Green Benefits of Improved Direct Plating Processes

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ABSTRACT

In recent years there has been an increase in environmental awareness globally, which has also influenced the PCB manufacturing industry. New "green" legislation such as WEEE, RoHS and REACH has been introduced to compel PCB manufacturers to employ less harmful manufacturing chemistries.

China for example, has enacted strict standards for new PCB shops especially with regards to wastewater generation, making it harder for manufacturers to acquire production licenses.

For the metallization process this has rekindled interest in direct plating (DP) processes, which although often regarded as being technically inferior, are deemed more environmentally friendly than electroless copper. Direct plating can generally be subdivided into two main categories i.e. Pd-based and Conductive Polymer based types.

Both are formaldehyde and cyanide free and the conductive polymer based processes are usually shorter than electroless copper with all associated environmental benefits.

My paper will use the example of Atotech's new Seleo CP Plus (conductive polymer) and Neopact (Pd-based) processes to illustrate the environmental benefits of direct plating as well as its technical limitations. Calculations will show relative chemistry and energy consumptions as well as wastewater generation in comparison to electroless copper.

Additionally, quick via pull (QVP) test results will demonstrate the relative strengths of the copper –copper adhesion at the capture pad of blind microvias.

GENERAL INTRODUCTION

Several direct plating technologies are available on the market. The most common systems employ one of the following technologies:

- Carbon
  - Carbon amorphous modification
  - Graphite crystalline modification
- Palladium/Tin
  - Pure Pd
  - Copper link
  - Sulpher link
- Palladium Organic Colloid
- Conductive Polymer
  - Pyrrole
  - Thiophene
- Hybid Processes

Carbon systems have a deep market penetration in most markets, where they are used especially for mass production of single and double sided boards. Other relatively common processes mostly employ palladium and conductive polymer technologies. These processes have a moderate acceptance especially in Europe and to a lesser extent in Japan. In Europe both palladium and conductive polymer based processes are used for a wide variety of applications including MLB and HDI applications. In Japan on the other hand, application is mainly limited to Flex/Flex-rigid production with palladium based processes seeming to be more favored.

Market penetration for these processes has been limited in large markets such as China and Taiwan where most producers prefer to use electroless copper processes.

However the stricter environmental legislation in China and elsewhere could herald a new dawn for direct plating processes as they can offer many environmental benefits in comparison to electroless copper.

ENVIRONMENTAL BENEFITS

Please note that the comparisons within this paper will be limited to electroless copper and the two types of direct plating (DP) process which I am familiar with i.e. Pd-based and conductive polymer based DP.

Dangerous Chemicals

Direct plating processes unlike electroless copper are formaldehyde and cyanide free. Formaldehyde is believed to be carcinogen while cyanide is a highly poisonous substance and needs to be handled extremely carefully. It is therefore environmentally highly beneficial to use direct plating processes for PCB metallization as opposed to using electroless copper.

Process Times and Equipment Footprint

In the following, typical process sequences and process times for electroless copper and direct plating are compared.

Diagram 1: Process Sequence Comparison

Table 1: Typical Module Lengths & Process Times with Horizontal Equipment

Process	Electroless Copper	Conductive Polymer	Pd-Based DP
Typical Module Length*	9600mm	**4400mm**	5900mm
Typical Process Time*	570s	**260s**	370s

* 1 m/min conveyor speed includes activation steps, excludes rinses

As can be seen in the comparisons above, the conductive polymer processes have the shortest process sequence, the shortest process times and the smallest equipment footprint.

Generation of Wastewater

The following diagrams show a comparison of the wastewater generated in active modules and that generated in rinse modules for electroless copper and direct plating.

Diagram 2: Wastewater from Process Modules

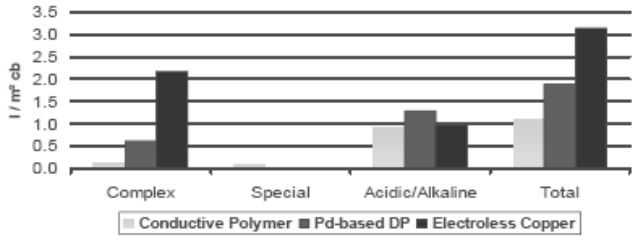
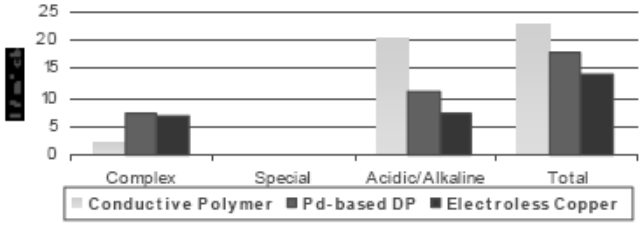


Diagram 3: Wastewater from Rinse Modules



Calculation Basis:

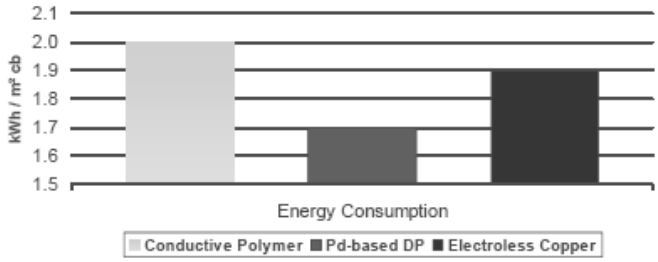
- Horizontal Production Line
- Line Speed 1m/min
- Throughput 100,000 m^2 cut board p.a
- Dragout 110ml/m^2

From the above diagrams it can be seen that in total, the conductive polymer process produces the least amount of complex containing wastewater.
The Electroless copper process has the least amount of acidic/alkaline and the Pd-based process is in the middle for both.

Energy Consumption

The energy consumption is lowest for Pd-based DP. Conductive polymer processes generally have much higher energy consumption mainly due to the high temperature which is required in the adhesion promoter.

Diagram 4: Comparison Of Energy Consumption



Calculation Basis:

- Horizontal Production Line
- Line Speed 1m/min
- Throughput 100,000 m^2 cut board p.a
- Dragout 110ml/m^2
- **Excluding cooling**

TECHNICAL PROS & CONS

One of the biggest problems encountered with horizontal electroless copper baths is that of bath stabilization and associated problems such as plate-out risk and particle formation. In horizontal

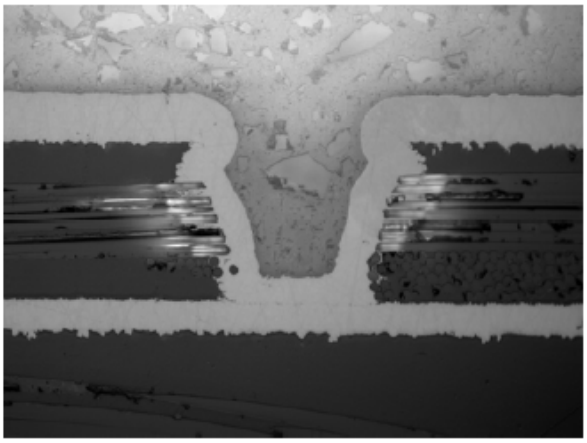
technology particles can lead to further problems such as dents and scratches on panel surfaces as well as blockages of through holes and blind microvias.
This problem is much less pronounced with direct plating processes, where there is mitigated plate-out and particle formation risk.

An advantage of the conductive polymer based processes is that they do not employ Pd. Palladium is used for activation of non conductive surfaces for electroless copper as well as Pd-based DP and it is a major cost factor for both process types.. The price of palladium has tended to fluctuate a lot historically and it is expected that this trend will continue in future.

Customer experience seems to also suggest that adhesion of the acid copper layer to the DP-layer could be much better than that to electroless copper. Experiments conducted to verify these assumptions have failed to provide conclusive results up to now.

Our customer experience shows that Pd-based DP is often confronted with skepticism with regards to the issue of interconnect reliability of Blind Microvias within the PCB industry. In this context interconnect reliability refers to the adhesion of the acid copper to the direct plating layer at the BMV capture pad. There seems to be a relatively widespread belief that Pdresidues from the direct plating process will remain at the capture pad and lead to poor adhesion with the electrolytic copper layer in the subsequent process.
Using quick via pull testing, for more than 1 million BMVs for each test series, it could be shown that standard HDI BMVs (90-100 µm wide/60-80 µm deep) can be processed with a failure rate of < 1ppm on FR4 and RCC material.
The following picture shows such a typical BMV processed by Atotech's Neopact process (Pd-based DP).

Picture 1: BMV Processed With Neopact After Acid Copper Process



The following table shows a comparison of technologies for which the different process types can be applied:

Table 2: Product Types Produced With Electroless Copper and Direct Plating

	Electroless Copper	Conductive Polymer	Pd-based DP
IC Substrate	+	-	-
HDI, MLB	++	+	+
Flex/Flex-Rigid	+	+	++

Key:

- + applicable
- ++ most suitable
- - not applicable

As can be seen from the table above electroless copper is best suited for high technology applications such as IC Substrate and HDI production. This could explain why many PCB manufacturers are still quite reluctant to invest in direct plating technology despite all the environmental benefits it has on offer.

CONCLUSIONS

Direct plating has several environmental advantages versus electroless copper. These could lead to a renewed interest in the PCB industry in the wake of the recent tightening of environmental legislation in several PCB producing countries especially China.
Currently capabilities of direct plating processes limit their use to lower technology applications as the technical performance of electroless copper remains superior especially for high technology applications such as IC Substrate manufacture.

ACKNOWLEDGEMENTS

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