Development of laser thermal printing device

Illhyun Park, Jin Hyuk Kwon, Jonghoon Yi*
Department of Physics, Yeungnam University, Gyeongsan 712-749, Korea
Phone:+82-53-810-2332, E-mail: jhyi@yu.ac.kr

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Abstract

A laser thermal printing system was developed to fabricate OLED. A single mode fiber laser beam was diffracted by an acousto-optic modulator. The diffracted beam was sent to a galvanometer to print organic film on ITO glass with resolution of 30 μm.

1. Objectives and Background

Fabrication of OLED device by laser thermal printing method is promising compared with ink-jet or thermal evaporation methods in view of mass productivity, large mother glass size, and high resolution. In this method, thin film of organic material is coated on a donor substrate. The donor substrate has laser absorbing material on the surface. The coated film is placed on the receptor surface and laser prints the pattern on the receptor surface. The OLED material on the irradiated area of the film is transferred from the donor substrate to the receptor surface.

The method has been applied to small molecule OLED as well as polymer LED [1-2]. In this work, we develop a laser thermal printing device intended to fabricate OLED on flexible substrate. We use fiber laser instead of conventional bulky Nd:YAG laser. Small laser volume made it possible to construct a rack size laser thermal printing device. The compact device showed a resolution of 30 μm. The device was used to draw organic film lines on a ITO film coated glass.

2. Experiment and Results

Figure 1 shows schematic diagram of the optical setup and vacuum stage. The single mode continuous wave (cw) fiber laser (IPG photonics) has infrared (IR) wavelength of 1070 nm. The laser is linearly polarized and collimated by a lens. The laser beam was diffracted by an acousto-optic modulator.

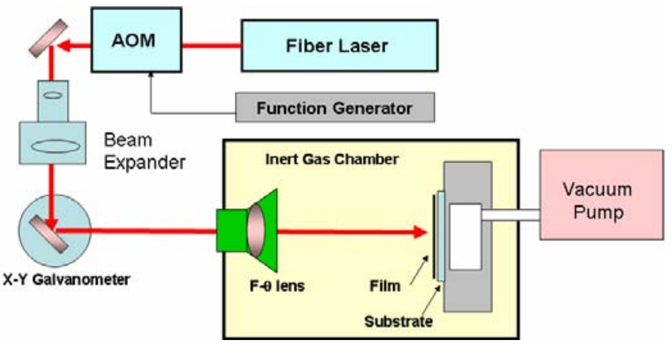


Fig. 1 Schematic diagram of optical setup and vacuum stage.

The variable beam expander (x2~x8) expands the diffracted laser beam width to 8 mm. The beam width at the focus determines the ultimate resolution. Wider beam width in front of the lens is advantageous for small spot size. The direction of the expanded beam is adjusted by galvanometer mirrors. A computer interface program controls the IR beam direction to pattern arbitrary pixel shape on the substrate. The working area of the stage is 10 cm x 10 cm. Maximum scan speed of the laser beam is 2m/s.

The acousto-optic modulator shifts the beam direction with efficiency around 80%. The beam direction is modulated according to the signal from the function generator. The frequency as well as the amplitude is adjusted by programmable function generator. The temporal behavior of the deflected beam determines total laser beam profile on the substrate.

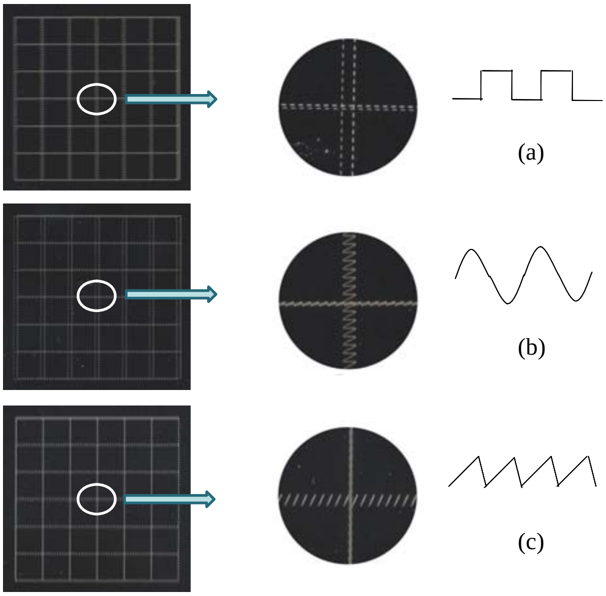


Fig. 2 The traces of laser beam when the modulation functions are (a) square wave, (b) sine wave, and (c) saw tooth wave.

