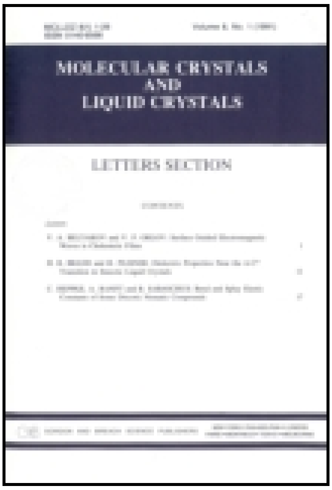
This article was downloaded by: [University Of Gujrat]
On: 11 December 2014, At: 13:48
Publisher: Taylor & Francis
Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



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

Blue Emission Color Control by Co-Deposition Method in Organic Light Emitting Diodes

Jaehyun Lee[a], Soo-Kang Kim[a], Hwangyu Shin[a] & Jongwook Park[a]
[a] Department of Chemistry/Display Research Center, Catholic University of Korea, Bucheon, Korea

Published online: 17 Nov 2014.

To cite this article: Jaehyun Lee, Soo-Kang Kim, Hwangyu Shin & Jongwook Park (2014) Blue Emission Color Control by Co-Deposition Method in Organic Light Emitting Diodes, Molecular Crystals and Liquid Crystals, 599:1, 139-144, DOI: 10.1080/15421406.2014.935976

To link to this article: http://dx.doi.org/10.1080/15421406.2014.935976

PLEASE SCROLL DOWN FOR ARTICLE

Taylor & Francis makes every effort to ensure the accuracy of all the information (the “Content”) contained in the publications on our platform. However, Taylor & Francis, our agents, and our licensors make no representations or warranties whatsoever as to the accuracy, completeness, or suitability for any purpose of the Content. Any opinions and views expressed in this publication are the opinions and views of the authors, and are not the views of or endorsed by Taylor & Francis. The accuracy of the Content should not be relied upon and should be independently verified with primary sources of information. Taylor and Francis shall not be liable for any losses, actions, claims, proceedings, demands, costs, expenses, damages, and other liabilities whatsoever or howsoever caused arising directly or indirectly in connection with, in relation to or arising out of the use of the Content.

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden. Terms & Conditions of access and use can be found at http://www.tandfonline.com/page/terms-and-conditions

Mol. Cryst. Liq. Cryst., Vol. 599: pp. 139–144, 2014
Copyright © Taylor & Francis Group, LLC
ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421406.2014.935976

Blue Emission Color Control by Co-Deposition Method in Organic Light Emitting Diodes

JAEHYUN LEE, SOO-KANG KIM, HWANGYU SHIN,
AND JONGWOOK PARK*

Department of Chemistry/Display Research Center, Catholic University of Korea, Bucheon, Korea

9,10-bis(3′′,5′′-diphenylbiphenyl-4′-yl)anthracene (TAT) and 4-(1′-(3′,5′-diphenylbiphenyl-4-yl)anthracen-9-yl)-N,N-diphenylaniline (TATa) which have electroluminescence (EL) maximum values of 441nm and 469 nm were used blue emitting materials in organic light emitting diodes (OLED). OLED devices were fabricated and characterized by co-deposited emitters of TAT and TATa with different ratios. C.I.E. values of the devices using TAT and TATa were changed from (0.148, 0.081) to (0.139, 0.194).

Keywords Organic light-emitting diode; blue emitting material; co-deposition method

Introduction

An organic light emitting diode (OLED) is a kind of optoelectronic devices and its theoretical background is based on the photoluminescence of π-conjugated organic materials. OLED is used for lighting applications and next-generation flat panel displays [1–5]. In order to achieve matched color to display such as mobile phone and TV as well as lighting, various blue color emitters are needed according to the applications. For example, mobile phone and TV need around 450 nm and 435 nm, and lighting needs 480 nm, respectively.

Because OLED is a self-emissive display unlike LCD with separate light sources and color filters, the light emitting materials in the OLED determine the whole performance of the device. Among the red, green and blue (RGB) light emitting materials used in a full color OLED, blue one is characterized especially as low efficiencies and short device lifetimes because its wide band gap for the blue light also represents a steep energy barrier at the hole and electron injection interfaces compared to the barriers in red and green emitting materials [6, 7].

In a recent paper [8,9], we have reported new high performance blue-light emitters based on compounds with same anthracene group as their cores. 9,10-bis(3′′,5′′-diphenylbiphenyl-4′-yl)anthracene (TAT) symmetrically contains a mixture of anthracene

---

*Address correspondence to J. W. Park, Department of Chemistry, The Catholic University of Korea, Bucheon, 420-743, Korea. Tel.: (+82)2-2164-4331; Fax: (+82)2-2164-4764; E-mail: hahapark@catholic.ac.kr

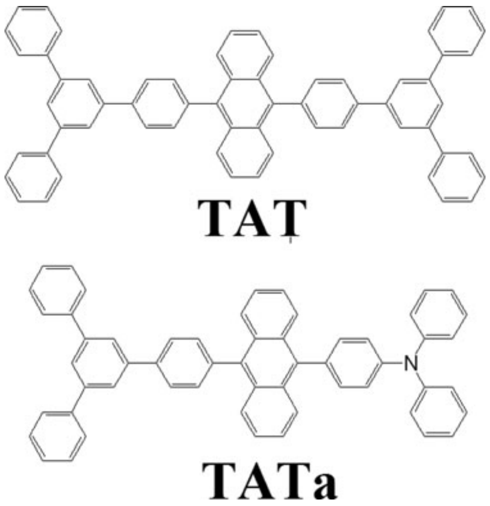


Figure 1. Chemical structures of materials.

and triphenylbenzene units, which are bulky side groups and 4-(1′-(3′,5′-diphenylbiphenyl-4-yl)anthracen-9-yl)-N,N-diphenylaniline (TATa) asymmetrically contains both triphenylbenzene and triphenylamine groups to anthracene core. TATa has better a lower operating voltage and high efficiency than TAT without using a doping method, but lower color purity.

