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Vertical, Continuous Plating Equipment for Printed Circuit Boards

Shigeo Hashimoto, Shushi-Morimoto, Koji-Shimizu*
C. Uyemura & Co., Ltd.
Hirakata, Osaka, Japan

Abstract
New vertical continuous plating equipment has been developed while taking into consideration production and environmental requirements. The vertical continuous plating equipment conveys printed circuit boards continuously without using any racks and carries out high quality plating. This paper discloses an outline and features of our newly developed vertical continuous plating equipment for printed circuit boards, and various data such as surface deposited thickness distribution and throwing power on the through hole and blind via holes (BVH).

Introduction
Needs for smaller size electronic components and computerization continue recent trends. Requests for thinner and higher density printed circuit boards are increasing. For forming fine patterns, uniform surface copper plated thickness is indispensable. Also, for forming inner circuits such as via hole (IVH), a plated surface free of nodules is necessary. In addition to these requests for increasing plating quality, in order to respond such requests as cost reduction and environmental conservation etc, rack-less continuous plating equipment has been developed.

In fact, various continuous conveyance systems have been introduced into the market and are now in use at many manufacturing sites.

In the development of continuous plating equipment, we have reached the following conclusion. That is, totally compared to each other, we believe the vertical method is superior to horizontal method in electroplating processing. We have developed a vertical process that carries out high quality and high speed plating, which exhibits excellent deposit thickness distribution.

However, in these days, to obtain an even coating and to handle build-up boards, requests for low current density plating are increasing. Accordingly, we set up the following targets and have developed new vertical continuous plating equipment for printed circuit boards. Required features for the system are as follows:

1) Low priced equipment capable of carrying out plating with a low current density
2) Excellent uniformity of deposit thickness
3) Capable of conveying thin boards (0.1 mm (0.004”))
4) Excellent in BVH covering

This paper describes the features of the new vertical system and the results of plating made using a prototype machine.

Outline of the Equipment
The equipment is a modified model of conventional pusher-type automatic plating equipment. Cathode hangers are provided with clamps with which printed circuit boards (referred to as “panel”) are conveyed continuously one by one through the plating baths without the use of racks.

Bath-in/out panel guide mechanisms, an auxiliary feed mechanism for adjusting space between the panels and a jet flood system for high current density plating are newly added.

An outline of the new system is shown in Figure 1.

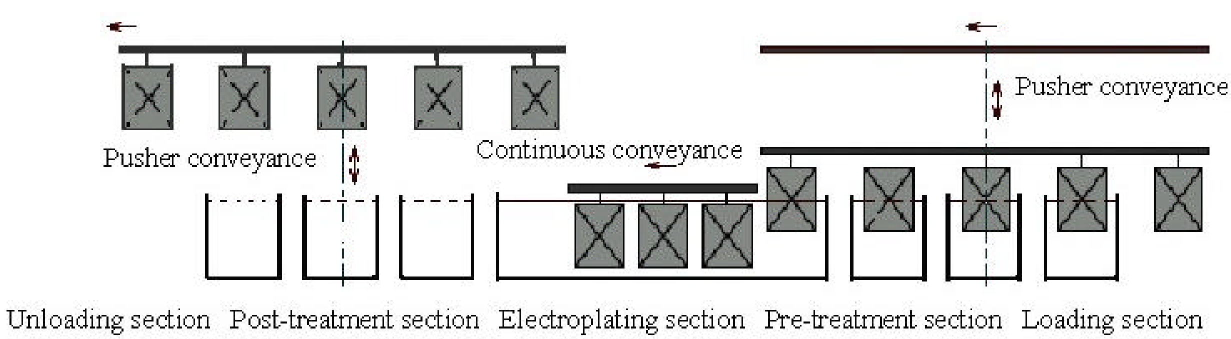


Figure 1 – Outline of the Vertical Equipment

The system is comprised of, from the right to the left, a loading section, a pre-treatment section, an electrolytic copper plating section, a post-treatment section, an unloading section and a clamp stripping section (not shown in the figures).

