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**NON-DESTRUCTIVE METHODS
FOR THE ACCEPTANCE OF
PLATING THICKNESS ON
PRINTED CIRCUIT BOARDS**

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ACCEPTANCE OF PLATING THICKNESS ON
PRINTED CIRCUIT BOARDS

By

W. B. Abel, Bendix Corporation, Kansas City Division

The Kansas City Division of The Bendix Corporation manufactures a variety of printed circuit boards as a contractor for the Atomic Energy Commission. Much of this production is characterized by short runs, small lot sizes, and expensive materials. In addition, an absolute requirement for reliability necessitates a very stringent control of the plating thickness applied to these boards. These conditions emphasize the need for speed and accuracy in the tests used for acceptance as well as the in-process control of plating thickness.

The microscopic measurement of cross-sections to determine plating thickness has some economic as well as functional disadvantages for this operation. The scrap and labor costs are high and the process is slow. Plating thickness measurements are removed from the actual plating operation by a minimum of two to three hours. The most serious disadvantage is that the test is destructive and not applicable to the actual product to be used.

The intent of this paper is to briefly and informally relate some of our experinece with several nondestructive techniques for measuring plating thickness on P.C. boards.

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The intent of this paper is to briefly and informally relate some of our experience with several nondestructive techniques for measuring plating thickness on P.C. boards.

The first method is the beta-backscatter measurement of copper thickness on the surface of P.C. board panels. Beta-backscatter is a well established technique for plating thickness measurement, and the particular probe used in these studies has a geometry as represented by the schematic. (Figure I) The beta source (Sr-90) is contained in a shielded collimator attached to a small arm extending out from the wall of the probe housing. A specimen mask is attached to the end of the probe to control the area of the sample exposed and the geiger type detector is located behind the source. The beta particles emitted from the collimator strike the sample and interact with the plating and substrate. The percentage of particles backscattered and detected by the geiger tube increases with the thickness of the copper plating. The system is calibrated by first measuring the backscatter rate from the bare-unplated substrate and then from a reference standard of known copper thickness.

As shown in Figure II (plot of count rate versus copper thickness) the sensitivity of this technique is favorable in the range from 1.5 to 3.5 mils. as indicated by the dashed line which has a slope of one. This sensitivity curve also shows that approximately 4.2 mils. of copper is the limit for accurate measurement.

Because the emission of the beta particles from the isotope source is random with time, the repeatability of this system improves with the counting time used for a single measurement. As seen in Figure III (repeatability study), two-minute measurements were not significantly better than the one-minute counting times, and

Figure 1
GEOMETRY
OF
BETA-BACKSCATTER PROBE

FIGURE II

Sensitivity - Test
Beta-Backscatter Measurement
of
Copper Thickness on P.C. Board Panels

FIGURE III

one-minute measurements have been adopted for this particular material combination.

Because of past reliance on microsectioning the evaluation of most nondestructive methods consists primarily of a comparison to the destructive test. In the first studies of the beta-backscatter method, a copper foil was laid over the substrate as a reference standard for calibration of the instrument. Thickness measurement were made with care taken to denote the exact spot so that the destructive tests could be made in the same area.

As shown in Figure IV, in every case the beta-backscatter measurement predicted a thicker copper plating than was measured by the microscopic method. The average difference was about .5 mils. with some individual samples as high as .9 mils. Several possible causes for this bias include:

- 1) density of the copper standard and the sample material,
- 2) purity of the copper standard, 3) variations in substrate composition and 4) the irregular interface between the copper foil and the substrate. All of these, except the copper purity were found to contribute in part to the poor correlation. The largest factor being the irregular interface between the copper foil and substrate as shown in Figure V. The process used to laminate the copper on the surface of the epoxy glass causes this uneven interface and is needed to improve the adhesion of the copper foil.

