Gravure Halftone Dots by Laser Direct Patterning

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ABSTRACT

Laser direct patterning of the coated photoresist (PMER-NSG31B) layer was studied to make halftone dots on the gravure printing roll. The selective laser hardening of the photoresist by Ar-ion laser(wavelength: 333.6~363.8 nm) was controlled by the A/O modulator. The coating thickness in the range of 5~11㎛ could be obtained by using the up-down directional moving device along the vertically located roll. The width, thickness and hardness of the hardened lines formed under the laser power of 200~260mW and irradiation time of 4.4~6.6 μsec/point were investigated after developing. The hardened width increased as the coating thickness increased. Though the hardened thickness was changed due to the effect of the developing solution, the hardened layer showed good resistance to the scratching of 2H pencil. Also, the hardened minimum line width of 10㎛ could be obtained. The change of line width was also found after etching, and the minimum line widths of 6㎛ could be obtained. The hardened lines showed the good resistance to the etching solution. Finally, the experimental data could be applied to make gravure halftone dots using the developed imaging process, successfully.

Keywords: Laser direct patterning, photoresist, gravure printing roll, halftone dot, imaging processing

1. Introduction

Micro patterning of photoresist coating layer is an important technology in fields of optoelectronics, micro machining, electronic circuit and PDP(plasma display panel) etc.[1-9] Also, the technology has been applied to prepare the gravure printing roll.[10-13] Gravure printing is an industrial printing process mainly used for the high speed production of large print runs at constant and top quality. Small and concave cells(halftone dots or ink pocket) on the printing roll transfer the ink and represent an image on the printing paper or materials.

In the conventional process, halftone dots on the gravure printing roll are formed by the exposure of ultraviolet(UV) light through a flim. The film containing the image of halftone dots are prepared after very difficult graphic art work. Also, when the film are wounded on the roll, skillful labor are demanded to finish the film joint and contact tightly the film to roll. Thus, a direct laser patterning system has been developed.[12] In the system, the UV laser can directly image a photoresist coated roll, thus eliminating the photographic film processing and reducing the processing time. However, the modification of halftone dots is impossible because the color of photoresist after laser exposure can not be visible. Also, a special coating system must be used.

In this paper, laser direct pattering technology was studied by using the photoresist, which is visible after laser exposure, and the coating device used in conventional film processing. The data for halftone dots from the original image are obtained by using the developed gravure software.[14]

2. Principle for gravure engraving

Fig. 1 shows laser engraving process for gravure halftone dots. The processing includes laser patterning (or hardening), developing and etching. The copper plated roll is coated with photo-hardening polymer or photoresist(see Fig. 1(a)). UV laser beam is irradiated selectively on the photoresist(see Fig. 1(b)). The roll then is developed with water or water based chemical, rinsed from the surface to carry away the unexposed photoresist, leaving the a laser hardened photoresist.(see Fig. 1(c)) The next step is a chemical etching process to etch away the exposed copper.(see Fig. 1(d)) After the remaining hardened photoresist has been removed, the concave cell(halftone dot) is formed on the roll.

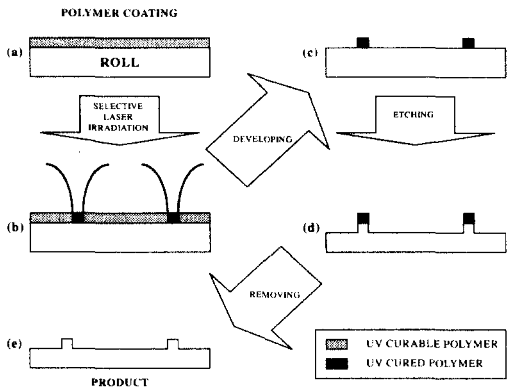


Fig. 1 Principle for engraving of gravure halftone dots

3. Experimenal method and system

The photoresist of PMER-NSG31B was coated on the copper plated roll by using the coating system as shown in Photo. 1. The diameter of roll is 129.1mm, and the coating thickness of photoresist can be controlled by the up-down directional speed of moving head. The color of PMER-NSG31B was changed to blue after laser irradiation (see Photo. 3~6). The coating thickness was measured by the surface roughness tester.

