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Selective Patterning for Organic Light-Emitting-Diodes by Physical Vapor Deposition of Photosensitive Materials

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1. Introduction

The performance of organic light-emitting devices (OLEDs) is approaching to an acceptable level as a single cell. However, for flat panel application, there still exist emerging issues of enlarging panel size, reducing power consumption and lowering the fabrication cost compared to LCD displays. Especially, the patterning process for producing large-size multi-color display panels is a key issue for commercializing OLED. To overcome the issue of panel production, many alternative methods, such as metal mask and ink jet printing have been proposed to place RGB pixels horizontally.

The authors have been investigating physical vapor deposition polymerization methods to produce polymeric thin films by evaporating their monomers [1]. This method was effective for OLED fabrication especially in terms of extending the lifetime by improving thermal stability of the deposited films. The polymerization can be initiated by electron or UV irradiation to the evaporated monomers to generate radicals. If the polymerization can be achieved selectively in arbitrary patterns on the substrate, the vapor deposition polymerization can be utilized for constructing patterned device structures. This paper reports the possibility of fabricating OLED patterns by selective polymerization of thin films prepared by depositing a photosensitive emission material.

2. Experimental

Figure 1 shows the scheme of patterning the emission layer by physical vapor deposition. The photo-sensitive emission layer was prepared by coevaporating 9H-carbazole-9-ethylmethacrylate (CEMA) host material and 4-dimethylamino benzophenone (DABP) photo-initiator on a glass substrate. The deposited film was exposed to UV light (wavelength 350 nm), and then rinsed

with an organic solvent to develop a pattern by removing non-polymerized region.

The OLED devices were fabricated in a structure shown in Fig. 2 according to the following procedure. Vinyl TPD (vTPD) and zinc acrylate (ZnAc) were coevaporated to a thickness of 20 nm, and were thermally polymerized to form a hole-transport layer on an indium-tin-oxide (ITO) transparent electrode. ZnAc played the role of crosslinker to stabilize the TPD polymer film against the following process of patterning the emission layer. The emission layer was prepared by coevaporating CEMA and DABP to a thickness of 20 nm. After photo-patterning the emission layer, a 40 nm-thick bathocuproine (BCP) electron transport layer, a 0.5 nm-thick LiF electron injection layer and a 100 nm-thick Al electrode were evaporated successively. The active device size was 2x1 mm². The device characteristics were measured with a constant driving voltage, and the luminance was measured with a photodiode array polychrometer. The device was operated in air without encapsulation.

3. Results and Discussion

In the first step, photo-patterning capability by the process shown in Fig. 1 was confirmed for a single layer of emission material. Figure 3 shows IR spectra of CEMA:DABP coevaporated film before (b) and after (c) UV irradiation in comparison with CEMA monomer (a). Absorption of C=C stretching and C-H in-plane deformation of vinyl group decreased after UV irradiation. The UV light was irradiated at a power of 8 mW/cm² for 0.5 min. This result indicates that selective polymerization can be achieved by photo patterning of the coevaporated film. Figure 4 shows visual inspection of the CEMA:DABP coevaporated film after the photo-patterning. The development was achieved by immersing into tetrahydrofuran (THF) for 5 min after the

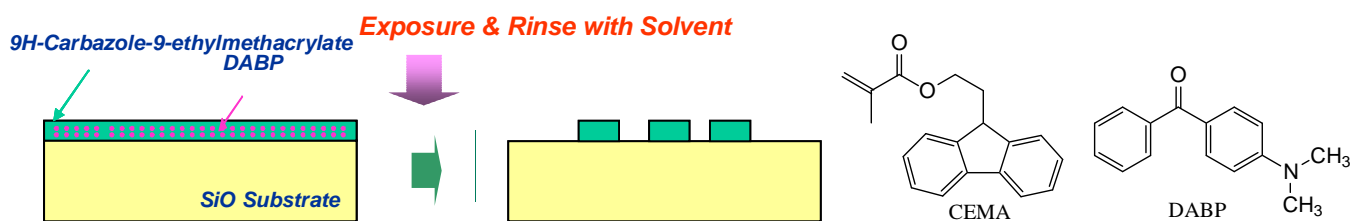


Fig. 1. The scheme of patterning for OLED emission layer in this study. Structures of materials are also shown.

UV irradiation. A uniform thin film was obtained by the coevaporation. However, the as-deposited film, which consisted of monomers, readily dissolved into THF. The UV irradiation through a photomask initiated radical polymerization, leaving a negative pattern of the irradiated region after immersing into THF. As a consequence, clear square patterns were observed on the substrate as shown in Fig. 4.

