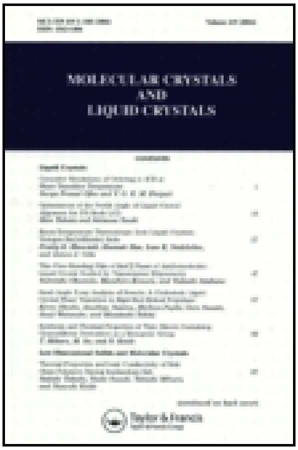


Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl20

Effect of Deposition Rate of Organic Layer on Electrical and Optical Characteristics of OLEDs

Young Hwan Lee [a], Weon Jong Kim [a], Tag Yong Kim [a], Jae Hoon Yang [a], Kyung Soon Cho [a], Jin Woong Hong [a], Jong Yeol Shin [b] & Tae Wan Kim [c]

[a] Department of Electrical Engineering, Kwangwoon University, Seoul, Korea

[b] Department of Car Mechatronics, Sahmyook University, Seoul, Korea

[c] Department of Physics, Hongik University, Seoul, Korea

Version of record first published: 17 Oct 2011

To cite this article: Young Hwan Lee, Weon Jong Kim, Tag Yong Kim, Jae Hoon Yang, Kyung Soon Cho, Jin Woong Hong, Jong Yeol Shin & Tae Wan Kim (2006): Effect of Deposition Rate of Organic Layer on Electrical and Optical Characteristics of OLEDs, Molecular Crystals and Liquid Crystals, 462:1, 143-148

To link to this article: http://dx.doi.org/10.1080/07370650601013088

Mol. Cryst. Liq. Cryst., Vol. 462, pp. 143–148, 2007

ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/07370650601013088

Effect of Deposition Rate of Organic Layer on Electrical and Optical Characteristics of OLEDs

Young Hwan Lee
Weon Jong Kim
Tag Yong Kim
Jae Hoon Yang
Kyung Soon Cho
Jin Woong Hong
Department of Electrical Engineering, Kwangwoon University, Seoul, Korea

Jong Yeol Shin
Department of Car Mechatronics, Sahmyook University, Seoul, Korea

Tae Wan Kim
Department of Physics, Hongik University, Seoul, Korea

We investigated the effects of deposition rate on the electrical characteristics and optical characteristics of organic light-emitting diodes(OLEDs) in the ITO(indium-tin-oxide)/N,N′-diphenyl-N,N′-bis(3-methyphenyl)-1,1′-biphenyl-4,4′-diamine(TPD)/tris(8-hydroxyquinoline) aluminum (Alq_3)/Al device. We measured current density, luminous flux and luminance characteristics of devices by varying deposition rates of TPD and Alq_3. It has been found that optimal deposition rate of TPD and Alq_3 was 1.5 Å/s. AFM measurement shows that surface roughness of the deposited film was the lowest when the deposition rate was 1.5 Å/s.

Keywords: current density; deposition rate; luminance; OLEDs; roughnes

The present research has been conducted by the Research Grant of Kwangwoon University in 2006.

Address correspondence to Prof. Jin Woong Hong, Department of Electrical Engineering, Kwangwoon University, 447-1 Wolgye-Dong, Nowon-Gu, Seoul 139-701, Korea. E-mail: ealab@daisy.kw.ac.kr

1. INTRODUCTION

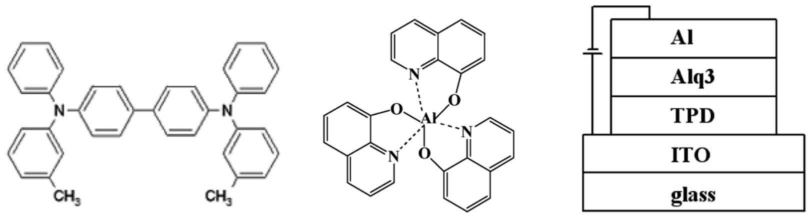
OLEDs are attractive because of possible application in display with low operating voltage, low power consumption, self-emission and capability of multicolor emission by the selection of emissive materials [1–3]. The first report on organic electroluminescence was published by Pope, Kallmann and Magnante in 1963 with single crystal of anthracene [4]. But there was not much progress in 1960s and 1970's because of limited size, difficulty of single crystal growth and high driving voltage. Tang and VanSlyke in Kodak Company reported double-layered organic electroluminescent diodes in 1987 [5].

In 1990, Friend *et al*. in Cambridge University reported first green light-emitting polymer diodes using poly phenylenevinylene (PPV) [6]. Since then, significant progress has been made to obtain highly efficient and stable light-emitting diodes [7–12]. In this paper, in order to enhance the performance of OLEDs, we report the effects of deposition rate of TPD and Alq_3 on the physical characteristics, electrical characteristics and optical characteristics of OLEDs.

