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MOISTURE AND AGING EFFECTS ON SOLDER WETTABILITY OF COPPER SURFACES

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ABSTRACT

Solderability is a critical property of electronic assembly that affects both manufacturing efficiency and product reliability. There is often a considerable time interval between the initial fabrication of a circuit board or component and its use at the assembly level. Parts are often stored under a variety of conditions, usually not controlled. Solder wettability can soon deteriorate during storage, especially in extreme environments. This paper describes the ongoing efforts at Sandia National Laboratories to quantify solder wettability on bare and aged copper surfaces. In addition, organic solderability preservatives (OSP's) were applied to the bare copper to retard solderability loss due to the aging environment. The OSP's generally performed well, although wetting did decrease with increasing exposure times.

INTRODUCTION

In an ideal manufacturing situation, components and circuit boards are brought together for assembly in perfectly clean conditions and remain so throughout the process. This is rarely the case. In reality, oxides and other nonmetallic compounds are usually present on surfaces that have been exposed to ambient atmospheres. These will often interfere with or inhibit solder wettability. The principal material used in joining electronic components is copper due to its high electrical conductivity (Ref. 1). Storing copper ages the surface. The primary aging process is oxidation, and the resulting oxide layer reduces solderability (Ref. 2).

The ability of a material to be wetted with solder is known as solderability. Solderability depends partly on the inherent character of the materials to be used, partly on the cleanliness of the surfaces after fabrication and partly on the aging by environmental attack during storage (Ref. 3). Perhaps the most common cause of solderability difficulties is related to the loss of wettability as a component ages between assembly steps. The intent of artificial accelerated aging is to increase the rates of the processes involved in solderability degradation so that their effects can be ascertained in a short period of time. Generally, solderability tests are performed after representative parts have been exposed to elevated temperature and/or humidity for a specified time period. There are three general types of accelerated aging: dry heat, humid heat and steam aging. The goal of each of these tests is to predict the solderability for a given storage time (Ref. 4).

In order to ensure an adequate level of solderability, especially after aging, some measures can be taken. One potential approach is to coat bare copper with an OSP. Although they are not new to the electronics industry, solder wettability can be maintained for extended periods of storage with these preservatives. They have been used primarily to inhibit chemical reactions between the ambient environment and conductive metallic surfaces on printed wiring boards (PWB's) (Ref. 5).

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A number of evaluation methods are available to determine solder wettability. They include the wetting balance method, globule method, rotary dip method and meniscus rise method to name a few. In this case, the wetting balance was used to quantify solder wettability. It is designed to furnish quantitative data on the wetting of a substrate by a molten metal under a closely specified set of conditions. The rate at which substrates and components are wetted by a filler metal and the degree of wetting or spreading are critical to solderability assessment.

MATERIALS AND TEST PROCEDURE

Oxygen free, high conductivity copper (OFHC Cu) was selected as the base material for the study. Test coupons were sheared from 0.25 mm wrought sheet stock. The test geometry was 25 mm x 25 mm square. The Cu samples were degreased in acetone, rinsed in isopropyl alcohol and air dried. They were then etched for three minutes in a 10% solution of hydrochloric acid and deionized water, rinsed in deionized water and rinsed a final time in isopropyl alcohol. They were then dried with technical grade nitrogen.

Two different organic solderability preservatives were selected for this experiment. The first was a 0.033 molar solution of benzotriazole (BTA) dissolved in methanol, while the second was a 0.033 molar solution of imidazole dissolved in isopropyl alcohol. The Cu coupons were immersed in the preservative for sixty seconds immediately following the etching procedure. They were then rinsed in isopropyl alcohol and again dried with technical grade nitrogen.

The coupons were aged in Sandia's Facility for Atmospheric Corrosion Testing (FACT) to simulate a typical indoor industrial environment. The test simulates corrosion and oxidation of electronic contact and connector materials (Ref. 6). The atmosphere consisted of 10 ppb H_2S, 200 ppb NO_2 and 10 ppb Cl_2 at 35°C and 70% relative humidity. This environment produces chloride-driven pore corrosion of thin films and is especially suitable on oxidation and sulfidation-sensitive Cu. Inhibited samples were exposed to the test atmosphere according to the following test schedule:

Test Time	Simulated Shelf Time
24 hours	260 days (8.7 months)
48 hours	521 days (17.4 months)
96 hours	1043 days (34. 8 months)
1 week	1,825 days (60.8 months)
2 weeks	10 years

Solderability testing was performed within one day of removing the coupons from the test cell. Solder wettability was then measured with a commercial wetting balance. The test method gave quantitative information on the wetting behavior of the defined test parameters. The tested substrate was held in a specimen holder, suspended from the load cell. The bath containing the molten filler metal was raised at a preselected speed to immerse the testpiece to a given depth. The bath was held in this position for a preset dwell time and then returned to its rest position (Ref. 1). Wetting force, time, and meniscus height data provide a quantitative method to compare different materials and test conditions.

