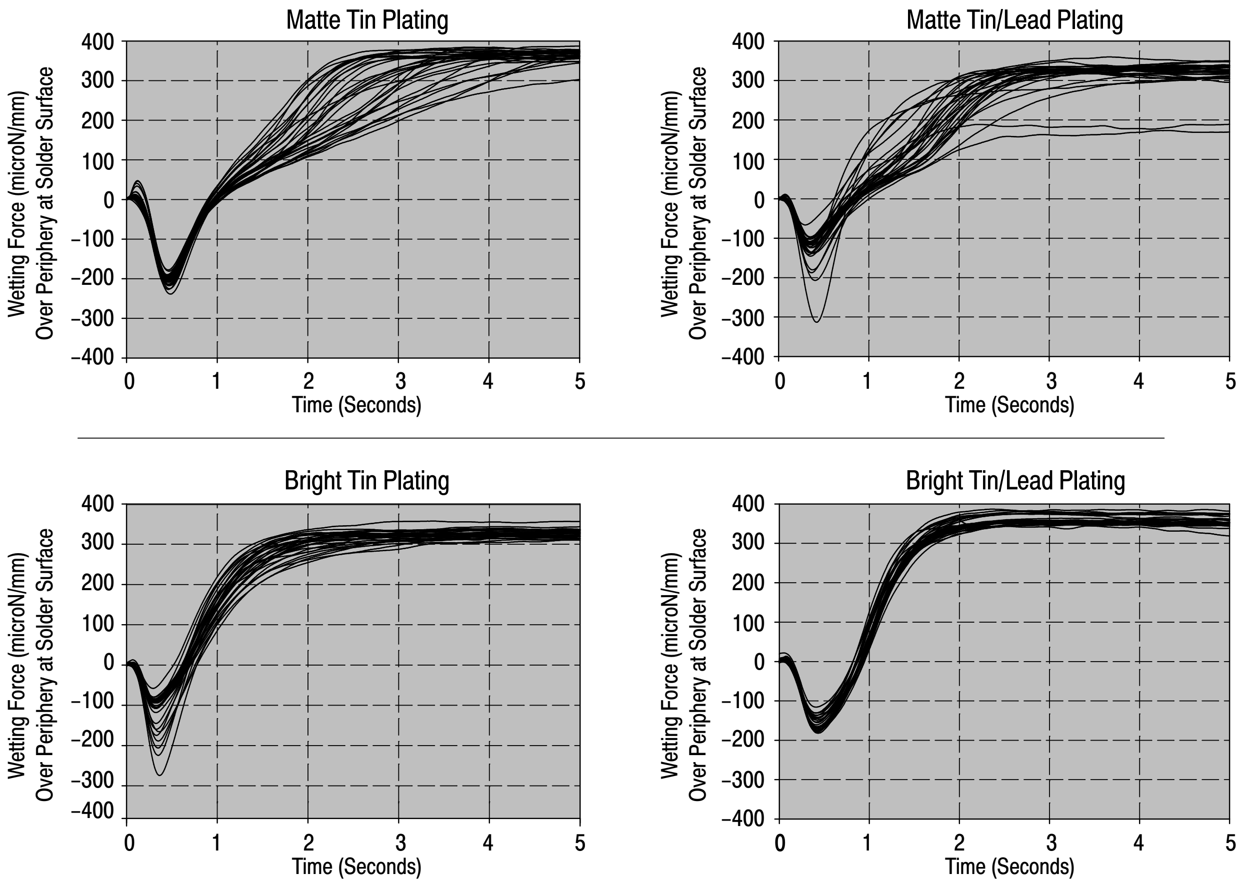
Note 2 Bath was Rohm and Haas Solderon—SC for the matte, and BHT90 for the bright.

Figure 9

Result

Graphs showing wetting forces versus time comparing matte tin to matte tin/lead platings and bright tin to bright tin/lead platings for tin/lead solder and comparing matte tin with nickel to matte tin/lead with nickel for lead–free solder are provided in Figure 10.

