A Study on the Void Free of Via Hole Filling by Vacuum Printing Method in PCB

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PCB 인쇄에서 진공인쇄 방식에 의한 Via Hole 충전의 Void Free에 관한 연구

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Abstract

본 연구에서는 PCB에 진공인쇄 방식이 적용된 스크린 인쇄방법을 이용하여 Pattern 및 Hole충전의 신뢰성을 향상시킬 수 있는 기술을 적용하였다. 새로운 dry process 기술인 직접회로 인쇄 기술은 일반적으로 사용되고 있는 wet process 중 도금, 에칭, 박리 등의 공정을 줄일 수 있어 제조원가, 공정 리드타임 감소, 폐기물 감소로 환경 친화적 공정이라고 할 수 있다. 직접회로 인쇄는 진공도 100 Pa, 인쇄압력 0.45 MPa, 인쇄 속도 30 mm/sec, 인쇄각도 85도, 스크린 마스크와 기판 사이의 Gap 2 mm에서 인쇄될 때 가장 좋은 결과를 보였다. 직접회로 인쇄에 사용된 인쇄기는 일반 PCB공정에서 사용되는 동일한 형태에 진공조건을 유지시킬 수 있도록 개선하여 사용하였다.

1. Introductions

Printed Circuit Boards(PCB) have advanced considerably in terms of more functions, smaller noise tolerance, and portability[1]. To continue further development, manufacturers must improve their process capability to meet customers' needs. New processes to produce micro patterns such as semi-additive and fully additive processes and laser patterning have been considered[1). However, cost has been a major issue than yield, manufacturing steps, and efficiency.

There are several steps in PCB fabrication involving image or pattern transfer directly from CAD data or through an intermediate step such as the phototool formation[1). Examples of the phototool formation can be found in drilling through-hole or micro via pattern, forming innerlayer and outerlayer circuit pattern, structuring a soldermask, and applying legend print. Photolithography, plating, printing arean important process for circuit formation of the board[2). Besides photolithography, etching, plating, and resist striping are required to complete the process.

To reduce costs, manufacturers have long tried to eliminate or alter some of the fabrication sequences using LDI, ink-jet printing, laser direct structuring and flow-guided deposition[3). However, there are some problems. First, new equipment is expensive and requires more technical expertise for operation. Even though the equipment is new, there is a lack of reliability in terms of weak peel strength of patterns and not fully filled vias by copper plating or other conductive pastes. Despite its deficiency, ink-jet printing has the potential to replace traditional imaging processes since product turn-around time and feature registration is the critical drivers[4). However, there are tradeoffs. It is difficult to control heights of patterns built by the process, filling the holes and vias.

So, direct pattern printing has been developed to overcome these problems. Using high resolution photosensitive material doubles to form fine patterns. After vacuum screen printing process, photosensitive material is not stripped and it holds fine patterns and gives more adhesion. This work has more potential benefits such as elimination of tools and reduction in process steps done after photosensitive material lamination. So additional cost saving can be realized. Because this process does not use wet process steps such as plating, etching, and stripping, process friendly to the environment is expected

In this study, vacuum printing method is applied to get rid ofvoids in the via holes when they are filled with paste by direct printing. A package substrate with higher reliability in via holes is made with this advanced printing method.[5-8)

2. Experimental

2-1. Materials

CCL (Copper Clad Laminates, Doosan DS-7408, Thickness of resin 800㎛, thickness of copper foil 12㎛) is used to form the core of PCB. And ABF (Ajinomoto Build-up Film, Ajinomoto, GX3, Thickness 35 ㎛) is laminated on the CCL. And photosensitive material is a normal dry film (Hitachi-RY-3215, 15㎛). To form circuit on the board, silver paste (Fujikura, XA-9076, Viscosity 450 Ps, solid content 95 w%) is printed by a vacuum printer (Toray Eng.).

2-2. Experimental

Direct printing pattern process is divided into several steps. (a) CCL, a substrate is needed. (b) Photosensitive material is laminated on the substrate. In this work, normal dry film is used instead of photosensitive material, but photosensitive material can be liquid type or other types with insulating ability. (c) After exposure and development progresses on the photosensitive material. (d) The circuits pattern are formed. (e) Insulator which is normally called a build up film is drilled to interconnect two layers; (f) The via holes are formed by CO_2 Laser. (g) Photosensitive material is laminated on the insulator. (h) After exposure and development progresses on the photosensitive material, the pattern are formed. (i) Pattern printing is directly done by filling all the patterns and via holes with conductive silver paste on the photosensitive material. When pattern printing is progressed, hole filling squeegee is used. After the pattern is printed, to remove all of the remained paste on the photosensitive perfectly and enhance the reliability, the surface is cleaned by a grinder or other ways. Through this process, build up layers are manufactured. Multi layered PCBs are made through repeating the pattern printing.

