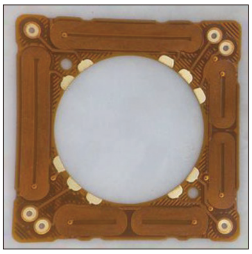
No. 96 · APRIL 2023
ELECTRONICS



Plating Technology for Fine-Pitch High-Aspect Ratio FPC

Kenji TAKAHASHI*, Yoshio OKA, Shoichiro SAKAI, Hiroki NOHARA, Masahiro ITO, and Daisuke SATO

With the recent miniaturization of electronic equipment, there is an increasing demand for high-density wiring in flexible printed circuits (FPC). We have developed a circuit formation technology using a semi-additive process that uses fine-pitch, high-aspect plating. The plating technology has enabled us to establish a manufacturing method for the fine-pitch FPCs that cannot be realized by conventional etching-based circuit formation processes. By applying this technology, mass production of actuator coils for image stabilization of high-performance smartphone cameras has been realized. This paper reports on the circuit formation technology using the semi-additive method and examples of its application to actuator coils, and introduces the latest developments.

Keywords: fine pitch, high aspect ratio, semi-additive process, plating

1. Introduction

With the progress of the miniaturization of electronic equipment, the need for flexible printed circuits (FPCs) with higher density wiring is increasing. The semi-additive process, in which circuits are formed by copper plating, is an important technology for realizing high-density wiring because it has an advantage over the conventional subtractive process, in which circuits are formed by etching, in achieving finer pitch patterns.(1) We are developing mass production technology using the semi-additive process and have realized the mass production of actuator coils used in smartphone cameras for image stabilization.(2)

In this paper, we report on the semi-additive process technology developed by us and the coil wiring with fine-pitch and high-aspect-ratio*1 circuit patterns realized by the technology.

2. Semi-additive Process

2-1 Comparison with the conventional manufacturing method

Figure 1 shows the subtractive process that has conventionally been used for manufacturing FPCs. The etching resist layer is formed on the copper foil layer, and the uncovered sections of the copper foil layer are dissolved and removed in the etching process. After that, the etching resist layer is removed, and the remaining sections of the copper foil layer become traces. In the etching process, etching progresses not only in the direction of the thickness of the copper foil layer, but also in the lateral direction (side etching), which makes it difficult to narrow the trace spacing in high-density wiring. In addition, due to the use of thick copper foil, a large amount of copper material needs to be etched, which causes a large variation in the progress of side etching and, therefore, a large variation in the trace width. Furthermore, the upper part of the copper foil layer, where etching begins, is etched more than the lower part, and as a result, the tops of the cross-sections of the traces are narrower than the bottoms, i.e., displaying poor rectangularity.

Figure 2 shows the semi-additive process. First, a thin seed layer, which serves as a current path in the plating process, is formed by sputtering or other alternative methods. A plating resist is formed on the seed layer, and copper is deposited in the openings by copper plating. After removing the plating resist, the seed layer is also removed by flash etching*2 to complete the circuit. Since less material needs to be etched compared to the subtractive process, there is less side etching, which is a great advantage over the subtractive process in forming circuits with fine-pitch

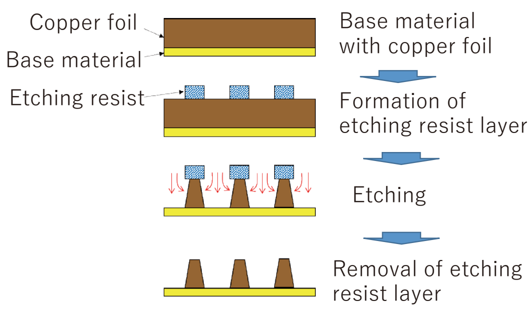


Fig. 1. Subtractive process

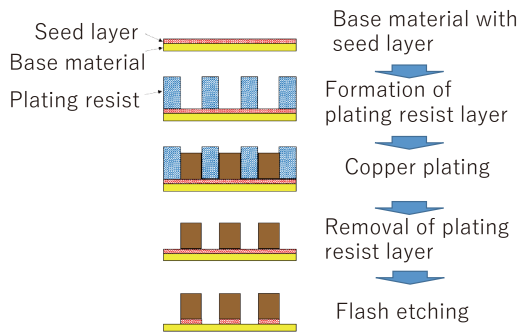


Fig. 2. Semi-additive process

patterns. Furthermore, it can be said that the lower amount of etched material is also advantageous in terms of variation in the trace width and the rectangularity of the trace cross-sections.

