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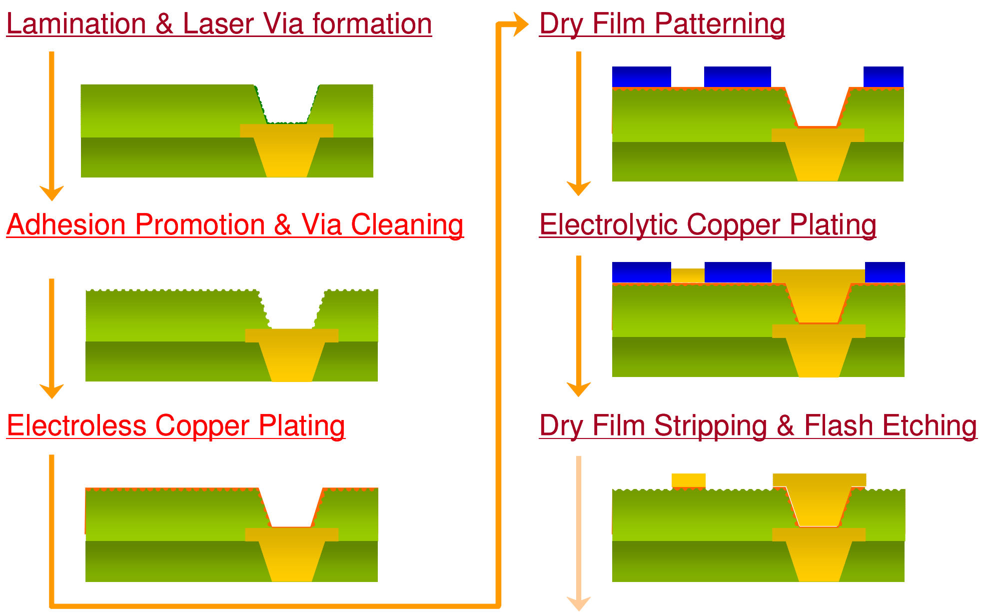

Full Build Electroless Copper for High Density Interconnection

Fully additive electroless copper plating systems were first used for PWB fabrication during the early 1960's (1, 2), but were limited at that time to relatively simple products, for example, double sided and low layer count multilayer printed wiring boards, due to the susceptibility of the copper deposits from early formulations to crack during thermal stress.

Over the next 15 years, improved formulations were developed, which produced deposits with much improved physical properties. Industry acceptance of this technology increased significantly in the mid 1970's, particularly when IBM (3) decided to use the technology for through-hole metallization of very high aspect ratio multilayer boards for mainframe computer applications.

However the use of full build electroless copper plating almost disappeared in the 1980's due to: (1) the relatively low deposition speeds of the full build electroless copper baths available during that period, which required immersion times in the 10 - 20 hour range to reach copper thicknesses of 25 microns, (2) lack of suitable alkaline-resistant plating resists that would allow pattern plate semi-additive processing and (3) the increased throwing power capabilities of electrolytic copper plating baths which permitted processing of even very high thickness and aspect ratio product.

applications, has now reached the point where limitations in plating resist resolution and undercut during subtractive flash etch steps leads to unacceptable line shapes and feature adhesion. These limitations have led to a renewed exploration of the use of fully additive fabrication techniques as a means to meet the demands for next generation products.

Since the plating thicknesses required for next generation ultra fine line products are much lower than for traditional PWB applications, the required electroless copper plating bath immersion times are much reduced, relaxing the demands on plating resist durability.

Comparison of Semi-Additive and Fully Additive Fabrication Processes for Ultra Fine Line Products

In order to demonstrate the benefits of a fully additive process, it is helpful to consider the limitations of a semi-additive process for production of product at 5µm/5µm line/space.

A typical semi-additive process flow (Figure 1 below) consists of the following steps: formation of an initial conductive layer (electroless copper seed layer) for electrolytic copper plating, feature patterning using a dry film photoresist, electrolytic copper plating, resist stripping and finally removal by etching of the seed layer between the conductor features.