OLEDs of arbitrary configuration can be fabricated by using the emission layer prepared in aforementioned procedure. However, the UV irradiation and developing process during the patterning might affect the electrical characteristic. Figure 5 compares the I-V characteristics of devices that were prepared with (a) or without (b) the patterning process. No significant differences were observed between the devices with or without the patterning process. The emission characteristics were also almost the same for these devices, giving a turn-on voltage of 7 V, and the luminance of 40 cd/m² at a driving voltage of 20 V. It can be concluded that the patterning process using a photosensitive emitting layer can be applied for device fabrication without affecting the OLED characteristics.

4. Conclusion

We have proposed a novel film patterning method by coevaporating monomer and photoinitiator. This method was applied for OLED emission layer without damaging the device characteristics. The new patterning method can be achieved only by combining the existing vapor deposition and UV irradiation techniques and eliminates the necessity for shadow mask for evaporation, photoresist, or advanced film formation methods. It has a potential applicability for producing large area display panels.

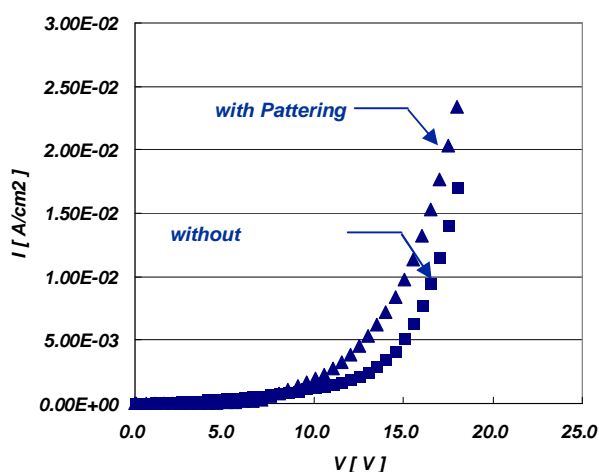


Fig.5. The I-V Characteristics of OLED devices with (a) or without (b) patterning process.

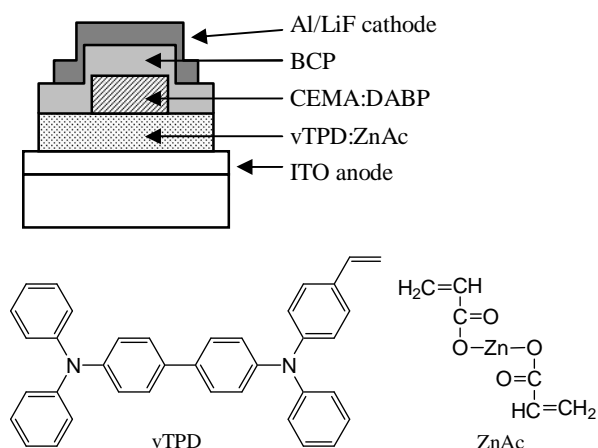


Fig.2. Structure of OLED prepared with photopatterned emission layer. The structures of vinyl TPD and zinc acrylate are also shown.

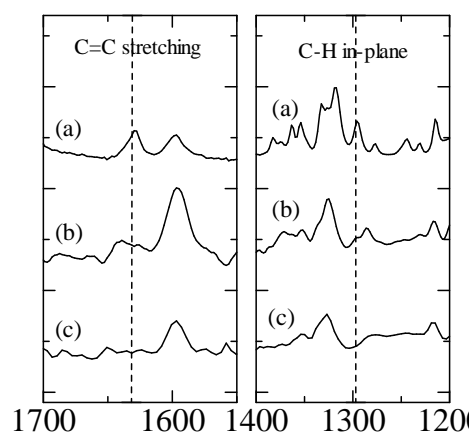


Fig.3. IR spectra of CEMA:DABP coevaporated film before(b) and after (c) UV irradiation. CEMA monomer spectrum is shown in (a).

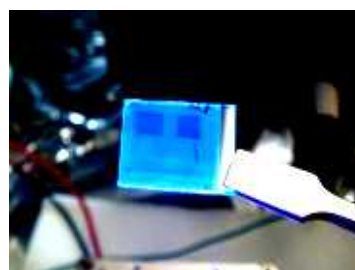


Fig.4. Photo luminescence image of CEMA:DABP coevaporated film on TPD before after patterning. 3 mm square patterns were obtained after UV irradiation followed by immersion in THF.

References

- [1] H. Usui, Thin Solid Films, **365** (2000), 22.