2-2 Circuit formation by our semi-additive process

We are working on the development of a semi-additive process in order to meet the need for high-density wiring, and the details are described below.

As described above, the semi-additive process is suitable for forming circuits with fine-pitch patterns, but there are also problems. One of them is the adhesion of traces to the seed layer. When forming traces by copper plating, if there are impurities or dirt derived from the resist material on the seed layer in the openings of the resist layer, the copper plating layer will not adhere properly to the seed layer, and as a result, the circuit becomes less reliable. In the flash etching process for removing the seed layer between traces after removing the plating resist layer, if the seed layer under the traces formed by copper plating is damaged due to excessive etching, the contact area between the traces and the seed layer becomes smaller and the traces can easily come off. Since this problem of adhesion becomes more conspicuous as the trace width becomes narrower, it is a major obstacle in realizing circuits with finer pitch patterns. We have optimized the conditions of all processes, from resist formation to plating and flash etching, thereby establishing a process that can ensure good trace adhesion even for fine-pitch circuits. Photo 1 shows a cross-sectional photograph of traces formed by our semi-additive process and the same of a circuit mass-produced by us using the subtractive process for comparison. A fine-pitch circuit pattern with an L/S (line and space)*3 of 10 μm/10 μm has been formed, which is difficult to achieve with the subtractive process. This L/S is at the level of high-density wiring required for application to displays, whose number of pixels continues to increase. In the latest development, we are working to realize even finer pitch patterns, and the realization of a superfine-pitch circuit with an L/S of 7 μm/7 μm has come within sight (Photo 2).

Another major problem is the variation in plating thickness.[(3),(4)] Unlike the subtractive process, in which copper foil with uniform thickness is used to ensure a uniform trace thickness, in the case of the semi-additive process, in which circuits are formed by plating, variation in the plating thickness directly leads to variation in the trace thickness. Therefore, it is an important issue in mass production to minimize variation in the plating thickness. We optimized the conditions of the plating process by leveraging our expertise in plating, which is our core technology field, thereby suppressing variation in plating thickness on the order of μm and realizing mass production of FPC products using the semi-additive process.

In the meantime, forming traces by plating also has an advantage in that the trace thickness can be increased flexibly by increasing the plating thickness. This means that the aspect ratio can be increased while maintaining the fineness of the pattern pitch. However, as the plating thickness increases, the variation in plating thickness also increases, and therefore, a high level of plating technology is required. By applying our fine-pitch and high-aspect-ratio plating technology, we have established technology for forming high-density FPC patterns with a trace spacing of 10 μm or less and a trace thickness of 50 μm or more.

One of the applications of our technology for forming circuits with fine-pitch patterns and high-aspect-ratio traces is the actuator coils used in smartphone cameras for image stabilization, and we are mass-producing the high-density wired coils required for recent high-performance camera modules. In the next chapter, we will report on the application of our technology to the manufacture of actuator coils.