The UV Ar-ion laser(maker: Coherent Co., model: Innova 328) was used for selective laser hardening of photoresist coating layer. The Ar-ion laser has multi-line wavelengths from 333.6nm to 363.8nm, maximum power of 1W, beam waist of 1.5 mm and divergence of 0.5 mrad. Among the multi-lines, 368.3nm and 351.5nm lines are strong. In case of the two lines, the Ar-ion laser shows the beam quality factor(M^2) of 1.51 and the beam mode of TEM_{00}.

Photo. 2 shows the developed laser direct patterning system. Laser irradiation is controlled by laser beam power, rotational velocity of roll and laser pulses/rotation. Laser beam pulse is controlled by A/O modulator(maker: Intra-Action Co.). The minimum optical rising time of A/O modulator is 55ns. The laser beam is focused at the surface of roll by lens of focal length of 25mm.

Photo. 1 Photoresist coating system

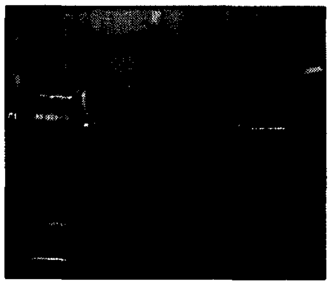


Photo. 2 Laser direct patterning system

Laser hardening of photoresist according to laser power and exposure time was investigated under various combinations of coating thickness, laser power and rotational velocity of roll. Fig. 2 shows a pattern for laser hardening of photoresist. The line is formed by continuous laser spots. Laser beam is irradiated on the surface of roll(diameter: 129.1mm) under 22,500pulse/rotation. The laser beam moves 18㎛ along the longitudinal direction of roll during 1 rotation(raster method). Thus the laser exposing time/pulse could be calculated as shown in Table 1.

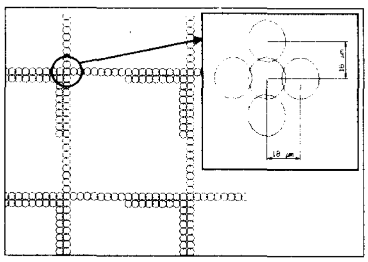


Fig. 2 Pattern for laser hardening of photoresist

Table 1 Laser exposing time/pulse at various rotational velocities under 22,500 pulse/rotation

Rotational velocity [rpm]	Laser exposing time/pulse [μ sec]
400	6.6
500	5.3
600	4.4

The line width of photoresist after developing was measured by the microscope with a scale of 1μm. The hardness of potoresist is evaluated by 2H pencil scratching method.(JIS-5400) The etching resistance of photoresist was investigated in the copper etching solution.

4. Results and Discussion

4.1 Coating thickness

Table 2 shows the coating thickness under various coating velocity at the coating system as shown Photo. 1. The coating thickness is thicker as the coating velocity increases. This may be due to that the coating speed is faster than the free flow of photoresist. When the coating speed is slower than the free flow of photoresist, the coating thickness has a limit value corresponding to the free flow of photoresist. From the experimental data, the coating thickness in the range of 5 ~ 11μm could be obtained by using the up-down directional moving device along the vertically located roll.

4.2 Laser hardening

Photo. 3 shows the laser hardened potoresist lines under the condition of Tables 1, 2 and Fig. 2. Tables 3~5 show the hardened line widths under various rotational velocities of roll and laser powers at the coating thickness 11μm, 7μm and 5μm, respectively. The hardened width of photoresist line increased as the coating thickness increased. The hardened line could not be overlapped when the line width is less than the moving space of laser spot 18μm.

