Choice of Sensor for PC Board Through-Hole Deposit Control in Electroless Copper Plating

By G. Bikulčius, M. Šalkauskas, V. Pelanis & K. Žukauskas

Electric resistance of the different-shape sensor has been measured during chemical metallization, using equipment specially designed for water electrolyte solutions. It has been proved that the rate of copper deposition is 2-3 times greater within the hole sensor than on the flat surface. By modeling the transformation of the through-hole wall into the plane surface it has been determined that the load size influences the copper plating rate.

The rapid development of electronics has been steadily increasing the demand for PC boards.[1] The most vulnerable spot on a PC board is a metallized hole. Spoilage during PC board manufacture is chiefly a result of defects in these holes. A number of factors—drilling, electroless copper deposition and electrodeposition, exert very great influence on hole quality. Care in these operations would help in attaining the best quality results.[2-4]

The quality of PC board hole metallization is determined by the proper maintenance of electroless copper deposition parameters (pH, temperature, ion concentration) within required limits.[5,6] Unfortunately, reliable control of electroless copper deposition processes is still not perfected. Copper, formaldehyde and stabilizer concentrations change very quickly in electroless copper solutions. The copper deposition rate depends on these parameters, while their continuous control is difficult. For example, the copper deposition rate usually increases with pH, but the opposite possibility is not excluded.[7] The quality of PC board hole metallization is usually checked after the process is finished.

Attempts have been made to control the thickness and the plating rate of PC board through-hole walls during chemical metallization.[8-11] In all cases, the resistance control method (*i.e.,* measurement of the electric resistance of a sensor dipped with the parts to be plated) has been used. It is obvious that measurement precision depends greatly on the sensor's suitability to cope with the task.

Experimental Procedure

Copper-clad laminate of glass-fiber-strengthened epoxide resin was chosen for the investigation because these PC boards are the most widely used.

Degreasing: Na_2CO_3, 20 g/L; sinthanol, 0.5 g/L; temp, 40 °C; treatment time, 5-10 min.

Etching: H_2SO_4, 180 g/L; H_2O, 30 g/L; temp, 20 °C; time, 1 min.

Activation in the solution: $PdCl_2$ 0.2 g/L; $SnCl_2 \cdot H_2O$, 12 g/L; NaCl, 200 g/L; HCl, 10 g/L; temp, 20 °C; time, 4 min.

Acceleration in the solution: HBF_4, 25 g/L; glycerine, 2 g/L; temp, 20 °C; time, 8 min.

Table 1
Copper Deposition Solution

Reagent	Concentration
Copper sulfate	10 g/L
EDTA, disodium salt	40 g/L
Glycine	5 g/L
Sodium hydroxide	16 g/L
Formalin	16 mL/L
Diethyl dithiocarbonate	0.5 mg/L
pH	12.4
Temp	50 ±1 °C

The copper metallization solution is listed in Table 1. Various sensors were selected for the investigation of metallization rate changes during copper deposition on surfaces of different shapes (Fig. 1).

A block diagram of the apparatus used for measuring sensor resistance is shown in Fig. 2. Various sensors can be switched into the measuring bridge by using the commutator, K. A differential amplifier allows elimination of slight phase-coherent imbalances of the measuring bridge. A narrow-band amplifier was used to decrease the external noise influence on measurement results. Other parts of the apparatus were used according to their preassigned functions. The measurements were carried out within the 20-400 Hz frequency band.[12]

A flat sensor (10 x 20 mm) was made of the same material as the PC board. The sensor surface area (S) was 28 times greater than the surface area (S) within the through-hole (∅, 1.1 mm; h = 2 mm) walls (Fig. 1a). A hole sensor was also made of the same material as the PC board and the through-hole diameter corresponded to that common to double-layered PC boards (Fig. 1b). A metallic sensor was made of copper foil, 30 x 2 x 0.04 mm (Fig. 1c).

