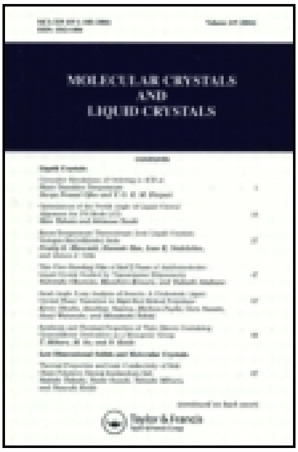

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Alkyl Group Effect on Small Molecule Emitter Based on Anthracene Moiety in Solution Process

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Alkyl Group Effect on Small Molecule Emitter Based on Anthracene Moiety in Solution Process

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OLED device was fabricated by using 4,4′-bis[4-(di-p-tolylamino)styryl]biphenyl (DPAVBi) as dopant and 2-tert-butyl-9,10-di-naphthalen-2-yl-anthracene (TBADN), 2-Methyl-9,10-di-naphthalen-2-yl-anthracene (MADN) and 9,10-di-naphthalen-2-yl-anthracene (ADN), which are organic compounds and commercial blue materials, as hosts. The OLED device and the efficiency in OLED of which the emitting layers are prepared by deposition method and spin-coating method were compared. Deposited device showed high efficiency of 4.6–7.0 cd/A in all the ADN derivatives. All ADN derivatives showed high efficiency of 4.6–7.0 cd/A in the deposited device. In the case of device that was made through spin-coating, TBADN and MADN showed efficiency of 1.5–2.1 cd/A, and in particular, no light was emitted for ADN. As a result of observing the film formed on PEDOT surface with spin-coating through SEM, TBADN and MADN exhibited an amorphous clear surface, but in case of ADN, crystalline domain had appeared. It was found that due to such crystallinity, light emission was prohibited as leakage current had increased due to increase of roughness on a surface. These results indicate that methyl and t-butyl groups at 2-position of anthracene prohibit crystallinity of molecule in spin-coating film.

Keywords OLED; SEM image; soluble process OLED; spin-coating device

1. Introduction

Recently, small organic molecule based organic light emitting diodes (OLEDs) are under intense researches in view of their promising future for large full color display applications. Additionally, OLED has been under active researches so far with its overlooking high potential for use in liquid crystal display (LCD) backlight and lighting field due to its low power consumption [1,2]. In the meantime, small molecule based OLED device (SMOLED), which is currently well-used, is already being commercialized due to its high efficiency compared to polymer based OLED device (PLED). Nevertheless, SMOLED has a problem of high cost as it utilizes a deposition method, which involves high costs for deposition equipment and large consumption of material [3–5]. Therefore, to solve such high cost problem, OLED

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is widely researched by using a solution process like ink-jet printing, screen printing or spin-coating that uses a simple device and consumes less material [6–9].

Materials applied to SMOLED have been developed for a deposition process so far. However, a deposition method and a solution process require very different material characteristics. Therefore, development of small molecule material that is suitable for a solution process is necessary. Thus, a research on small molecule emitting materials is very important for implementation of OLED for high efficiency solution process

The paper published by Lee *et al.* among the precedent researches had presented the difference according to the solution process and the deposition method by using 2-tert-butyl-9,10-di-naphthalen-2-yl-anthracene (TBADN), which are commercial blue emitting materials, as a host [10]. Therefore, this research compared efficiencies by using TBADN, 2-Methyl-9,10-di-naphthalen-2-yl-anthracene (MADN), and 9,10-di-naphthalen-2-yl-anthracene (ADN), the three small molecule blue materials, as a host and by checking scanning electron microscope (SEM) to clarify the accurate differences in performance and reason for a spin-coating device and a deposition device. The cause of the abnormal spin-coating film of ADN derivative was checked through the SEM morphology measurement of the film that was produced in a deposition method and a spin-coating method on ADN derivative. Main purpose and motivation of this study are not highly efficient OLED materials. It is why a certain material in solution processed OLED does not emit. This approach will be helpful to development of small molecule emitting system in solution process.