Table 2 Coating thickness under various coating velocities

Coating velocity	Coating thickness
0.09 cm/s	5 μm
0.27 cm/s	5 μm
0.42 cm/s	5 μm
0.52 cm/s	5 μm
0.70 cm/s	7 μm
0.83 cm/s	7 μm
0.96 cm/s	7 μm
1.04 cm/s	11 μm
1.19 cm/s	11 μm

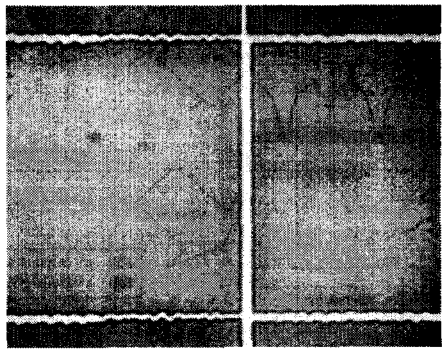


Photo. 3 Example of laser hardened pattern(× 50)

Table 3 Hardened line width under various rotational velocities and laser powers at the coating thickness of 11μm.

[unit:μm]

laser power / rotation velocity	200 mW		230 mW		260 mW		over lapp ing
	1 spot line width	2 spots line width	1 spot line width	2 spots line width	1 spot line width	2 spots line width	
400 rpm	29	51	32	49	37	55	o
500 rpm	29	51	32	47	33	53	o
600 rpm	29	48	32	46	30	51	o

Table 4 Hardened line width under various rotational velocities and laser powers at the coating thickness of 7μm.

[unit:μm]

laser power / rotation velocity	200 mW		230 mW		260 mW		over lapp ing
	1 spot line width	2 spots line width	1 spot line width	2 spots line width	1 spot line width	2 spots line width	
400 rpm	14	32	20	42	20	39	o
500 rpm	14	31	18	35	17	38	o
600 rpm	14	29	16	33	15	33	o

Table 5 Hardened line width under various rotational velocities and laser powers at the coating thickness of 5㎛.

[unit: ㎛]

laser power / rotation velocity	200 mW		230 mW		260 mW		over lapping
	1 spot line width	2 spots line width	1 spot line width	2 spots line width	1 spot line width	2 spots line width	
400 rpm	11	28	14	36	14	31	×
500 rpm	11	27	12	36	12	26	×
600 rpm	11	27	10	32	11	28	×

Fig. 3 shows the relation between the hardened line width under various laser powers, rotational velocities and coating thicknesses. The laser hardened line width of coating thickness 5㎛ and 7㎛ did not increase when laser power> 230mW. However, the laser hardened line width of coating thickness 11㎛ incresed as laser power increased over 230mW. Also, the hardened line width increased as the coating thickness increased at the same laser power and rotational velocity. This may be from that heat transfer through the coating layer is easier as increasing of coating thickness. The hardened minimum line width of 10㎛ could be obtained under laser power of 200~260mW and irradiation time of 4.4~6.6μ sec.

The selective laser hardened photoresist coating layer is developed with water or water based chemical as shown in Fig. 1(c). Table 6 shows the variation of coating thickness before/after laser hardening and developing, and the hardness of hardened coating layer. The coating thickness was thinner due to the effect of the developing solution, however, the hardened layer after developing showed good resistance to the scratching of 2H pencil. This hardness is the optimal condition in the gravure printing industry.

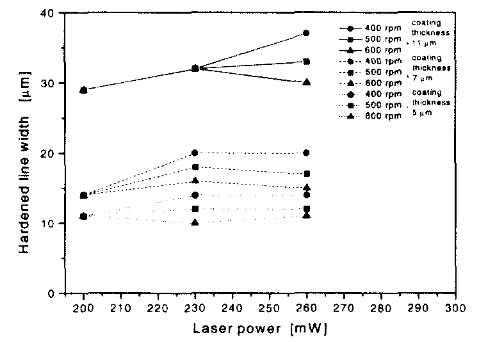


Fig. 3 Relation between hardened line width under various laser powers, rotational velocities and coating thicknesses.