The thickness of the copper coating was measured by various means. Independence of the sensor nature or configuration of the method was chosen: coulometric (7 percent error) for a flat dielectric (Fig. 1a), microscopic (8 percent error) for hole (Fig. 1b) and gravimetric (10 percent error) for a metallic band (Fig. 1c).

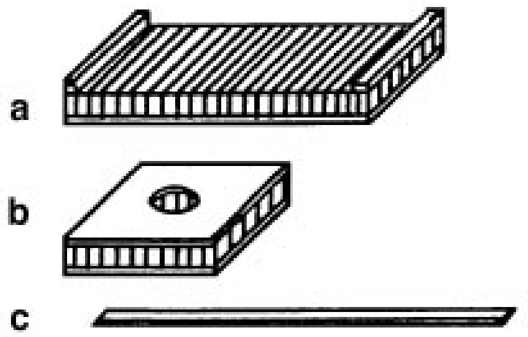

Fig. 1—Sensors: (a) flat; (b) hole; (c) band.

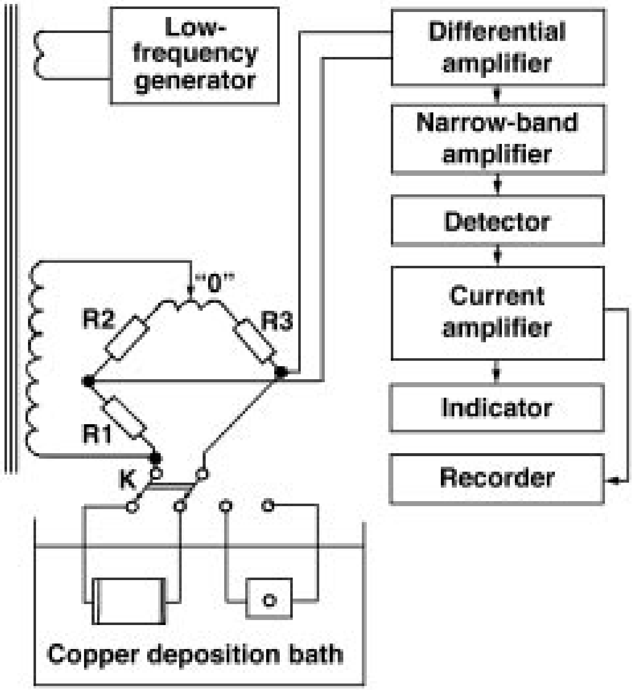

Fig. 2—Schematic representation of the resistance measurement system.

All sensors investigated were soldered to the electric contacts of the measurement circuit. All soldered places were isolated from the electroless plating solution by means of an organic varnish.

Results & Discussion

The curves of Fig. 3 show that a close relationship exists between the growing copper deposit and sensor resistance. The change of sensor resistance is a function of its geometrical dimensions. The thickness of copper, however, obtained on differently shaped sensor surfaces during the same metallization time, is not identical (Fig. 4). Comparison of curves 2 and 3 shows that the thickness of copper deposited in a hole is 2-3 times greater than that obtained on a plane surface during the same deposition time. It should be noted that this anomaly was observed earlier.[13-15] For more comprehensive investigation of this fact, the tests were conducted with the samples that allowed transformation of the hole into the plane. There were both one-hole (Fig. 5a) and multi-hole (Fig. 5b) models.

In Figs. 6 and 7, the results of the resistance measurements on the differently shaped sensors are shown. Comparison of the plating surface of the hole (Fig. 5a), the flat plated surface of dielectrics in the hole case, and in the multi-hole case (Fig. 5b) shows the growth resistance of the flat surface. Once again, this confirms the assertion that a difference exists between the rates of copper deposition in the hole and on the plane. Comparison of the results presented in Figs. 6 and 7, however, indicates that this irregularity has the tendency to diminish when the bath load is increased.