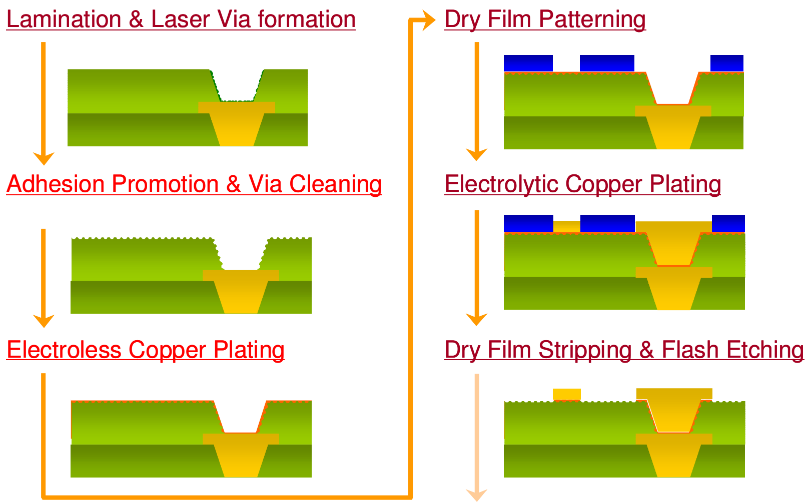

Fig.1 Semi-additive process flow for metallization of package substrate dielectric material

Fine pattern circuit formation relies heavily on both effective resolution of dry film photoresist and formation of sidewalls with proper profiles after development. Semi-additive processes are currently best suited for circuit formation around 10µm/10µm line/space, limited by the resolution properties of available dry film photoresists and the capability of current generation exposure and development equipment.

Selection of dielectric materials for ultra fine fine line sequential build substrates is based a variety of physical property and processing characteristics. It is always necessary to use a dielectric material with low CTE to maintain material dimensional stability during processing. Stable physical and electrical properties in the final service environment are also required. While the dielectric must be capable of forming a low profile surface (low roughness) condition after the desmearing process, it must also provide sufficient peel strength to maintain adhesion of both the plated deposits and also the photoresist used during processing. Formation of an excessive level of roughness (either R_a or R_z) must be avoided, as this may prevent complete removal of electroless copper residues from the dielectric material surface, leading to reduced line to line insulation resistance and the potential for electromigration failures during product service. Achieving the appropriate roughness target is critical to allow production of reliable end-products with 5µm/5µm line width and space.

Whenever an electrolytic copper plating process is used, some degree of variability in surface plating thickness is unavoidable. This variability leads to difficulties maintaining target dielectric thicknesses and planarity of the overall structure during sequential-build construction. In contrast, full build electroless copper plating thickness is inherently uniform and independent of surface feature density and design. It is therefore much easier to maintain tight control of both deposition thickness and uniformity variation when using a full build electroless plating approach.

The need for a subtractive flash etch step after electroplating and resist stripping in the semi-additive process, leads to attack on feature sidewalls and increased difficulty in achieving the desired final line width. While specialized copper flash etch formulations have been designed to have higher etch rates on the flash electroless copper deposit than the electrolytic deposit that forms the features, it is still not possible to completely eliminate feature degradation during a semi-additive process. Use of a fully additive plating process eliminates any need for a flash etch step after plating, increasing the consistency of feature dimensions.

When planning for next generation fine-line products, with a target of 5µm/5µm line/space, the capability limitations of semi-additive processes described above become critical quality gaps that may not have available solutions.

More modern “full build” electroless copper plating bath are now available with deposition speed of approximately 5µm per hour. This type of electroless copper bath is capable of producing ultra fine line product with circuit line / space features below 5µm/5µm, either in combination with a surface structured dielectric or with a photoresist with an appropriate level of alkaline resistance.

Full Build Electroless Copper:

Overview

Rohm and Haas full build electroless copper plating systems are suitable for deposition of thicknesses between 5µm and 50µm and are compatible with pretreatment processes using conventional (dielectric texturing, conditioning and catalysis) chemistries, with activation by Laser Direct Structuring and with pre-catalyzed substrates.

Typical formulations will contain the following classes of ingredients:

- Copper ion source
- Reducing agent (typically formaldehyde)
- Hydroxide ion source
- Chelating agent (for example, EDTA, Rochelle Salt or Quadrol)
- Stabilizers, brighteners and deposit modifying additives

Deposits have uniform grain structure and a slightly less reflective surface than electrolytic deposits. The density and electrical conductivity of full build electroless copper deposits are very similar to those of electrolytic copper.

Successful implementation of full build systems relies on a properly selected combination of bath formulation, equipment design and bath control.

Equipment Design

Rapid and uniform aeration must be provided within the plating bath, to maintain bath stability by removing excess hydrogen gas. Dissolved hydrogen has the capability to act as a secondary reducing medium, leading to changes in bath properties, including localized hyperactivity, changes in deposition rate and deposit surface morphology.

Solution heating should be provided with low density heating elements or heat exchangers that prevent excessive bath temperatures at heated surface.

Continuous overflow filtration, through a 5 to 25 micron polypropylene filter bag, should be provided and care should be taken to regularly change filters, to avoid build ups of significant amounts of extraneous copper.

