Cost Effective Method for Manufacturing Blind Microvias

Jim Watkowski, Tim Spencer
MacDermid, Inc.
Waterbury, CT USA

Abstract

The need to minimize PWB real estate requiring smaller holes and increasing circuit density has driven the technology towards via in pad and stacked microvia designs. This high density interconnect technology – HDI - has become part of the printed circuit board lexicon. Attributes of this technology are increased processing speed, which improves device performance, miniaturization which enables more functionality in the same or less amount of space, and portability which allows all these highly functional devices to fit conveniently in a small handbag or shirt pocket. The majority of these devices are consumer electronics and like all consumer driven markets, downward price pressure is constant and severe. Fabricators must find new methods to produce HDI technology at lower and lower costs while maintaining high quality standards.

This paper outlines an Integrated Metallization System that produces HDI technology at significantly reduced costs while maintaining high quality. This innovative metallization sequence incorporating a high degree of automation utilizes horizontal desmear technology coupled with a new direct metallization process and is followed by a continuous vertical plater containing in line electrolytic flash and via filling or via plating.

Introduction

Horizontal processing is well established in the PWB industry and the benefits are easy to quantify. Horizontal orientation enables improved solution exchange in the holes and blind vias through the application of ultrasonics for wetting and debris removal and the use of forced flood impingement systems. There are no rack effects common to batch type vertical processing and every panel sees the same conditions, improving consistency. While horizontal electroplating has advantages for transporting thin core substrates, the cost and the foot print required for a full panel plater, makes this option less appealing for high volume manufacture of standard thickness HDI. Vertical Continuous Platers (VCP) are capable of high volume through put in a limited amount of space, yield excellent micro/macrodistribution, possess the flexibility to run panel plating or pattern plate work, can be fitted with Direct Current (DC) or Period Pulse Reverse (PPR) rectification, and the equipment has a high degree of accessibility to the mechanicals (anode baskets, cathode bars, connections etc.). Integrating the benefits of horizontal primary metallization with the high productivity of vertical continuous plating, has produced a system that is a more cost effective for manufacturing HDI boards while maintaining high quality standards.

Primary Metallization

Desmear

The role of the desmear process is to effectively remove drilling smear from the copper interconnects and clean any laser residues off the capture pads of blind microvias, while imparting topography to the resin. To accomplish this task, an organic sweller is used to penetrate the resin and make it more susceptible to attack by alkaline permanganate. Combining a low surface tension organic sweller with high flow fluid heads removes any air bubbles that may be entrapped in the center of the through holes or in the bottom of blind microvias. The correct time and temperature ratio between the sweller and alkaline permanganate can produce a micro roughened epoxy surface (figure 1) while removing drill smear.

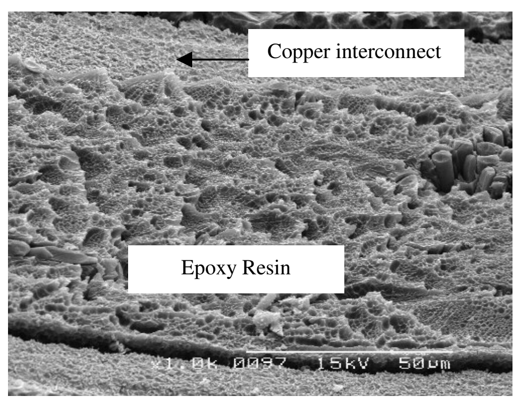

Figure 1

Clean copper is required for good electrical continuity while the roughened epoxy surface provides a base for excellent mechanical adhesion of the subsequent metallization process.

Primary Metallization
Direct Plate

The current industry standard for primary metallization is electroless copper. However, the cost reduction demands that fabricators must address are constrained by increasing electroless copper raw material prices, with palladium nearing US$ 700 per troy ounce (up more than US$300 over the past year) and copper reaching the highest price since July of 2008. Further cost reductions in electroless copper processing are unlikely.

A lower cost, horizontally integrated, production proven process is available. Recent advances in carbon based chemistries have improved performance and widened operating windows while maintaining a low cost of ownership.

Figure 2 illustrates the difference in process length between standard electroless copper and the new carbon process.

