Fine-pitch and High-density Printed Circuit Board

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Recently, the demand for high-density printed circuit boards has risen along with the trend of lighter, thinner, and smaller electronic equipment and the mounting parts and that of an increase in the number of multi pins of ICs.

Therefore, we established a fine wiring formation technology and a filling plating technology for fine through holes and developed ultra-high-density double-sided printed circuit boards called μ through hole double-sided flexible printed circuit (FPC).

We report on the features and technological development of μ through hole double-sided FPCs.

1. Introduction

Thinner printed circuit boards with denser wiring are required for lighter, smaller, and thinner electronic equipment. The Japan mounting technology road map forecasts that the design rule of the printed circuit board will require higher density as shown in Fig. 1. To satisfy this demand, it is necessary to narrow not only the width of wiring but also the interval of through holes or via holes. On the other hand, the thin printed circuit board can be manufactured by combining thin radical insulation materials with a thin circuit conductor. Thus, the flexible printed circuit board technology can satisfy such demands. To realize the above-mentioned thin, high-density printed circuit board, we developed the flexible printed circuit–μ through hole FPC–which has a fine through hole structure.

2. The structure, the process of manufacture, and the features

Figure 2 shows the structure of developed μ through hole FPC. This is a double-sided flexible printed circuit having through holes. The base material is a heatproof film of 12.5 μm-25 μm in thickness.

The through holes' diameter of μ through hole FPC is 10 μm while that of conventional FPC is about 100 μm-150 μm. The finer through hole was plated on the flat surface of the through holes.

The high degree of flatness enables the μ through hole FPC board with greater density of wiring to be mounted with parts and IC.

Figure 3 shows the circuit formation process in μ through hole FPC. The circuit formation method uses the semi-additive process. First, a fine through hole was formed in a heatproof film like a polyimide film.

Next, the conduction layer (seed layer) was formed on the surface of the film and the through hole wall. Then, plating resists formed, and the conductor circuit and the through hole were plated at the same time by electrolytic plating. After the plating resist was removed, the seed layer was removed by etching, and the circuit pattern was formed. After, the surface treatment was done, parts and ICs were mounted on the pattern.

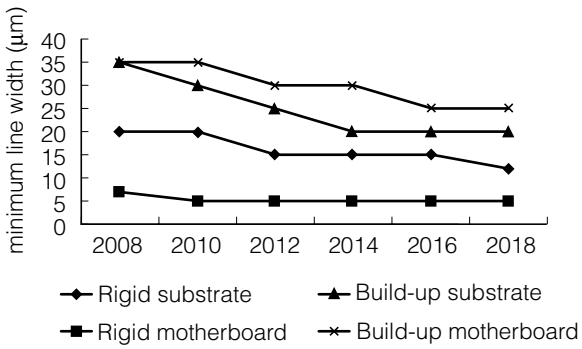

Fig.1. Trends of minimum width of several printed wiring boards.

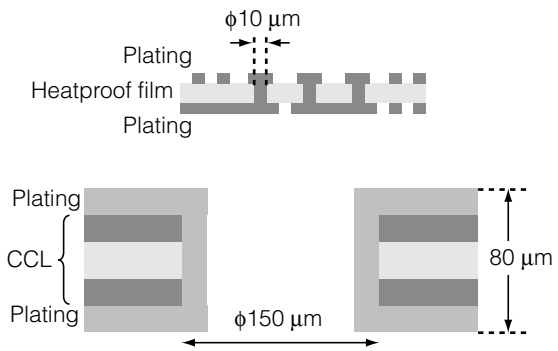

Fig.2. Comparison between a μ through hole FPC and a conventional through hole FPC.

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2 Cable Technology Research Department of Environment Energy Laboratory

Panel 1. Abbreviations, Acronyms, and Terms.

FPC—Flexible Printed Circuits

IC—Integrated Circuit

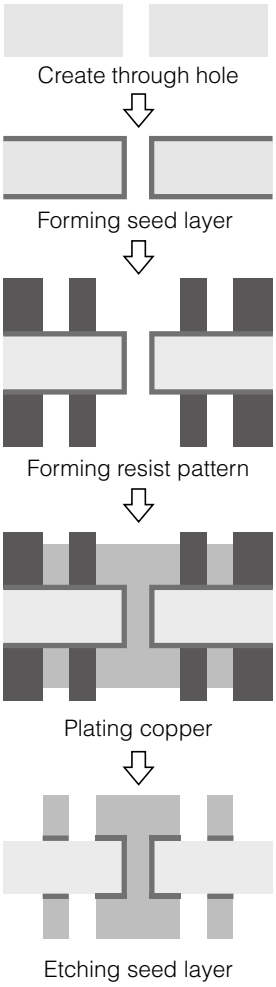


Fig.3. Process of μ through hole FPC.

The semi-additive process used to form the circuit of μ through hole FPC has an advantage in the forming of finer conductor circuit over the subtractive method, etching of the copper-clad laminate (CCL)[2)3)].