In the loading section, an automatic loader unit attaches horizontally postured panels to the hanger clamps one by one in vertical posture.

In the pre-treatment section, the panels fed from the loading section are pre-treated in a manner of acid cleaning and acid rinse as a standard pretreatment while being conveyed by means of a pusher conveyer.

In the electrolytic copper plating section, the panels are conveyed continuously while being copper-plated. From the post-treatment section to the unload section, the panels are conveyed by means of a pusher conveyer again.

In the unloading section, the panels are repositioned into horizontal posture, and are subjected to anti-tarnish treatment and are dried.

Features of the equipment are as described below:

1. In the loading section, in accordance with the size of the panel (length in conveyance direction), the clamper position is adjusted automatically. Even thin panels can be clamped reliably without panel damage. Also, when carrying the panels into or out of the treating bath, the thin panels are guided to avoid being bent.
2. In the electrolytic copper plating section, in accordance with the progression of the panels, the exclusive chain feeder feeds the hangers while keeping about 10 mm (0.4") space between the preceding panel and carries out continuous conveyance of the panels.
3. Know-how applied to preceding machines is adopted in the structure of the copper-plating bath (sparger, ring roller type panel guide and shielding plate). The shielding plate is driven to move up/down in 6 m (20ft) increments in order to adjust the depth in accordance with the panel size.
4. The power supply slide rail is disposed on the side of the plating tank to prevent any dust from falling into the plating solution to prevent nodules on the plated surface.
5. The clamp stripping section next to the unloading section is as long as the electroplating section. Since copper deposited on the clamps is removed chemically, daily maintenance of the clampers is not necessary. Also, the clamp stripping section serves as a space used for controlling the number of hangers.

Major Specifications of Standard Equipment

Major specifications of the standard equipment (panel size variable type) are as listed below. Clamper position and height of the shielding plate in the bath are automatically adjusted.

1. Panel dimensions
   Thickness: 0.1 mm - 1.6 mm (0.004"-0.062")
   (Copper foil: Minimum 12 micrometer)
   Length: (in forward direction): 330 mm - 510 mm (13" – 20")
   Height: (in depth direction): 340 mm - 610 mm (13.4" – 24")
2. Cathode current density: Up to 4 ASD (40ASF)
3. Plated copper film thickness: Adjustable by means of current density and conveyance speed.
4. Production capacity
   1 cell = about 2,500 m^2B (2,7000 ft^2B) / month
   2-cell = about 5,000 m^2B (54,000 ft^2B) / month
   4-cell = about 10,000 m^2B (107,000 ft^2B) / month
5. Rectifier: front/ back, 1 each per cell
6. Circulating capacity for filtering the plating solution: 12 turns / hour (10 - 15 turns). Recommended filtering accuracy: 0.5micrometer
7. Installation space (4-cell spec.)
   36 m - 4.7 m - 2.75 m (120ft – 15.4ft – 9ft) (including standard accessories.)
8. Different additives used depending on current density requirements

In addition to the standard model, a low priced model, fixed panel dimension type is also available (standard panel dimension: 405 mm×510 mm (16" – 20")).

Layout of the Standard Equipment

Figure 2 shows the layout of the standard equipment specified with 2 cells, production capability of 5,000 m^2B (54,000 ft^2B) / month (500Hr/ month), panel plating of 25 micrometer (1mil).

Figure 3 shows the sectional view of the equipment.

Standard process is constituted of loading, acid cleaning, hot drag out rinse, water rinse, water rinse, acid rinse, electroplating entry, electroplating, electroplating exit, drag back rinse, water rinse, hot water rinse, unloading, clamp stripping (hanger stock, controlling of the number of hangers), water rinse and hot water rinse in that order. The equipment is designed to install in straight-line configuration.