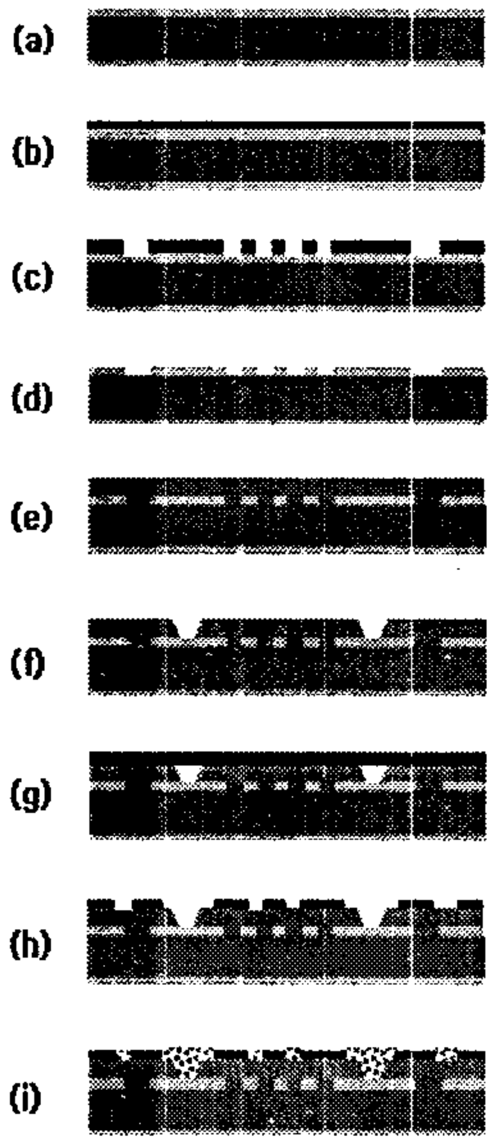

Fig. 1. Diagram of direct pattern printing process.

3. Results and Discussions

A series experiments to fill the circuit patterns and via holes carried out under different conditions.

First of all, the screen printer is a special chamber which gives new printing atmosphere by controlling chamber vacuum. The vacuum test condition is done under 100, 300, 500 Pa and atmosphere condition.

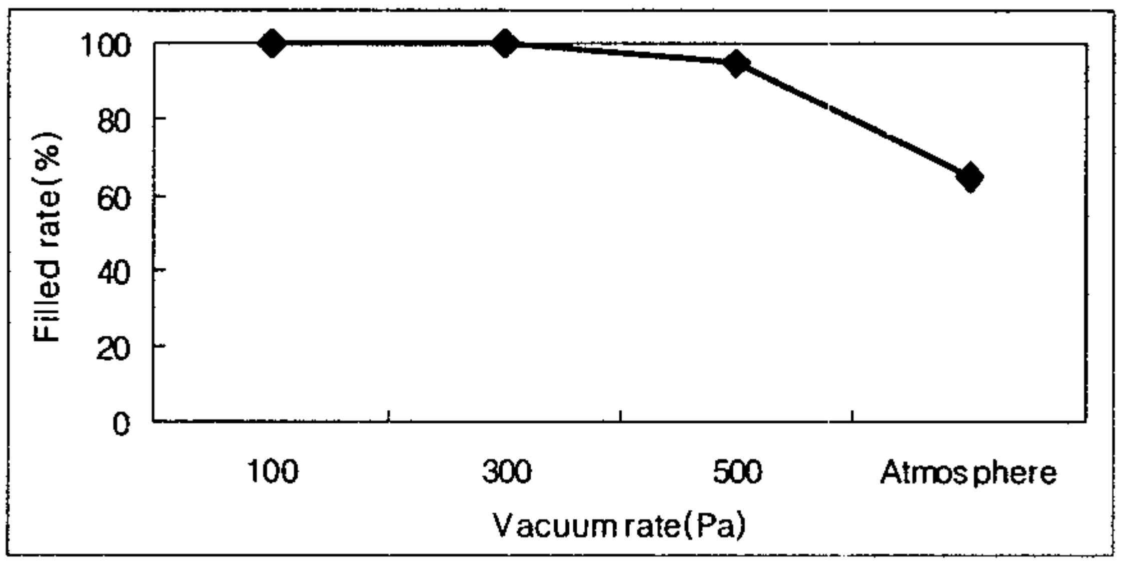

Fig. 2. The change of filled rate under various chamber vacuum conditions.

