Desktop Type Equipment of Thermal-assisted UV Roller Imprinting

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Desktop type equipment of thermal-assisted UV roller imprinting was developed. A remarkable advantage of the desktop type equipment is expected to be easy evaluation of replication results using different molds with small amounts of resin. Replication tests were carried out under various scanning speed of the stage, UV intensity, and roll temperature. Pattern replication was improved by heating roll under the same scanning speed of stage. Heating of the roll was effective to realize better pattern replication under the same scanning speed of the stage.

Keywords: UV roller imprinting, desktop type equipment, roll temperature

1. Introduction

Micro/nanofabrication technologies, specially lithography, are necessary for advanced information society. Presently photo lithography, electron beam lithography and other technologies are used for fabricating many kinds of micro/nanostructures. However, these methods have problems of high cost and low throughput.

On the other hand, ultraviolet nanoimprint lithography (UV-NIL) has attracted attention in a micro/nanopattern fabrication technology [1]. This method is expected to replace in some process steps by the conventional micro/nanostructure fabrication method. For mass production, UV-NIL is most cost-effective fabrication methods [2-4].

In addition, UV roller imprinting has been developed one of UV-NIL. This technique uses roll mold and film substrate.

In recent years, UV roller imprinting has much attention as micro/nanofabrication technology for flexible optical element, electric paper, liquid

crystal display and personal computer [5-7]. UV roller imprinting is carried out in research and development for mass production with large equipment. In this way, high throughput patterning using UV roller imprinting is being achieved [7,8]. However, replication property of UV roller imprinting is in the research step. In this study, we developed desktop type equipment for evaluation of UV roller imprinting replication. Advantage of this equipment is expected to be easy evaluation with small amounts of resin. In addition, a metal thin film resistance heater was integrated with the equipment to evaluate thermal property.

2. Desktop type equipment of UV roller imprinting

Figure 1 shows photograph of the developed equipment for UV roller imprinting and Figure 2 is the concept of the developed equipment.

Roll diameter is 32 mm and width is 50 mm. Length of stage movement is 100 mm and possible

replication area is 30 mm × 100 mm. The maximum revolutions of DC servomotor are 3000 rpm and it is converted scanning speed of stage to 200 mm/min. Sheet substrate width is 30 mm and length is 320 mm. Resistance heater and temperature sensor can be integrated with the roll shaft.

By DC servomotor rotating, the roll synchronizes with the stage movement and the substrate sheet is transported.

In order to keep the tension of the transported sheet to be constant, the spring was integrated with the attachment. UV intensity can be controlled by changing slit width. The slit width can be changed from 1mm to 3mm. Plastic film mold curling around the roll is used.

It is necessary for high throughput replication to make faster scanning speed of the stage. However, fast scanning speed decreases UV exposure and filling time. Filling behavior of UV-curable resin is expected to be improved by heating the roll, because the resin viscosity is lowered.

Fig. 1 Photograph of the developed equipment for thermal-assisted UV roller imprinting

Fig. 2 Concept of the developed equipment

3. Experimental

3.1. Film mold fabrication

Fabrication process of the film mold is shown in Figure 3a. The Si master mold is fabricated by conventional photolithography and Deep-RIE. The size of Si master mold is 4 inches in diameter.

Plastic film mold is fabricated by hot embossing equipment (EVG®520HE from EV Group Co.). Cyclo olefin polymer (COP(ZF14-100® from Zeon Co.)) film is used as the film mold. COP film is so flexible that film mold is easily curled around the roll. The film mold is put up with tape. COP has high mold releasability, because of its low surface free energy [9]. Mold release agent was not used in this experiment. In addition, COP film of high glass transition temperature of 138°C can stand up for high roll temperature. The embossing temperature was 162°C and the pressure was 12000N. Thickness of COP film is 100 μm.

Fig. 3 (a) Film mold fabrication by hot embossing. (b) coating of UV-curable resin. (c) UV roller imprinting.

The film mold has dot patterns of 3 μm in width, 5 μm in height and pitch is 6 μm .

3.2. UV roller imprinting

The process of UV roller imprinting is shown in Figures 3b-c.

Transferred film is curled around the roll and used as the roll mold. Then, UV-curable resin (PAK-02 from Toyo Gosei Co., Ltd.) is coated on the sheet substrate by bar coater. Polyethylene terephthalate (PET (COSMOSHINE[®] A4100 from Toyobo Co.,Ltd.)) is used for the sheet substrate. Thickness of the PET sheet is 100 μm . In this study, scanning speed of stage, roll temperature, UV intensity, and width of slit were changed and evaluated. Table 1 shows the conditions of UV roller imprinting.

Table 1 Conditions of UV roller imprinting

Scanning speed of the stage (mm/min)	30 ~ 200
UV intensity (mW/cm^2)	32, 50
Width of slit (mm)	1, 3
Roll temperature ($^{\circ}\text{C}$)	23, 80

4. Results and Discussion

Figure 4 shows the top SEM image of transferred pattern and Figure 5 shows the cross-sectional SEM image of transferred pattern with UV intensity of 50 mW/cm^2 , slit width of 3 mm, scanning speed of stage of 67 mm/min, roll temperature of 23 $^{\circ}\text{C}$.

Fig.4 Top SEM image of transferred pattern

Fig.5 Cross-sectional SEM image of transferred pattern

Figure 6 shows measuring result of pattern replication of height with UV intensity of 50 mW/cm^2 (3 mm in slit width). Depth of the transfer pattern under the 23 $^{\circ}\text{C}$ (room temperature) and 80 $^{\circ}\text{C}$ was almost same. Under faster scanning speed of the stage, the depth of the transfer pattern is getting shallower.

Then, Figure 7 shows measuring depth of the transfer pattern with UV intensity of 32 mW/cm^2 (1 mm in slit width). In this case, transfer pattern depth was obviously improved by heating roll.

Fig. 6 Relationship between the pattern replication and scanning speed of stage with UV intensity of 50 mW/cm^2

Fig. 7 Relationship between the pattern replication and scanning speed of stage with UV intensity of 32 mW/cm^2

The width of pattern replication was also improved by heating. Figures 8 and 9 show width of the transfer pattern.

Some transfer patterns show larger width than the pattern size of the film mold. The depth of the transfer pattern became shallower at the faster scanning speed of stage. On the other hand, fine transfer pattern width was not obtained under fast

scanning speed of the stage. Since UV roller imprinting encompasses lateral movement compared to the conventional UV imprinting, lateral errors are observed. However, pattern replication is improved under the small amounts of UV exposure by heating the roll.

These results indicate that heating the roll is effective in UV roller imprinting.

Fig. 8 Relationship between the pattern replication and scanning speed of stage with UV intensity of 50 mW/cm²

Fig. 9 Relationship between the pattern replication and scanning speed of stage with UV intensity of 32 mW/cm²

5. Conclusion

This paper reports development of desktop type UV roller imprinting equipment. The developed equipment is thermal-assisted by heating roll. Elevating the temperature of the roll is key issue to realize fine replication.

The pattern replication was evaluated under

different conditions of UV roller imprinting.

As a result, the pattern replication is improved by heating the roll (80°C).

We are currently investigating the detailed relationships between heating effect and replication behavior of UV-curable resin.

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