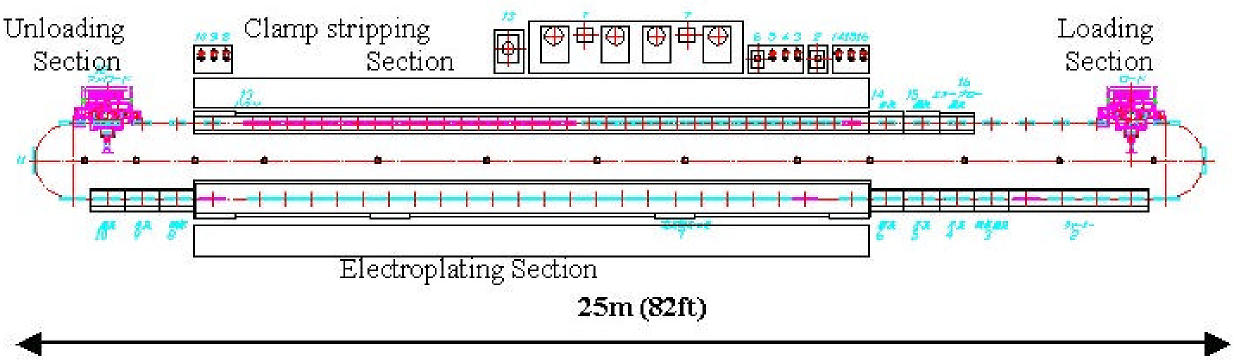


Figure 2 - Standard Layout (5,000 m^2B (54,000 ft^2B) / Month)

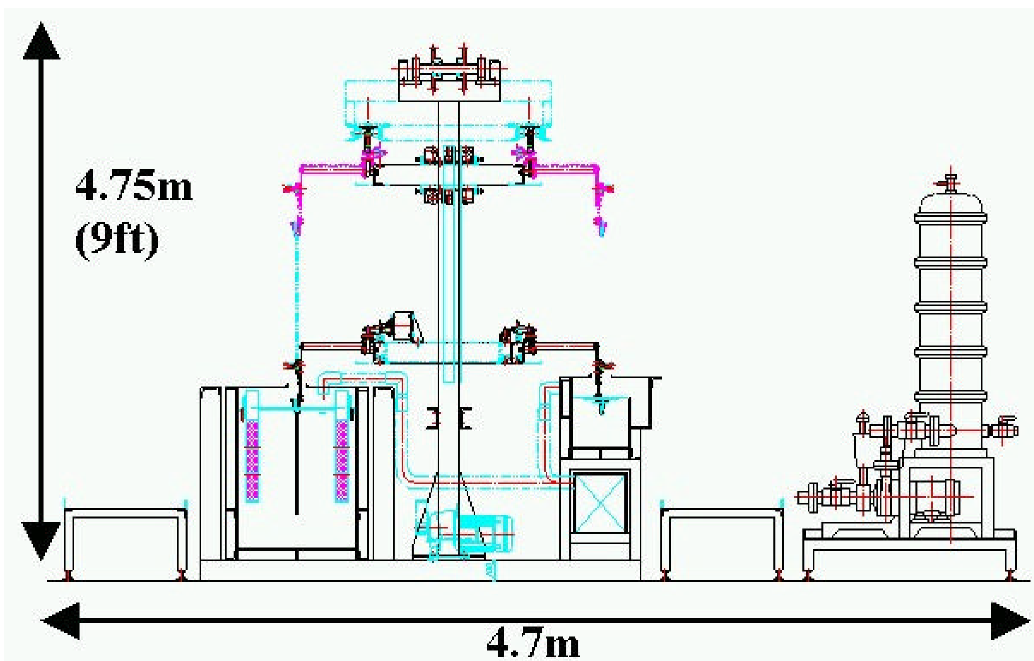


Figure 3 - Sectional View

Plating on the Prototype Equipment

Figure 4 is a photograph of prototype equipment that is installed in our laboratory.