Fig. 2 shows the change of pattern and hole filled rate under chamber vacuum conditions. When the printing process is done under 100, 300 Pa, the pattern and hole are perfectly filled. According to the cross section pictures, it is known the pattern and via hole printed under atmosphere is not filled with paste fully and some void is observed.

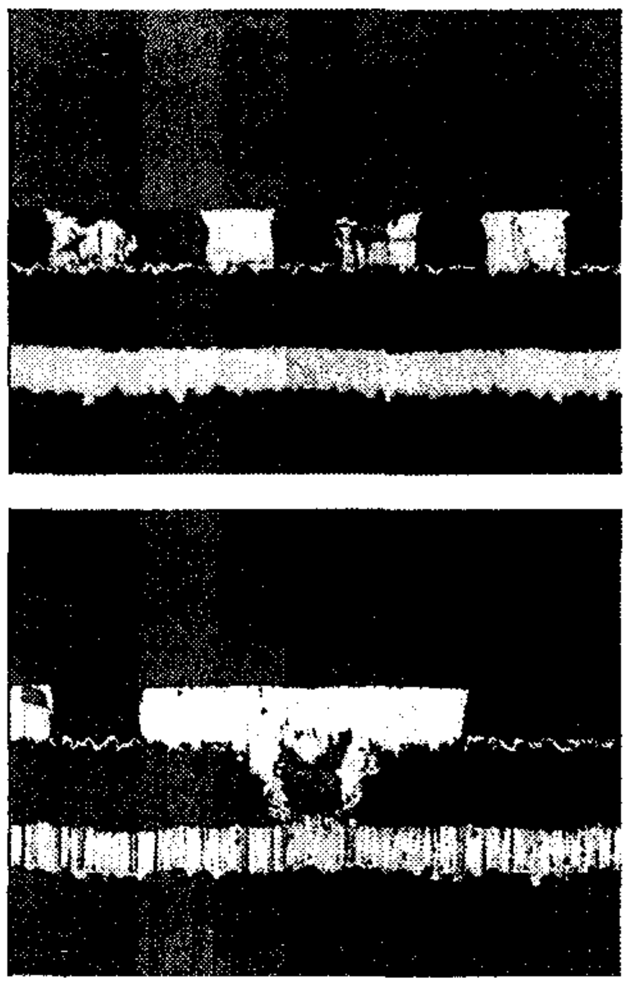

Fig. 3. The picture of cross section of patterns which is printed under atmosphere condition.

The pattern and via hole printed under vacuum condition of more 500 Pa are not filled then those under other conditions. Voids are observed in patterns and holes under more 500 Ps.

