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EFFECTS OF PRE-STRESSING AND FLUX ON THE FLOW OF SOLDER ON PWB COPPER SURFACES

by

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ABSTRACT

A variety of test methods are available to evaluate the solderability of printed wiring board [PWB] surface finishes. A new test has been developed which better simulates the capillary flow physics of typical solder assembly processing, especially surface mount soldering. The work was conducted under a cooperative research and development agreement between Sandia National Laboratories, the National Center for Manufacturing Sciences, and several PWB fabricators (AT&T, IBM, Texas Instruments, and United Technologies Corporation/Hamilton Standard) to advance PWB interconnect systems technology. Particular attention has been given at Sandia to characterizing the effects of accelerated aging in a simulated indoor industrial environment on subsequent PWB solderability. The program's baseline surface finish was copper. Solderability testing on "as-fabricated" and "pre-stressed copper" pad-strip geometries was performed with Sn-Pb eutectic solder and three different fluxes at four different reflow temperatures.

INTRODUCTION

With the push toward more environmentally compatible processes, a variety of fluxes have been evaluated for solder wettability. There is substantial interest in evaluating low solids and no-clean fluxes that are environmentally friendly and minimize hazardous chemical use. Although flux type is an important environmental concern, wetting is essential to the soldering process. Solder fluxes are used to promote wetting by allowing the solder to come into intimate contact with the base metal forming a true metallurgical bond [Ref. 1]. The effectiveness of a rosin mildly activated (RMA) flux, low solids (LS) flux, and citric acid-based (CA) flux were all evaluated in this investigation.

Flux residues are also a concern, since most solvents used to remove them are typically environmentally hazardous. Washing or cleaning printed circuit boards is necessary to remove flux residues which are left after soldering. The need for cleaning is closely related to the choice of flux. Flux residues may remain on the board or must be removed. The major constituent in a solder flux that contributes to residue on a board is the percentage of solids in the flux. Solids comprise the rosin and the activator [Ref 2]. Organic solvents are often necessary to remove RMA flux residues. They are not biologically degradable and have potential environmental effects on both ground water and the atmosphere [Ref. 1]. The CA flux, on the other hand is water soluble and can be removed with hot water.

Since flux type affects the solderability of different PWB surface finishes, Sandia National Laboratories' Center for Solder Science and Technology has been characterizing capillary flow on baseline and pre-stressed

test coupons. One of the objectives of this study was to quantify storage effects on solder wettability. Environmental stressing is a very discriminating way to determine the materials and processing effects on solder wettability. The capillary flow test vehicle (CFTV) used in this study is especially sensitive to evaluating different processing conditions. Common to the CFTV's geometry is a metal strip of width δ, connected to a circular base pad having radius r. Theoretical and experimental analyses suggest that a line width to pad radius ratio (δ/r) of 0.5 or greater is necessary for solder to flow onto the strip [Ref 3].

MATERIALS AND TEST PROCEDURE

The capillary flow test vehicle was fabricated using conventional PWB materials and fabrication technologies. The CFTV substrate was an epoxy resin laminate, 0.060" thick, reinforced with glass fiber cloth (FR-4). Copper patterns (0.5 oz.) were printed and etched per the specified "lollipop" test geometry. Additional copper was electrodeposited on the vendor-etched Cu to a final conductor thickness of 35 μm [1 oz. Cu].

Latex gloves were used when handling individual specimens to minimize contamination from oils, greases and other foreign debris. Teflon coated tweezers were used to transport all samples.

The CFTV design is illustrated in Figure 1. The substrate has duplicate test patterns with line width-to-pad ratios (δ/r) of 0.25, 0.50, 0.75 and 1.0. The pad radius is a constant 0.040" with line widths of 0.010, 0.020, 0.030 and 0.040". The maximum line length or possible capillary flow is 1.5" or 38 mm. One millimeter reference marks were also patterned onto the test board. An azole-based organic solderability preservative (OSP) was also deposited onto the bare copper surfaces to retain solderability during subsequent storage and handling prior to testing.