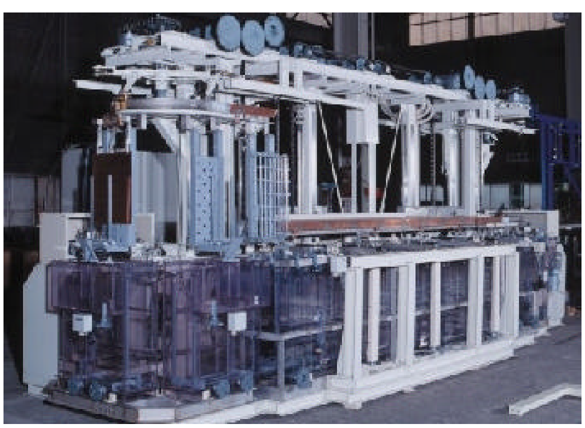


Figure 4 - Prototype

Loading section is positioned at the right end of the equipment. The sequence is acid rinse, copper plating, and water rinse. Disposed at the corner is the water rinse, and disposed at the left end in the backside of the equipment is the unloading section. In the area opposite to the copper sulfate plating bath in the backside of the equipment, the clamper stripping bath and water rinse section are disposed.

Prototype equipment specifications:

- Effective length of the plating bath: Approx. 2.2 m (7.2ft)
- Conveyance speed: 40 mm (1.6")/ minute - 400mm (16") / minute
- Current density: Max. 4 ASD (40ASF)

Panel dimensions:

- Thickness 0.1 mm - 1.6 mm (0.004" - 0.063")
- Height 330 mm - 600 mm (13" – 23.6") (in case of a thin panel, 510 mm (20") or less)
- Length 250 mm - 510 mm (10" – 20") (in case of a thin panel, 405mm (16") or less)

Plating Conditions
Measurements were made on surface thickness distribution, throwing power in through hole, throwing power in BVH using our company's mid-current density and low current density bath additives for copper sulfate plating.

Measurement of surface thickness distribution and throwing power in through hole were made using the panels of 400 mm in width, 500 mm in height, 1.6 mm in thickness and 0.3, 0.4, 0.6 and 0.8 mm in hole diameter, respectively.

Preparation of the samples was made with our horizontal conveyance type electroless copper plating equipment using our company's alkaline catalyst process and our company's electroless copper for thin plating.

In the electrolytic copper cell, plating was carried out at a current density of 2, 3, 4 ASD (20,30,40 ASF) respectively using our company's additives for mid-current densities.

In addition, plating was carried out at a current density of 1, 2, 3 ASD (10,20,30 ASF), respectively using our company's low current density additives. Measurements were made after plating.

Measurement of BVH throwing power was made using the panels of 400 mm in width, 500 mm in height, 0.8 mm in thickness, 165 micrometer in BVH depth, 130, 160, 180 and 200 micrometer in hole diameter, respectively.

Preparation of the samples was made with an ordinary dip line using our company's Sn-Pd colloid catalyst process and our electroless copper for thick plating.

In the mid-current density acid copper system, plating was carried out at a current density of 2 ASD (20ASF) to form approximately 25um in plated thickness. While in the low current density system, plating was carried out at a current density of 1, 2, 3.5 ASD (10,20,35 ASF), respectively, to form approximately 20 micrometer in plated thickness. And then, measurements were made. As for the plating conditions other than the current density, the standard conditions of the respective chemicals were adopted.

Measurement of Surface Thickness Distribution
Regarding the common features of continuous conveyance type plating equipment, since the panels are conveyed through the identical path and plated under the identical conditions, plated thickness distribution in the conveyance direction is excellent and little thickness variance is found among the panels. Almost all variations in plated thickness are found in the vertical direction. Accordingly, herein, surface thickness distribution in the vertical direction of the panels is described.

Measurement of surface thickness was made in the area 10mm inside from the edge of the panel.

Surface Thickness Distribution for Mid-Current Density System
Figure 5 shows surface thickness direction in the vertical (depth of bath) direction. X-axis represents a distance from the upper end of the panel (clamp side). In Figure 5, the minimum value represents the film thickness at a point 10 mm away from the upper end, which is influenced by the clamp. The influence of the clamp at the upper of the panel is a major factor of the thickness variance.

Surface Thickness Distribution for Low Current Density System
Figure 6 shows surface thickness distribution for the low current density system. Same as the case of mid-current density system, satisfactory results were obtained. Every minimum film thickness is the value at the point of the clamp. At 10 – 20ASF current density, thickness falls approximately -5% at a point 15mm away from the upper edge. At 30ASF of current density, thickness falls within -10%.