Wetting Force Vs Time for Tin/Lead Solder


Matte Tin Plating
Matte Tin/Lead Plating
Bright Tin Plating
Bright Tin/Lead Plating

Wetting Force Vs Time for Lead-Free Solder

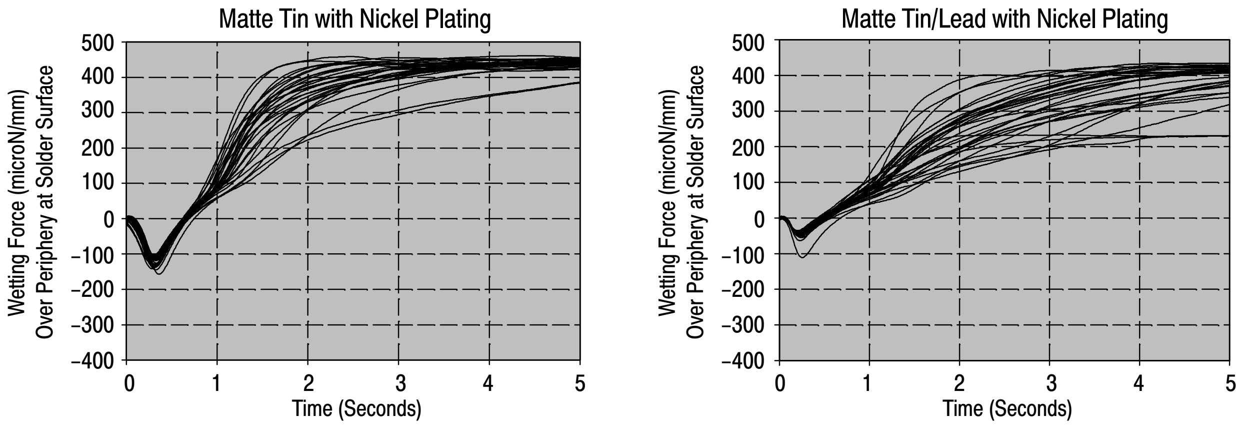

Matte Tin with Nickel Plating
Matte Tin/Lead with Nickel Plating

Figure 10

As defined in J–STD–J002B, the critical measurement and suggested evaluation criteria for solderability performance is provided in Figure 11.

Critical Measurement	**Description**	**Suggested Evaluation Criteria** **See Note 1**	
		Set A	**Set B**
T_0	Time from zero to buoyancy	Less than or equal to 1 second	Less than or equal to 2 seconds
F2	Wetting force (m N/mm) at 2 seconds from start of test	50% of maximum theoretical wetting force (MTWF) at or before 2 seconds **See Note 2**	Positive value at or before 2 seconds
F5	Wetting force (m N/mm) at 5 seconds from start of test	At or above the positive value of F2	At or above the value of F2

Note 1 Specimens meeting Set A criteria are applicable to a larger soldering process window than specimens meeting Set B criteria. It should be recognized that specimens meeting Set B criteria may be completely acceptable to a larger process window; however, the user must determine which criteria better represents their process.

Note 2 MTWF (in units of mN) is defined as: MTWF = (t)(P)(cosine α) − (d)(g)(V)

Where: t = surface tension of solder
P = specimen/solder surface periphery in millimeters
α = optimal wetting angle is 0^0
d = density of the solder at temperature
g = gravitational constant equals 9.8 m/s^2
V = volume of specimen at the maximum immersion depth in cubic millimeters

Where P and V are calculated from the geometry of the base part being tested, the calculated base part 50%MTWF for the specimens used in this test are 177 and 170 μN/mm.

Figure 11

Details are provided in Figure 12.