The substrates were pre-cleaned by degreasing in trichloroethylene followed by an isopropyl alcohol rinse. A commercially available OSP was applied to the test coupons by the manufacturer at the time of fabrication and was not removed for this study in order to assess the effects of environmental aging on solderability. Capillary flow experiments were conducted with eutectic Sn-Pb (Sn63-Pb37, wt.%) solder pellets. As noted earlier, three types of fluxes were selected for the study based on current industry needs and trends. The RMA flux was diluted to 25% solids for this study.

Test boards were coated with flux immediately following the cleaning procedure. A Q-tip was used to saturate the test board with flux. Solder pellets of known weight were dipped in flux and placed on the center of the flux-coated pads. Based on previous experiments, the flux was allowed to dry for 30 minutes prior to testing, since a preheat was not incorporated into the original test procedure. This significantly improved the capillary flow results by permitting the alcohol carrier in the flux to completely evaporate [Ref. 4].

Accelerated aging was performed in a flowing mixed gas (FMG) chamber. The test simulates corrosion and oxidation of electronic contact and connector materials [Ref. 5]. A Class II environment was chosen for the study that closely simulates exposure to a typical indoor industrial environment. The atmosphere consists of 10 ppb H_2S, 200 ppb NO_2, and 10 ppb Cl_2 at 35°C and 70% relative humidity. The Class II environment produces chloride-driven pore corrosion of thin films and is especially suitable on oxidation and sulfidation-sensitive Cu [Ref. 5]. Samples were exposed to the Class II atmosphere to simulate an eighteen month shelf life.

Capillary flow tests were conducted by floating samples on a standard thermostatically controlled solder pot. Test temperatures of 215, 230, 245 and 260°C ± 2°C were used for this experiment. The CA flux was tested only at 245°C. CFTV's were floated for 90 seconds to capture the complete wetting event. Samples were then carefully removed from the solder bath, minimizing agitation of the molten solder on the test pads and strips. RMA and LS flux residues were removed by ultrasonically cleaning in trichloroethylene and isopropyl alcohol. The CA flux residue was removed with flowing hot tap water followed by a flowing deionized water rinse.

Capillary flow data were analyzed from recorded video images. A black and white, charged-couple device (CCD) camera and professional video tape recorder with time code generator was used to record the capillary flow test images. The solder flow images were recorded on video tape and stored on a hard disk attached to a personal computer. Digital image analyses were then conducted with a PC-based image processor and commercial image analysis software. Data was taken at 30 frames per second.

RESULTS AND DISCUSSION

Capillary flow experiments were conducted with baseline and class II aging conditions. The effects of temperature and flux type were investigated. Wetting results are summarized in Table 1.

Under baseline conditions, capillary flow was minimal at the lowest temperatures with all fluxes. Wetting increased with temperature at all linewidths at both the baseline and pre-stressing conditions. The RMA flux had the best wettability, although repeatability was somewhat diminished from sample to sample. Poor wetting and poor repeatability were observed with the LS flux at all temperatures. The CA flux showed moderate wetting but good repeatability from sample to sample. Baseline conditions with all fluxes at all temperatures are shown in Figure 2. Wetted distances were particularly sensitive to test temperature, especially on the finer 20 mil strip.

Under Class II conditions, even with an OSP coating on the Cu, wetted distances substantially decreased with the RMA flux. Capillary flow was somewhat diminished with the CA flux but good wetting was still obtained. The wetting peaks remain fairly constant at approximately 5 mm with the LS flux before and after aging. Wetting distances decreased across all temperature ranges for all fluxes.

The 30 mil line best reflects the capillary flow trends, as predicted by the 0.5 linewidth to pad radius ratio (δ/r) relationship described earlier. The wetted distance generally peaked on the 30 mil line at each test temperature. This was particularly true for the baseline-RMA capillary flow teats (Fig 2). Figure 3 illustrates baseline versus Class II wetting with RMA flux for the 30 mil linewidth. Under these test conditions, capillary flow significantly decreased after aging. Only 10-30% of the baseline wetting distance was recovered. Increasing the test temperature on the aged coupons slightly improved solder flow.

The wetting decrease due to aging was less pronounced with the CA flux. The aged 30 and 40 mil lines yielded approximately 60% of the baseline flow distance, while the 20 mil line results were almost equivalent (Fig. 2). The improved flow results after aging were attributed to the higher activity of the CA flux. Similar results were observed on wrought copper coupons [Ref. 6].