2. Experimental Method

ADN, MADN and TBADN (all three compounds, purchased from LumTec Corp.) doped with DPAVBi (95w/5w) were dissolved in toluene. A water-dispersed PEDOT/PSS mixture (Baytron P VP CH8000, H. C. Starck GmbH) was spin-coated on top of indium tin oxide (ITO) in air to achieve films. The spin-coated films were baked on a hot plate at 140°C for 5 minutes in air and 100°C for 5 minutes in vacuum dry oven. The emitting layer was deposited either by spin-coating or by vacuum evaporation (at a pressure about 10^6 Torr) to obtain a thickness of 80 nm. The solution-processed films were baked on a hot plate (80°C, 5 min) and 100°C for 5 minutes in vacuum dry oven. Electron-transporting layers (TPBI) with a thickness of 20 nm were deposited by vacuum evaporation. LiF (1 nm) and Al films were sequentially deposited on the electron-transporting layer under vacuum (at a pressure about 10^6 Torr). I-V-L characteristics of the OLED devices were obtained using a Keithley 2400 source measure unit and a Minolta CS-1000A spectrophotometer.

3. Results and Discussion

In this study, as shown in Figure 1, the derivatives of ADN, a commercial blue material, were used as hosts, and DPAVBi was used as emitting material, dopant. As for a device structure, the device was fabricated as ITO/PEDOT (50 nm)/Emitting layer (80 nm)/LiF (1 nm)/Al.

In case of a deposited device, experiment results were summarized as shown in Figures 2, 3 and Table 1. As for luminance efficiency (cd/A), the efficiency was high with the maximum of 6.3 cd/A at 3 V when TBADN was used as a host. The luminance efficiencies of TBADN, MADN, and ADN at 10 mA/cm^2 were 5.4, 7.0 and

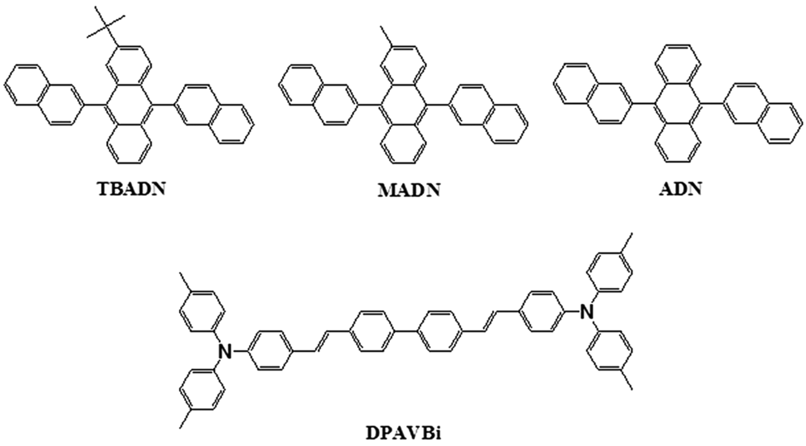

Figure 1. Host and dopant chemical structures of deposited or spin-coated OLED device.

4.6 cd/A, with MADN showing the highest value and ADN showing the lowest. As for power efficiency, TBADN, MADN and ADN showed 5.0, 3.1 and 1.9 lm/w values with TBADN as the highest and ADN as the lowest.

The reason TBADN shows higher power efficiency even if it shows less luminance efficiency compared with MADN is because the device that used TBADN as a host has less operating voltage than MADN as shown in the I-V characteristics graph of Figure 4. In the case of device produced as emitting layer in the spin-coating method, TBADN and MADN implement normal electroluminescence light, but ADN does not emit light. As shown in the I-V curve of Figure 4, TBADN and MADN showed a similar I-V curve shape, but on the other hand, ADN showed an abnormal I-V curve. Figures 2 and 3 indicated that luminance efficiencies of