The results in Table 2 show that, when the hole is transformed into the plane at 0.14 cm²/L load, the relative sensor resistance changes from 1.0 to 2.0, but when the load is 0.56 cm²/L, the relative sensor resistance changes from 1.0 to 1.3 (Table 3). It is known from the literature[7] that the chemical metallization solution is characterized by several technical parameters—deposition rate, solution life, utilization efficiency and solution sensitivity to activation. The sensitivity to activation means the least quantity

Table 2
Relative Resistance Depending on Sensor Configuration

$S_{\circ}/S_{\circ}$	$2S_{\smile}/S_{\circ}$	$S_{\Box}/S_{\circ}$
1.0	1.3	2.0

Hole dia. ∅ 1.1 mm, h = 2 mm, deposition time 45 min, load 0.14 cm²/L

Table 3
Relative Resistance Depending on Sensor Configuration

$8S_{\circ}/S_{\circ}$	$16S_{\smile}/8S_{\circ}$	$S_{\Box}/8S_{\circ}$
1.0	1.1	1.3

Hole dia. ∅ 1.1 mm, h = 2 mm, deposition time 45 min, load 0.56 cm²/L

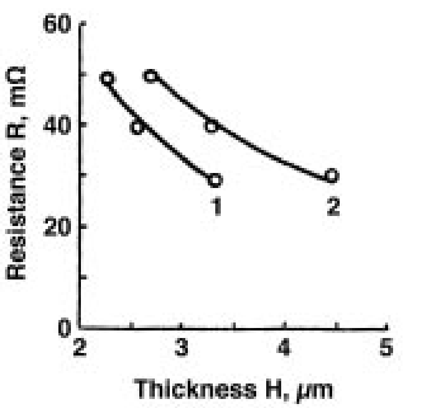

Fig. 3—Sensor resistance, R, as a function of deposit thickness, H. Sensors: Hole (∅ 1.1 mm, h = 2.0 mm), curve 1; hole (∅ 0.9 mm, h = 1.6 mm), curve 2.

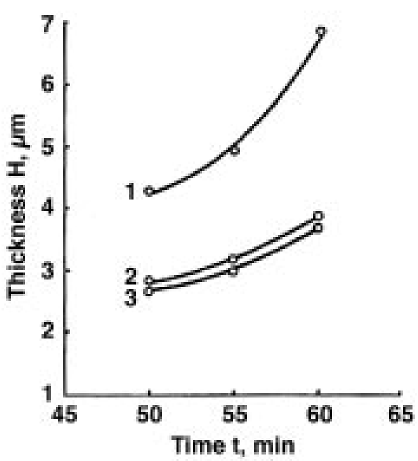

Fig. 4—Deposit thickness, H, as a function of deposition time: Curve 1, hole sensor (∅ 1.1 mm, h = 2.0 mm); curve 2, flat metallic sensor (170 x 5 x 0.4 mm); curve 3, flat dielectric sensor, (10 x 20 mm).

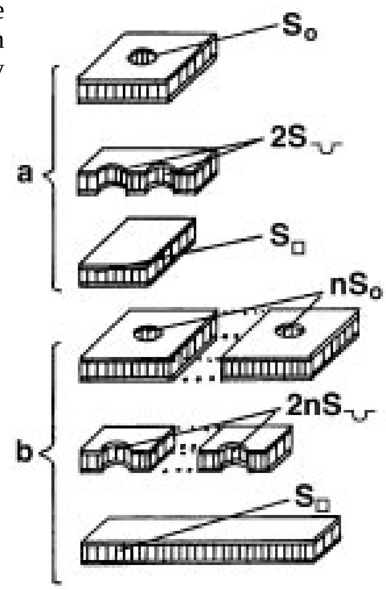

Fig. 5—Sensor configurations: Hole surface area, $S_{\circ}$; half of hole surface area, $S_{\smile}$; surface area of plane, $S_{\Box}$. Models: (a) one hole; (b) multi-hole.