FIGURE IV

Correlation Study - Part 1
Measurement of Copper Thickness
on
Printed Wiring Board Panels

FIGURE V

Schematic of P.C. Board Cross-Section
Showing How the Destructive Tests
Were Measured in Parts 1 & 2

In examining a large number of cross sections, it was found that the average magnitude of this irregular condition is about 0.3 mils.

As indicated by the earlier repeatability study, these results do not represent the true capability of the beta-backscatter method. The studies were repeated using reference standards which were made from the exact same material as the samples in place of the copper foil. The thickness of these standards was established using the same destructive procedures to which beta-backscatter measurements were compared. As shown in Figure VI, the beta-backscatter measurement predicted the destructive result within $\pm .1$ mil. using this calibration technique.

A second non-destructive technique is the resistance measurement of plated through holes. In the last few years, several commercial instruments have been made available to make this type of test. The basic principle is represented by the schematic shown in Figure VII. A constant current is applied through the plated through hole by probes positioned on opposite sides of the board but on the same side of the hole diameter. Voltage or measuring probes are similarly located on the other side of the hole diameter thus forming a four-point type resistance measurement. AC current is used to eliminate the effect of DC voltages arising from the dissimilar metal contacts. A standard calibration shunt incorporated within the instrument to provide a calibration reference. Proper interpretation of

FIGURE VI

Correlation Study - Part 2

Measurement of Copper Thickness
on
Printed Wiring Board Panels

FIGURE VII

the measured resistance value for a particular hole not only gives a measure of the copper plating thickness in the hole, but also will detect any flaws which seriously affect the current carrying capability of the plating from one side of the board to the other. We have found this to be an extremely useful technique in evaluating the quality of plating on finished product, although we did find it necessary to develop a set of calibration curves for different hole diameters and board thicknesses. There is also evidence that the calibration is not consistent from instrument to instrument and we are currently working on a new probe configuration for this technique which we hope will solve this problem.

A third nondestructive test method which we have found useful is a modification of the plated through hole resistance tester. In this case, the four-point resistance measurement is applied to the path of a printed circuit board to measure the cross-sectional area of the path. Using a special probe, which has configuration as shown in Figure VIII, the constant current is applied to the path through the two probes on the outside and the other two center probes are used to measure the voltage drop or the resistance of the path is that discrete section. As expected, this technique works out very well because the actual values for resistance obtained very closely approximate the theoretical values. Figure IX shows the data we collected on numerous paths of varying widths and thicknesses as determined by destructive tests. The curve drawn through these test points is the theoretical curve as represented by the simple expression

FIGURE VIII

ARRANGEMENT
OF
FOUR POINT RESISTANCE PROBE

FIGURE IX

for the resistance $R = \frac{\rho L}{A}$. An advantage of the resistance measurement for paths as well as plated holes is that it can be made after the application of tin lead overplate. From experience, the influence is less than two percent of the actual resistance value measured.

The last technique to be discussed is the use of a light section microscope to measure the path width and thickness of printed circuit boards. The light section scope is an optical device which projects the image of a built-in slit vertically down on the profile of the circuit board path. This produces a narrow bright light section which is observed through an optical path at right angles to the projected light. The effect is as though you were looking at a magnified view of an actual cross section of the path. Using a micrometer stage and a filar-eyepiece, the path thickness and width can be measured. The data in figure X is representative of the results of tests made to compare the measurement of path thickness using the L.S. scope to destructively test. It is believed that the apparent bias is due to the fact that the epoxy-glass substrate is not completely opaque. The effect is not as pronounced when the substrate is compounded with AL 0 .
2 3
The comparison for the measurement of path width is more accurate. As seen in Figure XI, the light-section scope will predict the destructive measurement within 2 mils. This method of path width measurement is particularly useful when used in conjunction

FIGURE X

FIGURE XI

with the resistance test for cross-sectional area.

As stated earlier the sole intent of this paper is to relate the practical experience of a user of these techniques. The author would welcome the opportunity to discuss these methods or others with anyone interested in the nondestructive measurement and in-process control of plating thickness on printed wiring boards.