Step	Electroless Copper	Step	Carbon Technology
1	Clean/Condition	1	Clean/Condition
2	Rinse	2	Rinse
3	Microetch	3	Carbon-based Dispersion
4	Rinse	4	Dry
5	Predip	5	Microetch
6	Activation	6	Rinse
7	Rinse	7	Antitarnish
8	Acceleration	8	Rinse
9	Rinse	9	Dry
10	Electroless Copper		
11	Rinse		
12	Acid Dip		
13	Rinse		
14	Antitarnish		
15	Rinse		
16	Dry		

Figure 2

Chemical steps are reduced from 8 to 4 and rinse steps are reduced from 6 to 3. Factoring in that the carbon chemistry is non-dynamic (no breakdown upon idling), it is clear to see how this system reduces total cost of ownership.

Based on 4000 panel square meter production per month, the savings in labor (figure 3), water (figure 4), power (figure 5), and analysis time (figure 6) make the carbon system the most cost effective method for primary metallization.

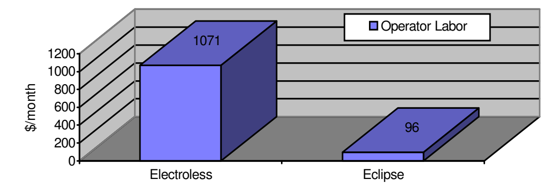

Figure 3

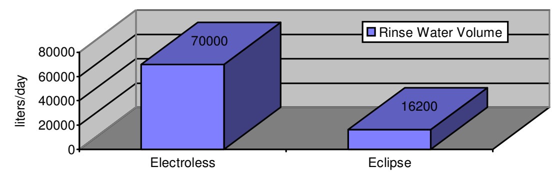

Figure 4

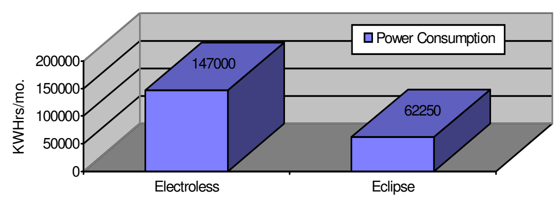

Figure 5

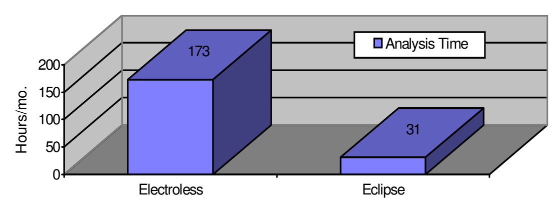

Figure 6

Additional advantages to the carbon system is its simplicity and environmental benefits. The carbon chemistry has no side reactions. The chemistry does not change as a function of time. There is no plate out, and no generation of hydrogen gas during application eliminating the possibility of bubble entrapment causing voids. The carbon process does not contain heavy metals, or carcinogens and is completely RoHS compliant.

Electrolytic Metallization

HDI technology calls for the ability to electrolytically plate the through holes and fill the blind microvias. Most commercially available chemistries require the filling of microvias, followed by a planarization step to remove some of the surface copper. These panels are then sent to mechanical drilling, PTH, and electrolytic copper plating in order to complete the process. These

additional steps add cost and cycle time to the manufacturing process. The ability to take product directly from the carbon process, with all laser and mechanical drilling complete, and build up the required copper in the through holes and fill the microvias, without the need to planarize later, is a huge benefit in materials, cycle time and labor.
Plating through holes and filling vias without the need for subsequent planarization can be accomplished through chemical/mechanical design. MacDermid, a pioneer in the development of vertical continuous plating applications, continues to work with VCP equipment suppliers to optimize designs.
A cross sectional view of the plating cell is shown in figure 7.

