

Investigation of electroless copper plating with high plating coverage in small BVH for next generation fine pattern SAP

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Abstract

Printed wiring board (PWB) used for package substrates are required to have higher circuit densities. We anticipate that PWB circuit patterns and blind via hole (BVH) will continue to be miniaturized due to higher density requirements. The electroless copper plating solution generally used has less chemical material supply to the inside of the BVH than the surface of the substrate. As a result, the copper thickness at the bottom of the BVH tends to be thinner than that on the surface of the substrate. It is difficult to uniformly deposit the electroless copper plating in the BVH on the package substrate by the semi-additive process (SAP), especially when the BVH are becoming smaller. Therefore, we investigated additives that suppress the electroless copper plating deposition on the surface of the substrate and additives that improve the permeability of the plating solution into the BVH. Two additives have been discovered that dramatically improve the plating uniformity in the small BVH compared to the conventional bath. In addition, we used this plating solution with the new additives to evaluate the internal stress and peel strength of the electroless copper plating film. As a result, it was confirmed that both internal stress and peel strength were improved compared to the conventional bath.

Key words

Blind via hole, Electroless copper plating, Fine pattern, Semi-additive process, Throwing power

I. Introduction

PWBs used for package substrates are required to have higher circuit densities [1]-[2]. We anticipate that PWB circuit pattern and BVH will continue to be miniaturized due to higher density requirements [3]. The electroless copper plating solution generally used has less chemical material supply to the inside of the BVH than the surface of substrate under the chemical plating reaction. As a result, the copper film thickness at the bottom in the BVH tends to be thinner than that on the surface of substrate. It is difficult to uniformly deposit the electroless copper plating in the BVH on the package substrate for the SAP, especially when the BVH are becoming smaller. Therefore, we investigated additives that to suppress the electroless copper plating deposition on the surface of substrate and to improve the permeability of the plating solution into the BVH. We used the electroless copper plating solution with these additives and evaluated the plating characteristic.

II. Evaluation Method

The evaluation of electroless copper plating with high plating coverage in small BVH consisted of deposition rate, internal stress, adhesion strength on the resin, surface morphology of deposit film, throwing power in the BVH, electrochemical polarization measurements, surface tension and permeability of the plating solution.

Plating process

Table 1 shows the electroless copper plating process. This process is used the package substrate for the SAP.

Measurements of plating thickness

ABF GY-50 of interlayer insulation resin (manufactured by Ajinomoto Fine Techno) was plated with an electroless copper plating bath, and the plating thickness was measured by cross-sectional observation with FIB.

Internal stress

The 0.5 dm² specimen was plated and the internal stress was measured using a spiral contract meter (Made by Yamamoto MS corp., LTD) used.

Adhesion by peel strength

After electroless copper plating on ABF GY-50, 25um of electro-plated copper was deposited. The plated film was peeled off from the resin with an autograph (Made by Shimadzu) in the 90-degree direction, and its adhesion by peel strength was measured.

Surface morphology of plating film

The surface morphology of the electroless copper plating film on the ABF GY-50 of the development bath was observed by SEM.

Throwing power in the BVH

The throwing power in the BVH (30umφ x 30umh and 10umφ x 10umh) on the interlayer insulation resin of GX-92R (manufactured by Ajinomoto Fine Techno) and GY-50 was observed in cross section by SEM and FIB.

Electrochemical polarization measurements

The polarization curve of the electroless copper plating solution excluding HCHO as the reducing agent was measured with using electrochemical measurement equipment. The measurement was carried out with a three electrode system: platinum disk electrode was used as working electrode, silver/silver chloride electrode was used as reference electrode, and copper plate was used as counter electrode. Electrochemical measurement conditions are shown in Table 2. The influence of the agitation on the polarization curve was investigated by controlling the rotational speed of the disk electrode at 100 and 1000 rpm.

Surface tension

After heating up the plating solution to the working temperature excluding HCHO as the reducing agent, we measured the surface tension by Surface Tensiometer (Made by Kyowa Interface Science).

Permeability

After heating up the plating solution to the working temperature excluding HCHO as the reducing agent, a piece of test felt was floated on the solution surface. We measured time with a stop-watch from floating until sinking below the solution surface.

Table 1. Electroless Copper plating process

Steps
Cleaner conditioner
Soft etching
Acid rinse
Pre-dip
Activator
Reducer
Accelerator
Electroless Copper

※Except for after the accelerator, hot water or water rinsing process is performed between each process.