Table 6 Variation of coating thickness and hardness of hardened coating laser

coating thickness before laser hardening	hardened coating thickness after developing	hardness of hardened coating layer after developing
5 ㎛	1.5 ㎛	2 H
7 ㎛		
7 ㎛	2 ㎛	2 H
7 ㎛	2 ㎛	
11 ㎛	3 ㎛	2 H
11 ㎛	4 ㎛	

4.3 Etching resistance

As shown in Fig. 1(d), a chemical etching process is continued after developing to etch away the exposed copper. During the etching process, the hardened photoresist is also damaged by the etching solution. Fig. 4 shows the comparison of the hardened potoresist line width after/before etching. The hardened line was obtained under laser power of 260mW, coating thicknesses of 11㎛ and 5㎛. The change of line width was also found after etching, and the minimum line width of 6㎛ could be obtained.

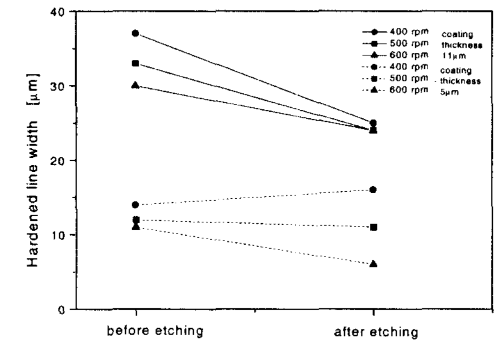


Fig. 4 Comparison of hardened line width after/before etching.

4.4 Application to gravure halftone dots

The schematic diagram of the laser direct patterning system is illustrated in Fig. 5. Data for halftone dots could be obtained by the developed gravure s/w(see Fig.

6). The laser beam is controlled according to the on/off signal of A/O modulator. Laser direct patterning process is accomplished by synchronizing of A/O modulator and data for halftone dots..

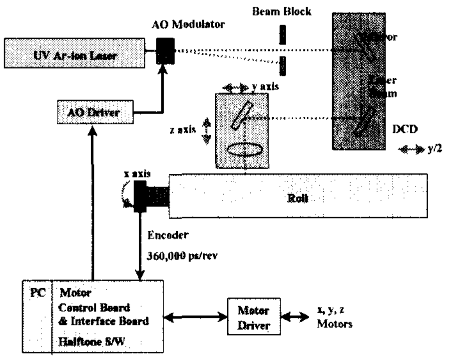


Fig. 5 System schematic diagram for laser direct patterning.

Software such as adobe photoshop could be used to obtain the data for halftone dots from original drawing. However, It is impossible to get the source program to modify and interface with the system shown in Fig. 5. Thus, the developed gravure halftone s/w14 shown in Fig. 6 was used in the laser direct patterning system.

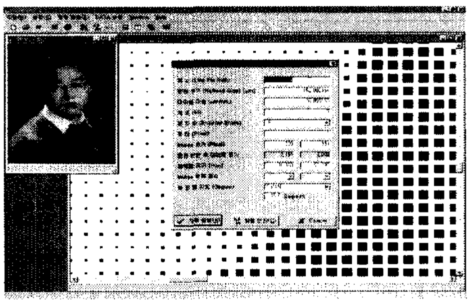
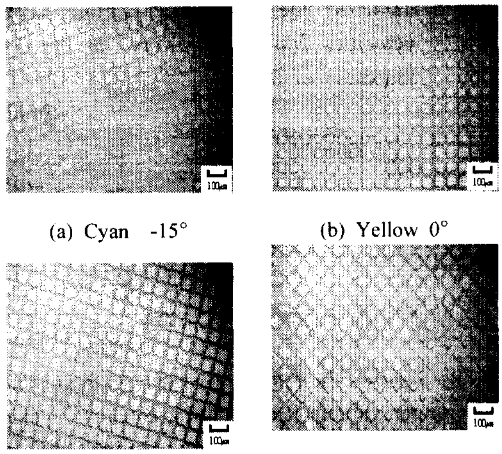