Tin/Lead Solder

Critical Measurement	**Suggested Evaluation Criteria**							
	Set A				**Set B**			
	Tin Plating		**Tin/Lead Plating**		**Tin Plating**		**Tin/Lead Plating**	
	Matte	**Bright**	**Matte**	**Bright**	**Matte**	**Bright**	**Matte**	**Bright**
T_0	Fail	Pass	Pass	Pass	Pass	Pass	Pass	Pass
F2	Fail	Pass	Fail	Pass	Pass	Pass	Pass	Pass
F5	Pass	Pass	Pass	Pass	Pass	Fail■	Fail■	Pass

■ Each failure represents 1 out of 30 data points and had dewetting of 1% or less.

Lead-Free Solder

Critical Measurement	**Suggested Evaluation Criteria**			
	Set A		**Set B**	
	Matte Tin Plating	**Matte Tin/Lead Plating**	**Matte Tin Plating**	**Matte Tin/Lead Plating**
T_0	Pass	Pass	Pass	Pass
F2	Pass	Fail	Pass	Pass
F5	Pass	Pass	Pass	Pass

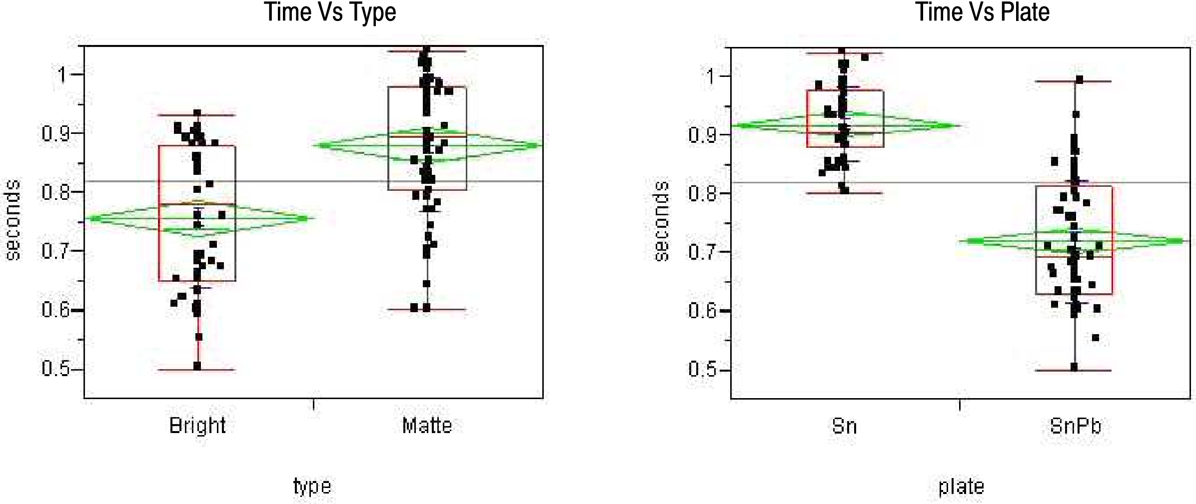
Figure 12

Box plots showing solderability performance for tin–lead solder in time, wetting force, and wetting time versus type (matte and bright) and plate (tin and tin/lead) for each of the three critical measurements (T_0, F2, and F5) are provided in Figure 13.

Box plots showing solderability performance for lead–free solder and matte tin plated specimens in time and wetting force for each of the three critical measurements (T_0, F2, and F5) for are provided in Figure 14.

Tin/Lead Solder

T_0
(Time From Start)



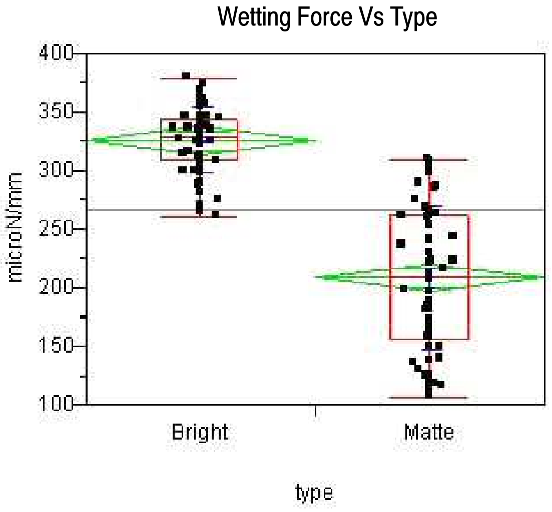
Shows the <u>statistically better</u> T_0 solderability performance of bright platings over matte platings.

