The Institute for Interconnecting and Packaging Electronic Circuits
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IPC-TM-650
TEST METHODS MANUAL

Number	
2.5.17.2	
Subject	
Volume Resistivity of Conductive Materials Used in High Density Interconnection (HDI) and Microvias, Two-Wire Method	
Date **11/98**	Revision
Originating Task Group **HDI Test Methods Task Group (D-42a)**	

1 Scope This test method covers the two-wire resistance test for the determination of the volume resistivity of polymer-based conductive pastes and other conductive materials used in HDI. This test is valid for conductive materials with volume resistivity on the order of 10^{-5} Ω-cm or higher. For measuring resistivity on highly conductive materials or any material that cannot be patterned into a circuit pattern, a four-wire (Kelvin Probe) test method, such as IPC-TM-650, Method 2.5.14, is recommended.

1.1 Definition Volume resistivity is a material property that can be utilized to calculate the resistance in a circuit design. For materials with high resistivity, a two-wire resistance test may be used to measure the volume resistivity.

The resistance in any sample (R in units of Ω) is related to the dimensions of the test circuit and the volume resistivity (ρ) inherent in the material (see Figure 1).

$$R = \rho\left(\frac{L}{tW}\right)$$

L, W, and t are the length, width, and thickness respectively of the test circuit (in cm). The quantity L/W is called a square, (□). The volume resistivity can then be expressed as:

$$\rho = \frac{Rt}{\left(\frac{L}{W}\right)} = \frac{Rt}{\square}$$

with units of ohms-cm (Ω-cm).

2 Applicable Documents

IPC-TM-650 Test Methods Manual

2.5.14 Resistivity of Copper Foil

3 Test Specimen The test specimen is a 0.5 mm wide serpentine circuit pattern (see Figure 2) with a length of between 200 □ and 1000 □ (length equal to 200 to 1000 times the width) prepared by screen printing or other methods. Specimens may be prepared by other methods, as long as they have measurable dimensions. If materials cannot be prepared in a circuit pattern, see 6.2.

Example test pattern. 0.5 mm lines and spaces. Total length of 10 cm to 50 cm (200 squares to 1000 squares)

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Figure 2 Serpentine Pattern

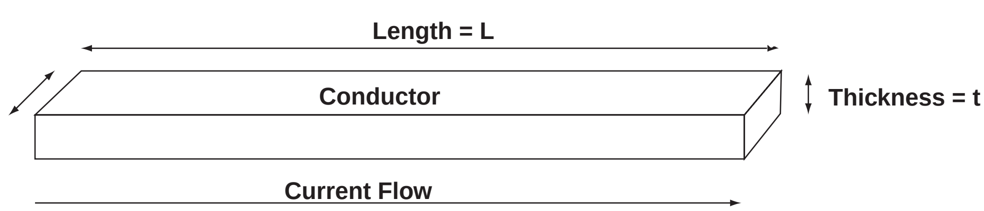

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Figure 1 Resistivity Diagram

3.1 Conductor Any high resistance conductor used in HDI applications (polymer thick film, via fill, metal, metal composites, transient liquid phase sintering, organometallic, conductive polymer, etc.). Copper foils used in HDI should be tested according to IPC-TM-650, Method 2.5.14.

3.2 Substrate Unless otherwise specified, the substrate shall be a PCB laminate, etched to remove all copper. Other acceptable substrates (when specified) may be plate glass, insulated metals, or flexible circuit base material.

3.3 Screen For materials that are screen printed, unless otherwise specified, the screen shall be as outlined in 3.3.1 through 3.3.3.

3.3.1 Type 200 mesh, stainless steel, 35 µm wire

3.3.2 Emulsion <15 µm emulsion build up

3.3.3 Wire Angle 22.5° to 45°

3.4 Typical Patterns

3.4.1 Pattern Serpentine with 0.5 mm wide lines and spaces and 200 □ to 1000 □ long (10 cm to 50 cm). The larger the number of squares, the higher the resistance and more accurate the measurement.