The μ through hole FPC has features of through holes filled by plating and higher flat surface above the through holes. Figure 4 shows the fine-pitch conductive circuit by semi-additive method.

This time, the filling and the flat surface by plating were found to be challenging. This paper reports on the development result for the challenges.

3. Plating filling of fine through hole

Usually, the interior surface of the through hole of an FPC is plated with copper, and the center of the through hole is empty. The feature of the μ through hole FPC is a filled through hole by plating. And, we thought that making the through hole diameter smaller was necessary to achieve a through hole filled by plating. However, filling a through hole by plating was not successful by making the hole diameter smaller, as bubbles (voids) were generated in the central part of the through hole (Fig.5).

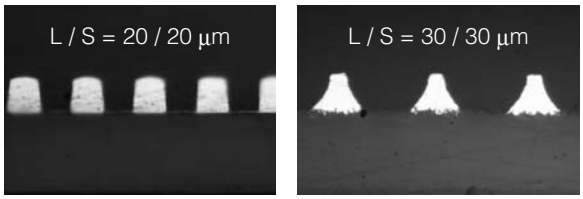


Fig.4. Circuit shape by semi-additive method (left) and subtractive method (right).

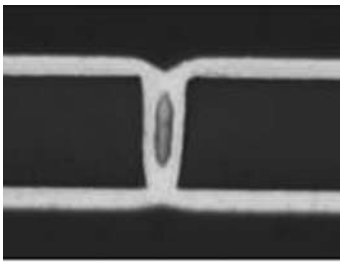


Fig.5. Void inside through hole.

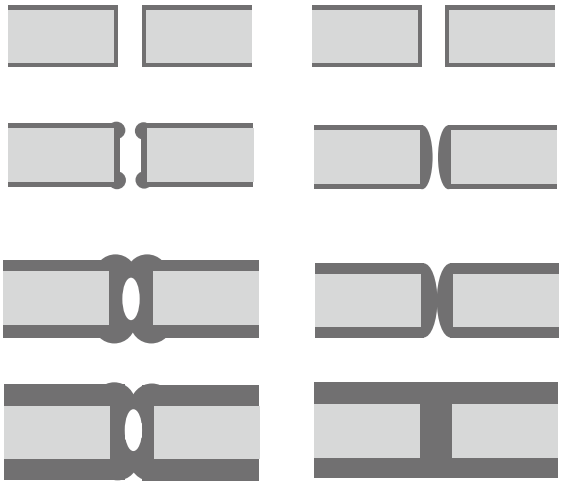


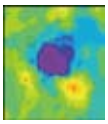
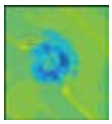
Fig.6. Filling mechanism of ordinary plating (left) and filling plating (right).

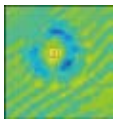
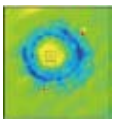
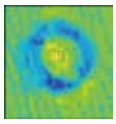
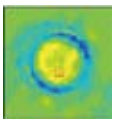
It is necessary to develop a plating method that does not form voids, because voids decrease the reliability of a through hole. Then, we analyzed the void generation mechanism and developed a through hole plating method by which voids are not generated.

The electrolytic plating is carried out by utilizing electric power supplied from an external power supply as driving power. The current concentrates on the edge part in a through hole when double-sided FPCs are plated by a usual electrolytic plating method.

Therefore, one edge of a through hole is connected

Table 1. Surface image and surface measurement above through hole.

Plating thickness	1 µm	2 µm	3 µm	4 µm
Surface image				
Depth profile	Can't measure			

Plating thickness	5 µm	6 µm	7 µm	8 µm
Surface image				
Depth profile				

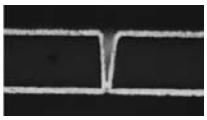
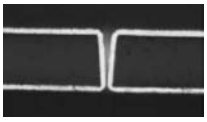
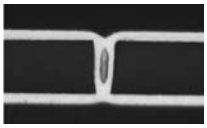
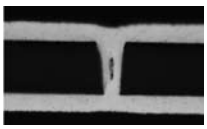
Thickness	Additive A	Additive B
3 µm		
5 µm		
8 µm		

Fig.7. Cross-sectional view of additive A (left) and additive B (right).