Shows the <u>statistically better</u> T_0 solderability performance of tin/lead (Sn/Pb) platings over pure tin (Sn) platings.

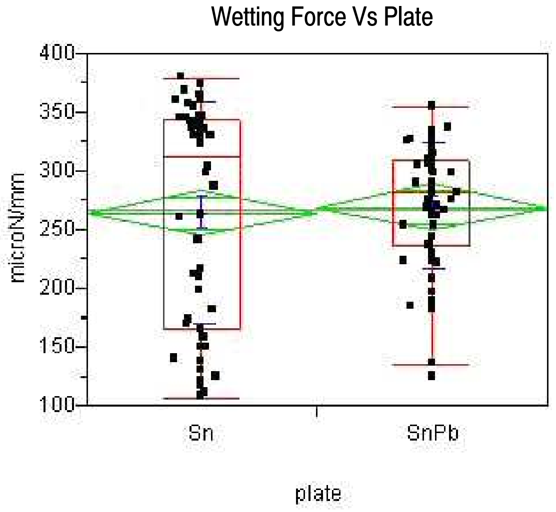
Figure 13 (Cont'd)

Tin/Lead Solder

F2
(Wetting Force at 2 Seconds)

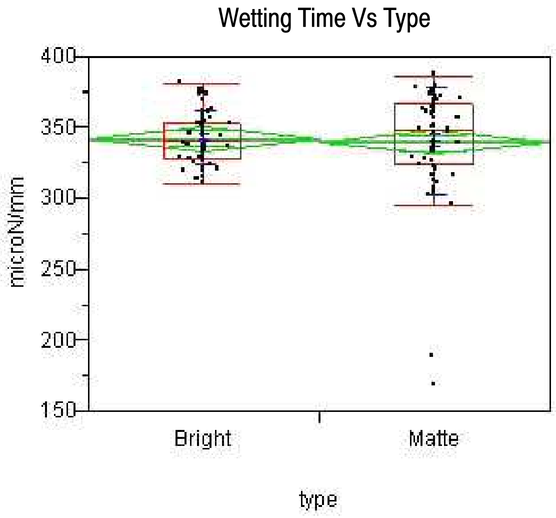


Shows the statistically better F2 solderability performance of bright platings over matte platings.

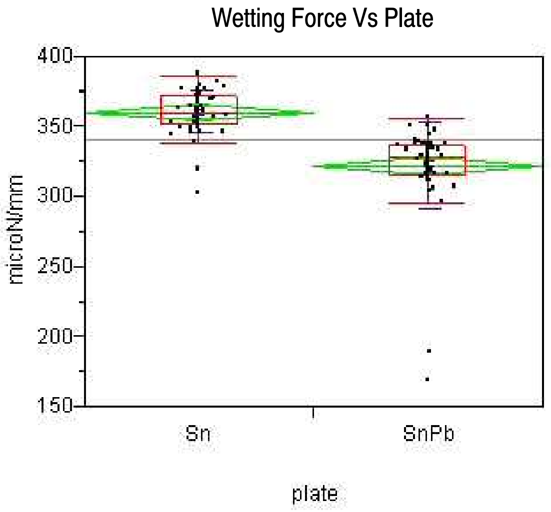


Shows the statistically equivalent F2 solderability performance of pure tin (Sn) platings with tin/lead (Sn/Pb) platings.

F5
(Wetting Force at 5 Seconds)



Shows the statistically equivalent F5 solderability performance of bright platings with matte platings.

