Development of Build-up Printed Circuit Board Manufacturing Process Using Rapid Prototyping Technology and Screen Printing Technology

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ABSTRACT

Generally, the build-up printed circuit board manufactured by a sequential process involving etching, plating, drilling, etc, which requires many types of equipments and long lead time. Etching process is suitable for mass production, however, it is not adequate for manufacturing a prototype in the development stage. In this study, we introduce a screen printing technology for prototyping a build-up printed circuit board. As for the material, photo/thermal curable resin and conductive paste are used for the formation of dielectric and conductor. The build-up structure is made by subsequent processes such as formation of a liquid resin thin layer, solidification by a UV/IR light, and via hole filling with a conductive paste. By use of photo curable resin, productivity is greatly enhanced compared with thermal curable resin. Finally, the basic concept and the possibility of build-up printed circuit board prototyping are proposed in comparison with the conventional process.

Key Words : build-up printed circuit board, screen printing technology, photo curable resin, conductive paste

1. Introduction

Generally, MLB (Multi Layer Board) is manufactured by a sequential process involving etching, plating and drilling. Therefore, it requires many types of equipments and long lead time. Etching process is suitable for mass production, but it is not adequate for manufacturing a prototype in development stage. In this study, a screen printing method to prototype a MLB is introduced. As for the material, photo/thermal curable resin and conductive paste are used for the formation of dielectric and conductor. The multi-layer structure is made by sequential processes such as formation of a liquid resin thin layer, the solidification by a UV/IR light, and via hole filling with a conductive paste. In this work the basic concept and the possibility of multi-layer MLB prototyping are presented. Also, the merits of this process are compared with the conventional process.

In general, the sequential build-up method has mainly been used for the MLB production and recently, development of new build-up methods is drawing attentions. As for the build-up methods, there are laser via process, photo via process, plasma via process and so on and the laser-via process is most commonly used[1]. The RCC process, which is one of the laser via processes, will be explained in greater detail.

In the laser via process, the RCC (Resin Coated Copper Foil) is pressed and heated in the upper and lower side of the core (double sided PCB or multi layer PCB) developed by the conventional process. The dielectric layer is revealed by etching the

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processing part of the via hole and then the via hole is created through the laser drill. If the via hole is copper-plated and etched to create a circuit, a layer is completed[2]. The RCC process, which is one of the laser via processes, is shown in Fig. 1.

However, RCC process requires expensive equipments like laser drill for via formation and it also needs to repeat plating and etching process for every layer. Also, the cost is high and waste-water treatment problems due to the by-products of prototyping and production exist.

In RP processes long curing time of the MLB dielectric layer in conventional process can be shortened by using screen printing and uncured photo polymer, which is the layer formation method of SGC (Solid Ground Curing)[3].

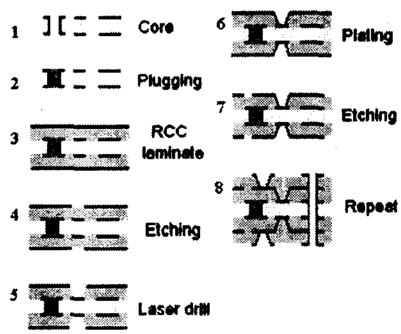


Fig. 1 RCC process

2. Experimetal set up

2.1 Screen printing

As for screen printing, it is a printing method to get a desired section by pushing the printing material by squeezing it under a constant pressure after fixing the screen with the mesh on the frame with a constant tension[4]. It can be applied to a variety of products including art, wrapping container, and electronics.

If screen mesh number is chosen, it can be used in the printing process after stretching, in which it fastens to the frame by proper tension, and photoengraving, in which the 2D shape is generated on the screen. When the screen is fastened to a frame, it has to be within a certain fixed angle with respect to the printing direction so that we can get a fixed resolution regardless of the printing direction. It is generally known that 45° is the most effective. This is because the friction force between the filaments of the screen and the printing material is invariable.

