# ENHANCED METHOD OF THROUGH-HOLE COPPER PLATING

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**Abstract**: This paper is dealing with an introduction of novel approach conceived towards the optimization of widespread through-hole copper plating process. Main objective in this context is to achieve significantly increased process reliability and overall fabrication yield also for the small-scale production runs or prototyping purposes of printed circuit boards. Essential aspect of the procedure outlined in this paper is inherently connected with the activation of printed circuit board surface, which serves as the basis for the subsequent step that involves the conformal copper plating of holes drilled through the substrate compound. An innovative part of the whole process can be recognized in activation of drilled holes surface by means of employing combination of vacuum (low pressure environment) and ultrasound within the dedicated setup. The application of the suggested procedure helps to considerably reduce the failure ratio (i.e. the presence of holes with faulty surface plating) even in case of drilled holes at considerably small dimensions and, as a direct consequence, improves the overall process reliability.

**Keywords**: Through-hole technology, copper plating, PCB

## 1. INTRODUCTION

Nowadays, there exists a large variety of methods that are suitable for the purpose of through-hole copper plating in case of the high-volume fabrication flow, as well as in the prototyping domain. In fact, the actual copper plating procedure variant is typically selected with respect to a given application scenario, and it may involve e.g. direct current plating, pulse plating or reverse pulse plating. In case of lower production volumes and smaller holes diameters pulse or reverse pulse plating [1, 2] is typically chosen. Switchable reverse pulse plating technique is considered to deliver more uniform copper plating for difficult aspect ratios and smaller holes. Reverse pulse plating method is also very useful for small holes on high-density PCBs and improves production reliability during the soldering phase as well. Reverse pulse plating uses precisely controlled reverse pulses to remove excess material during the plating process [3].

The combined influence of diverse parameters makes the through-hole plating process rather complex task, which is more than symptomatic for low-volume or prototyping conditions. In that way especially the problem of variability behind the commonly used processes comes into attention as one of the key hurdles preventing satisfactory results and stable yield. One of the significant issues is clearly associated with the preparation of holes surface before the actual copper plating takes place. Activation of surface can be performed by means of using a few special chemical solutions (for example solution of copper sulfate, calcium hypophosphite and ammonium hydroxide [4]), but the principle is straightforward - homogenously activate and finally cover surface of drilled holes.

Main goal behind this paper is focused on possible mitigation of at least some of the aforementioned challenges through the introduction of an innovative method for copper plating, where the attention is predominantly given to the aspects of sample surface preparation for the following process stages. The proposed method is based on using reverse pulse plating feature at its core while the main innovation dwells in usage of lower ambient pressure during an activation of the surface, which should help to expel the formation of air bubbles from the holes openings that prevent the activation liquid from even penetration into the confined holes volume. It is obvious indeed that the careful surface treatment and preparation of the drilled holes plays an important role within the effort to ensure the reliability of copper plating technique with the aid of an electrical energy. Furthermore, this process step is crucial in terms of the formation and uniformity control of the conformal layers that allow adhesion and succeeding growth of the copper layer [3].

## 2. METHODOLOGY

The purpose of this chapter is to provide closer insight into the methods, equipment and materials, which were used throughout the implementation and subsequent verification of the innovative approach to the widespread through-hole plating technique.

### 2.1. INNOVATIVE METHODS IN THROUGH-HOLE PLATING

As this observation was already mentioned within the introductory chapter of this paper, the introduction of additional techniques may bring significant benefits for the activation of non-conducting surface (drilled holes). One of the innovations behind the standard process is the intentional addition of lower pressure for better propagation of activator liquid into drilled holes of smaller dimensions. It is well known fact that already low vacuum helps to notably decrease the surface tension of liquids and causes expansion of gasses. From a technical perspective it simply allows the air confined into the typically small volume of holes to go outside and lets the activator solution to penetrate inside along the whole drill path [5].

Other promising technological concept is building upon the exploitation of ultrasound transfer to the test vehicle. An ultrasonic wave is reflected when it strikes an interface between materials with different speeds of sound (acoustic impedance). Furthermore, an interface between materials with a larger difference in acoustic impedance reflects ultrasonic waves with a higher force and that with a smaller difference in acoustic impedance reflects them less strongly and lets part of them travel through [6].

### 2.2. TEST VEHICLE

Test vehicle used for the experimentation can be seen on the Fig. 1. Dimensions of test coupon are approximately 70 x 13 mm. Through holes are represented by green circles. Test pads are fabricated on the both sides of the PCB and they are connected to the VIAs. Holes diameter is in the range 0,2 – 1,5 mm. Holes with different diameters are positioned uniformly for better control of plating process. Two rows of holes are mirrored in sequence to each other. FR4 substrate was used as a base material with both sides plated with 18 μm of copper.

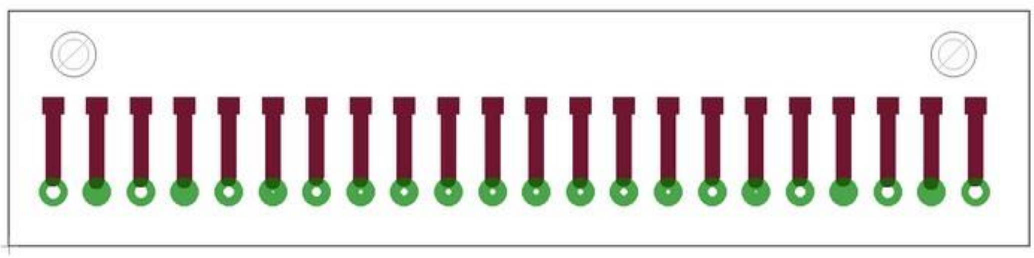

**Figure 1:** Test vehicle

### 2.3. EQUIPMENT

Copper plating facility was available as a LPKF MiniContac RS unit with closed circulation of individual baths content (Fig. 2). This device is using the principle of reverse pulse method for copper plating or deposition. That method, reverse pulse copper plating, provides sufficient parameters for conformal coating of copper during plating.


