Electronic Materials

DOW ELECTRONIC MATERIALS

INTERCONNECT TECHNOLOGIES

Electroplating Apparatus and Method Considerations for High Aspect-Ratio Through-Hole Copper Electroplating Process

The article is presented at IMPACT, October 2010

Ming-Yao Yen, Yuk-Nam Hung, Kwok-Wai Yee, Hsien-Chang Chen, Hsin-Sen Liang, Mark Lefebvre

Abstract

As the electronic products become multi-functional and complicated, relatively high-density pattern must be designed to meet these requirements. As a result, multilayer printed circuit boards (PCBs) with high aspect ratio (AR>13) through hole metallization become the main trend in fabrication. That is, how to metalize the PCBs by Copper deposit with high throwing power and reliability becomes a major research. In this topic, a batch system of electroplating equipment designed for the use in the pilot line for acid Copper plating is discussed. It includes a comparison of distance between anodes, anode and cathode, different types of solution agitation, such as air, paddle, and cathode vibration. According to the study results, the throwing power for plate-through hole and microvia plating and deposition distribution could be improved by the adjustment of anode distance (anode/anode or anode/cathode), solution agitation (both air and paddle), and rock vibration, of cathode during plating.

Introduction

Rapid growth of 2G+ (GPRS/EDGE) and 3G telecommunication technology is driving rapid growth of infrastructure. Those new technologies require both higher bandwidth capacity and data transmission speeds. In order to meet these requirements, more complex PCB designs must be used, whose manufacture is more and more difficult. e.g., use of new laminate materials, reduction of hole size, increased layer count, wide application of microvia technology(1).

In order to support this trend, layer counts will increase to over 40, with increased use of microvias, while High Aspect Ratio (HAR) board thicknesses will remain similar (3 - 6 mm). The minimum diameter of through holes will decrease from 0.3 mm to 0.2 mm. Through hole (TH) copper plating, using conventional DC technologies, is capable of providing good throwing power and relaibility (2-4). While Pulse Reverse plating can be used on HAR boards, process complexity is greater and more careful process control is required to maintain product performance and relaibility.

To meet this growing market demand, a new DC acid copper electrolyte has been developed, designed to be operated at low cathode DC current density (2-20 ASF). This system is suitable for both panel and pattern plate processes, and provides outstanding throwing power in conventional vertical process equipment.

In this paper, the influence of anode distance (anode/anode or anode/cathode), solution agitation (both air and paddle) and rack vibration on throwing power in plated-through holes and blind vias is described, and optimum conditions identified.

EXPERIMENTAL

The schematic electroplating process flow diagram is shown in Figure 1. PCB boards with THs formed by mechanical drilling and laser ablated microvias were used for plating evaluations. The dimensions of the PCB board were 24 × 18 inches. The sidewall of the microvias and TH were first metallized using electroless copper plating, and subsequently flash-plated with copper, to increase the thickness of the initial copper layer to 2 ~ 3 μm before electroplating. Six anode baskets with phosphorus-containing copper balls were used as anodes and were directly placed in a plating bath with a working volume of 450L. Plating was conducted in the Dow Electronic Materials pilot line labs in Taiwan.

The composition of the base electrolyte used in all plating tests was 0.30 M $CuSO_4 \cdot 5H_2O$, 2.35 M H_2SO_4. The plating additives used were: suppressor, accelerator, leveler, and chloride.

The throwing power performance was assessed based on cross-sections of both thought holes and microvias, which were examined using an optical microscope (OM) (Olympus BX-51).

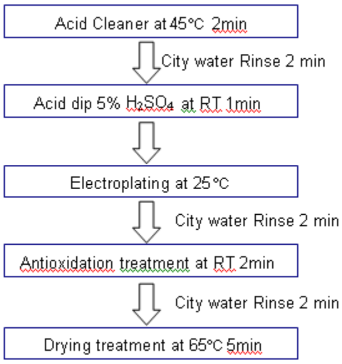


Figure 1. Schematic process flow for electroplating of both through-holes and microvias with copper.

RESULTS AND DISCUSSION

The Throwing power (TP) of through holes and microvias are defined in Fig. 2. TP is an good overall metric to describe the covering capability of a copper plating solution.

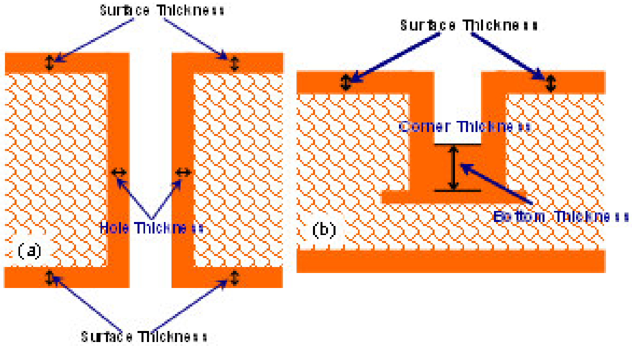


Figure 2. Definition of throwing power for (a) through hole and (b) blind via. (a) Through hole TP% = average of hole thickness/ average of surface thickness, (b) Microvia TP% = average of bottom thickness/ average of surface thickness.

