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A Novel Horizontal Copper Pattern Plating System with High Throughput

Mustafa Özkök, Andreas Schatz, Akif Özkök, Henning Hübner, Simon Chien

Atotech Deutschland GmbH

Erasmusstraße 20, 10553 Berlin, Germany

Atotech Taiwan Ltd.

15, Chingkuo Road; 5th Floor; Taoyuan; Taiwan (R.O.C) 330

Mustafa.oezkoek@atotech.com

ABSTRACT

Horizontal copper plating processes have been used in high volume production to produce PCB's for MLB, Flex-rigid, IC substrates and HDI applications. As the lines and spaces (L/S) requirements have become more and more challenging over the years, panel plating technology has hit the barrier in the range of L/S 35/35 µm in combination with a request for rectangular shape of the traces. Pattern plating mode and the use of (a)mSAP processes becomes a must to achieve L/S in the range of 20/20 µm. So far these kind of applications were difficult to be produced in standard horizontal equipment because of following aspects:

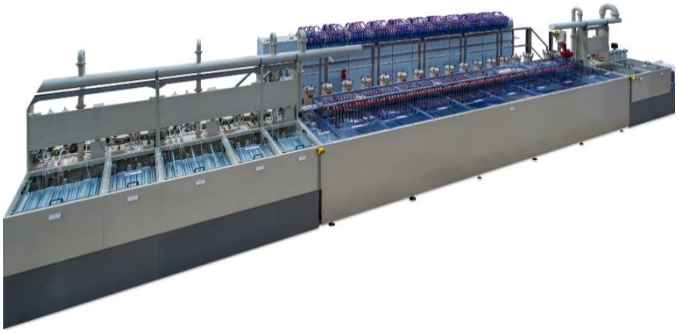
1st. The panel thickness for these applications is usually in the lower range less than 60 + 2 × 9 µm Copper clad and it was difficult to transport these thin panels in horizontal mode in all cases.

2nd. The solution flow arrangement is not sufficient for thin panel transportation and pattern plating.

3rd. The former horizontal copper electrolytes have not been designed for pattern plating.

4th. Dry film damages in pattern plating mode.

This paper will describe a new horizontal copper plating process especially designed to transport very thin panels with a thickness down to 30 µm (25 µm Substrate with 2×2 µm copper clad). No other horizontal copper plating equipment has such thin panel transport capabilities. Furthermore the horizontal equipment has been reengineered from top to bottom, based on the experience of nearly 1,000 built horizontal plating lines.

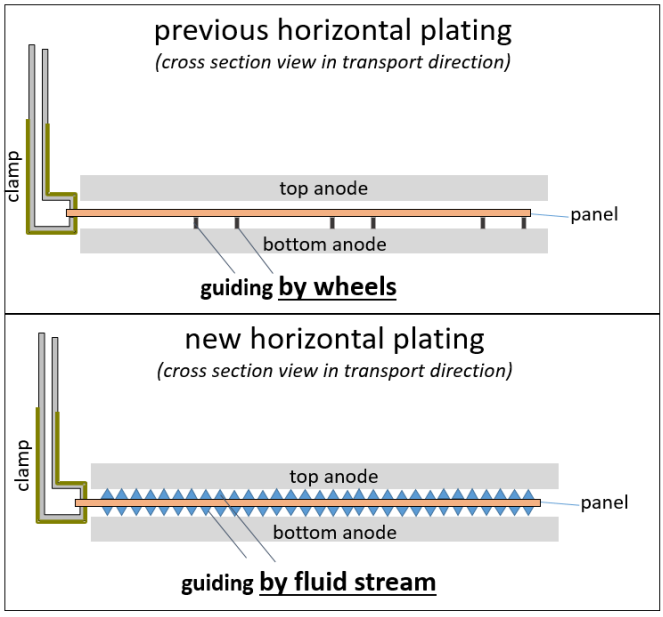


NEW GENERATION HORIZONTAL EQUIPMENT,
PICTURE #1

In addition a new type of copper electrolyte has been designed in order to fit perfectly into the newly developed horizontal plating equipment. Finally, the new system offers the possibility for pattern filling structures in horizontal mode with current densities of up to 4 A/dm². On top of this a surface distribution of less than ± 10% has been achieved in panel plating mode on thin substrates.