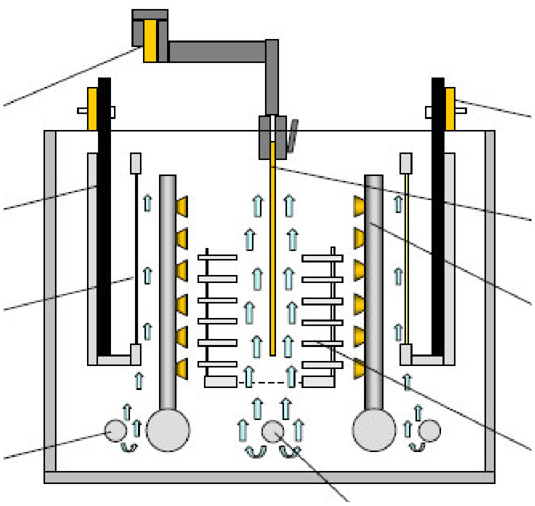

Figure 7

The design incorporates the use of eductors and air agitation. The anode type can be soluble (copper) or insoluble. The anode area is enclosed to prevent any particulate from the copper balls, (if using soluble anode) or the gas evolved at the anode (if insoluble anode) from mixing with the bulk solution.
The viafill chemistry was specifically designed for VCP plating. The additives have been balanced to work synergistically with the equipment to provide good through hole plating while simultaneously filling the microvias. The VCP / chemistry combination provides excellent macrodistribution across every panel (+/- 10%) while keeping the surface copper thickness 20 microns or less.
The plater incorporates an in line flash as the first electrolytic step. This flash section propagates copper through the holes and into the blind microvias and begins the filling process. A proprietary predip is used after the flash step to greatly enhance the bottom up filling mechanism. The final result is completely filled vias with minimum surface copper. Figure 8 shows the via filling capabilities.

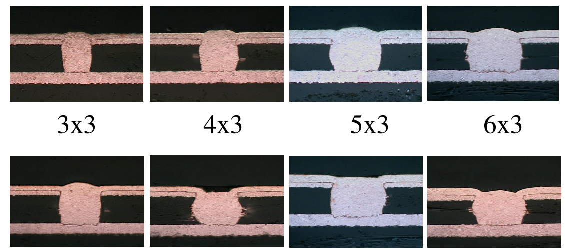

Figure 8

Systems Integration

Combining equipment with chemistry is not a new concept. Integrated horizontal systems have been on the market for years with good success, but there are drawbacks. Total horizontal systems tend to be quite long and take up a large foot print in manufacturing. Horizontal electrolytic plating will always have a place for transporting thin core materials, but tends to be maintenance intensive, does not offer easy access to the internal mechanisms, and requires high initial capital costs.
This integrated system unites the best attributes of horizontal processing for deburr, desmear and carbon metallization with the high productivity and lower cost of vertical continuous plating. In this continuous process, panels are fed into the deburr machine after drilling and are removed from the VCP completely plated.

Final Product Reliability

Reduced costs at the same or better quality levels is the expectation of every OEM. The reliability data collected meets all industry standards. Figure 9 shows the test results for JESD specifications.

Reliability Test	Condition	Results
L3 Preconditioning	JESD22-A-113E (30ºC, 60% RH, 192 hr, 150ºC)	Pass 303/303
TCT	JESD-A-104B (-55ºC to 125ºC, 1000 cycles)	Pass 105/105
HAST	JESD22-A110-B (96 hr, 130ºC, 85%RH, 3.7V)	Pass 92/92
PCT	JESD22-A102-C (96hr, 2 ATM, 121ºC, 100% RH)	Pass 106/106

Figure 9

A total of 303 parts were L3 preconditioned, then divided into the different specific tests. The first number is the number of parts that passed the test and the second number is the total parts tested.
Another set of reliability data is based on specific OEM standards. Results are summarized in figure 10.

Metric	Spec	Result
Corner Crack	None	Pass
Smear	None	Pass
Laminate Void	None	Pass
Nodule	None	Pass
Pull Away	None	Pass
Delamination	None	Pass
Cu Thickness (Min)	Min 14 µm	18 µm
Delamination	None	Pass
Land Lift	Max 80 µm after thermal shock	Pass
Wicking	Max 100 µm	21.4 µm Pass
Hole Roughness	No hole diameter reduction by Roughness & Nodule	Pass
Nodule		Pass
Corner & Barrel Crack	None	Pass
Void	None	Pass
Negative Etch Back	Max 25 µm	4.4 µm Pass
Smear	None	Pass
Inner layer Separation	None	Pass

Figure 10

Parts were thermal stressed prior to evaluation using the above metrics. The thermal stress parameters were 3 time solder float at 288ºC.
Further reliability testing is underway. Air to air thermal stress (AATS) and interconnect stress (IST) data is currently being gathered. This data will be published in a second paper.

Conclusion

The integrated process described in this paper achieves the goals of reducing costs while maintaining high quality. The cost savings come from lower chemical usage, water conservation, reduced power consumption, and lower labor costs due to automation and fewer process steps. The capability to plate through holes and simultaneously fill vias eliminates the need for duplicate processing which saves cycle time. The elimination of the planarizing step further reduces cycle time and prevents the waste of some of the electroplated copper deposit. Capital cost savings are realized through shorter metallization steps (carbon versus electroless copper and VCP versus horizontal).
The final HDI product passes all industry standards for quality.