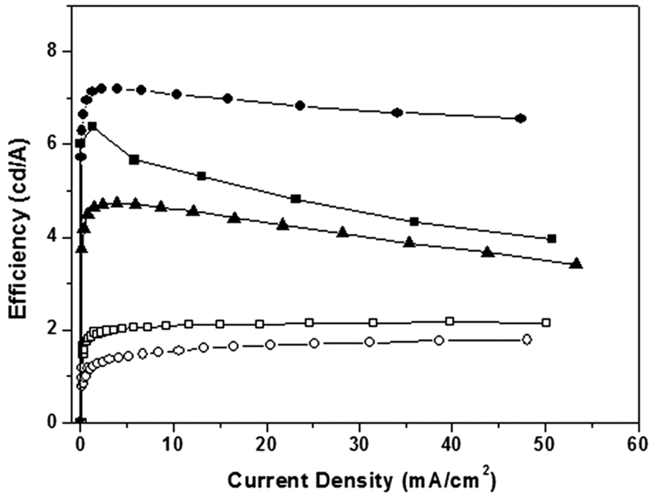

Figure 2. Luminance Efficiency of deposited (closed) and spin-coated (open) device: TBADN (square), MADN (circle), ADN (triangular).

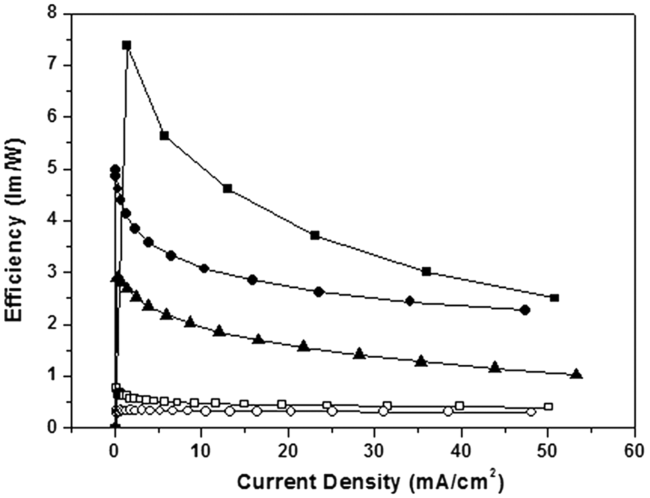

Figure 3. Power Efficiency of deposited (closed) and spin-coated (open) device: TBADN (square), MADN (circle), ADN (triangular).

TBADN and MADN in a spin-coating device were 2.1 and 1.5 cd/A, and power efficiencies were 0.49 and 0.33 lm/w at 10 mA/cm^2.

In the spin-coating device, unlike the deposition device, TBADN and MADN virtually showed slightly different efficiency values on luminance efficiency and power efficiency. It is estimated that the film formation condition of two materials showed difference in a deposition process, but not so much in a spin-coating process. The SEM experiment was conducted and a surface of the created film was observed in order to investigate the correlation between morphological characteristics of film and device efficiency.

It was found out that deposited films (a, b, c) all showed smooth film surface, and were not significantly affected by OLED device (see Fig. 5). On the other hand, in the case of spin-coating films, the TBADN and MADN of d and e showed smooth surface, and ADN film showed many crystallized domains. Such crystalline domains make film characteristics rough, which causes leakage current problem and therefore prevents light emission [11,12]. That is presumed to be causing occurrence of ADN

Table 1. EL performances of multi-layered devices with the synthesized compounds at 10 mA/cm^2. Device structure: ITO/PEDOT (40 nm)/ADN derivatives: DPAVBi (95w/5w, 80 nm)/TPBi (20 nm)/LiF (1 nm)/Al

	Spin-coated		Deposited	
Compounds	L. E.[a] (cd/A)	P. E.[b] (lm/w)	L. E.[a] (cd/A)	P. E.[b] (lm/w)
TBADN	2.1	0.49	5.4	5.0
MADN	1.5	0.33	7.0	3.1
ADN	–	–	4.6	1.9

[a] Luminance Efficiency.
[b] Power Efficiency.