Table 2. Test conditions of electrochemical measurement

Electrochemical measurement conditions	
Electrochemical measurement equipment	HOKUTO DENKO HZ-7000
Working electrode	Pt disk electrode(19.6mm ²)
Reference electrode	Silver/Silver chloride electrode
Counter electrode	Copper plate
W.E. rotation speed	100, 1000 rpm
Potential sweep speed	10 mV/s
Measurement potential range	Spontaneous potential ~ -1 V

III. Results and Discussion

In order to improve electroless copper deposition uniformity in the BVH, the first tests utilized several additives to suppress the electroless copper plating deposition on the surface of the substrate and the results of cross-sectional observations by SEM are shown in Figure 1. We confirmed that the copper film thickness on the resin surface was suppressed by 35% and the copper film thickness on the bottom of the BVH was suppressed by 15% due to the effect of Additive A.

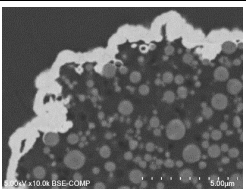
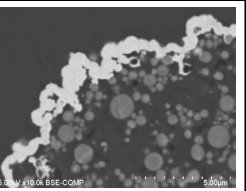
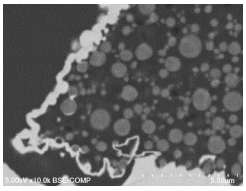
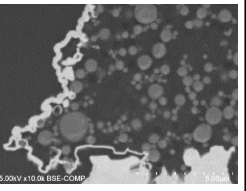
Additive	not Additive	A
Surface [μm]	 0.66	 0.43
Bottom [μm]	 0.33	 0.28

Figure 1. Cross-sectional observations after electroless copper plating film with additive having the suppression effect in the BVH of ABF GX-92R

It is expected that this additive A will strongly suppress plating deposition in the area where solution agitation is fast, such as the resin surface, and weakly suppress plating deposition in the area where solution agitation is slow such as inside the BVH. Therefore, an electroless copper plating solution without a reducing agent was used, the rotation speed of the rotating disk electrode was changed, the flow of the plating solution was reproduced, and the suppression effect of additive A was confirmed by electrochemical polarization measurements. The result of the electrochemical polarization measurements is shown in Figure 2. When compared with the current density at -0.9 V, which is the deposition potential of the electroless copper plating solution, the current density changed little with or without additive A when the rotation speed was slow. In other words, the solution agitation was weak such as inside of the BVH. However, it was confirmed that the current density reduced with the addition of the additive A when the rotation speed was fast. In other words, the solution agitation was strong on the resin surface. This suggests that the suppression effect worked strongly in the area where the flow of the plating solution was fast.

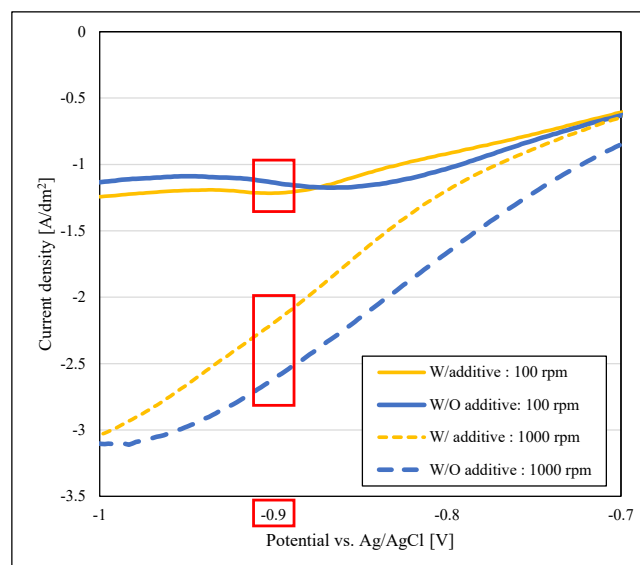


Figure 2. Effect of additive A with an electroless copper plating solution without a reducing agent by electrochemical polarization measurement

Secondly, we plated with several additives to improve the permeability of the plating solution into the BVH, and the results of cross-sectional observation by SEM are shown in Figure 3. We confirmed that the copper film thickness on the resin surface did not change, and the copper film thickness on the bottom of the BVH was promoted by 43% due to the effect of Additive D. Subsequently, we measured the surface tension and permeability and the results are shown in Table 3. We think that the Additive D has a low surface tension and a very high permeability, so that the plating solution penetrated into the BVH and a high concentration plating solution could be supplied into the BVH. As a result, it is assumed that the copper film thickness at the bottom of the BVH is promoted.