Figure 7 shows measurement results of surface thickness of 6 successive panels from the first panel in a lot, which are plated using the mid-current density system at 40 ASF to form an 8μm deposit thickness.

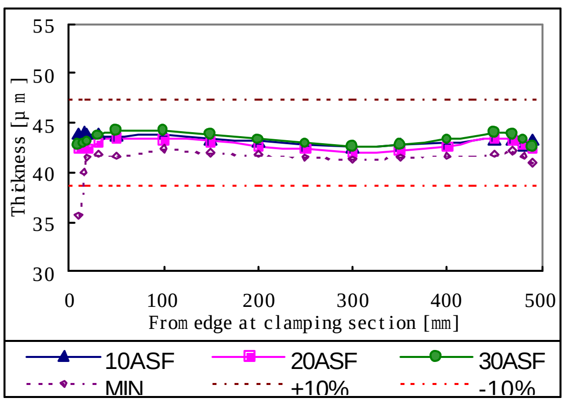


Figure 5 – Mid-Current Density Additive Thickness Distribution

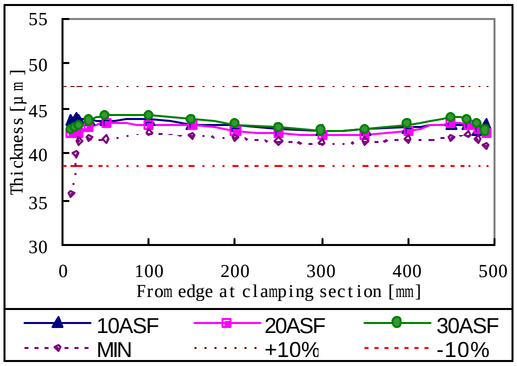


Figure 6 – Low Current Density Additive Thickness Distribution

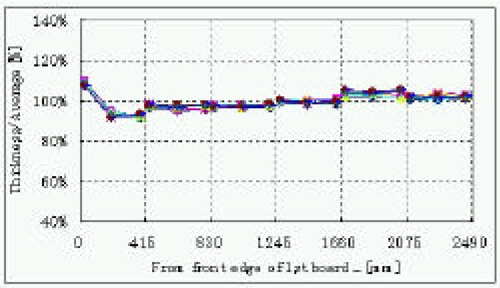


Figure 7 - Comparison of First 6 Panels' Thickness (Comparison with Average Value)

Dispersion in Thickness Among The Panels (Mid-Current Density)

Although the thickness distribution in the first panel is remarkably poor, almost all thickness distribution of the following panels falls within ± 10% of the average thickness, and a satisfactory distribution was obtained. Features required for continuous plating equipment was verified.

Based on the results, the necessary number of dummy panel(s) for a low current density is that a single dummy plate is sufficient. For high current density, or particularly when precise thickness distribution is required, it is recommended to use 2 - 3 dummy panels.

Measurement Results of Surface Thickness

Table 1 shows results of surface thickness measurement. Excluding the clamp area, the diffusion range (ratio with respect to the average value of the maximum value - minimum value) falls within ± 15%. Further, the distribution in the central area 20 mm away from the edge of the panel is extremely uniform. Comparing the measurement results of area excluding 10 mm (0.4") away from the upper end, and area 15 mm (0.6") away from that, differences due to the current density are remarkably found around the clamp area. Especially, they are found clearly in low current density acid copper system.

For comparison, data for this machine and data obtained on a hoist type plating equipment (4-panel setting) are provided. The equipment is designed based on the know-how of previous equipment designs. Compared to conventional equipment, the equipment is sufficiently improved and the obtained data of the equipment is close to the data of previous designs.