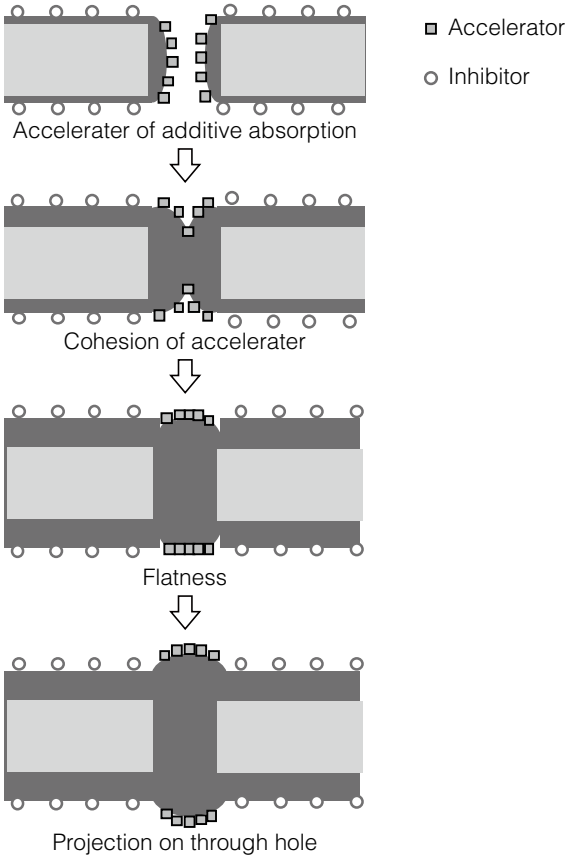


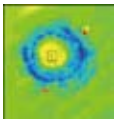
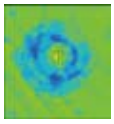
Fig.8. Mechanism of filling and surface flatness of copper filling plating.

to the other, and the plating growth in a through hole stops (left of Fig.6). To fill a through hole completely without generation of voids, the plating growth speed in the central part of a through hole should be made faster than that in the upper and lower part (on the right of Fig.6). Usual copper sulfate plating bath is composed of sulfuric acid, copper sulfate, chlorine, and various additives. Additives consist of three kinds of chemicals, brightener, surface-active agent, and leveler, and these additives influence the growth speed of plating and physical properties of the film greatly. It was thought that it was possible to solve this problem by adjusting these brighteners and surface-active agents and leveler balances to fill a through hole by plating without generating voids. Figure 7 is a comparison of the through hole filled by plating by adding additive A used for usual copper sulfate plating bath and adjusting additive B. As a result of plating, it has been understood that a usual additive is insufficient to fill a through hole by plating, and the adjustment of the additive is necessary.

4. Flatness of plating

Parts and ICs can be mounted on the surface of a

Table 2. Surface image and surface measurement above through hole by using additive B (left) and using additive B and C (right).

Plating thickness	6 µm	6 µm
Surface image		
Surface measurement		
	Additive B only	Additive B and C

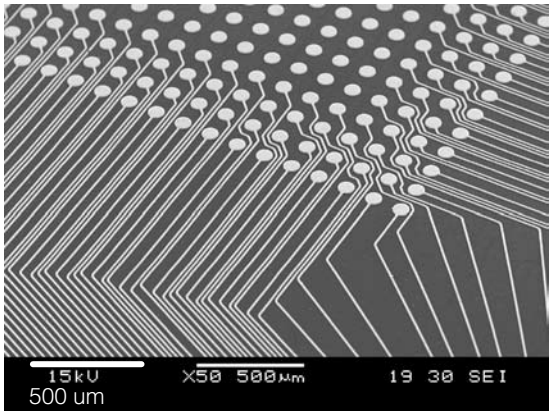


Fig.9. Image of µ through hole FPC.

through hole by improving the flatness to increase the density on a printed circuit board.

Then, to achieve a high degree of flatness of the surface of a through hole, we investigated the change in flatness on the surface of a through hole.

Table 1 shows a surface image of a through hole and the surface measurement result with a three-dimensional surface measurement machine when the thickness of plating is changed from 1 to 8 µm.

The result of the three-dimensional shape measurement shows that red to yellow color means the level of the surface is higher than the surroundings while purple to blue means that the level of the surface is lower than the surroundings.

Table 1 shows that plating grows rapidly when the thickness of plating is 2 µm or more and that the center of the through hole is higher than other area when the thickness is 4 µm or more.

Moreover, under this condition, pits grew in the outer area of the through hole surface when the thickness of plating of a through hole is 5 µm or less. On the contrary, projections grew in the central area of a through hole when the thickness of plating of a through hole is 7 µm or more. The result shows that the surface was the flattest when the thickness of plating of a through hole was 6 µm. We conclude that the cohesion of the additive of current plating greatly influenced the growth of plating (Fig.8).

In addition, we tried another method to improve the flatness. A plating bath containing an additive different from that of the original plating bath was prepared, and the original plating bath was replaced with the new one in the middle of plating. Plating additive C, which is able to improve the flatness, was used as the new additive. Table 2 shows evaluation results of flatness of plating. By this method, the flatness of a through hole surface was increased.

5. Prototype

Recently, the demand for thinner packages has grown as the number of pins of ICs has increased. Figure 9 is a prototype that combined a µ through hole FPC with an APIC (All Polyimide IVH Collaminated) that our company developed. The µ through hole FPC can be used as a substrate for a thin IC package.

6. Conclusion

Highly reliable through holes filling by plating was carried out by optimizing plating conditions. The surface of the through hole filled by plating has a high flatness, so that parts and ICs can be mounted. It is thought that the µ through hole FPC can respond to miniaturizing of parts and the increase in the density and the number of pins of high-performance ICs.