Development of Patterning Technique Using a Stamp Method and Evaluation of Characteristics for Polymer OLED

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Abstract: *The stamping method using soft-lithography requires a very simple process compared with the current spreading method and has a lot of merits that easily fabricate the uniform thickness of the respective pixel materials, surface uniformity and pattern's shape. Those bring on problems when we fabricate the fine pattern according to the form of the stamp.*

Keywords: polymer LED; soft-lithography; stamp method; PDMS.

Introduction

Electroluminescence (EL) is non-thermal generation of light directly from electrical energy between anode and cathode. The physical process for EL involves several steps: charge injection (electrons and holes are injected separately from two electrodes), charge transport (electrons and holes move under a bias voltage toward each other in a semiconductor), charge recombination to form excitons (electrons and holes recombine to form excited state of electron-hole pair (EHP), and radiation of excitons for light emission. OLED (Organic Light Emitting Diode) device is distinguished between monomer and polymer device from the molecular structure [1]. The former has been already developed till production stage over the world, but the latter remains yet R&D level caused by problems of the life time and surface uniformity. Recently the spin-coating, ink-jet printing and roll-to-roll method are used for the technique defining polymer LED device, and yet those techniques have respectively several problems. First of all, spin-coating method has difficulty patterning each pixel and then it is not easy to define the color pixel. Secondly, Ink-jet printing method needs the fabrication of partition for the isolation. Furthermore, it has difficulty forming the uniform film because the dropped ink's curvature is changed by a delicate difference. It contains the importance of the surface uniformity about roll-to-roll method.

In this paper, we proposed the stamp method using soft-lithographic technique to define the polymer LED's color pixel. This is subjected to using the merits of a spin-coating method or an Ink-jet printing method applying the roll-to-roll method [2]. This method requires a very simple process compared with the current spreading method and has a lot of merits that easily fabricate the uniform thickness of the respective pixel materials, surface uniformity and pattern's shape that brings on problems when we fabricate the fine patterns according to the form of the stamp [3]. On the other hand, the surface uniformity of the patterns is a critical point when the polymer ink is hardened. To solve it, we used the PDMS (polydimethylsiloxane), which is elastomeric material.

To examine the bias characteristics of the device fabricated with the 4 layer structure (ITO / PEDOT / EML / Metal), we measured I-V characteristic, the driving voltage by using Toluene and CB (Chlorobenzene) as a solvent material and compared it with the device using the spin-coating method.

Experiment and Results

The device fabricated in this study has 4-layer-structure such as Anode, HIL, EML and Cathode. A 170 nm thick ITO sputtering with a sheet resistivity of 15 Ω/□ has been used to pattern Anode. EML, polymer ink, is stamped by using soft-lithography after making easy hole-injection with spin-coating PEDOT (Poly(3,4-ethylenedioxythiophene)) on ITO patterned by using photo-lithography. Lastly, the device was completed with aluminum deposition by using thermal evaporator.

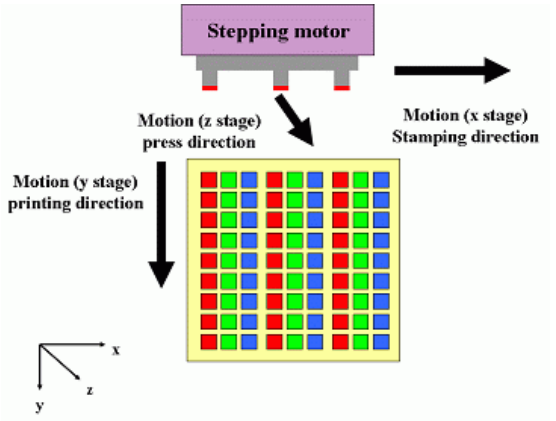

Figure 1. Schematic outline of the stamp method.

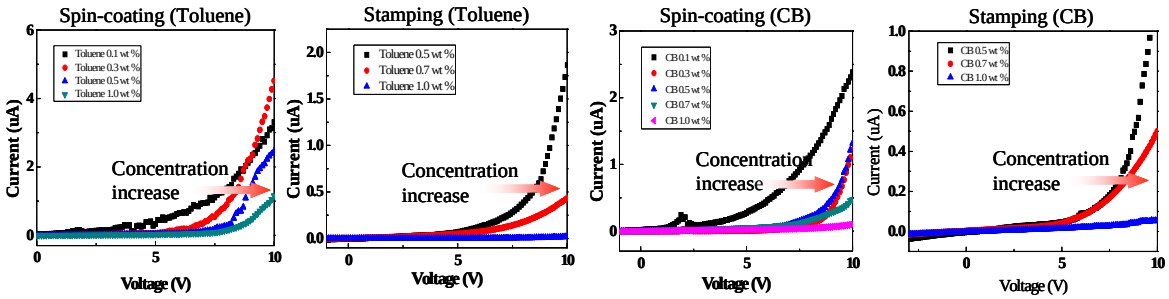

Figure 2. Current versus voltage characteristic curves for spin-coating and stamping method using 2 solvents, Toluene and CB (Chlorobenzene).

ITO substrates are patterned by using photo-lithography. Prior to spin-coating the hole injection layer (HIL), substrates are treated by O_2 plasma (10^{-3} *Torr*, 150 *W* and 20 *sccm*) to enhance work function of ITO.

PEDOT is coated on the ITO substrate about 40 nm thick. The spin velocity is 4500 *rpm* and the duration time is 1 minute. The organic polymer (ADS108GE) which has luminous characteristic for Abs. max. 479 nm and P.L. max. 539 nm has been used. After that, polymer solution that is melted in Toluene and CB (Chlorobenzene) are made such as 0.1 wt%, 0.3 wt%, 0.5 wt%, 0.7 wt% and 1 wt%.

We fabricated the stamp by using the PDMS mold, and stamped by using x, z stage (Fig. 1). Finally, the device is deposited with aluminum. It is compared with the spin-coating device which is coated for 1 minute with 4500 *rpm*. Bias characteristic is measured by using the probe-station, and the surface uniformity is measured by using FE-SEM.

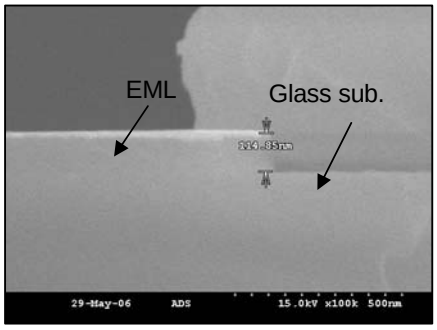

Figure 3. SEM photograph of polymer ink after stamping.

As a result, the device using Toluene shows better characteristics within the framework of the power consumption than the device using CB. We also confirmed that the device fabricated by using stamp method is similar in the device fabricated by using spin-coating method within the framework of the bias-characteristics (Fig. 2). The surface state through the FE-SEM was confirmed 114 nm (±5 %) and the device fabricated with the stamping method has lower driving voltage than spin-coating device (Fig. 3). We know that the more polymer concentration was in high, the more I-V characteristic was shifted on the right.

Conclusion and Future works

We know that the case of Toluene makes the electric current send more two times than the case of Chlorobenzene at the same voltage. In the end, we are able to expect the better aging effect based on the low-power consumption.

Polymer LED is concerned the surface uniformity of polymer ink as a critical factor. Therefore, we expect that some experiments are added with regard to drying condition after stamping, shape of the stamp's pattern and adhesion between stamp and polymer ink. Especially, prior to printing, the stamps will have to be hydrophilised in an oxygen plasma for anti-adhesion between ink and PDMS stamp.

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