NEW HORIZONTAL PANEL TRANSPORTATION CONCEPT

In the previous generation of the horizontal plating equipment the panels have been guided by wheels during transportation within the plating module. With the new horizontal equipment, the guidance of the panel is realized via a fluid stream. The main feature of the new anode box is a newly developed fluid delivery system with an increased number of nozzle elements which ensures that the panel is held in the middle by the fluid stream created by the top and bottom anode boxes.



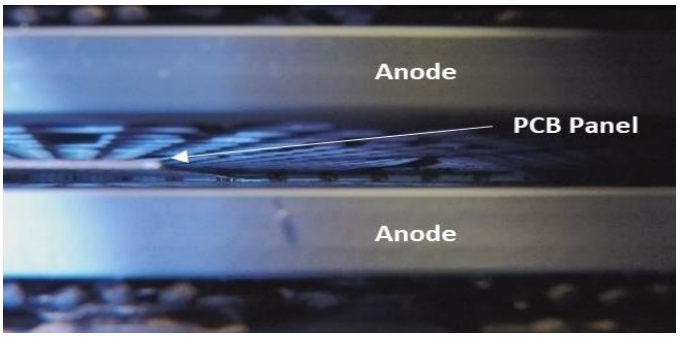
NEW HORIZONTAL PLATING SYSTEM WITH GUIDANCE VIA FLUID STREAM
PICTURE #2

This new developed fluid delivery system brings three main benefits for the plating process:

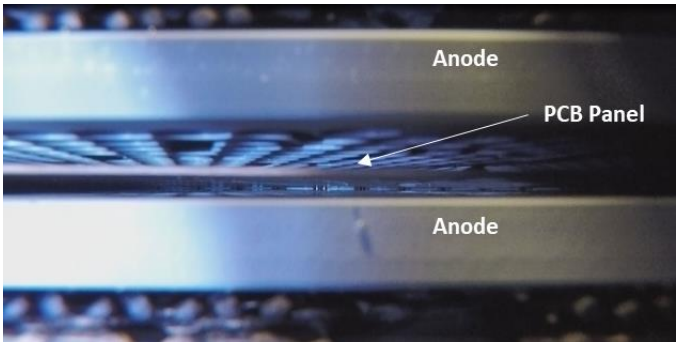
1st. The panel is guided on the fluid stream and therefore surface impact can be avoided during the plating process.

2nd. The fluid distribution between the anodes enables a stable panel transport with limited movement of the panel.

3rd. These positive effects also influences the top/bottom current distribution so an equal plating can be achieved with excellent surface distribution on both sides of the panel.

