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The evolution of electroless copper plating technology for high density and reliability electronic devices

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The evolution of electroless copper plating technology for high density and reliability electronic devices

The plating technology behind electronic devices requiring high speed, multi-functionality and high performance

As electronic devices become more sophisticated, electroless copper plating technology remains essential to the formation of high-density interconnects. Improved adhesion to the substrate to compensate for reduced trace width, capacity to adapt to a variety of substrate materials, uniform deposition in features such as smaller through holes and vias, the ability to form dense deposits on fine structures and improved interconnection reliability for reduced junction areas in smaller vias, are all required to further improve performance.

The newly developed "CIRCUPOSIT™ 3328 Conditioner " has adopted unique chemistries to control the adsorption properties on inorganic-organic composite materials and molecular interactions. The resulting electroless copper plating deposit provides reliable and high-density performance. The following describes the process characteristics and performance.

- **Electroless Copper Plating Technology**

The typical electroless copper plating process sequence used to manufacture high-density build-up printed circuit boards and semiconductor packages is follows.

1) Conditioning
2) Microetching
3) Catalyst adsorption
4) Catalyst activation
5) Electroless copper plating

Different types of materials are used to improve high frequency characteristics and high thermal reliability, and also to improve dimensional stability. Through hole and via diameters are becoming smaller for higher density boards, as are the interconnection structures in the joint areas. Changes and diversification in the materials and structure and reliability requirements, require the electroless copper plating process to provide improved functionality and performance as discussed below:

a) Homogeneous deposition on micro-structure
→ Smaller through holes and vias, applicability to low profile dielectric surfaces

b) Applicability to wide range of materials: resin, glass, filler

→ Applicability to changes in the structures and materials

c) Joint reliability at the innerlayer copper interfaces

→ Applicability to interface area decreases

d) Thermal reliability of interfaces

→ Applicability to high temperature environment and lead-free assembly

Both the formulations of the individual electroless metallization process steps and also the process sequence affect the overall system performance.

However, the conditioning step is one of the most important surface treatment steps, due to its strong influence on the density of catalyst adsorption, the electroless copper plating deposition and the interconnection reliability.

- **"CIRCUPOSIT™ 3328" Conditioner Performance**

In general, conditioning baths contain surfactants as the main component to provide positive charge on the surface of dielectric materials (resin, glass cloth), to enhance adsorption of catalyst on these materials.

However, in addition to this requirement, the following characteristics must also be considered to improve the connection reliability for high-density interconnect and interlayer formation.

a) Uniform adsorption at the molecular level

→ Uniform and dense catalyzation and copper deposition

b) Easy removal of material from copper material to ensure copper joint reliability

→ Improved thermal reliability and interconnection reliability

- **Electroless copper plating deposition (both uniformity and density)**

Figure 1 shows the substrate surface after the deposition of electroless copper using CIRCUPOSIT™ 3328 ™ Conditioner. As a control, another conditioner is used for comparison. CIRCUPOSIT™ 3328 Conditioner shows fewer defects of the electroless copper deposit in a back light test. A very dense and uniform copper deposit is obtained on glass fibres, on which it is often difficult to adsorb conditioner and palladium catalyst materials. Thus, the conditioner provides superior performance to meet requirements including applicability to various laminate materials and uniform deposit on micro structure.

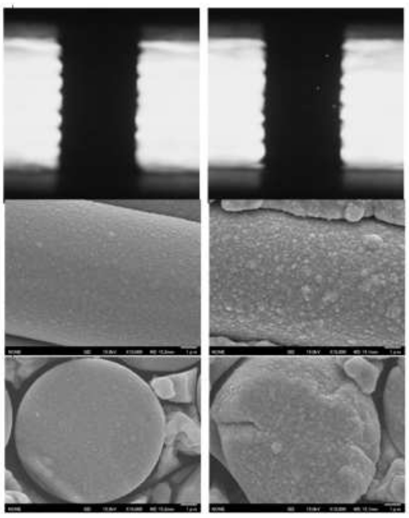

Figure 1 Electroless copper deposit morphology on glass fibres in the hole
(Left: 3328, Right: Control)

Figure 2 shows an AFM (Atomic Force Microscope) image of a catalyzed glass substrate after processing through the conditioner.