Coupons were dipped into a rosin mildly activated (RMA) flux, diluted 1:1 with isopropyl alcohol, and allowed to dry for 10 minutes. All wetting balance testing was conducted at 245°C with Sn60-Pb40 solder, weight percent. They were immersed in the solder bath for 10 seconds at an immersion rate of 20 mm/second. Each wetting balance data set consisted of five samples to satisfy statistical sampling.

RESULTS AND DISCUSSION

The wetting results are summarized in Table 1. Significant differences in wetting were observed between the three different conditions. Wetting is affected by the difference between the base metal-flux and base metal-solder surface tensions. The difference, which is the force measured by the wetting balance, represents the cleanliness of the base surface and metallurgical reaction between the base metal and solder alloy. This parameter must be maximized to optimize wetting (Ref. 7). The average maximum wetting force (F_{max}), plus or minus one standard deviation is shown below in Fig. 1 for each condition. F_{max} is low on the bare copper surface and degrades very quickly with aging, indicating a contaminated surface. The BTA coated surface has higher initial wetting and degrades very slowly until week 2, when there is a significant decrease in wetting. Wetting of the imidazole coated surface is high and remains so throughout the aging process. Neither OSP appear to degrade solderability and good wetting is maintained, even after aging.

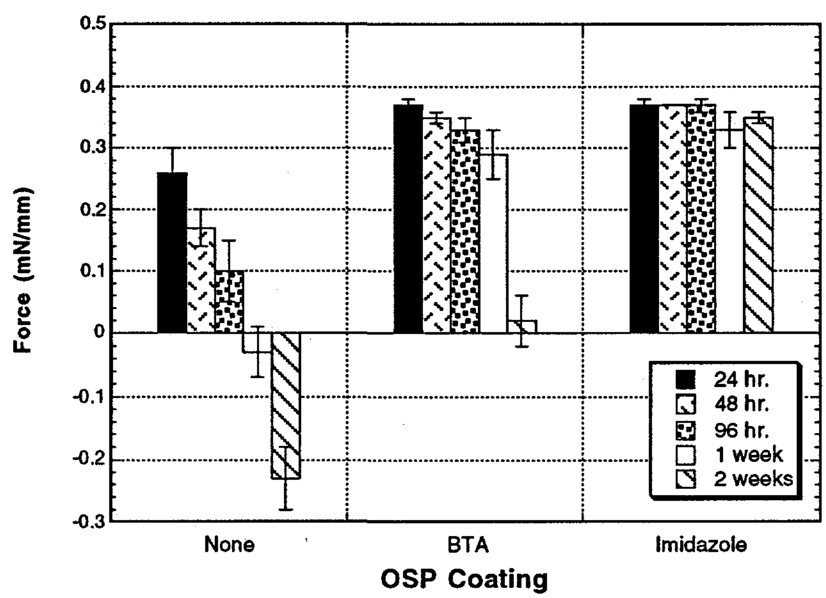

FIGURE 1. Average maximum wetting force of copper samples as a function of surface condition.

Time to 90° turnaround (solder bath perpendicular to the immersed coupon) is also a significant factor in evaluating solderability. The wetting times follow the same general trend as the maximum wetting force data. Those results are shown below in Fig. 2. It takes significantly longer times for the solder to wet the surface of a contaminated coupon than one that has been protected with an organic solderability preservative. Bare Cu took 3.77 ± 0.32 sec. after 24 hrs. to reach 90°

turnaround and increased significantly as the part was aged. There was also a larger spread in the data. After two weeks, the bare Cu had not reached 90° turnaround at the conclusion of the 10 sec. test. The BTA coated Cu had wetting times of less than four seconds for all conditions except the two week aging. Wetting time increased significantly from 3.26 ± 0.28 sec. to 8.85 ± 0.86 sec. between one week and two weeks. The imidazole coated Cu had the shortest wetting times, even after aging. The 24, 48 and 96 hr. tests wet the surface in less than two seconds, while the one and two week conditions wet in less than three seconds.

