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Deposition characteristics of small molecule organic thin film ($CBP:PBD:TPD:Ir(mppy)_3$) by modified electrospray deposition

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Abstract

Development of solution based small-molecule organic thin film deposition technique is an attractive step for further prevalent of organic devices. In this study, we investigated deposition characteristics of organic thin film by modified electrospray deposition (ESD) technique with three typical spraying modes of the Tylaor-cone, the convergent-jet and the multi-jet. It was revealed that multi-jet mode can deposit smallest droplets with narrowest size distribution. Using multi-jet modes, we could obtain pinhole-free smooth deposition of $CBP:PBD:TPD:Ir(mppy)_3$ small-molecule organic film with a RMS surface roughness of 5 nm.

1. Introduction

In formation of organic material, small molecules material deposited by vacuum evaporation has been used as a standard for high-efficiency OLEDs. However the vacuum evaporation has difficulty in fabricating large-scale devices, makes in efficient use of expensive raw materials, and has high manufacturing cost. On the other hand, many of solution processes have advantages of low cost, large scale manufacturability, and efficient use of materials, but also have drawbacks of difficulty in use with low-solubility small molecules and tend to form pinholes [1].

We focused on electrospray deposition (ESD) as a candidate of solution based deposition technique enable to form small-molecule thin film. Using ESD, micro/nano-sized charged droplets are generated from solution by electrospray phenomenon and the droplets are deposited on a substrate. The ESD is expected to have many attractive qualities, including multilayer deposition, large-area deposition, ability to use small-molecules etc. These features arise from the wet-dry controllability of the fine droplets, Coulomb repulsion of the droplets, and use of a dilute solution. Recently, ESD has begun to be used for OLEDs fabrication [2, 3].

In this study, we observed the characteristics of small-molecule ($CBP:PBD:TPD:Ir(mppy)_3$) [5] organic thin film deposited by ESD to investigate the surface morphology of small molecules thin film.

2. Experimental Method

In this study, we employed a three-electrode ESD system called nano-mist deposition (NMD) with an extraction electrode near the nozzle tip to improve the controllability of ESD. The system consisted of a glass syringe equipped with a metal nozzle (1st electrode), a syringe pump, an extraction ring electrode (2nd electrode), a ground plate (3rd electrode), and two high-voltage power supplies. The ground plate was maintained at 25 °C. The nozzle voltage (V1) and extractor voltage (V2) were set to 4.8 or 5.3 kV and 3.0 kV, respectively. Distance (L) was varied from 4.0 to 10.0 cm.

Indium-tin-oxide (ITO) coated glass was used as substrate. ITO glass substrate was cleaned by acetone, methanol and deionized water and treated to UV-ozone environment for 10 min respectively. Then, Al-doped zinc oxide (AZO) deposited on it (20nm) by ion beam sputtering. After cleaning and treating again, a blends of CBP: PBD: TPD: $Ir(mppy)_3$ that concentrations were 60, 15, 10 and 5 wt%, respectively in chlorobenzene with 10 vol% dimethyl-sulfoxide (DMSO) solution was used for NMD. To evaluate the surface morphology of $CBP:PBD:TPD:Ir(mppy)_3$ film was observed by fluorescence microscope and white light interferometer.

3. Result and Discussion

In ESD, three typical spraying modes of the Tylaor-cone (TC), the convergent-jet (CJ) and the multi-jet (MJ) were used [4]. NMD can control the spraying mode by the potential difference between V1 and V2. Figure 1 shows photographs of each spraying modes at the tip of nozzles and histograms of deposited droplet mark size observed by scanning electron microscope (SEM). TC and CJ mode have a broad distribution characteristic. It was clearly shown that MJ mode has a smallest averaged droplet size and narrowest size distribution.

Figure 2 shows fluorescence microscope images and surface morphologies of $CBP:PBD:TPD:Ir(mppy)_3$ films deposited by CJ and MJ modes. In CJ mode, a number of pinholes had been formed at L = 6.0 cm due to wet condition. The small-molecule film tend to form pinholes in wet condition. For the case of CJ mode at L = 10.0 cm, pinholes were not formed due to dry condition but the surface morphology was very rough. On the other hand, in MJ mode, pinholes were not formed and surfaces morphology was very smooth with RMS surface roughness of 5 nm. This drastic improvement seems to be brought about small droplet size and uniform size distribution in NJ mode. Figure 3 shows distance (L) dependence of thin film surface roughness (RMS) of CJ and MJ modes. MJ mode can form smooth film in wide range of deposition distance.

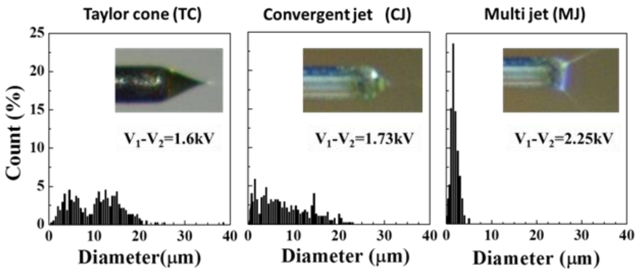

Fig. 1. Photographs of each spraying modes at the tip of nozzles and histograms of deposited droplet mark size.

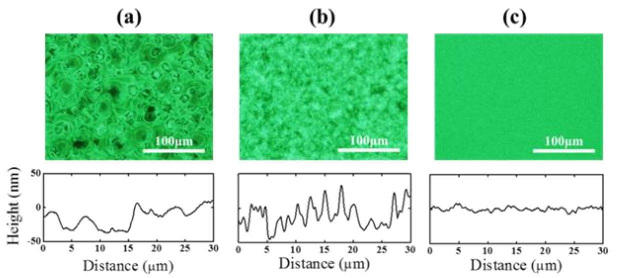

Fig. 2. Fluorescence microscope images and surface m orphologies of CBP:PBD:TPD:Ir(mppy)$_3$ films deposited by CJ mode at L = 6.0 cm (a), CJ mode at L = 10. 0 cm (b) and MJ mode at L = 5.0 cm (c).

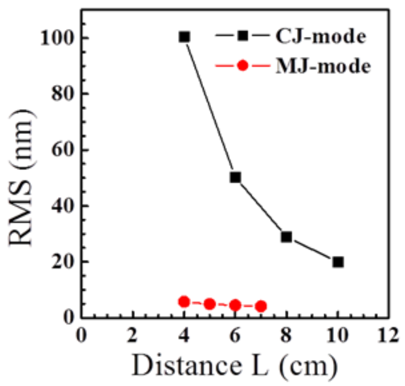

Fig. 3. Distance (L) dependence of thin film surface r oughness (RMS) of CJ and MJ modes.

4. Conclusions

We investigated the deposition characteristics of small molecule organic thin film (CBP:PBD:TPD:Ir(mppy)$_3$) by modified ESD technique named nanomist deposition (NMD). It was shown that multi-jet (MJ) mode spraying is suitable for small-molecule organic film deposition. The averaged droplet size and size distribution is smaller than typically used Tylaor-cone (TC) mode or the convergent-jet (CJ) mode. The small molecular CBP:PBD:TPD:Ir(mppy)$_3$ film deposited by MJ mode was pinhole-free with small surface roughness (RMS) of 5 nm.

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