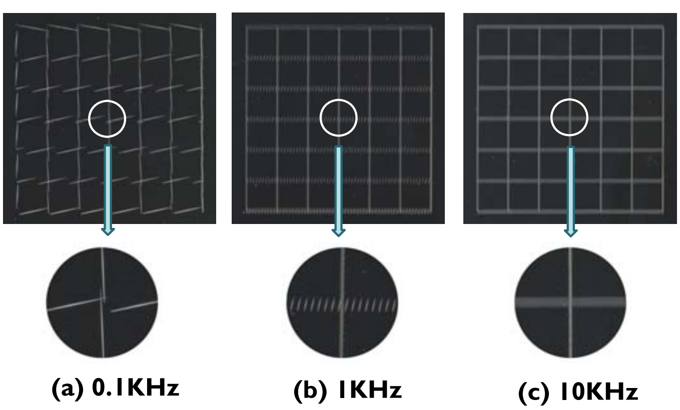


Fig. 3 The traces of laser beam when the modulation frequencies are (a) square wave, (b) sine wave, and (c) saw tooth wave.

To observe the modulated beam trace, the laser pattern was recorded by burning photographic plates. The beam traces are shown in Fig. 2. The waveform from the function generator decides the trace as can be seen in the figure. The traces are the more clear and wide in vertical lines because vertical galvanometer mirror direction is parallel to the modulation direction in acousto-optic modulator.

By reducing the scan speed or increasing the modulation frequency, the laser can be the more closely spaced. These result in almost square hat shaped beam profiles as can be seen in Fig. 4(c). The profile is helpful for clean and sharp printing.

Fig. 4 shows indium tin oxide (ITO) film coated glass surface. An f-θ lens with focal length of 160 mm focuses the beam on the ITO glass with 30 μm resolution, which is close to the theoretical limit [3]. The ITO film was melted and evaporated by the laser irradiation. Before the laser was irradiating, the glass was fixed on the stage with help of vacuum suction. The vacuum stage was installed inside a vacuum sealed chamber where inert gas was filled to prevent oxidation of organic material and invasion of humidity while printing. As the laser beam was cw, peak power was very low. Thus, the ITO was not removed completely. However, the result indicates that this device has 30 μm resolution in printing organic material.

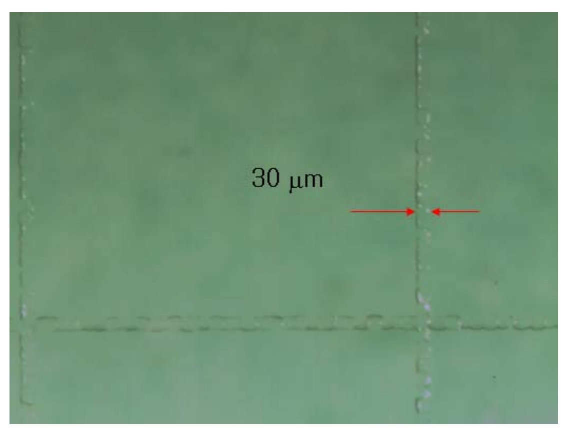
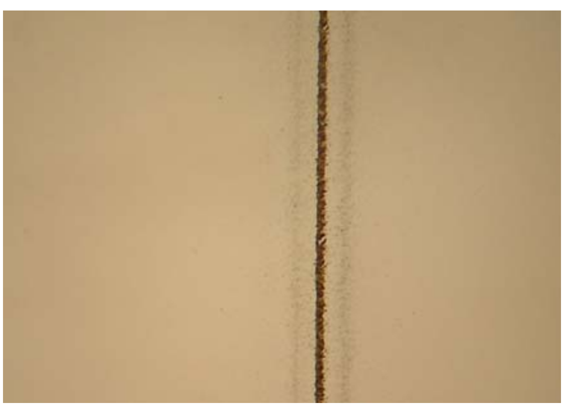


Fig. 4 Crossed line patterned ITO glass by cw fiber laser.

To test thermal printing of organic material, a glass plate was spin-coated with carbon film. Alq_3 was over coated on the carbon film. The thickness of Alq_3 film was about 500 nm. An ITO coated glass was in close contact with the Alq_3 coated glass plate. The fiber laser was irradiated on the carbon coated donor plate. The absorbed laser generates heat. The evaporated Alq_3 molecule vapor adhered to the cold surface of

ITO glass. Fig 5(a) shows the printed Alq_3 stripe on ITO glass plate when the laser power was 3.0 W. The width and boundary of coated Alq_3 stripe was irregular. When the laser power was increased more than this, carbon particle began to sputter and the sputtered particle was deposited on the ITO glass surface. At even higher power of 8.4 W, carbon particles began to form narrow line as can be seen in Fig. 5(b) although the Alq_3 stripe became the clearer. The carbon line was formed in the center of the stripe where the laser power was the highest.

(a)



(b)

Fig. 5 Coated Alq_3 film on ITO glass surface by laser thermal printing when the laser power was (a) 3.0 W and (b) 8.4 W.

3. Summary

The fabricated compact device could be used for thermal printing of OLED material on the substrate with panel size less than 10 cm x 10 cm. For the larger device, implantation of translation stage is planned as an improved design. As the laser focuses thermal energy on film, polymer plate can be also used as a substrate, which can be used for flexible display fabrication. A stack of organic material can be also attached to the various surfaces with this method. Optimal laser power condition and suitable intermediate layer between carbon film and organic film is required.

4. Acknowledgements

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5. References

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