CONCLUSIONS

A test method was developed to characterize capillary flow of typical PWB surfaces. The test is based on solder flow from a pad onto narrow strips or lines. Experiments demonstrated that capillary flow was sensitive to the ratio of pad radius to line width (δ/r), flux type and pre-stressing. The best flow results were consistently obtained with a $\delta/r = 0.5$ and a citric acid-based flux. Environmental aging generally degraded capillary flow.

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Table 1: CFTV Solderability Wetted Distances (mm)

		215°C	230°C	245°C	260°C
BASELINE (unaged)					
Flux Type	**Linewidth (mil)**				
RMA	20	0.9 ± 0.3	7.8 ± 9.9	14.5 ± 9.9	27.6 ± 4.2
RMA	30	13.8 ± 8.3	25.9 ± 2.5	25.0 ± 4.3	30.3 ± 8.4
RMA	40	13.1 ± 4.0	20.8 ± 2.1	13.5 ± 6.8	28.3 ± 1.7
LS	20	1.8 ± 1.5	2.9 ± 2.0	3.1 ± 1.9	4.5 ± 2.4
LS	30	4.1 ± 1.9	4.6 ± 1.4	5.6 ± 1.1	5.1 ± 3.0
LS	40	4.0 ± 1.6	6.0 ± 1.8	6.9 ± 1.9	6.3 ± 2.8
CA	20			18.0 ± 12.7	
CA	30			34.0 ± 4.2	
CA	40			28.5 ± 3.5	
48 Hr. CLASS II (aged)					
RMA	20	0	2.6 ± 4.6	10.4 ± 10.3	3.8 ± 6.8
RMA	30	0.8 ± 0.3	3.5 ± 3.7	6.0 ± 7.0	8.9 ± 8.8
RMA	40	3.4 ± 3.2	6.9 ± 0.8	9.9 ± 3.7	13.8 ± 3.9
LS	20	0.3 ± 0.3	1.3 ± 2.2	2.1 ± 2.3	1.3 ± 2.5
LS	30	1.1 ± 1.9	3.0 ± 2.2	3.5 ± 2.6	2.8 ± 3.2
LS	40	2.3 ± 1.5	3.4 ± 1.4	3.3 ± 3.0	6.3 ± 1.3
CA	20			17.3 ± 5.3	
CA	30			19.5 ± 4.9	
CA	40			16.5 ± 4.9	

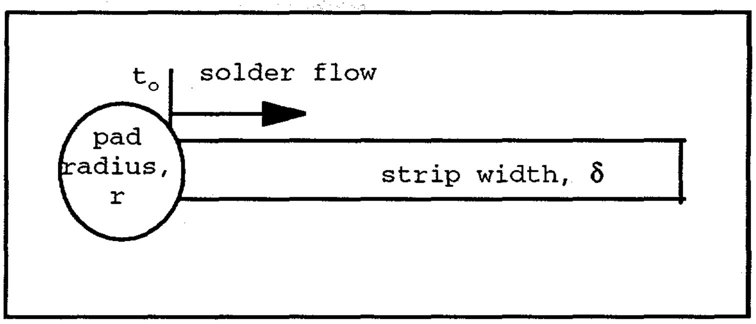

FIGURE 1. Capillary flow test geometry for controlling solder wetting. The ratio of line width to pad radius (δ/r) can be varied to control solder spreading from the metal base or pad onto the connected metal strip.