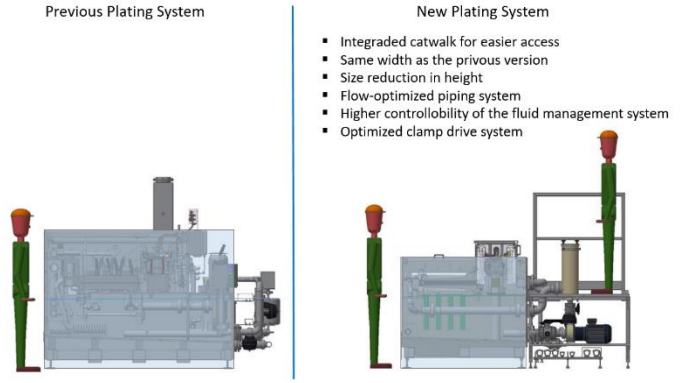


PCB PANEL ENTERING THE NEW HORIZONTAL EQUIPMENT OVER A FLUID FILM, PICTURE #3



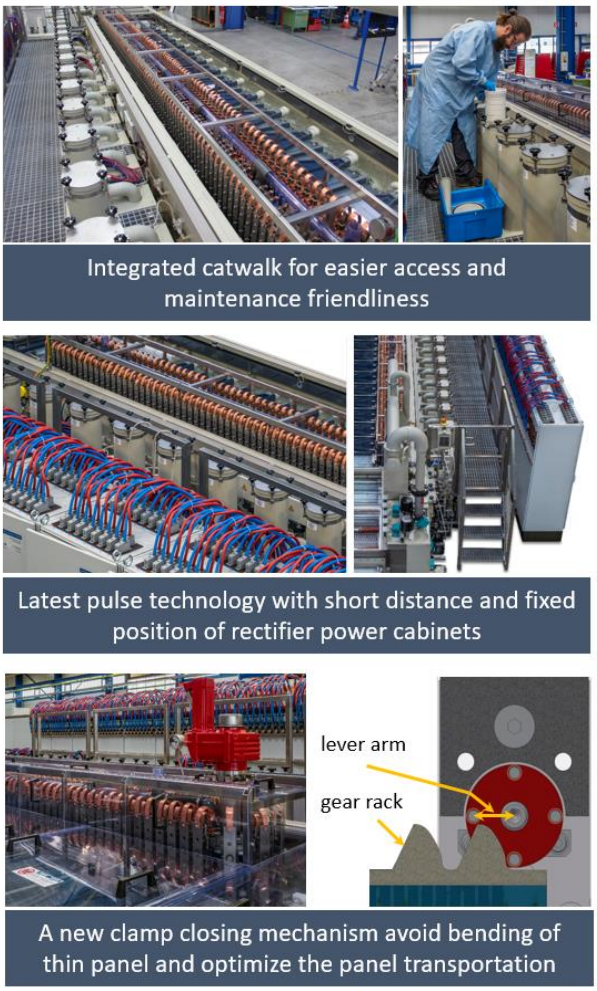
FURTHER MOVEMENT OF PCB PANEL THROUGH THE NEW HORIZONTAL EQUIPMENT OVER A FLUID FILM, PICTURE #4

This feature is essential for transporting thin panels with L/S down to range of 20/20 µm through a horizontal electrolytic copper plating line without damage to the sensitive dry film by mechanical impact. This allows production of finest L/S with a high yield in this new equipment generation.



COMPARISON OF OLD DESIGN AND NEW DESIGN OF THE NEW HORIZONTAL EQUIPMENT, PICTURE #5

Picture 5 shows the comparison of the previous plating system and the new plating system. The complete module design has been optimized. Based on the experience of nearby 100 built equipment modules, the key technology features have been optimized. One development target was to create a new compact design with reduced height and a better access from the operator side and maintenance side. By integrating a catwalk on the maintenance site, a safe and fast filter change is possible (Picture 6).



FEATURES OF THE NEW HORIZONTAL EQUIPMENT, PICTURE #6

The new plating system uses rectifier cabinets with the latest pulse technology. Shortened and firmly defined rectifier cable lengths avoid disturbances in the signal and current transfer. The new mechanical design of the clamp gear system creates a smooth movement of the clamp parts during the clamp closing sequence which leads to a reduction of panel bending and a reliable clamp contact to the panel. This feature is essential for thin panels.

TECHNICAL DATA OF THE NEW EQUIPMENT AT A GLANCE

Transport capability	• Panel size: 610 × 460 mm • Panel Plating: core 25 µm + 2 × ≥ 2 µm up to 1.3 mm (xs+) • Pattern Plating: core 150 µm + 2 × ≥ 2 µm up to 1.3 mm (xs+) transport capability. (0.2-1.6 mm by adjustment of top anode box)
Line Speed	• 0.1 - 1.5 m/min
Temperature	• 20-40°C
Surface distribution	• < 10% (panel plating), BMV filling performance like previous equipment

TECHNICAL DATA OF THE NEW PLATING EQUIPMENT
TABLE #1

POSSIBLE PROCESS VARIATIONS WITH THE NEW DEVELOPED EQUIPMENT

The new developed equipment is able to produce substrates in panel plating mode or in the mSAP/amSAP pattern plating modes; in each cases the process flow may vary inside the equipment as shown in picture 7.

	Panel plating	mSAP	amSAP
Acid Cleaner	CupraPro HC	CupraPro HC	CupraPro HC
Rinse	Uniplate rinse module	Uniplate rinse module	Uniplate rinse module
Etch Cleaner	Securiganth C	Securiganth C	-
Rinse	Uniplate rinse module	Uniplate rinse module	-
Acid Dip	Sulphuric acid (10% by vol.)	Sulphuric acid (10% by vol.)	Sulphuric acid (10% by vol.)
Copper Flash	Inpulse 2HFU	Inpulse 2HFU	-
Copper Fill	Inpulse 2HF	Inpulse 3MSAP	Inpulse 3MSAP

PROCESS POSSIBILITIES IN THE NEW DEVELOPED EQUIPMENT
PICTURE #7

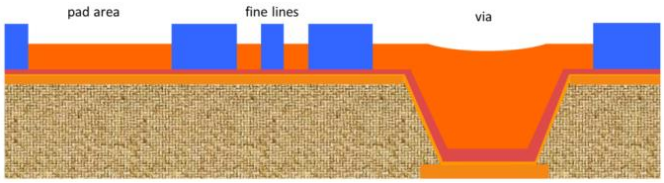
The process was mainly developed to have pattern plating capabilities in order to drive the mSAP and amSAP technology. However also panel plating to plate very thin substrates is an option which can be driven in the new equipment.