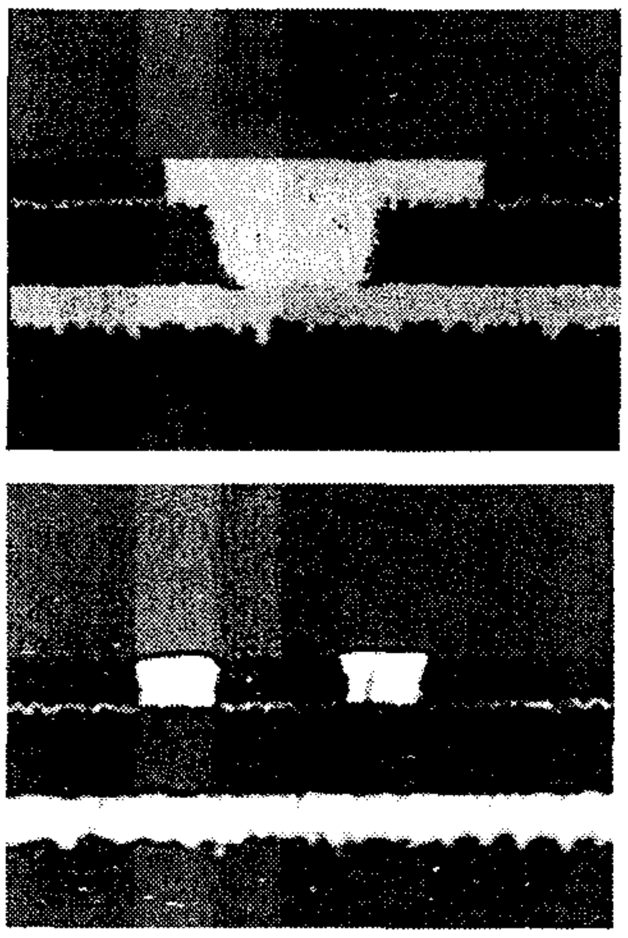

Fig. 4. The picture of cross section of pattern and hole which are printed under vacuum condition of 100 Pa.

Therefore the best result will be expected when the printing is performed under the vacuum condition of 100 Pa.

Also second of the important conditions in screen printing, pressure of a squeeze is controlled in various conditions 0.25, 0.35, 0.45 MPa. Fig. 5 shows the result of the pattern and hole filled rate under various pressure of a squeeze.

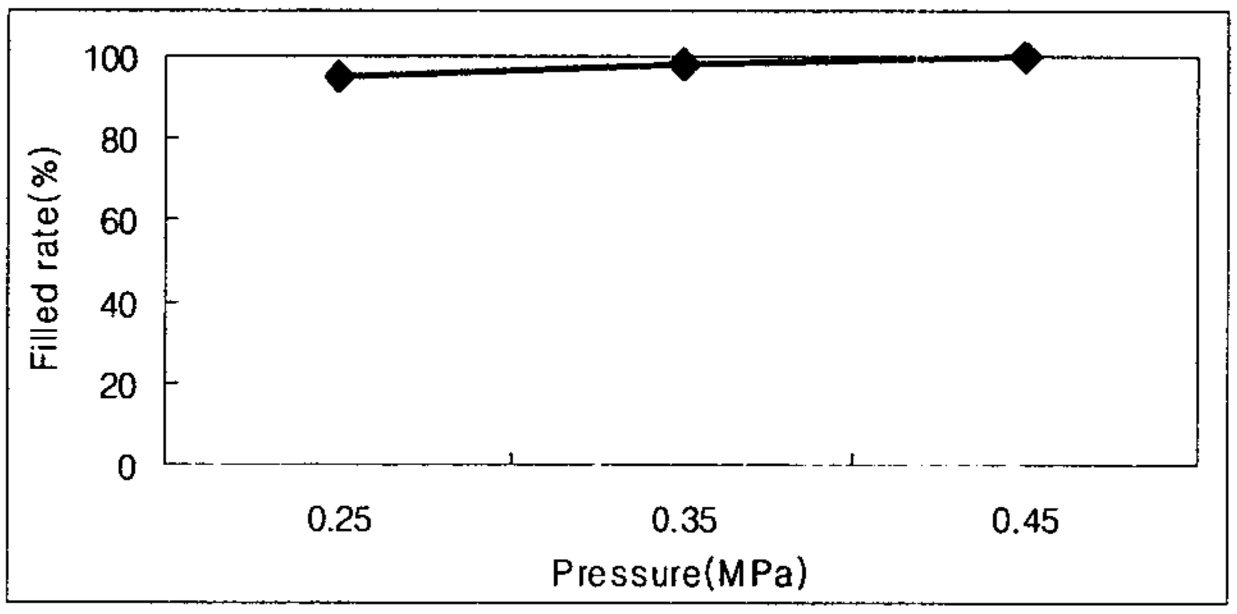

Fig. 5. The change of pattern and hole filled rate under various pressure conditions of a squeeze.