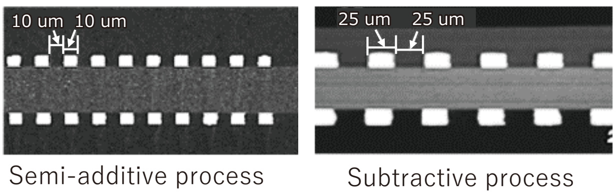


Photo 1. Example cross-section of traces formed by our semi-additive process

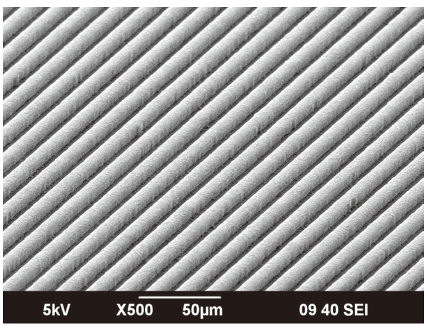


Photo 2. Fine-pitch circuit pattern with an L/S of 7 μm/7 μm

3. Application of Our Semi-additive process—Actuator Coils for the Image Stabilization Function of Cameras

3-1 Outline of actuator coil

A camera module with an optical image stabilization function[(5)] has pairs of actuator coils and magnets arranged around the lens or image sensor. In response to the detected camera shake, an electric current is applied to the coils, and the magnetic force acting between each coil and magnet moves the lens or image sensor in a direction that cancels out the camera shake, thereby stabilizing the captured image (Fig. 3). In order to effectively cancel out camera shake, actuator coils are required to be designed so that they can generate a greater magnetic force.

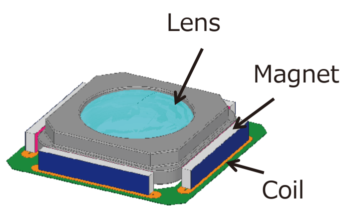


Fig. 3. Image stabilization system using actuator coils

3-2 Actuator coils with high-aspect-ratio traces and fine-pitch circuit patterns

In order to create a compact actuator coil that can generate a large magnetic force, it is necessary to form high-density copper wiring in a limited area because the magnetic force generated by a coil is proportional to the number of turns. Also, as the number of turns increases, the circuit length also increases. As a consequence, the electrical resistance to the current flowing through the coil also increases. Due to the necessity of suppressing the increase in the electrical resistance, it is required to increase the cross-sectional area of traces. In order to increase the cross-sectional area of copper traces arranged in a limited area, it is necessary to increase the trace thickness, i.e., form copper traces with a high aspect ratio. For this reason, it is required to form coil circuits with high-aspect-ratio traces and fine-pitch patterns.

Our semi-additive process enables the formation of circuits with a trace spacing of 10 µm or less and a trace thickness of 50 µm or more. Therefore, it is considered that very high-performance coils can be manufactured by applying this method to the wiring of coils that have to meet the requirements described above.

Table 1 shows a result of our CAE simulations of the performance of an actuator coil designed on the assumption of being manufactured using our semi-additive process. For comparison, the simulated performance of an actuator coil designed on the assumption of being manufactured using the conventional subtractive process is also shown. The area occupied by the circuit is the same for both cases, and the pitch (L/S) of the winding circuit is 30 µm/10 µm in the case of the semi-additive process and 35 µm/35 µm in the case of the subtractive process. As for the trace thickness, we assumed 50 µm, which can be achieved by thick plating, in the case of the semi-additive process, and 18 µm in the case of the subtractive process as the thickness of copper foil commonly used in this method.

Table 1. Simulated performance of a coil designed on the assumption of being manufactured using our semi-additive process

	Our semi-additive process	Subtractive process
Area occupied by circuit	1.5 mm × 4.5 mm	1.5 mm × 4.5 mm
L/S	30 µm / 10 µm	35 µm / 35 µm
Trace thickness	50 µm	18 µm
Number of turns	34 turn	20 turn
Magnetic force	44.0 mN/A	28.5 mN/A
Resistance	3.20 Ω	5.13 Ω

The coil manufactured by the semi-additive process has a larger number of turns due to its narrow trace spacing of 10 µm, and as a consequence, it can generate a larger magnetic force than the coil manufactured by the subtractive process. In terms of resistance, the coil manufactured by the semi-additive process has a longer circuit length due to the larger number of turns. However, it has a thicker trace thickness achieved by our high-aspect-ratio plating technology, and as a consequence, its cross-sectional area per trace is larger than that of the coil manufactured by the subtractive process. Therefore, the total resistance of the coil manufactured by the semi-additive process is smaller than that of the coil manufactured by the subtractive process.

As can be seen, the application of our semi-additive process technology to actuator coil circuit formation makes it possible to create low-resistance coils that can generate a large magnetic force, and it can be said that this technology is realized by our expertise in copper plating that can form circuits with high-aspect-ratio traces and fine-pitch patterns.