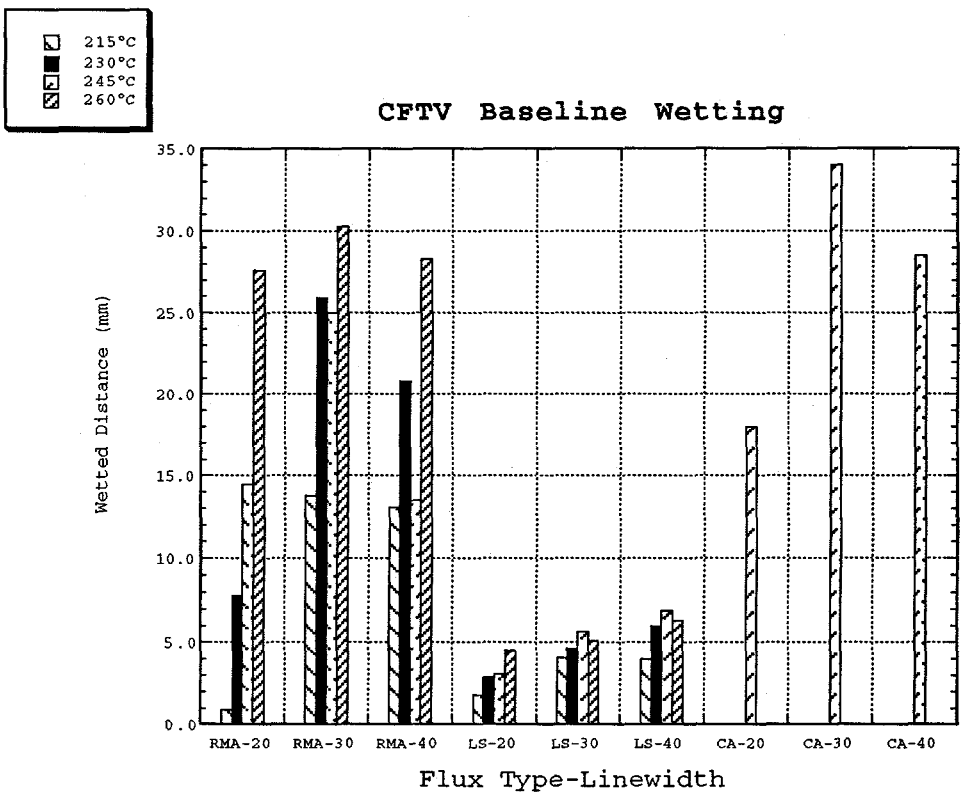

FIGURE 2. Wetted distance as a function of test geometry (line width, mm) and flux type, and test temperature.

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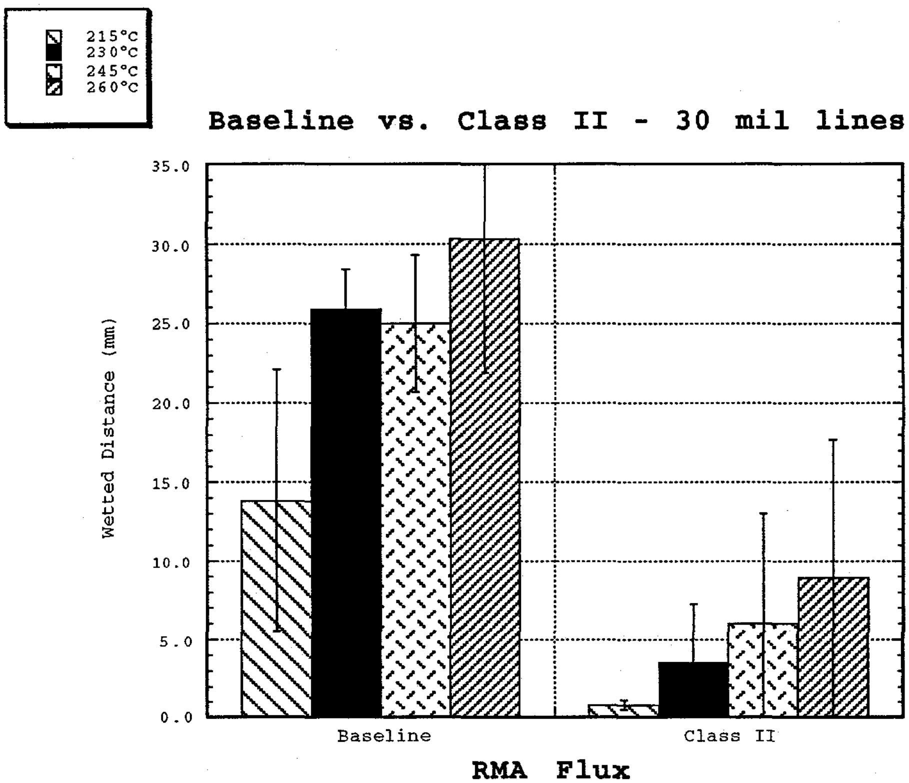

FIGURE 3. Comparison of capillary flow on a 30 mil line with Sn63-Pb37 and a RMA flux at 230°C, before (baseline) and after aging (Class II).

DISCLAIMER