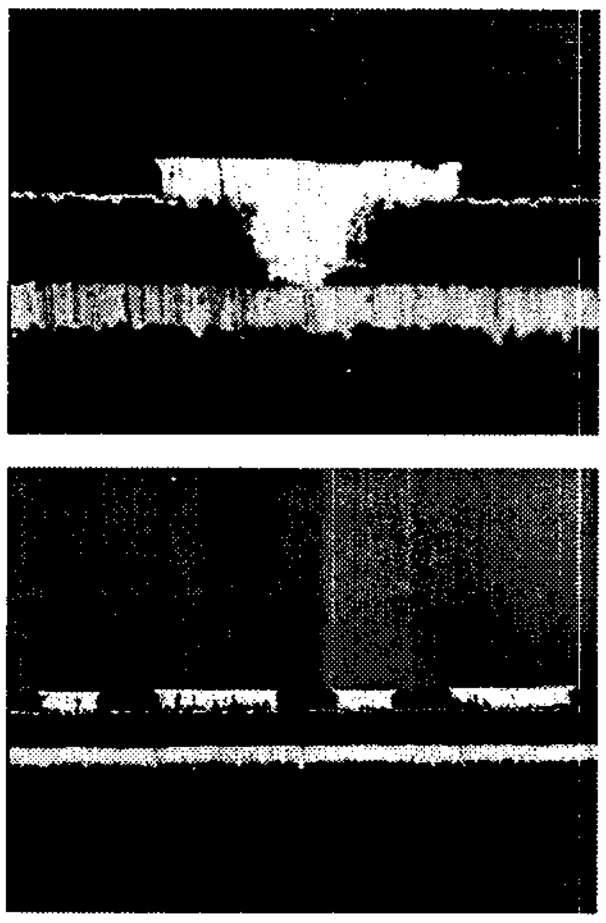

Fig. 6. The picture of cross section of pattern and hole which are printed under printing pressure condition of 0.25 MPa.

When the pressure a squeeze is 0.45 MPa, pattern and hole are well filled. The higher pressure of squeeze disturbs the flow of paste which goes to the inside patterns on the contrary as the viscosity of paste is lower 250 dPa.s.

The third condition is printing speed. It is usually known that more paste get through out the screen and fill the pattern and hole with more paste as printing speed is slower when the viscosity of the paste is higher 400 dPa.s. As it is expected, pattern and hole are filled more paste when the printing speed is slower. But the filled rate of pattern and hole are lower when the printing speed is more than 90 mm/s. Fig. 7 shows the change of pattern and hole filled rate under printing speed.

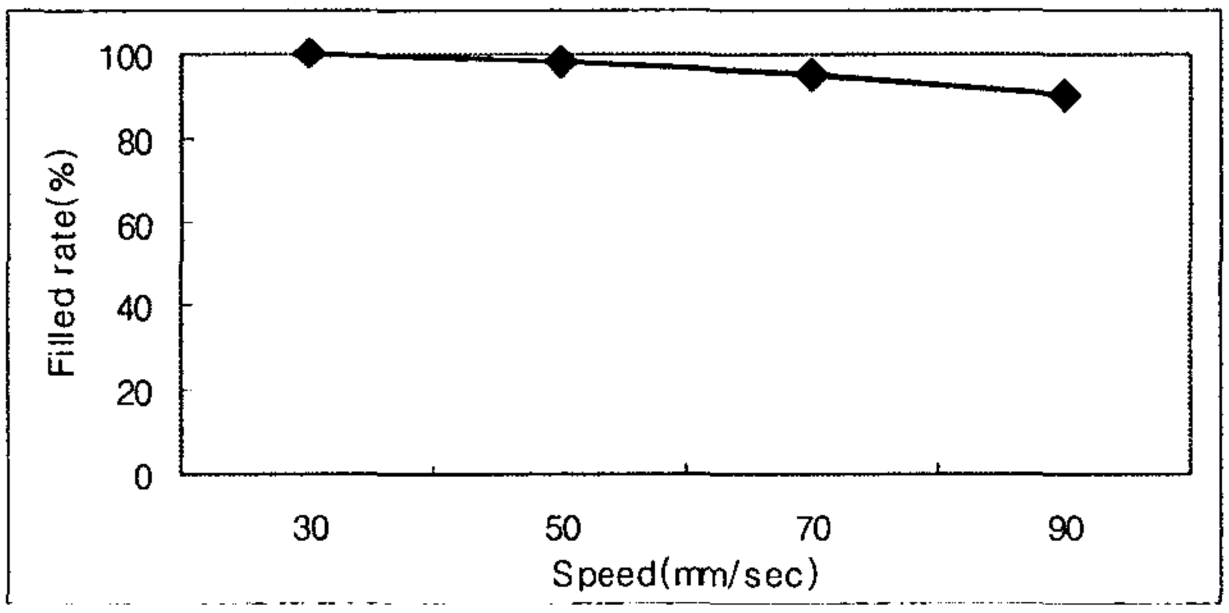

Fig. 7. The change of pattern and hole filled rate under various speed conditions of a squeeze.