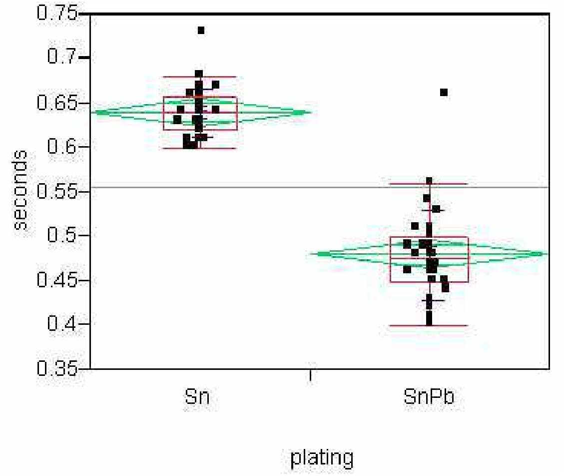


Shows the statistically better F5 solderability performance of pure tin (Sn) platings over tin/lead (Sn/Pb) platings.

Figure 13 (End)

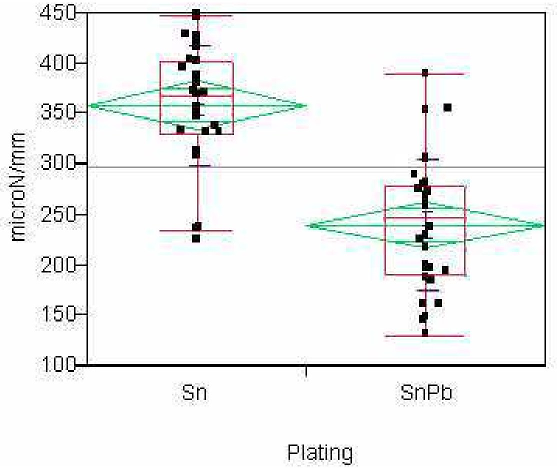
Lead-Free Solder

T_0
(Time From Start)



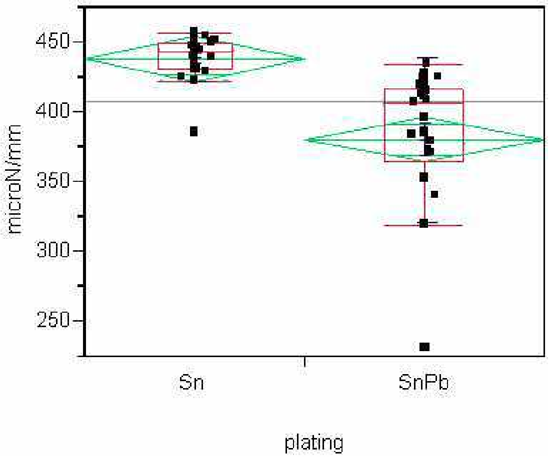
Shows the statistically inferior T_0 solderability performance of pure tin (Sn) platings compared to matte tin/lead (SnPb) platings. Time for both finishes was less than 1 second.

F2
(Wetting Force at 2 Seconds)



Shows the statistically better F2 solderability performance of matte tin (Sn) platings over matte tin/lead (SnPb) platings. Thus, pure tin platings are more forcefully wet by lead-free solders than by matte tin/lead platings.

F5
(Wetting Force at 5 Seconds)



Shows the statistically better F5 solderability performance of matte tin (Sn) platings over matte tin/lead (SnPb) platings. Thus, pure tin platings are more forcefully wet by lead-free solder than by matte tin/lead platings. The standard deviation of the pure tin plated parts is tighter than the matte tin/lead plated parts.

Figure 14

References

[1] EU Directives: ELV (2000/53/EC), RoHS (2002/95/EC) and WEEE (2002/96/EC). Available from http://www.tycoelectronics.com/leadfree.

[2] NEMI Tin Wisker User Group. Interim Recommendations on Lead–Free Finishes for Components Used in High–Reliability Products, March 2004. Available from ftp://nemi.org/webdownload/projects/ese/TW_User_Group_position0304.pdf.

[3] Garner, C.M. et al. 2000. Electronics Packaging Technology Conference, IEEE, pp 6–9.