NEW DEVELOPED MSAP/AMSAP COPPER ELECTROLYTE FOR THE NEW HORIZONTAL EQUIPMENT

As the new horizontal equipment offers the advantage to apply pattern plating technology also a new type of copper electrolyte has been developed in order to combine the advantages of the new developed equipment with the advantages of a new developed copper electrolyte especially designed for mSAP/amSAP technology.

Difference of mSAP vs. amSAP

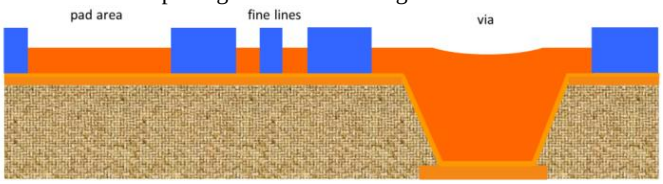
The difference between mSAP (modified SAP) and amSAP (advanced modified SAP) is mainly the electrolytic strike plating which is applied after the e'less copper plating step.



MSAP PROCESS WITH STRIKE PLATING (DARK RED AREA), PICTURE#8

For mSAP technology following steps are used:

- Thin CCL (<5 µm)
- E'less Copper - approx. 0.4 µm
- Strike Copper plating
- Dry-film
- Pattern plating with BMV Filling



AMSAP PROCESS WITHOUT STRIKE PLATING, PICTURE#9

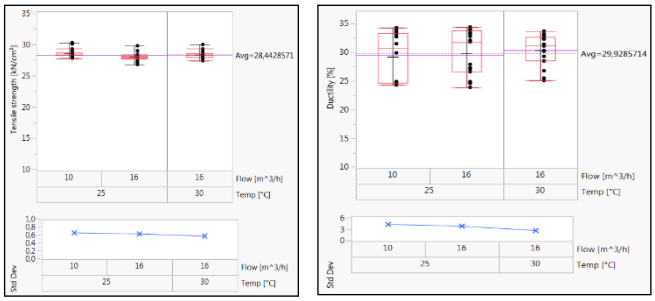
For amSAP following steps are used:

- Thin CCL (< 3µm)
- E'less Copper - approx. 1.0 µm
- *(no strike plating)*
- Dryfilm
- Pattern plating with BMV Filling

The use of amSAP process does allow finer lines and spaces as this technology can operate with less copper on the surface. Nevertheless the mSAP technology still is used in a large amount as the additional strike plating provides greater reliability and higher yields as shown in other studies[1].

Ductility & Tensile Strength of the new Cu Electrolyte

The ductility and tensile strength have been measured as illustrated below.

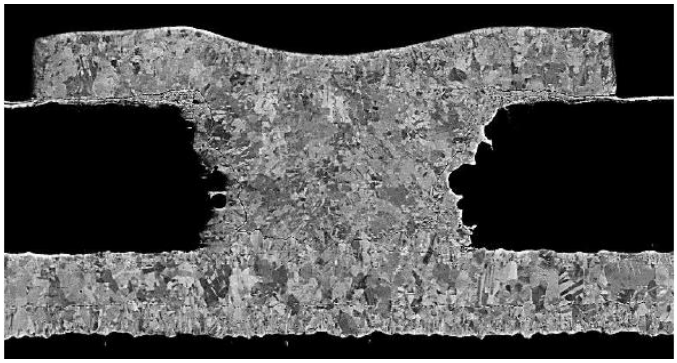


TENSILE STRENGTH (LEFT) AND DUCTILITY (RIGHT) OF THE NEW CU ELECTROLYTE, PICTURE #10

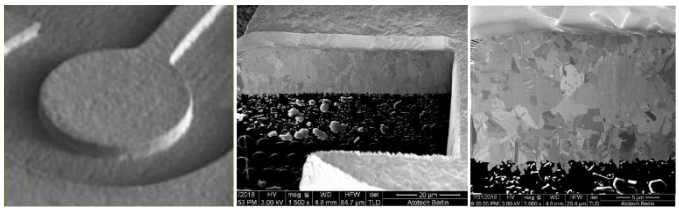
Based on the test results shown in picture 10 an average ductility of 29.9% (min. 25%) and a tensile strength of 28.4 kN/cm² (min. 27.5

kN/cm²) could be achieved. These are very nice results showing that the crystal structure is correct to give a reliable copper properties.