The best result comes out when the printing speed is 30 mm/s. When the printing speed is more than 90 mm/s, the faster speed disturbs the flow of paste as the results.

The forth condition is printing angle. When the angle of printing is 85 degree, pattern and hole are well filled. Fig. 8 shows the change of pattern and hole filled rate under printing angle.

The last condition is gap of screen mask and substrate. Filled rate of pattern and hole are well filled at gap 1 to 2 mm. Fig. 9 shows the change of pattern and hole filled rate under gap of screen mask and substrate.

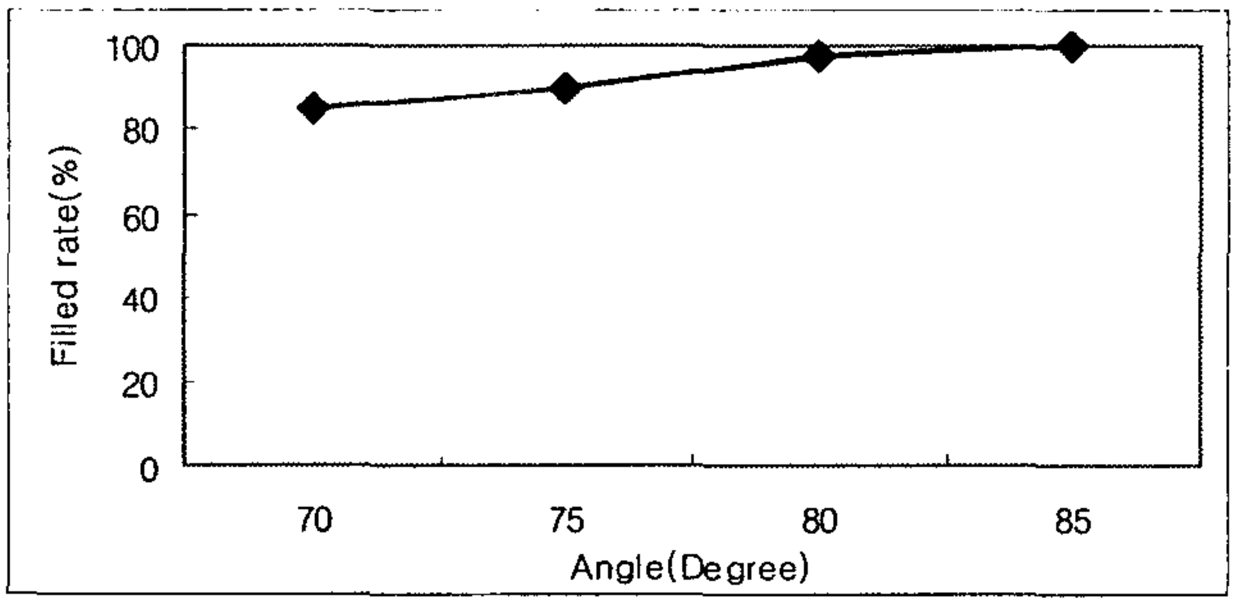

Fig. 8. The change of pattern and hole filled rate under various angle conditions of a squeeze.