Fig. 6 Gravure software

For the gravure printing, the shapes of halftone dots are divided into four types according to the angle such as Cyan(blue, -15o), Magenta(red, -15o), Yellow (0o), blacK(45o). The CYMK is to prevent the Moire phenomena in color printing.15,16) Experimental results after laser hardening and developing are shown in Photo. 4 by using laser direct patterning system of Fig. 5 and gravure s/w of Fig. 6.

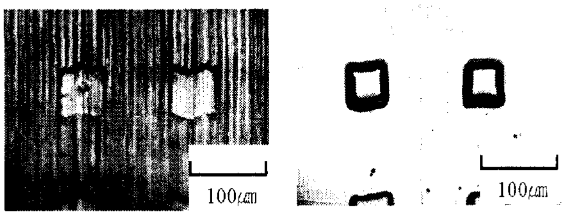


(a) Cyan -15° (b) Yellow 0°

(c) Magenta 15° **(d) blacK 45°**

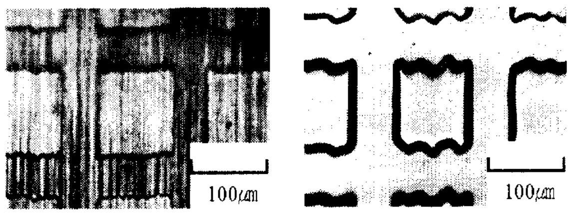
Photo. 4 Examples of laser hardened halftone cell (x 50)

Photo. 5 and 6 show halftone dots after laser hardening and etching. The accuracy of line is 100LPI(line/ inch) and the shape of halftone dot is a regular tetragon. The sizes of halftone dots in Photo. 5 and 6 are respectively 6 × 6 pixels (50μm × 50μm) and 10 × 10 pixels(83μm × 83μm).



(a) after laser hardening (b) after etching

Photo. 5 Halftone cell of 6×6 pixel (×200)



(a) after laser hardening (b) after etching

Photo. 6 Halftone cell of 10 ×10 pixel (×200)

The printing ink is put into the regular tetragon (halftone dot) in Photo. 5(b) and 6(b) and transferred to printing paper or materials. Thus, the printing image from Photo. 5 is brighter than Photo. 6. Some waves are found in horizontal direction of halftone dot such as Photo. 6(b). This may be due to the accuracy of encoder in the system of Fig. 5. Thus, the wave can be minimized as the pulses/rotation of encoder increases

5. Conclusions

Laser direct patterning of the coated photoresist (PMER-NSG31B) layer was studied to make halftone dots on gravure printing roll. The selective laser hardening of photoresist by UV Ar-ion laser(wavelength: 333.6 ~ 363.8nm) was controlled by the A/O moduator. The obtained results are as follows;

(1) PMER-NSG31B used in the conventional gravure film processing showed blue color after laser hardening and developing. Thus, modification and identification of haftone dots can be easy.

(2) The coating thickness in the range of 5 ~ 11μm could be obtained by using the up-down directional moving device along the vertically located roll. The hardened width increased as the coating thickness increased. This is due to the heat transfer through the coating layer.

(3) The hardened minimum line width of 10μm could be obtained under the laser power of 200 ~ 260mW and irradiation time of 4.4 ~ 6.6μ sec/point. Though the hardened thickness was changed due to the effect of the developing solution, the hardened layer showed good resistance to the scratching of 2H pencil. The change of the line width was also found after etching, and the minimum line width of 6μm could be obtained. The hardened lines showed the good resistance to the etching solution.

(4) The experimental data for CYMK halftone dots could be applied to make gravure halftone dots using the developed imaging process, successfully.

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