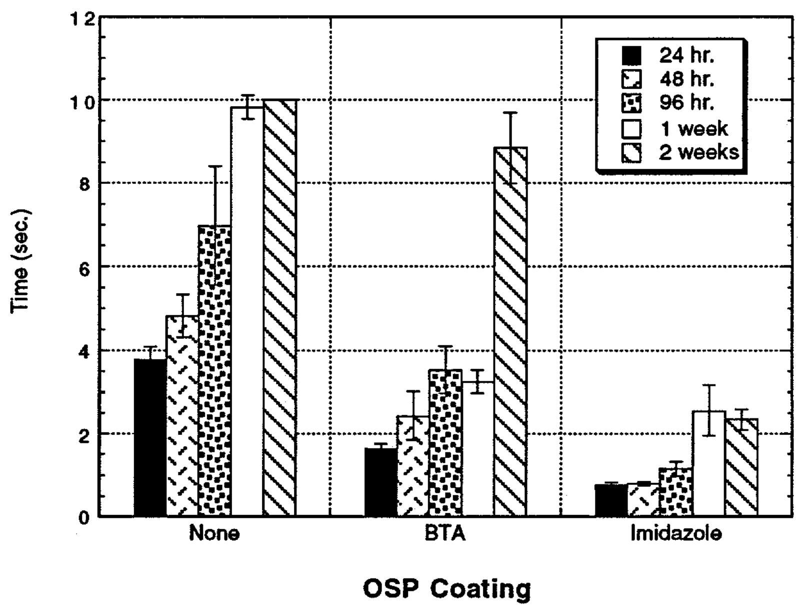

FIGURE 2. Average time to 90° turnaround as a function of surface condition.

CONCLUSIONS

Organic solderability preservatives appear to combat the effects of moisture and aging on copper surfaces that are stored for extended periods of time and offer the potential for retaining solderability. Moisture effects on bare copper are immediately apparent. Solderability is decreased after only 24 hrs. aging and degraded completely after 96 hrs. Although wetting was somewhat slower with BTA than imidazole, both OSP's offer good alternatives to storing bare copper in a production environment. The imidazole performed better than the BTA, especially after two weeks.

ACKNOWLEDGMENTS

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Table 1.

Wetting Data of OSP Coated and Bare Cu Samples

OSP Coating	F_{max} (mN/mm)	Time to 90° Wetting (sec.)	Time to 2/3 F_{max} (sec.)	Time to Max. Wetting (sec.)
None-24 hr.	0.26 ± 0.04	3.77 ± 0.32	7.15 ± 0.43	10
None-48 hr.	0.17 ± 0.03	4.82 ± 0.51	8.14 ± 0.44	10
None-96 hr.	0.10 ± 0.05	6.98 ± 1.42	9.11 ± 0.56	10
None-1 week	-0.03 ± 0.04	9.83 ± 0.29	10	10
None-2 weeks	-0.23 ± 0.05	10	10	10
BTA-24 hr.	0.37 ± 0.01	1.63 ± 0.13	3.89 ± 0.27	10
BTA-48 hr.	0.35 ± 0.01	2.43 ± 0.58	4.77 ± 0.85	10
BTA-96 hr.	0.33 ± 0.02	3.54 ± 0.56	6.51 ± 0.57	10
BTA-1 week	0.29 ± 0.04	3.26 ± 0.28	6.32 ± 0.31	10
BTA-2 weeks	0.02 ± 0.04	8.85 ± 0.86	9.94 ± 0.16	10
Imidazole-24 hr.	0.37 ± 0.01	0.76 ± 0.06	1.40 ± 0.12	5.10 ± 0.39
Imidazole-48 hr.	0.37 ± 0.00	0.80 ± 0.05	1.66 ± 0.15	7.98 ± 1.26
Imidazole-96 hr.	0.37 ± 0.01	1.16 ± 0.18	2.90 ± 0.56	9.36 ± 1.01
Imidazole-1 week	0.33 ± 0.03	2.56 ± 0.61	5.89 ± 0.90	9.88 ± 0.18
Imidazole-2 weeks	0.35 ± 0.01	2.35 ± 0.25	5.33 ± 0.72	9.98 ± 0.04