Table 1 Classification of screen

Material	Silk, Nylon, Polyester, Stainless steel, Metal
Thread	Mono filament type, Multi filament type, Mixed type
Number of mesh	Low, Medium, High

The screen creates a space for the printing material to get out, creating a mesh by intersecting the longitudinal filaments and the lateral filaments with silk, synthetic, stainless steel fiber, and so on. The classification of screen is shown in Table 1.

One of the screens classified according to the conditions and purpose of printing in Table 1 can be chosen and used for a specific application.

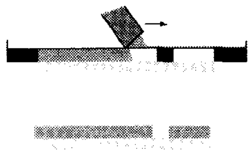
A squeeze plays a role of transmitting the printing material to the printed part during the process. Polyurethane with the hardness of Hs 50~90 is most commonly used as a squeeze material. In the printing process, the transition amount of the printing material is determined by the angle between the squeeze and the printing side as well as the pressure on the squeeze[5]. Therefore, the angle and the pressure of the squeeze play a key part in the printing process.

2.2 Experimental material

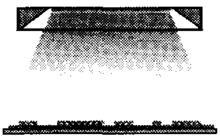
In this study, in order to give two different properties in the same slice, conductive and dielectric materials were used. A photo-curable resin which is widely used in rapid prototyping was used as the dielectric material and a conductive paste was used as the conductive material. In case of the conductive paste two kinds of commercial pastes were experimented.

2.3 Process

Generally, conductive patterns can be produced by plating and etching. This paper describes a method of rapid production of MLB by printing the conductive patterns with conductive paste, which is different from the conventional methods. A dielectric layer could be created by printing the liquid dielectric resin. Then, in the novel process, the via holes could be filled with the conductive paste as shown in Fig. 2.



(a) Photo curable resin printing



(b) Photo curable resin curing with UV

(c) Conductive paste printing

(d) Conductive paste curing with IR

Fig. 2 Manufacturing process

2.4 The equipments

As shown in Fig. 3, a UV lamp was used to cure the photo-curable resin. A manual type printing machine was used in the printing experiment, as in Fig. 4. The specification of the UV lamp is given in Table 2.

This experiment used screens of three different kinds of mesh in order to estimate the viscosity of the printing material and the printing resolution for each mesh. Screens of 300, 350, 420mesh, which are generally used for precise printing, were used.

Test chart No.1-T in Fig. 5 suggested by the Society of Electrophotography of Japan was used for evaluating the screen printing resolution. The figure in resolution pattern represents the number of lines per mm. For example, 1.6 means 312.5㎛ pitch between the lines. As shown in Fig. 6, the number of lines per mm increases from top to bottom at the fixed rate of $2^{1/3}$. With this resolution pattern, the resolution for each pattern and the mesh of screen were estimated.

Table 2 Specification of UV lamp

Wave length(nm)	Power (kW)	Energy (mW/cm²)
325	Max. 2 (Variable)	30

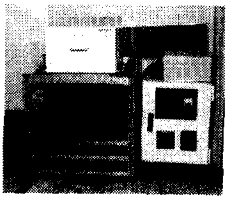


Fig. 3 Photograph of UV lamp

Fig. 4 Photograph of manual printer

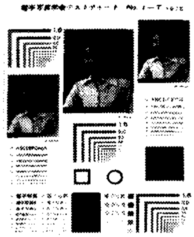


Fig. 5 Test chart No.1-T

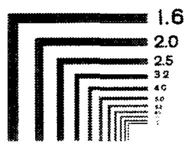


Fig. 6 Resolution chart

3. Experimental results

3.1 Photo curable resin

To obtain suitable viscosity and thixotropy for screen printing, carbonic calcium ($CaCO_3$) was added to conventional photo-curable resin. Viscosity change according to the content of $CaCO_3$ is shown in Fig. 7. In the printing experiment, in case of 20% $CaCO_3$ content, printing was possible without spread and the viscosity was 2.8Pa·s. The viscosity of $CaCO_3$-free photo-curable resin was 10% higher than that of 10% $CaCO_3$ photo-curable resin, which was considered to be the effect of thixotropy.