Crystal Structure & Cu Purity of the new Cu Electrolyte



CU CRYSTAL STRUCTURE IN 65/40 µm BMV, PICTURE #11

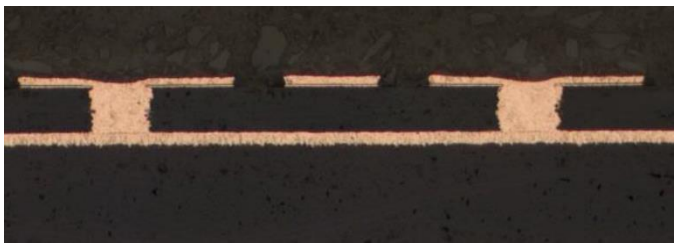


CU CRYSTAL STRUCTURE 100 µm PAD, PICTURE #12

In the micro sections the Cu crystals are showing polygonal crystals with no preferred orientation and no grain boundary defects as illustrated in pictures 11 and 12. The purity of the deposited Cu has been determined by SMA method with a result of 99.98%.

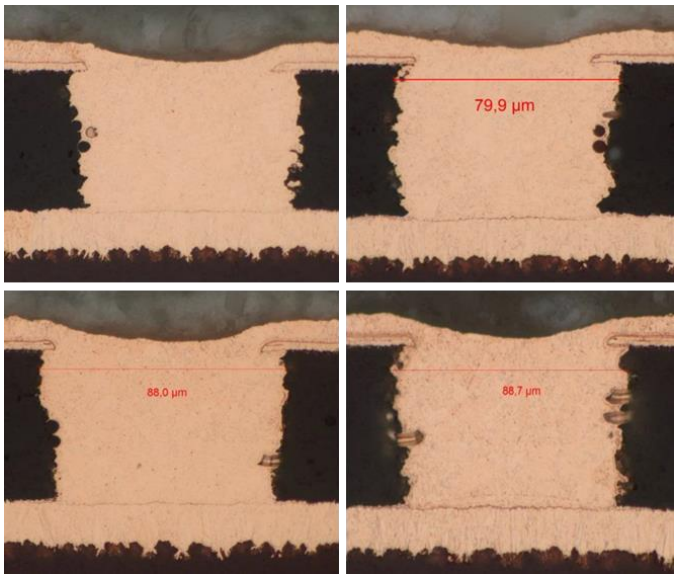
BMV filling performance of the new Cu Electrolyte.

The BMV filling capability of the new copper electrolyte designed for mSAP or amSAP is excellent, with high productivity and technology at the same time. The BMV filling performance results below has been obtained by using a PCB test board designed for this purpose.



EXAMPLES OF BMV'S IN PATTERN PLATING STRUCTURE PICTURE #13

The following pictures are showing the BMV filling of dimensions from 80-90 µm diameter and 50-60 µm depth.



EXAMPLES OF BMVS PLATED WITH MSAP TECHNOLOGY IN THE NEW HORIZONTAL EQUIPMENT WITH THE NEW CU ELECTROLYTE AFTER DIFFERENTIAL ETCHING, PICTURE #14

These BMVs from picture 14 were plated within 27 min at 3.1 A/dm² and 7.5 µm surface thickness within the new horizontal equipment.

SUMMARY

The results illustrated and presented in this paper are the first results from first customer qualification for the new horizontal copper plating process, where plating equipment and plating chemistry is designed as a system. The new horizontal equipment has been developed especially to plate pattern plating structures down to L/S 20/20 µm and lower. This paper shows that the new horizontal transport system is working almost "touchless" during the copper plating step, enabled by a fluid stream guiding the panel. The newly developed horizontal copper electrolyte furthermore enables a pure copper deposition with a very good crystal structure and balance between tensile strength and ductility. Furthermore pattern plating structures and production technologies like mSAP and amSAP are possible as shown and presented. The previous generation of copper plating equipment was built close to 1,000 times. It is expected that this new generation of horizontal plating equipment may outperform the success of the previous copper plating equipment generation. Further investigations are ongoing and will be updated later in 2020.

REFERENCES

[1] Y.H. Chen, *ZDT Group Avary's Board Business Strategy -- Quality and Reliability*. Tokyo, Japan: 48th Nepcon Japan, 16-18th January 2019.