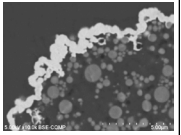
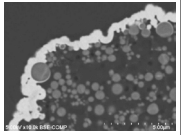
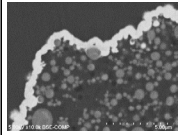
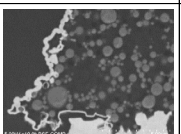
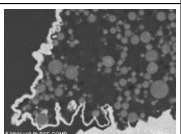
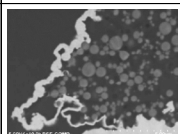
Thickness	Additive A	Additive A	Additive A
	Additive B	Additive C	Additive D
Surface [μm]	 0.43	 0.40	 0.42
Bottom [μm]	 0.28	 0.30	 0.40

Figure 3. Cross-sectional observations after electroless copper plating film with several additives having the permeability effect in the BVH of ABF GX-92R

Table 3. Measurement of surface tension and permeability with the several additives

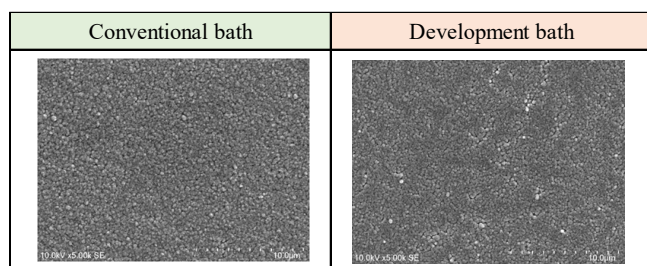
Additive	A	A	A
	B	C	D
surface tension [mN/m]	64	31	30
permeability [sec]	not permeability	60	2

Finally, We compared and evaluated the plating characteristic of the developed bath with both the additive A, additive D and the conventional bath. The results of the deposition film thickness, internal stress, and adhesion with peel strength on ABF GY-50 are shown in Table 4. Except for the deposition film thickness, the results were similar to the conventional bath. This is because the developed bath was adjusted to low deposition speed due to the need for thin deposits for the next generation fine pattern. The results of SEM observation on the plating film surface are shown in Figure 4. The plating surface morphology of the developed bath was the same as the conventional bath.

Table 4. Plating characteristics

Reaction	Target	Conventional	Development
Deposition rate [$\mu\text{m}/15\text{min}$] with ABF GY-50	0.15	0.45	0.15
Internal stress [Mpa] 1 μm thickness	150	100	100
Peel strength [gf/cm] with ABF GY-50	500	510	635

※ The deposition rate was measured by FIB with cross-sectional observation.

**Figure 4.** Surface observation of the electroless copper plating film on the ABF GY-50 by SEM

The results of cross-sectional observations in the small BVH after electroless copper plating by FIB are shown in Figure 5. It was confirmed that the difference in the film thickness of copper between the top and the bottom of BVH was very small in the developed bath as compared with the conventional bath, and that copper film was uniformly deposited in the BVH. We think that this is due to the synergistic effect of the two additives, Additive A which suppresses copper deposition on the surface of BVH and Additive D which has an effect on the permeability of the

plating solution. In addition, it is also evident that the plating is well deposited on the bottom of the BVH.

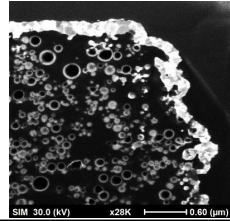
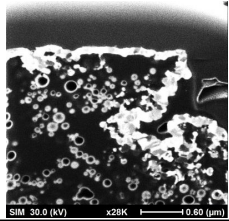
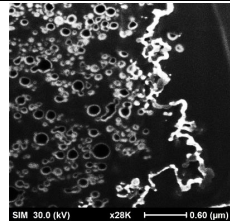
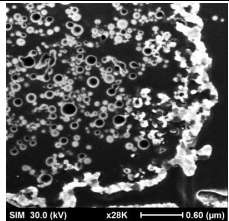
Thickness	Conventional bath	Development bath
Surface [μm]	 0.18	 0.14
Bottom [μm]	 0.06	 0.12

Figure 5. Cross-sectional observations after electroless copper plating film in the small BVH of ABF GY-50

IV. Summary

In this research and development, we investigated an electroless copper plating solution to uniformly deposit in the small BVH. Various comparisons with the conventional bath were carried out, and the performance was almost equal to that of the conventional bath. But the deposit uniformity in the small BVH with the development bath was dramatically improved. Therefore, it can be applied to the small BVH on the package substrate by SAP in the future and is expected to expand the technical plating capabilities allowing higher circuit density packages.

V. References

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