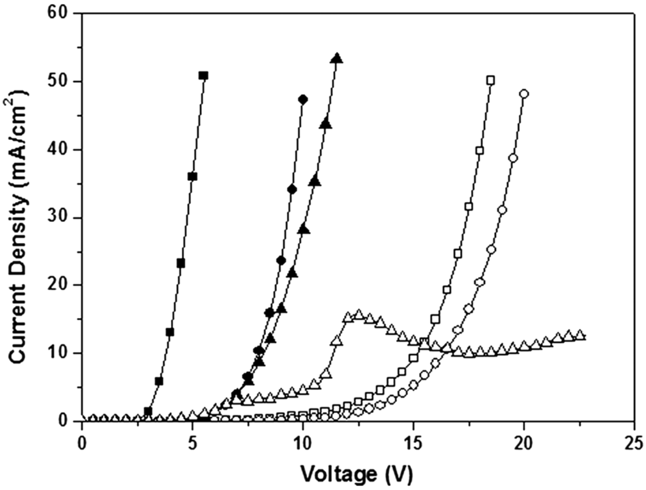

Figure 4. I-V characteristics of deposited (closed) and spin-coated (open) device: TBADN (square), MADN (circle), ADN (triangular).

crystallization easily due to a planar chemical structure of ADN. In the case of TBADN and MADN unlike ADN, it is analyzed that t-butyl and methyl group are attached to the 2-position of anthracene and they prevent packing while spin-coating films are formed, and therefore it improves amorphous characteristics.

To investigate the film morphology of ADN derivatives prepared by the deposition and spin-coating methods, the surface depth profile of thin films on top of ITO/PEDOT was measured by atomic force microscopy (AFM). Unlike a deposition film, spin-coated film was prepared by thermal annealing on a hot plate

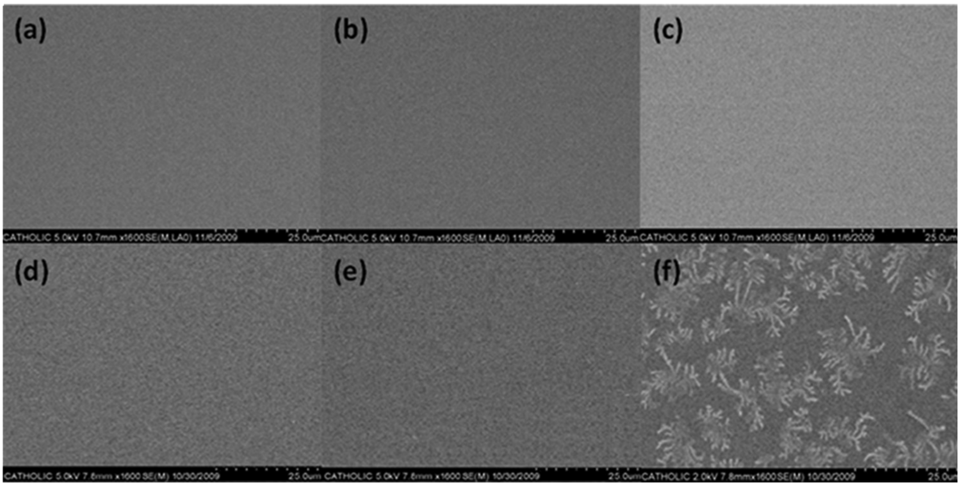

Figure 5. SEM images of ADN derivatives/DPAVBi (95w/5w) films on ITO/PEDOT substrate a) TBADN (deposited), b) MADN (deposited), c) ADN (deposited) d) TBADN (spin-coating) e) MADN (spin-coating), f) ADN (spin-coating).

(80°C, 5 min) in air and 100°C for 5 minutes in vacuum dry oven in order to apply the same condition of OLED device.

Figure 6 shows the AFM surface images of vacuum deposited films (Fig. 6A-column) and spin-coated and annealed films (Fig. 6B-column). The root mean square (RMS) roughness of ADN derivatives in deposition case was in the range of 0.6~5.9 nm, but in the case of spin-coating including thermal annealing, RMS roughness was increased to 1.7~9.8 nm. Especially, ADN spin-coated film exhibited relatively rough surface of 9.8 nm compared to other films and big surface profile change of 3.9 nm between deposition and spin-coating films. Also all vacuum deposited films of ADN derivatives as well as spin-coated TBADN and MADN except ADN showed amorphous surfaces, but ADN exhibited crystallized domains as shown in Figure 6B.