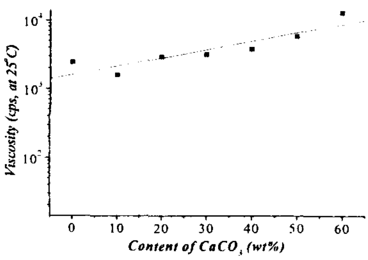


Fig. 7 Viscosity graph

Viscometer and measurement condition for the viscosity experiment are shown in Fig. 8 and Table 3, repectively.

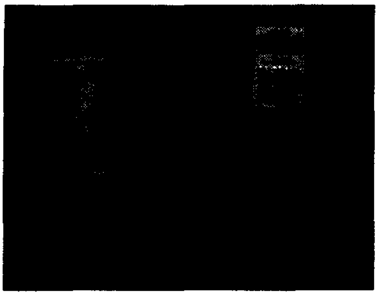


Fig. 8 Brookfield viscometer DV Ⅱ+

Table 3 Measuring condition of viscosity

rpm	Spindle No.	Temperature(℃)
5	5	25

It the particles are dispersed in a non-Newtonian fluid and then sheared at a constant rate, the apparent viscosity decreases with time until a balance between structural breakdown and structure re-formation is reached. This property is called thixotropy[6]. From a rheological point of view, thixotropy is a very important property in the printing process. This is because the printing material should flow only when being printed on to the appropriate surface and immediately attain the shape after printing. Fig. 9 shows the thixotropy behavior[5].

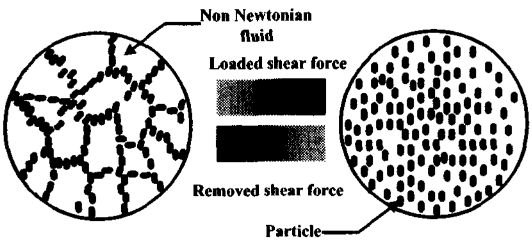


Fig. 9 Thixotropy behavior

As for the photo-curable resin, printing was possible with only one content condition. In case of less than 20% content, too much spread was occurred and for over 20% content printing break-off was found. After printing, the printed photo-curable resin was hardened for 10 seconds with 2kW UV source. Line width and spread rate according to the screen mesh are shown in Fig. 10 and Fig. 11. As for the photo-curable resin, the higher the screen mesh was, the finer was the printed line. Spread rate showed a similar tendency that the higher the screen mesh was, the less was the spread rate.

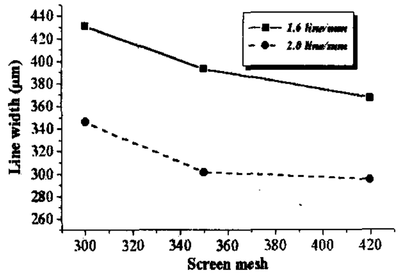


Fig. 10 Graph of line width as screen mesh

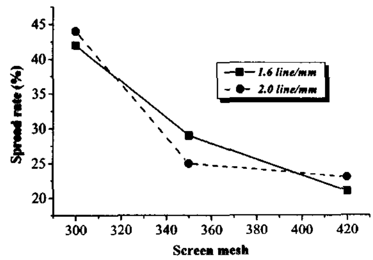


Fig. 11 Spread rate of photo curable resin

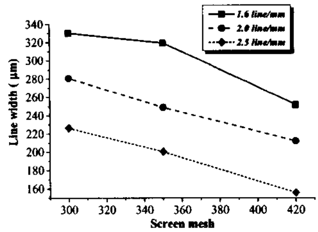
3.2 Conductive paste

To find out the viscosity effect on the resolution, two kinds of conductive pastes were experimented. Properties of the pastes are shown in Table 5.

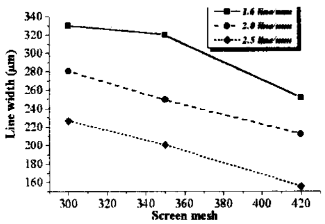
Table 5 Properties of conductive materials

	Dupont 5007	TAIYO
Viscosity (Pa · s)	20~40	4.5~5.0
Bulk resistivity (10^{-5}Ω · cm)	3~4	6~7

In case of the conductive paste, , a thermo-curable paste was used instead of a photo-curable paste. Curing condition was 150℃ for 30 minutes. In Fig. 12 and Fig. 13, line width and spread rate of the two pastes are given, respectively.