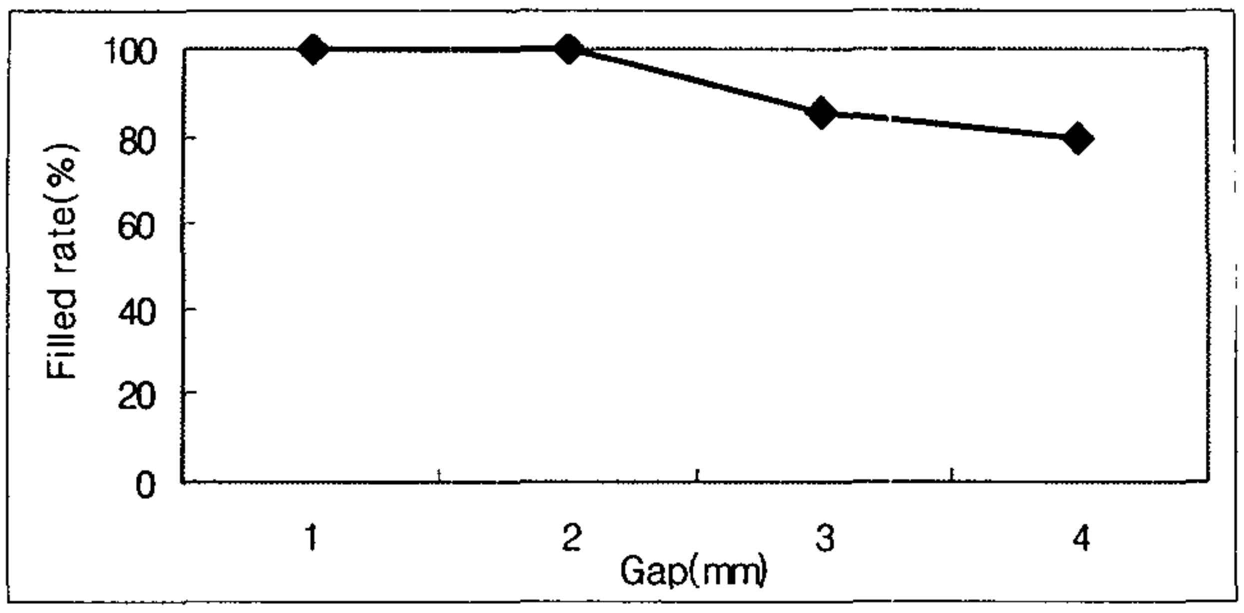

Fig. 9. The change of pattern and hole filled rate under various gap conditions of screen mask and substrate.

The series experiment is performed under five different parameters. To get the best result, the direct pattern printing has to be progressed under condition of vacuum condition 100 Pa, squeeze pressure 0.45 MPa, printing speed 30 mm/s, printing angle 85 degree and gap 2 mm. Fig. 10 is the picture of the pattern to optimized condition.

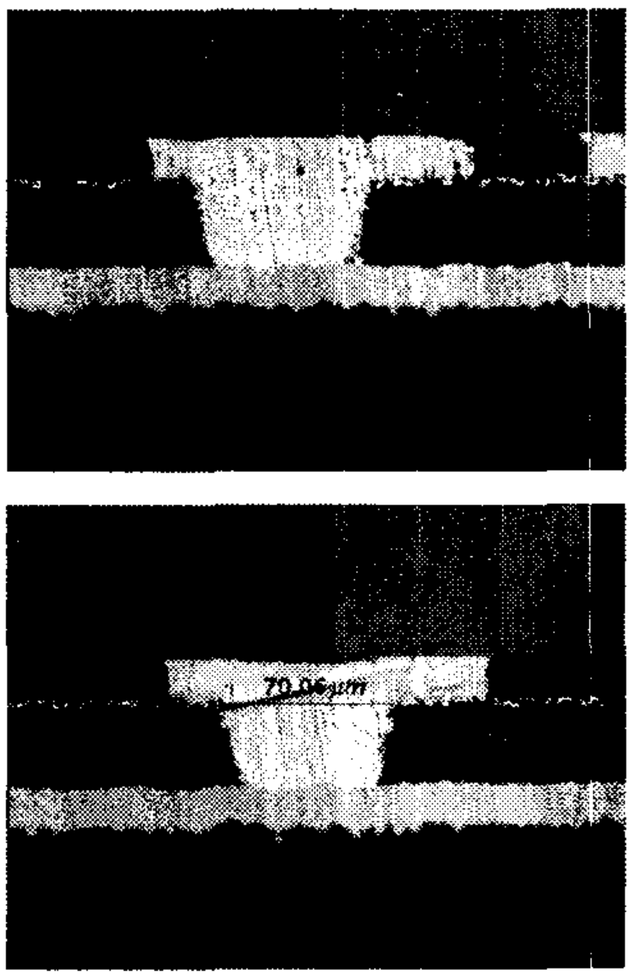

Fig. 10. The picture of the pattern to optimized condition.

Direct printing is redone to prove the result under best printing conditions and new result is made as the printing is repeated more than once on the same PCB.

When the direct pattern printing is done once, the pattern and hole are fully filled. Before second printing is progressed, the printed board is left in the heating oven for 30 min at 80℃ and when printing is over, it is cured for 1h at 150℃. This step is needed to stabilize the paste.

All of the parameters through the series experiments is applied to one of the packaging PCBs, FC BGA. FC BGA has narrow line and space, high cost and also needs high technology. Fig. 11 is the application example of direct pattern printing. It is applied to FC BGA and succeed in embody the file patterns up to 18㎛.