3.4.2 Print

1.25 mm snapoff
0.2 Kg to 1.0 Kg squeegee pressure per cm squeegee length
2.5 cm/sec. to 12.5 cm/sec. draw speed

3.5 Cure Conditions The conductor shall be cured according to the manufacturer's specifications. Parts are allowed to cool to room temperature, after which they are measured for resistance.

4 Equipment/Apparatus

4.1 A digital multimeter capable of resolving 0.1 Ω resistance is required. This unit must be accurately calibrated. An example would be a Fluke 70 series digital multimeter. For improved accuracy in this measurement, a larger number of □ and/or a more sensitive multimeter can be utilized.

4.2 A screen printer capable of making 0.5 mm line/space circuitry, or any other method for preparing the desired circuit pattern

4.3 Equipment to measure the test circuit conductor length, width, and thickness. If the number of squares is accurately known (length/width of circuit) from the artwork and standard process conditions, then only the thickness needs to be measured on each specimen. Thickness can be determined by various methods: cross-section/optical microscopy, profilometer measurement, or calculation from deposition weight and material density. If the circuit thickness is very uniform, then optical sectioning is the preferred method for obtaining the thickness. If the circuit thickness is thought to be non-uniform, thickness may then be determined by averaging profilometer readings or determining average thickness from the weight of the material deposited (knowing the length, width, and density that the thickness can be determined).

5 Procedure

5.1 Samples Prepare a minimum of five test specimens according to 3.1 through 3.5.

5.2 Conditioning Condition the specimens at 23°C ± 5°C, 50% RH (± 5%) for 24 hours.

5.3 Measurement

5.3.1 Measure the circuit length, width, and thickness using the equipment described in 4.3.

5.3.2 Apply the digital multimeter leads to the pads at each end of the circuit. Measure and record the resistance in ohms. For a resistance less than 2 Ω, see 6.1.

5.3.3 Measure the resistance of a minimum of five specimens and average the values.

5.4 Calculation Calculate the volume resistivity for each specimen from the equation below:

$$\rho_i = \frac{Rt}{\left(\frac{L}{W}\right)}$$

where:

R = average resistance of a single specimen in ohms
t = thickness of the conductive specimen in cm
L = length conductive specimen in cm
W = width conductive specimen in cm

Note: The ratio L/W is the number of squares.

Calculate the average resistivity from the sum of the specimen volume resistivities:

$$\rho_{ave} = \frac{\sum_{n} \rho i}{n}$$

where:

n = number of specimens measured

Note: The units of resistivity are Ω-cm.

5.7 Report

5.7.1 Report the volume resistivity in units of Ω-cm.

5.7.2 Report the substrate used in the test.

5.7.3 Report the test circuit length, width (or squares), and thickness.

6 *Notes*

6.1 Low Resistance Measurements For test circuits with a resistance less than 2.0 Ω, the contact resistance between the probe and the pads will be significantly relative to the resistance arising from the test circuit. The 2.0 ohm lower limit, in combination with the 0.1 ohm sensitivity of the multimeter, provides for a minimum error of 5%.

One solution is to increase the length of the circuit (increase the number of squares) to increase the resistance. Another solution for measuring resistivity on a highly conductive material is to change to a four-wire (Kelvin Probe) test method, such as IPC-TM-650, Method 2.5.14.

6.2 Test Circuit Specimens It is anticipated that some materials cannot be formed into a uniform test circuit, as called out for in this test method. It is recommended that these materials be tested with a four-wire method (IPC-TM-650, Method 2.5.14) and an alternative construction.

For example, a thin film of conductive material (i.e., paste or conductive film) can be placed between two metal plates and the resistivity may be determined using the four-wire (Kelvin Probe) method. The material thickness and contact area must be known, and the material must be sufficiently compliant to completely wet (contact) the two plates.

6.3 Other References

Gilleo, Ken, Polymer Thick Films, Van Nostrand Reinhold, 1996