**Figure 2:** MiniContac RS

Substantial innovation in this standard process is represented by the creation of vacuum chamber (Fig. 3) for activator solution, which enables reliable activation of holes with smaller diameter than before. Chamber was made from special chemical resistant plastic compound. This chamber was also used for the activation during the simultaneous exploitation of ultrasonic waves generator.

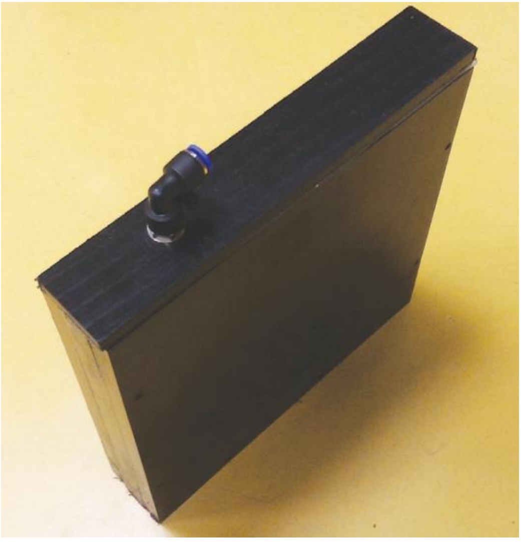

**Figure 3:** Additional equipment – vacuum chamber

For investigation of the plated holes reliability the current overload test method was chosen. Plated holes were be tested for their structural integrity once exposed to the current reaching the level of 1 amp. On the Fig. 4 can be seen the fixture for current load measurement. Pictures on the right top corner are providing closer view on the measurement pins. It can be seen that two pins are placed from top side and two from bottom. This particular arrangement is due to the selected usage of pins for four-point method (two pins for current, two pins for voltage). Between top and bottom pins there are also placed the measured pattern of test vehicle. During the test procedure the individual measurements were focused on the evaluation of voltage/resistance of the plated holes.

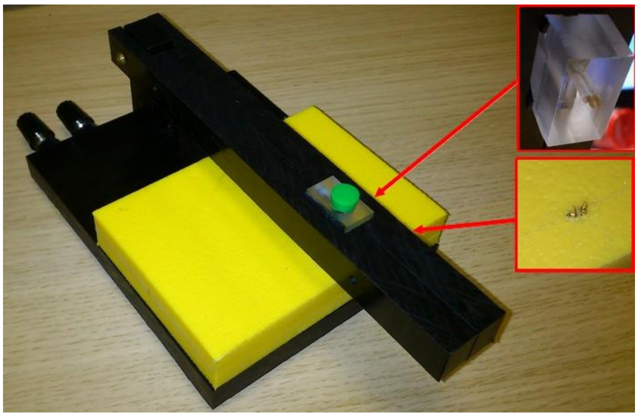

**Figure 4:** Fixture for current load measurement

## 3. RESULTS

Samples were fabricated by means of using the standard method (reference sample) and optimized method based on utilization of vacuum chamber (sample fabricated with using vacuum).

First analysis comprised electrical testing of resistivity. There were seen two cases of resistivity, resistivity under 0,01 Ω (plated holes) and very high resistivity (unplated holes). Defects were identified mainly for 0,2 mm diameter holes. Approximately 30 % of these small holes were unplated.

Second analysis was conducted with the assistance of X-Ray inspection equipment. Results are presented on the figure 5 and figure 6. The former of them is showing unplated through-hole of reference sample. On the contrary, figure 6 depicts plated hole of sample fabricated with the usage of vakuum-equipped chamber.

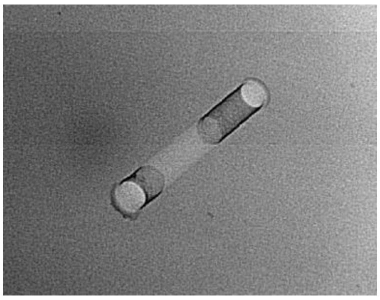

**Figure 5:** Reference sample – unplated hole

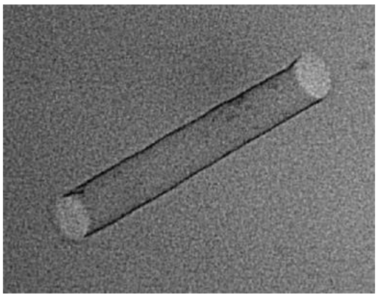

**Figure 6:** Vacuum activated sample –plated hole

Microsections show the same behavior as X-ray figures. On the figure 7 is shown microsection of reference sample and on the figure 8 is shown microsection of vacuum activated sample.

**Figure 7:** Microsection - reference sample

**Figure 8:** Microsection - vacuum activated sample

## 4. CONCLUSION

Copper plating methods are well-known and field-proven technologies across the electronic fabrication industry. Settings of the process parameters are depends on quality/purity of solvents and knowledge/responsibility of operator. Therefore using of vacuum or ultrasound during activation process can bring new enhanced process of through-hole plating. Reliability of copper plated holes activated with the parallel assistance of vacuum and ultrasound has shown notable benefits in comparison with the reference sample, which was fabricated using the conventional approach.

In summary, this paper contains description of the first results obtained during the avaluation of the innovated process of copper plating. Further research and development activities will be focused on the reliability (stress test, microsections, etc.) improvement and overall process refinement.

## ACKNOWLEDGEMENT

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