Photo 3 shows one of the actuator coils developed by us using our semi-additive process. High-aspect-ratio traces formed by copper plating are arranged at very narrow intervals of 10 µm or less, and this structure makes it possible to generate a large magnetic force as designed. As mentioned above, we have realized the mass production of actuator coils with such characteristics by optimizing plating conditions and thereby suppressing variation in the plating thickness, a weak point of the semi-additive process.

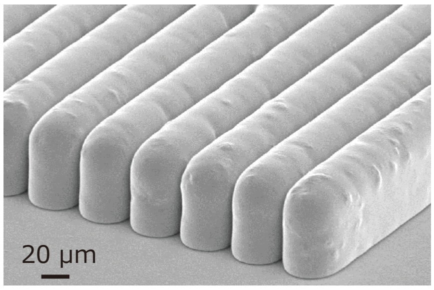


Photo 3. Example actuator coil developed using our semi-additive process (SEM image)

Finally, as one of our latest development targets, we introduce a technology for the simultaneous formation of high-profile circuits and low-profile fine-pitch circuits. By combining the fine-pitch circuit formation technology described in Section 2-2 with the high-aspect-ratio trace formation technology for producing actuator coils, we aim to form both power supply circuits, which are required to carry high current, and fine-pitch signal circuits on the same FPC board, as shown in Photo 4.

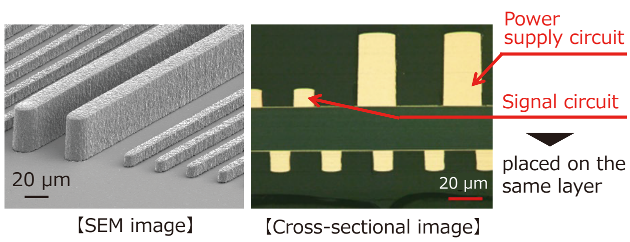


Photo 4. Simultaneous formation of high-profile circuits and low-profile fine-pitch circuits

4. Conclusion

We are developing FPC manufacturing technology using the semi-additive process, and have succeeded in forming fine pitch circuits, such as those with an L/S of 10 µm/10 µm, which is difficult to achieve with the subtractive process. In addition, we have achieved mass production of compact and high-performance actuator coils for image stabilization by establishing high-aspect-ratio and fine-pitch circuit pattern plating technology.

Technical Terms

∗1 Aspect ratio: The ratio obtained by dividing the trace thickness by the trace width.

∗2 Flash etching: The seed layer etching process in the semi-additive process is called "flash etching" because the thin seed layer is etched in a short period of time.

∗3 L/S (line and space): L/S refers to the trace width ("line") and the trace spacing ("space"). It is used as an indicator of pitch fineness.

References

(1) T. Sasabe, M. Akiyama, and K. Kato, "Hontou ni jitsumu ni yakudatsu purintohaisemban no mekki gijutsu," NIKKAN KOGYO SHIMBUN, Ltd. (2012)

(2) Sumitomo Electric Industries, Ltd., Sumitomo Electric Group e-magazine "id," vol.16 (2021)

(3) K. Takagi, "Requirements of Plating Thickness Control for Printed Wiring Boards," J. Surf. Finish. Soc. Jpn, 61, pp. 350-356 (2010)

(4) S. Nishiki, "Uniformity in Film Thickness by Plating Bath Composition," J. Surf. Finish. Soc. Jpn, 61, pp. 362-365 (2010)

(5) Y. Serita, "Structures of Shake Compensation for Digital Cameras," KOGAKU, 33, pp. 550-555 (2004)

Contributors

The lead author is indicated by an asterisk (∗).

K. TAKAHASHI*
• Assistant Manager, Energy and Electronics Materials Laboratory

Y. OKA
• Senior Assistant General Manager, Energy and Electronics Materials Laboratory

S. SAKAI
• Ph.D., Group Manager, Energy and Electronics Materials Laboratory

H. NOHARA
• Assistant Manager, Sumitomo Electric Printed Circuits, Inc.

M. ITO
• Assistant General Manager, Sumitomo Electric Printed Circuits, Inc.

D. SATO
• Group Manager, Sumitomo Electric Printed Circuits, Inc.