2. EXPERIMENTAL

In our experiments, we used TPD as a hole transport and Alq_3 as an electron transport and emissive materials. The ITO glass, having a sheet resistance of $15\,\Omega/\square$ with a ITO thickness of 170 nm, was prepared. A 5 mm wide ITO strip line was patterned by selective etching using a vapor of etchant which is a mixture of hydrochloric acid (HCl) and nitric acid (HNO_3) at a volume ratio of 3:1 for $10\sim20$ minutes at room temperature. The distance between the ITO layer and the etchant was approximately 2 cm. The patterned ITO glass was cleaned ultrasonically in chloroform for 20 minutes at 50°C, after which the ITO glass was heated at 80°C for 1 hour in a solution made with deionized water, ammonia water and hydrogen peroxide at a volume ratio of 5:1:1. We sonicated the substrate again in chloroform solution for 20 minutes at 50°C, in acetone for 20 minutes at 50°C and in deionized water for 20 minutes at 50°C. After sonication, the substrate was dried with N_2 gas stream and was stored under vacuum. Figure 1(a) and 1(b) are molecular structure of TPD used as a hole-transport material and Alq_3 used as an emitting and electron transport material. Figure 1(c) is a device structure of the ITO/TPD/Alq_3/Al device that we investigated.

Based on the confirmed TPD:Alq_3 optimal thickness ratio of 4:6 [13], while we maintain the thicknesses of TPD and Alq_3 layers at 40 nm and 60 nm respectively, we used various deposition rates on these



(a) TPD (b) Alq_3 (c) device structure

FIGURE 1 Molecular structures of organic materials and device structure.

two layers to study the effect of the deposition rates on the characteristics of the devices. The deposition rates were in the range of $0.5 \sim 2.0$ Å/s under a base pressure of 5×10^{-6} torr. We measured current density, luminous flux and luminance characteristics of devices by varying deposition rates of TPD and Alq_3 layer.

3. RESULTS AND DISCUSSION

We first measured surface roughness of the deposited Alq_3 film. As shown in Table 1, surface roughness of the Alq_3 film is the lowest when it was deposited at 1.5 Å/s. The same deposition rate of 1.5 Å/s also resulted in the lowest surface roughness for TPD film as well. It is speculated that such low surface roughness in the deposited films yield relatively uniform deposition of thin films which consequently results increased contact surface at the interface between the TPD and Alq_3 films.

Figure 2 shows a series of images of atomic force microscopy (AFM) for various samples with different deposition rates for TPD and Alq_3 thin films. For the sample with low deposition rate (0.5 Å/s) (Fig. 2(a)), it can be seen that the deposited film surface is very rough

TABLE 1 Roughness of Organic Materials depending on the Deposition Rates

Materials	Deposition rate [Å/s]	Maximum roughness [nm]	Average roughness [nm]	Root mean square [nm]
TPD	1.0	10.718	0.66566	0.983432
	1.5	5.66656	0.560627	0.729421
	2.0	5.6852	0.659144	0.843754
Alq_3	0.5	30.5696	2.54538	3.5601
	1.0	18.8264	1.05387	1.45088
	1.5	10.6248	1.18535	1.51643
	2.0	13.7004	1.46101	1.83622

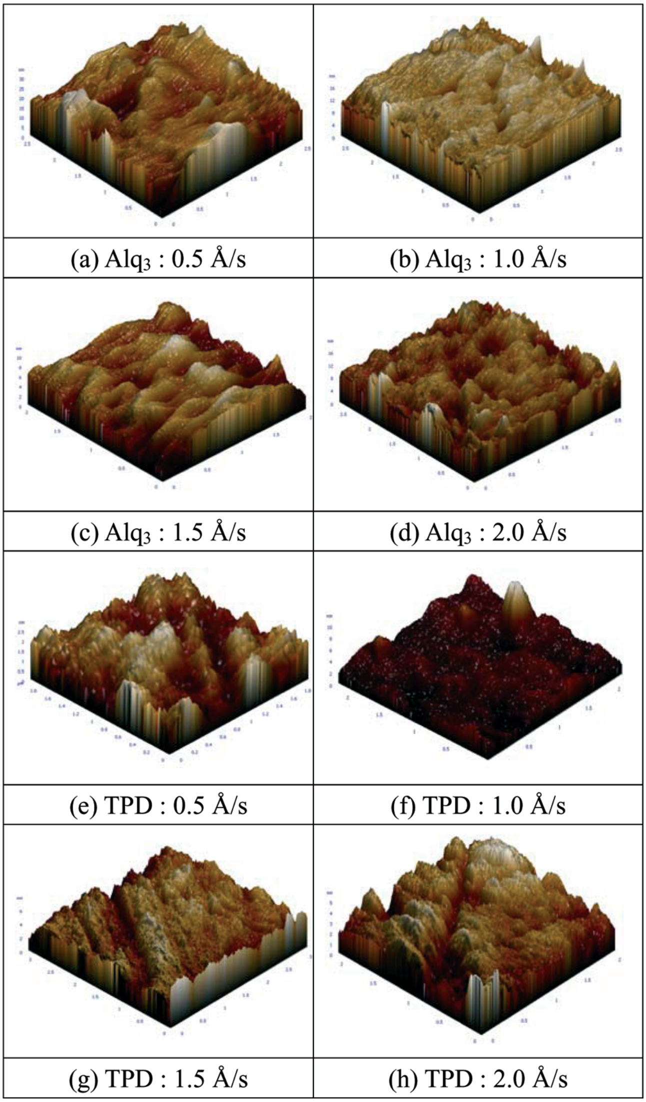


FIGURE 2 AFM surface images of TPD and Alq_3 layer depending on the deposition rates. (See COLOR PLATE II)

and irregular. But, for the sample with 1.0 Å/s deposition rate (Fig. 2(b)), surface roughness becomes much lower and the surface looks relatively flat. Figure 2(c) shows that 1.5 Å/s deposited sample has low surface roughness. It is clear that deposition rates greater than 1.0 Å/s yield lower surface roughness. However, the sample with high deposition rate (2.0 Å/s) shows sharp profiles which result in reduction of contact surfaces at the interface between the TPD and Alq_3 films.