The plating bath should be transferred out of the plating tank regularly, to allow the tank and associated plumbing to be stripped of any copper plate-out.

Bath Control:

Consistent performance of a full build electroless copper bath can only be achieved if the bath is maintained within the correct range of chemical composition. It is important to monitor and maintain the concentrations of all critical bath components, in order to keep the plating rate and deposit physical properties stable. Use of automatic controllers is the recommended approach to ensure optimum plating bath performance.

Deposition rate:

As with all electroless copper systems, the deposition rate depends, to a varying degree, on temperature, copper ion, hydroxide ion, reducing agent and additive concentration, and also bath loading.

Figure 2 demonstrates the stability of plating rate that can be achieved with baths of this type. At an operating temperature of 56°C and a bath loading of 0.45dm^2/liter, the deposition rate for a copper concentration of 2.5g/liter is 4.6 µm/hr. At a copper concentration of 3.0g/liter, the rate increases only slightly, to 4.8µm/hr.

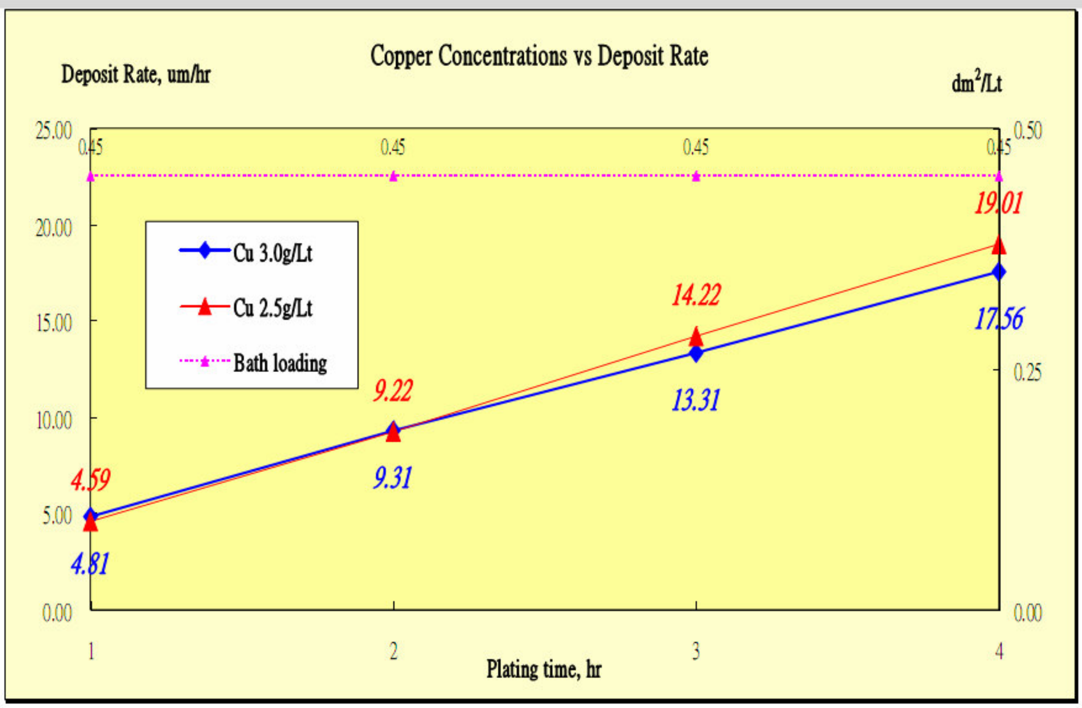

Figure 2: Deposition rate versus copper concentration

Summary:

While "full build" electroless copper processes have been used in the PWB for many years, a number of factors have restricted their usage to a relatively small number of facilities.

Currently, emerging requirements for Laser Direct Structuring and fine line / space package substrate products have made full build systems viable candidates for these applications. For these fine line products, the uniformity of deposition thickness uniformity is much better than for electrolytic-based metallization processes and the elimination of need for a flash etch etch process improves feature dimensional control.

Rohm and Haas, with many years of experience in development of electroless copper processes for PWB applications, can now offer full build systems with improved deposition speed and lower operating temperatures and anticipates significantly greater usage of these types of products.

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Rohm and Haas Electronic Materials LLC is a global supplier of a comprehensive range of printed circuit fabrication products, including SBU imaging and metallization processes.

1) US Patent 3,095,309
2) US Patent 3,259,559
3) W. A. Alpaugh and J. M.

McCreary, "Copper Plating Advanced Multilayer Boards," Insulation/Circ.24, No. 3, 27-32 (1978).