Table 1 – Summary of Surface Thickness Measurement (Plated Thickness: 25 Micrometers)

Bath type / Current density	**Mid C.D. / 20ASF**		**Mid C.D. / 30ASF**		**Mid C.D. / 40ASF**	
Calculation exemption range	Standard deviation	(Max-Min.)	Standard deviation	(Max. - Min.)	Standard deviation	(Max. - Min.)
10 mm from every edge	1.18	+/- 16%	1.51	+/- 24%	1.22	+/- 19%
Clamp area: 15 mm	1.13	+/- 12%	1.19	+/- 16%	1.05	+/- 14%
20 mm from every edge	0.76	+/- 9%	0.81	+/- 10%	0.71	+/- 9%
Bath type / Current density	**Low C.D. / 10ASF**		**Low C.D. / 20ASF**		**Low C.D. / 30ASF**	
10 mm from every edge	0.96	+/- 11%	1.02	+/- 19%	1.32	+/- 21%
Clamp area: 15 mm	0.92	+/- 8%	0.81	+/- 9%	1.15	+/- 15%
20 mm from every edge	0.82	+/- 7%	0.69	+/- 7%	0.85	+/- 8%
Comparison data						
Ucon / EUC	70ASF (30um)		Hoist-type upper clamp		25ASF (18um)	
Clamp area: 15 mm	1.20	+/- 10%	13mm from every edge (Calculation of 4 panels)		2.93	+/- 24%
20 mm from every edge	0.80	+/- 6%				

Throwing Power in Through Hole Plating
Measurement was made on throwing power in through holes of 0.3 mm - 0.8 mm in hole diameter on a panel of 1.6 mm in thickness (ratio of minimum thickness at the center of through hole to surface thickness). Measurement results are shown in Figure 8 (mid-current density bath) and Figure 9 (low current density bath).

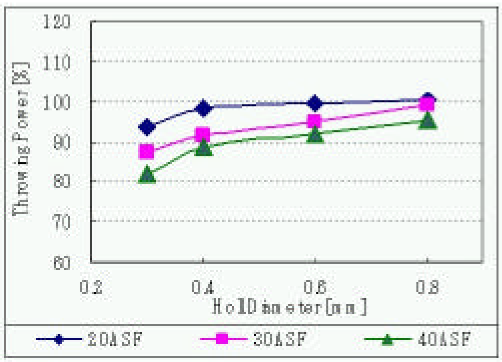


Figure 8 – Thru-Hole Throwing Power for Mid-Current Density Bath (1.6mm thk.)

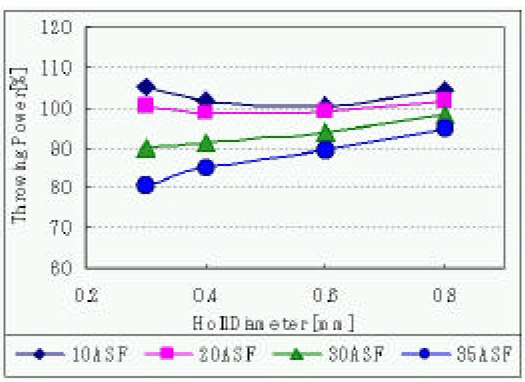


Figure 9 – Throwing Power for Low Current Density Bath (1.6mm thk.)

Throwing power largely depends on the effect of the additives and the influence of the bath solution composition.

In the mid-current density bath, even at a high current density, throwing power decreases slightly. Accordingly, it is possible to carry out plating on panels with low - medium aspect holes. It is excellent in productivity. The low current density bath exhibits excellent covering ability on small diameter hole at a current density 20 ASF or less.

BVH Plating Throwing Power
Measurement of throwing power was made on BVH of 165micrometer in depth (resin thickness: 150micrometer), 130 – 200micrometer in hole diameter (ratio of the minimum thickness on the bottom face of the BVH to surface thickness). Measurement results are shown in Figure 10 and sectional views are shown in Figure 11.

In case of plating on small diameter holes of deep BVH with aspect ratio exceeding 1, it is necessary to usew the low current density bath at a low current densities. When the aspect ratio is 0.8 or less, throwing power exceeding 80% is obtained with the mid-current density bath.