Based on the AFM scanning results, we fixed the deposition rate of 1.5 Å/s for Alq_3 thin film and varied the deposition rate for the TPD thin film to create devices to study the effect of the TPD deposition rate on the device characteristics. Figure 3 shows current density and luminance characteristics as a function of voltage for several deposition rates of organic layers in ITO/TPD/Alq_3/Al device. The current density increases as the applied voltage increases and starts to decrease at around 2 V. It starts to increase rapidly at approximately 6 V or higher applied bias. It is found that the sample with TPD and Alq_3 films prepared using 1.5 Å/s deposition rate shows higher current density than the ones prepared with other deposition rates. It is speculated that the surface roughness of both TPD and Alq_3 films are the lowest for 1.5 Å/s deposition rate which results in better transport of hole and electrons to the hole transport layer and the emitting layer.

Luminance increases very slightly as the applied voltage increases up to 5 V. Light emission starts when 5 V or higher bias is applied, and the luminance rapidly increases as the applied bias becomes higher. Figure 3 shows that the device with TPD and Alq_3 films prepared using 1.5 Å/s deposition rate has the best current density and luminance characteristics. Again, it is our understanding that the low surface roughness increases contact surface at the interface between the TPD and Alq_3 films, which is the primary factor to yield such

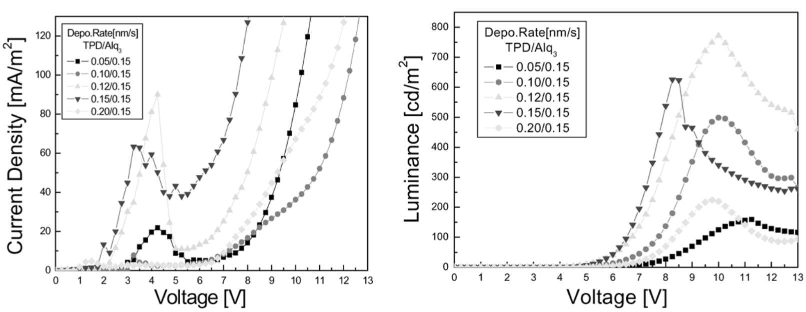


FIGURE 3 Current density and luminance characteristics as a function of voltage for several deposition rates in device.

results. For the sample with 2.0 Å/s deposition rate, it is speculated that the current density and luminance characteristics are not good because sharp profiles of the deposited thin films would narrow down the hole injection path of the device.

4. CONCLUSION

In this work, we studied the effect of deposition rates of thin films in the OLED fabrication. It is found that the deposition rates of TPD and Alq_3 thin films greatly affect on the device characteristics. In our experiment, the TPD and Alq_3 films prepared with 1.5 Å/s deposition rate shows low surface roughness and increases contact surfaces at the interface between the TPD and Alq_3 layer, which result in excellent I-V and luminance characteristics due to increased transport efficiency of charge carriers through the hole transport layer and the emitting layer.

REFERENCES

[1] Blanchet, G. B. *et al.* (2003). *Appl. Phys. Lett.*, *82*, 463.
[2] Huitema, H. E. A. *et al.* (2002). *Advanced Materials*, *14*, 1201.
[3] Hung, L. S. & Chen, C. H. (2002). *Materials Science and Engineering*, *R. 39*, 143.
[4] Pope, M., Kallmann, H. P., & Magnante, P. (1963). *J. Chem. Phy.*, *38*, 2042.
[5] Tang, C. W. & VanSlyke, S. A. (1987). *Appl. Phys. Lett.*, *51*, 913.
[6] Friend, R. H., *et al.* (1990) *Nature*, *347*, 539.
[7] Kuro, K. (2005). *Current Applied Physics*, *5*, 337.
[8] Jiang, C., *et al.* (2004). *Advanced Materials*, *16*(6), 537.
[9] Lee, H. S., *et al.* (2004). *J. of the KIEEME*, *17*(2), 196.
[10] Kim, S. K., *et al.* (2002). *Mol. Cryst. Liq. Cryst.*, *377*, 129.
[11] Kim, S. K., *et al.* (2002). *Mol. Cryst. Liq. Cryst.*, *377*, 133.
[12] Kim, S. K., *et al.* (2003). *Synthetic Metals*, *137*, 1041.
[13] Junji Kido, *et al.* (1992). *Appl. Phys. Lett.*, *61*, 761.