Fabrication of Micro Wall with High Aspect Ratio using Iterative Screen Printing

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Abstract

Micro wall is fabricated using iterative screen printing that it is able to fabricate the pattern as low cost, simple process, formation of pattern at large area on the various substrates. In the process of micro wall fabrication using screen printing, the printing result with pressure change in process and improvement of surface roughness using hydrophillic plasma treatment are included. Height of micro wall increase linearly and precision of iteration is very high. Error rate of printed pattern width is very high, but change rate of width is under 10 %. Fabricated micro pattern have minimum width 48.75 µm and maximum height 75.45 µm with aspect ratio 1.55.

1. Introduction

Recently, the study is in progress about fabrication of printed electronic devices. In the fabrication of printed electronic devices, there are several methods such as gravure, flexo, screen, roll-to-roll and make an effort about development of materials for printing processes. In particular, in order to fabricate the printed electronic devices such as printed organic light emitting diode (OLED)[1], printed organic thin film transistor (OTFT)[2] and solar cells, development of high resolution printing method is required. The method of pattern fabrication can be applied by various printing processes, but fabrication of high resolution and high density electronic devices is needed to realize micro pattern. Not only printed electronics but also applications of printed electronics, such as protection film, EMI shielding filter, micro wall of color filter, are required with width of large aspect ratio. However, it is difficult to fabricate micro pattern using existing printing method. Generally, functional micro pattern under 100 µm is fabricated by photolithography. Photolithography is able to fabricate the pattern with large aspect ratio. In this method, the cost of equipment is very expensive and the cost of raw materials is also expensive because of removal of unnecessary parts using solvent or an alkali aqueous solution and environmental problem should be considered[3]. Due to complexity and high cost of process, development of new patterning technology is required. The precision of new patterning technology should be guaranteed with similar level to photolithography and it should be possible to form a pattern by simple process[4]. Therefore, in this paper, as an alternative to the photolithography, we fabricate the micro wall using iterative screen printing that it is able to fabricate the pattern as low cost, simple process, formation of pattern at large area on the various substrates.

2. Screen printing process

Screen printing is the process of pressurization using stencil. It has disadvantage of low processing speed, but it is suitable for printing of large scale substrate because it has advantage that not affected by ink and substrate. Screen printing can proceed the formation of thin-film and patterning in atmosphere also it has advantage of low cost and less time. The mechanism of screen printing consists of four processes[5].

First, Rolling mechanism is the rotation of paste for forward direction by squeegee. Second, ejection mechanism is ejection of paste on the screen mask opening by generated force by elastic deformation that is caused transferred force from incline forward direction. Third, separation mechanism is the separation between paste and mask. Paste is stayed on the substrate separated from the screen by itself after ejection of paste along the move of squeegee. Fourth, leveling is the mechanism of surface leveling and keep their form on the substrate by surface tension after plate separation.

Screen printer for experiment is the semi-automatic screen printer to work with pneumatic and it is capable precise alignment. It is important process condition, for example, printing speed, pressure and distance with screen mask to form micro pattern with high aspect ratio. In order to form a micro wall, we use the iterative screen printing using precise alignment as shown in Fig. 1. Printing process is iterative process that printing process to print on the substrate(Fig. 1(a)), curing process to cure the printed surface(Fig. 1(b), (d)) and iterative printing process to print on the printed surface again(Fig. 1(c)). In order to print iteratively, need the curing process about printed surface, again.

In this work, we fabricated screen mask patterns onto a steel used stainless(SUS) meshed substrate having which dimensions 320 x 320 mm^2 . Screen mask pattern is designed 20 μm line width and 50 μm channel length with diagonal line and cross line. Mesh tension of screen mask is from 1.14 mm/kgf to 1.15 mm/kgf and mesh thickness is 28 um. Emulsion thickness and mesh angle are 5 μm, 45°, respectively.

3. Experiment and results for formation of micro wall

Materials for experiment have 8000 cps viscosity based on pigment and cure the material using UV light. It is suitable for screen printing material. The results of printing change by characteristics of film surface. PEN(Polyethylene Naphtalate) and PET (Polyethylene Terephthalate) plastic films are usually used to fabricate the printed electronics devices.

Contact angle about two films are similar, but films need not to deform while curing process. The thicknesses of PET film and PEN plastic films are 188 μm, 200 μm, respectively, and its maximum process temperature is 140 ℃ and 150 ℃, respectively. To reduce the deformation for processing, we used the PEN film and used other films for each process from 1 time to 5 times. To form a high micro pattern, theoretically, printing speed should be increased and pressure should be reduced gradually. In experiment, printing speed is same for all process and pressure reduced 0.1 kgf for each process. Fig. 2 represents the printing results about pressure change. To fabricate a micro wall with high aspect ratio, pressure of squeegee must reduce in iterative screen printing process. Therefore, we compared the height and width of printing result about pressure change. Not only process condition but also characteristic of plate affect the printing quality, importantly.