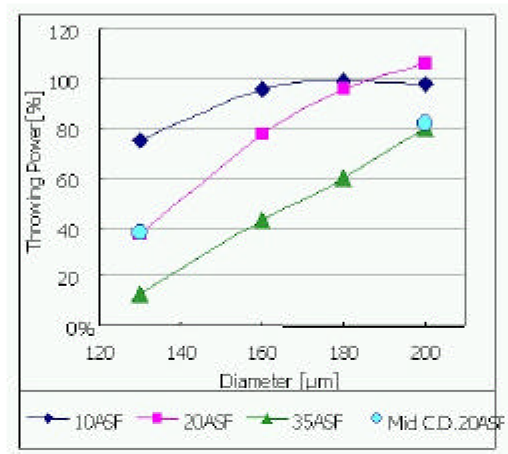
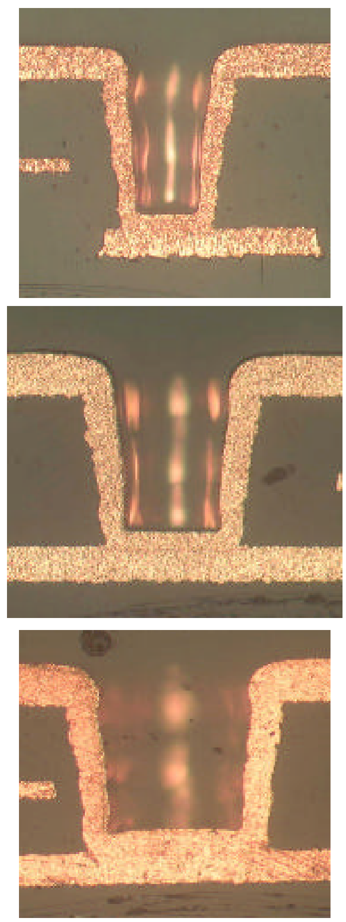


Figure 10 - Throwing Power in BVH (165um Depth)



Diameter: 130um,
Depth: 165um
Low CD Bath
10ASF
T.P.=75%

Diameter: 160um,
Depth: 165um
Low CD B
20ASF
T.P.=78%

Diameter: 200um,
Depth: 165um
Mid CD B 20ASF
T.P.=82%

Figure 11 - Photo Showing Sectional Views of BVH Plating

Summary

In a conventional pusher conveyer type continuous plating equipment, although it is low priced, some disadvantages remain. That is, it is hard to respond to changes in panel size and poor uniformity in plated thickness. Further, it is hard to convey thin panels without using a rack or frame.

Uyemura's new equipmnt was developed to solve the above-mentioned disadvantages, and at the same time, to provide plating performance similar to the previous esigns at a reasonable price.

As for the points to be noted, the productivity of the continuous plating equipment decreases when the number of the product models to be processed (height of panel, plating thickness etc) increases. Even a single error or failure may result in a danger that every panel within the line becomes unacceptable.

Finally, features of the new equipment will be described below:

1. Conveyance of thin panels is realized utilizing a clamp adjusting mechanism at the loading section in accordance with the bath entrance guide and the guide in the bath.
2. The new equipment is a continuous conveyance system. Since every panel is processed in the identical path, stable quality of plating is obtained.
3. Know-how of preceding equipment designs is adopted and thickness distribution within a panel is 25micrometer ±10%.
4. Our low current density acid copper bath exhibited excellent coverage on every BVH.
5. Power supply slide rail is disposed on the side of the plating tank to avoid dust falling into the plating solution, and to prevent nodules on the plated surface.
6. The automatic loader and unloader are connectable with a horizontal conveyer. They can be connected to our horizontal conveyer type electro-less copper plating equipment.
7. Size (feed direction) of the panels is selectable at random. The shielding panel is adjusted automatically in the height direction (bath depth direction).
8. Since the equipment is designed as rack-less, drag out is small. The plating bath is provided with a small port. Accordingly, it is easy to exhaust and working conditions are improved compared to conventional equipment.
9. Since the structure of the equipment is simplified, operation is easy, and few troubles will occur. Also maintenance time will be reduced.
10. Conventional rack-maintenance cost is eliminated. Amount of processing solution can be reduced resulting in a cost saving relevant to the maintenance of plating solution. Automated operation results in reduction of the running cost.

References

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