Impact of Anode / Cathode Spacing on Through Hole TP

Figure 3 shows cross-sections of 16:1 aspect ratio (AR) through holes after copper electroplating, for three different distances between anode and cathode. The TP performance was found to better at shorter distances, with a maximum TP of approximately 75.8%. As the distance between anode and cathode becomes shorter, the resistive (IR) drop in solution becomes smaller (4).

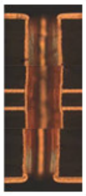
Thickness of board 4.8 mm, Hole diameter 0.3 mm, AR=16				
Spacing Distance		Short	Medium	Long
Sectioning Location within Through Hole	Top			
	Center			
	Bottom			
Throwing Power		TP 75.8%	TP 72.8%	TP 70.7%

Figure 3. Through Hole Throwing Power as a function of anodes to cathode spacing (at 10 ASF and 25μm copper thickness)

Effect of Anode – Anode Spacing on Through Hole TP

Figure 4 shows cross-sections of 16:1 aspect ratio (AR) through holes after copper electroplating at three different anode to anode spacing. Of the three test conditions, highest TP was obtained at the shortest anode to anode spacing.

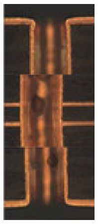
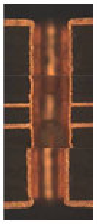
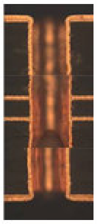
Thickness of board 4.8 mm, Hole diameter 0.3 mm, AR=16				
Anode-Anode Spacing		Short	Medium	Long
Sectioning Location within Through Hole	Top			
	Center			
	Bottom			
Throwing Power		TP 75.8%	TP 70.8%	TP 67.4%

Figure 4. Through Hole Throwing Power as a function of anode to anode spacing (at 10 ASF and 25µm copper thickness)

Effect of Solution Agitation on Through Hole TP

Figure 5 shows cross-sections of 12.8:1 aspect ratio (AR) through hole after copper electroplating at two different levels of solution agitation. The TP was found to be best when a combination of Air and paddle agitation is used, with an increase in TP of approximately 11%. Use of paddle agitation can increase the rate of mass transfer of copper ion into the through holes.

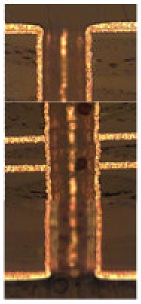
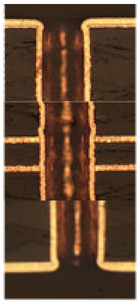
Thickness of board 3.2 mm, Hole diameter 0.25 mm, AR=12.8			
Solution Agitation		Air	Air + Paddle
Sectioning Location within Through Hole	Top		
	Center		
	Bottom		
Throwing Power		TP 71.8%	TP 82.5%

Figure 5. Through Hole Throwing Power as a function of solution agitation : Air versus Air + Paddle (at 10 ASF and 25µm copper thickness)

Effect of Solution Agitation on Blind Via TP

Figure 6 shows cross-sections of blind vias after copper electroplating with and without cathode vibration, The results indicate that TP in blind vias is increased when vibration is applied to the cathode. Cathode vibration enhances the mass transfer of copper ion into the blind vias, and increases the TP.

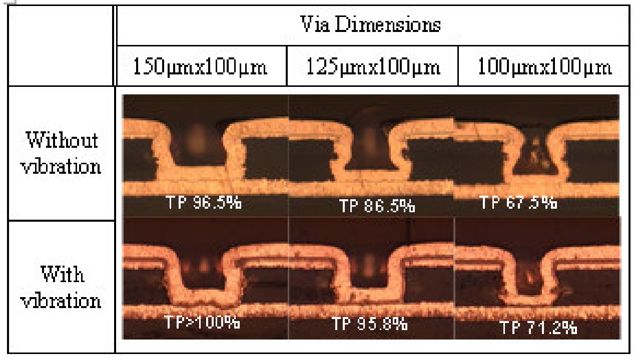


Figure 6. Blind Via Throwing Power as a function of solution agitation : Air versus Air+Paddle (at 10 ASF and 25µm copper thickness)

Summary

Based on the results of this evaluation, three adjustments may be made to obtain improvements in through hole throwing power in High Aspect-Ratio boards: shorter spacings (both anode/anode and anode/cathode)and increased solution agitation (combination of air and paddle). For blind microvias, cathode vibration was also found to improve throwing power.

The results are provide additional operating flexibility and help to meet end user requirements.

References

1. Takagi, K., Honma, H., Sasabe, T.(2003), “Development of sequential build-up multilayer printed wiring boards in Japan”, IEEE Electr. Insul. Mag., Vol. 19, pp. 27-56.
2. Yung, E. K., Romankiw, L. T., and Alkire, R. C.(1989),” Fundamental Study of Acid Copper Through-Hole Electroplating” J. Electrochem. Soc., Vol. 136, No. 206, pp. 756-767
3. Hazlebeck, D. A., and Talbot, J. B.(1991), “Modeling of the Electroplating of a Through-Hole with Flow Reversal and Downstream Counterelectrode Configurations”, J. Electrochem. Soc., Vol. 138, No. 7, pp. 1998-2002.
4. Chern, Ja-W. E., and Cheh, H. Y.(1996), “Modeling of Plated Through-Hole Processes”, J. Electrochem. Soc. Vol. 143, No. 10, pp. 3139-3144.