In order to see the variation of pattern height using iterative screen printing, process condition of printing is shown in Table 1. Figs. 3(a) and 3(b) represent the screen printing results from 1 time to 5 times. First printed pattern have 4.77 μm (0.1 μm) height and 52.7 μm (0.1 μm) width. The results that change process condition and follow the procedure, 5 times printed pattern have 75.45 μm height and 54.531 μm width. As repeated process, the height of pattern is increased gradually from 4.77 μm (6.65 μm) to 75.45 μm (45.84 μm) and the width is increased at first print. However, the widths did not increased continuously and kept the width similarly with first printed pattern and printed patterns are in layers. Look into the experimental result, printed pattern looks like a shape of V. This phenomenon caused by viscosity of pigment. This effect of viscosity ignores from existing state of things, but it is able to very serious defect. It is able to make by flat pattern using O_2 plasma treatment. If the printed pattern cures the plasma treatment not UV, we were able to form a flat pattern.

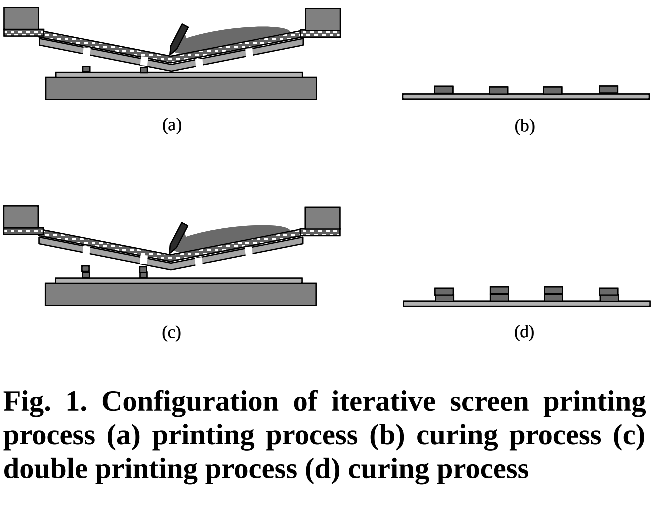

Fig. 1. Configuration of iterative screen printing process (a) printing process (b) curing process (c) double printing process (d) curing process

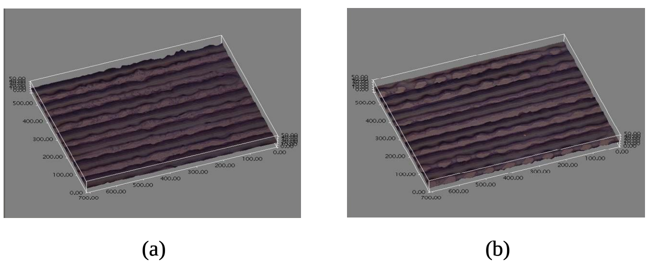

Fig. 2. 3D Image of printed micro-wall pattern depending on pressure change (a) 2.1 kgf, 150 mm/s [height : 4.860 um, width : 55.340 um] (b) 1.7 kgf, 150 mm/s [height : 7.064 um, width : 46.116 um]

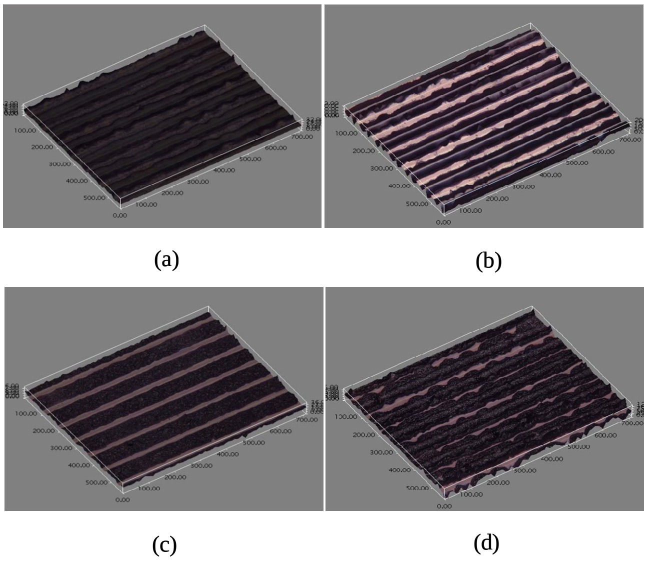

Fig. 3. 3D Image of printed micro-wall pattern and with plasma treatment using iterative screen printing (a) 1st printing (b) 5th printing (c) 1st printing with plasma treatment (d) 5th printing with plasma treatment

TABLE 1. Periodic table of elements

No. of printing	Printing pressure(kgf)	printing speed(mm/s)
1st	2.1	150
2nd	2.0	150
3rd	1.9	150
4th	1.8	150
5th	1.7	150

Plasma treatment makes more flat patterns than UV curing. To fabricate flat patterns with rectangular shape in cross sectional area, plasma treatment is more profitable than UV curing. The characteristic of interactive printed micro wall is shown in Fig. 4. However, plasma treatment has disadvantages that it makes low penetration and large pattern width. Fig. 3(c) and 3(d) represent the screen printed pattern using plasma treatment.