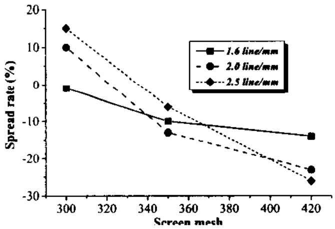


(a) Dupont 5007

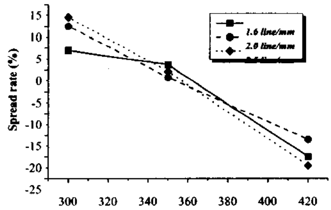


(b) TAIYO

Fig. 12 Graph of line width as screen mesh



(a) Dupont 5007



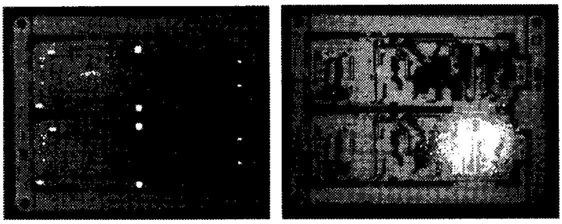
(b) TAIYO

Fig. 13 Spread rate of conductive materials

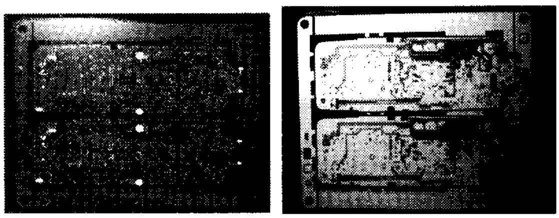
4. A build-up case study

Generally, the conductive pattern can be produced by plating and etching. In this work, a method which can produce the part swiftly by printing the conductive pattern with the conductive paste unlike other conventional methods is suggested.

A dielectric layer can be created by printing the liquid dielectric resin and the via hole can be filled with the conductive paste in the MISO process. The process can reduce the production equipment and time period by using the screen printing method, which is a dry process, instead of the etching method, which is a wet process. The desired shape of MLB has been produced by repeating the process.



(a)After dielectric printing (b)After conductor printing



(c)After dielectric printing (d)After conductor printing

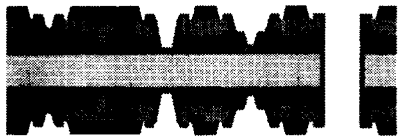
Fig. 14 Actual build-up process

The process can be achieved by the full build-up process, unlike the conventional process. The step by step process layer pictures are shown in Fig. 14. The cross section of MLB produced by the MISO process and that by the RCC build-up process are shown in Fig. 15.

It is found that the new process can create more layers than the conventional process for the same thickness. This is a major benefit since the electronic parts are getting thinner. Also, the new process can create the via hole to connect the upper and lower layers more freely.

Fig. 15 compares the profiles and thickness of the product for a conventional RCC build-up process and the suggested novel process. Moreover, vertical arrangement of the via holes could allow higher mounting density with the new MLB process.

(a) Cross-section of MISO build-up PCB



(b) Cross-section of RCC build-up PCB

Fig. 15 Comparison with RCC build-up PCB

It was confirmed that rapid prototyping techniques could be used to expand its applications to electrical (new MLB process) applications by joining with other manufacturing technologies. With the new MLB process by RP, thinner shape MLB was fabricated in a short time compared with the existing MLB process.

5. Conclusion

In this study a new RP screen printing method using a liquid dielectric resin for fabricating laminated layers of different materials was presented. This process can be used for MLB production in the electronic industry. The following conclusions may be drawn from this work.

1. It was confirmed that rapid prototyping technologies can be used to produce electronic components though the conventional process has been applied to many other areas.
2. The dry process which does not require the core, etching, plating and drilling processes was achieved, unlike the conventional MLB process.
3. The thickness of MLB was reduced by about 60%, compared with the conventional MLB process.
4. In case of using more than two materials, a functional product can be made since every electric component, such as printable device can be directly equipped.
5. A genuine functional part can be made if the new process is combined with the conventional method of using a master model.

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