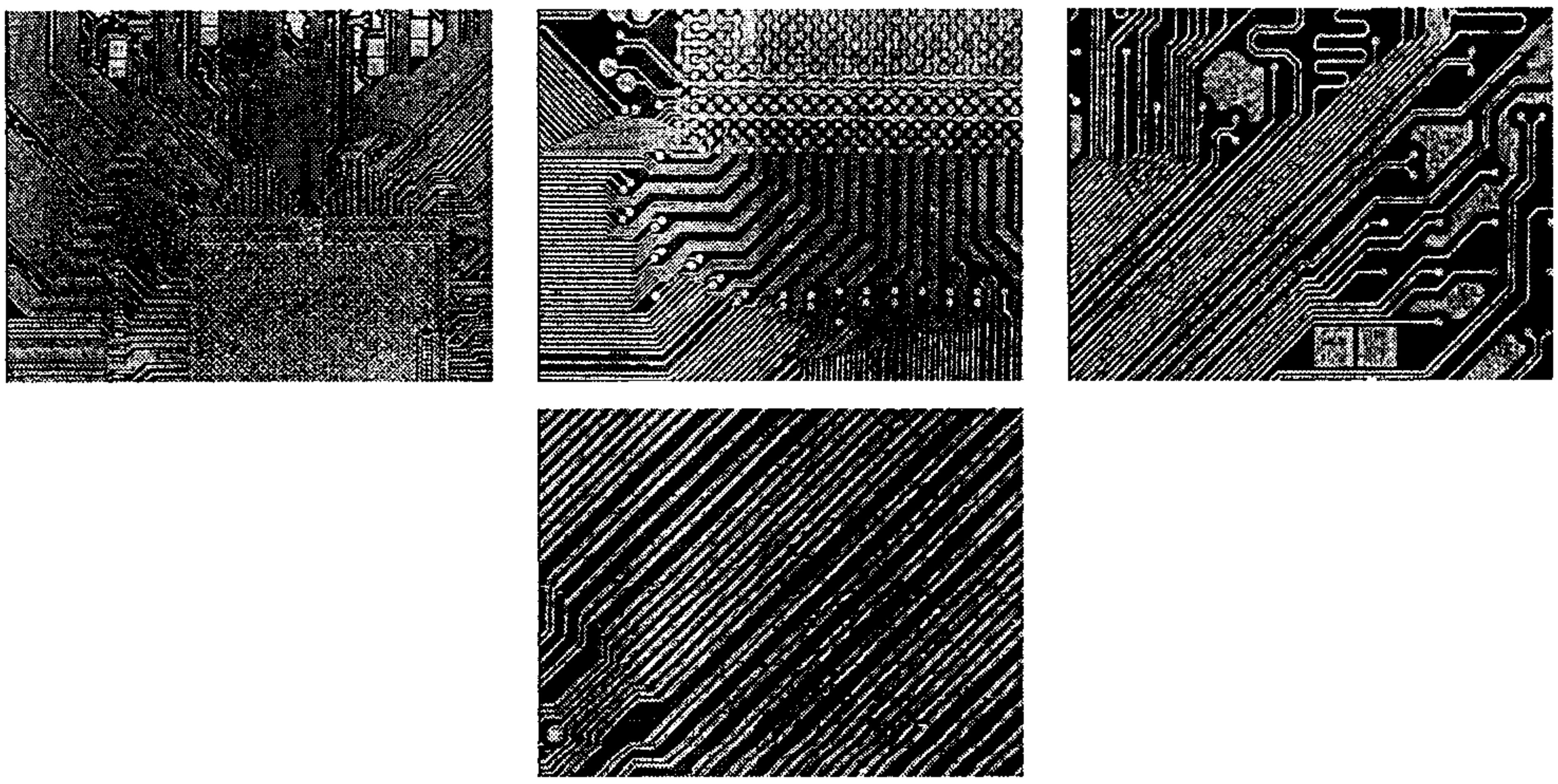

Fig. 11. Direct pattern printed FC BGA.

4. Conclusion

New dry process can print up to 18㎛ and is convenient and simple. Direct pattern printing process has great potential to replace traditional wet processes. New processes reduce cost and improve reliability in terms of better peel strength. A normal screen printer is only needed. Environmental issues are being studied for future Green PCB's.

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