Fig. 5 compares the contact angle of ink on the plastic substrate with the contact angle of ink on the printed pattern for initial time and 1 minute later. The contact angle of ink on the printed pattern is larger than on the plastic film. These means that printed pattern on the printing result is higher than printed pattern on the plastic substrate.

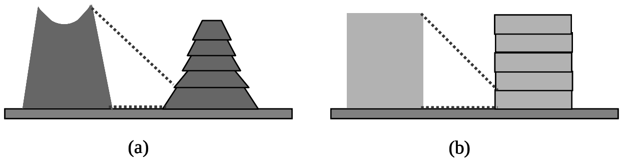

Fig. 4. The characteristic of interactive printed micro wall plasma treatment, (a) before plasma treatment (b) after plasma treatment

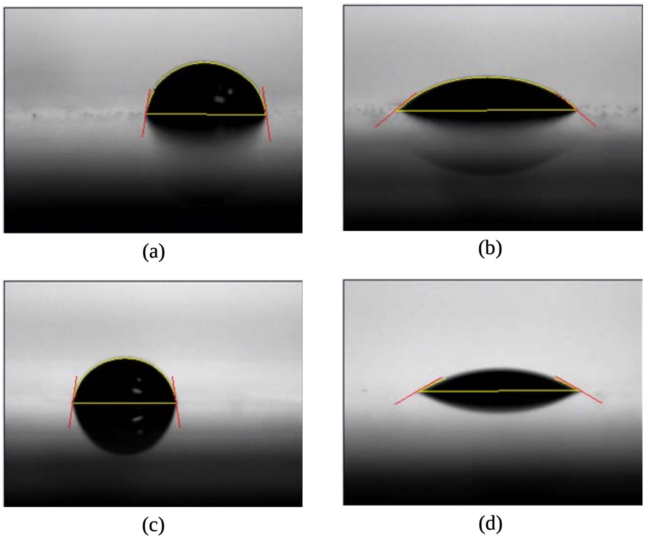

Fig. 5. Contact angle of ink (a) on the cured ink (81.44°), (b) on the cured ink at 1 minute later (40.4°), (c) on the plastic substrate (81.71°) and (d) on the plastic substrate at 1 minute later (30.58°).

Printed width increased 100% or more, but precision is very high. We knew that the width is controllable through the design of plate and change the process condition. Fig. 6 represents the variation of printed width and height. Hydrophobic film is more profitable than Hydrophilic film for formation of micro wall. The printing results on the substrate of hydrophilic film increased the line width because result pattern spread out after the printing. Therefore, we knew that selection of substrate film affect the printing results. As you show in Fig. 6, we compare the width of printed pattern from first printing to fifth printing. The line width is compared from 1st printing result to 5th printing result and is fabricated with 10 μm error. We knew that error rate of printed pattern width is very high, but change rate of width is under 10 %.

Height of printed pattern increased linearly from first printing to fifth printing. The printing results on the plastic substrate and printed pattern could be

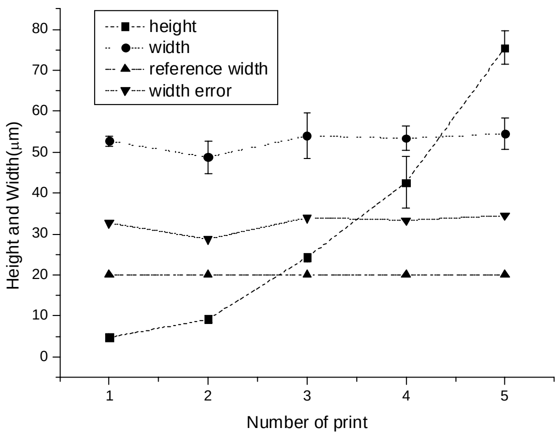

Fig. 6. Variation characteristics of number of screen print versus height and width

different depending on surface energy, but heights of patterns are increased as pressure become smaller.

4. Conclusion

Through experimental results of micro wall fabrication, we confirm the possibility of application as formation of micro wall pattern using iterative screen printing. These results represent that screen printing is an alternative idea of photolithography. In this experiment, we fabricate the micro wall with minimum width 48.752 μm and maximum height 75.450 μm with aspect ratio 1.55 to optimize the process condition. The principle of screen printing process is ejective process using pressure, so it is difficult to control pattern width. Therefore, we study continuously such as design of plate, selection and manufacture of materials, decision of optimal process condition and applications.

Acknowledgement

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5. References

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