The control conditioner shows larger catalyst adsorption structures (right). However, after conditioning with CIRCUPOSIT™ 3328 Conditioner, very fine and uniform catalyst adsorption can be seen.

This shows that the conditioning agents and their functional groups are uniformly distributed onto the substrate with CIRCUPOSIT™ 3328 conditioning.

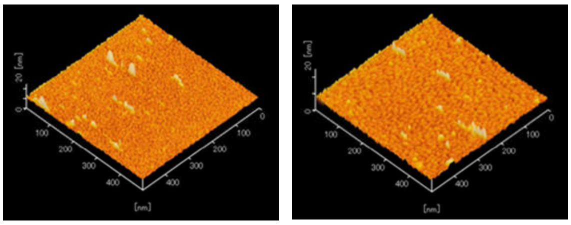

Figure 2 AFM analysis of the substrate surface after catalyst adsorption
(Left: 3328, Right: Control)

- **Reliability of copper interconnections**

Figure 3 shows the result of a peeling test, carried out to evaluate the adhesion of copper to the bottom of copper vias.

For the control conditioner, no residual copper foil is left attached to the vias after peeling (right). However, when CIRCUPOSIT™ 3328 Conditioner is used, residual plated copper foil is still attached to via bottoms after the peel test.

This result indicates that higher copper to copper joint reliability can be achieved by eliminating residual conditioner components at the interface between copper substrate and plated copper.

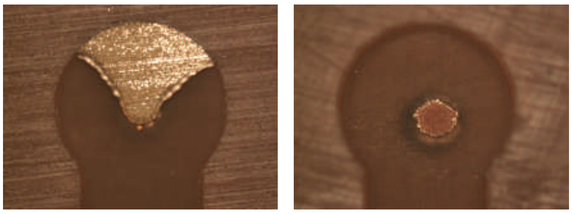

Figure 3 Peel test at via bottom after plating
(Left: 3328, Right: Control)

Hot oil test results are shown in Figure 4. An FR-4 daisy-chain pattern test panel, with via diameters of 100µm and a dielectric thickness of 60µm was used. The panel processed using the control conditioner showed increasing resistance after 194cycles (165min elapsed time). This result corresponds to failures at the interfaces at the bottom of the vias.

For CIRCUPOSIT™ 3328 Conditioner, no increase of resistance can be seen. This result indicates that interconnect integrity is maintained throughout the test.

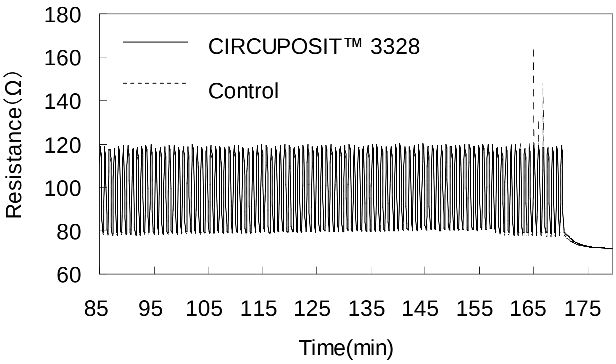

Figure 4 Hot oil test
260℃ 10sec ⇔ 20℃ 10sec, 200 cycles

- **Evolution of electroless copper plating technology**

CIRCUPOSIT™ 3328 Conditioner has been developed to resolve particular issues with traditional conditioners, so as to achieve an electroless copper deposit with high reliability for high-density interconnect designs.

We will continue to promote the development of functional chemical surface treatment technologies for each step to contribute to further progress in the realization of high-speed processing of electronic devices and high performance/multi-functionality.

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