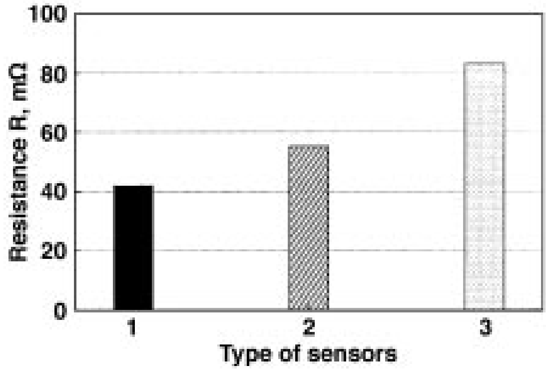

Fig. 6—Histogram of copper plating resistance of differently shaped sensors: (1) one hole; (2) two half-holes; (3) flat dielectric surface. Deposition time, 45 min; load, 0.14 cm²/L; hole, ∅ 1.1 mm.

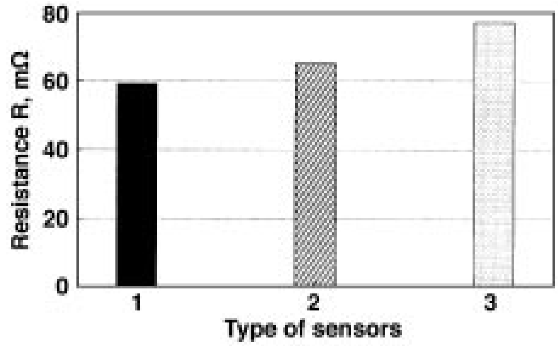

Fig. 7—Histogram of copper plating resistance of differently shaped multi-hole sensors: (1) 8-hole; (2) 16 half-hole; (3) flat dielectric surface. Deposition time, 30 min; load, 0.56 cm²/L; hole, ∅ 1.1 mm.

of the activator on the dielectric surface sufficient to initiate the catalytic reaction. This parameter is connected with solution stability (*i.e.,* the less stable the solution, the easier the beginning of the reaction on a small active surface).

In this case, the solution sensitivity to activation is atypical. Accordingly, we can suppose that the load of the solution has the influence on the anomaly described above. Partially, this assumption was confirmed by the Japanese.[16] It was pointed out there that the uniformity of the metal deposit in PC board holes depends on the load size. For example, the deposit uniformity in the holes of PC boards (∅ = 0.4 mm, h = 3.2 mm) changes from 55 to 100 percent when the load increases from 17 dm²/L to 70 dm²/L.

The value of the results obtained in this study may be illustrated by a few examples. It is known that the resistance measurement method has been used for deposit control during chemical metallization.[9] For this purpose, a flat resistance sensor is placed on the surface of a PC board and a copper deposit simultaneously grows on the sensor. The sensor resistance is measured during the deposition process. According to the resistance value, a microprocessor calculates deposit thickness and copper deposition rate.

We are of the opinion that such a sensor is not sufficiently suitable, considering two aspects. First, resistivity of the sensor material is not identical with that of the PC boards. Second, the resistivity sensor is flat. As indicated in the Japanese patent,[11] the thickness of metal deposits could be monitored by a flat sensor made of the same material as the metallized component and placed in the metallization solution. The sensor doesn't fit the case when the thickness of copper deposits in PC board holes must be measured, because, during the copper deposition process, the rate of metal deposition in the hole differs from the deposition rate on a flat dielectric surface.

Findings

It has been determined by the electrical resistance measurement method that deposit thickness on through-hole walls is 2-3 times greater than that on the flat dielectric surface. Accordingly, the most suitable sensor for monitoring the rate of copper deposition on PC-board through-hole walls would be the hole sensor. This through-hole metallization control method permits an increase in reliability of PC boards, reduces spoilage and improves overall quality.

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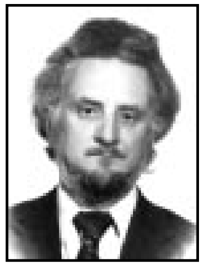

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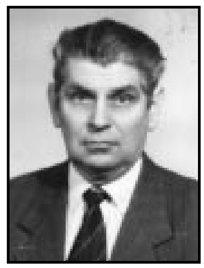

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