Consequently, it means that alkyl group of ADN derivatives prevents crystallization and it improves amorphous characteristics.

It is believed that researches on the correlation of film performance and OLED characteristics according to such molecular structure in a solution process will significantly contribute to the development of organic molecules for a solution process in the future.

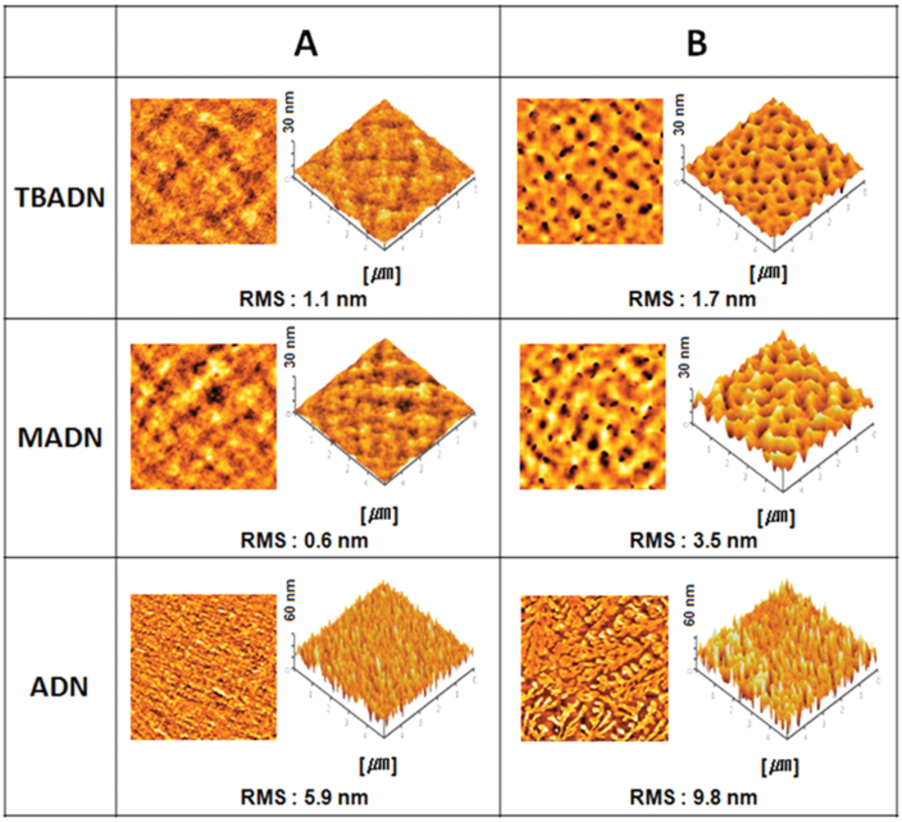

Figure 6. AFM images of TBADN, MADN and ADN films on ITO/PEDOT substrate: (Column A) deposited film and (Column B) spin-coated film including thermal annealing on a hot plate (80°C, 5 min) in air and 100°C for 5 minutes in vacuum dry oven.

4. Conclusion

OLED device was fabricated by using TBADN, MADN and ADN, the derivatives of ADN that is a commercial blue emitting material in the OLEDs field. The emitting layer was formed through a deposition method or a spin-coating method, and its efficiencies were compared. In the deposition device, TBADN, MADN and ADN all showed high efficiencies of 4.6–7.0 cd/A. In the case of the spin-coated device, TBADN and MADN showed normal efficiencies of 1.5–2.1 cd/A. However, in the case of ADN, no light was emitted.

Therefore, film surface was observed to investigate the correlation of film morphological characteristics and device efficiency through SEM experiment. In the case of the spin-coated film, TBADN and MADN showed an amorphous smooth surface, but in the case of ADN, crystallized domain was shown. Therefore, for the case of ADN spin-coated device, it is analyzed that film roughness increases and no light is emitted due to leakage current. However, TBADN and MADN, unlike ADN, are analyzed that t-butyl and methyl group are attached to the 2-position of anthracene and they improve amorphous characteristics by preventing packing while spin-coating films are formed.

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