In the present study, OLED devices in which the emitting layer was a co-deposited mixture of TAT and TATa were prepared and characterized. We demonstrate that these co-deposited devices show a tunable EL spectrum without a doping effect.

Experimental

The method of synthesis for TAT in Fig. 1 is published in J. Chem. Mater [8]. TATa is also introduced by Organic Electronics [9]. The optical absorption spectra were obtained by HP 8453 UV-VIS-NIR spectrometer. Perkin Elmer luminescence spectrometer LS50 (Xenon flash tube) was used for photo-luminescence (PL) spectroscopy. The current–voltage-luminance (I-V-L) characteristics of the fabricated EL devices were obtained by Keithley 2400 electrometer and light intensity was obtained by Minolta CS-1000 A, respectively.

Preparation of OLED Device

OLED devices were fabricated as the following structure: ITO / 2-TNATA(60 nm) / NPB(15 nm) / TAT : TATa = 100 : 0, 20 : 80, 50 : 50, 80 : 20, 0 : 100 (30 nm) / TPBi (30 nm) / LiF(1 nm) / Al(200 nm), triphenylamine (2-TNATA)-hole injection layer, N,N′-bis(naphthalen-1-yl)-N,N′-bis(phenyl)benzidine (NPB)-hole transporting layer, l,3,5-tris[2-N-phenylbenzimidazol-z-yl]benzene (TPBi)-electron transporting layer, LiF-electron injection layer, ITO-anode and Al-cathode. The organic layer was vacuum-deposited by using thermal evaporation at a vacuum pressure of 10^{-6} torr and the rate of deposition being 1 Å/s to give an emitting area of 0.04 cm^2. The aluminum layer was continuously deposited under the same vacuum condition.

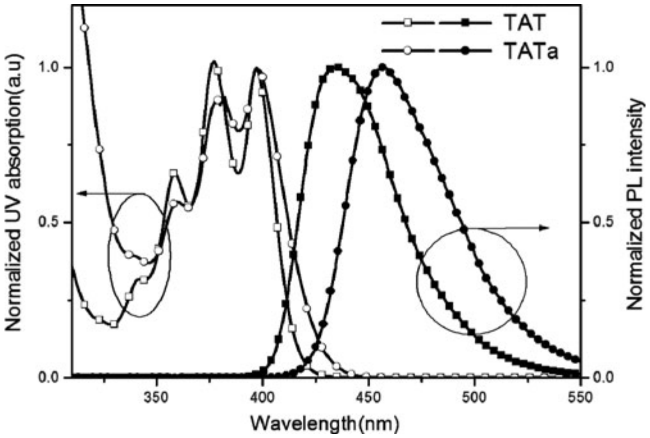


Figure 2. UV-Visible absorption and PL spectra in film state.

Results and Discussion

Figure 2 shows the UV–Visible (UV–Vis.) and PL spectra of TAT and TATa in the film state. The UV–Vis. spectra of both materials showed a UV-Vis. peak corresponding to the anthracene moiety in the range of 350–404 nm. In the PL spectra, the TAT maximum peak was measured at 444 nm, which is blue shifted by more than 22 nm with respect to the TATa maximum peak of 466 nm. Highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO) values of the blue materials have −5.54, −2.60 for TAT and −5.37, −2.50 for TATa, respectively. The reason of different HOMO, LUMO and PL maximum peak in used materials is because a substituted amine unit in TATa [9]. As shown in Fig. 2, TATa absorbed small wavelength region of around 425 nm in the PL wavelength range of TAT, suggesting that if both materials are jointly vapor-deposited, the doping effect that acts through Föster energy transfer will be negligible [10].

To test this effect, we examined five devices in which TAT and TATa were co-deposited at various ratios as an EML. Figure 3 shows the I-V-L properties of the five devices.

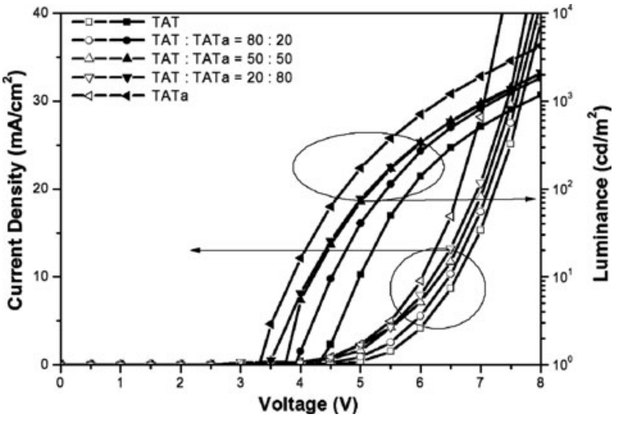


Figure 3. I-V-L characteristics of EL devices: ITO / 2-TNATA(60 nm) / NPB(15 nm) / TAT : TATa = 100 : 0, 20 : 80, 50 : 50, 80 : 20, 0 : 100 (30 nm) / TPBi (30 nm) / LiF(1 nm) / Al(200 nm)

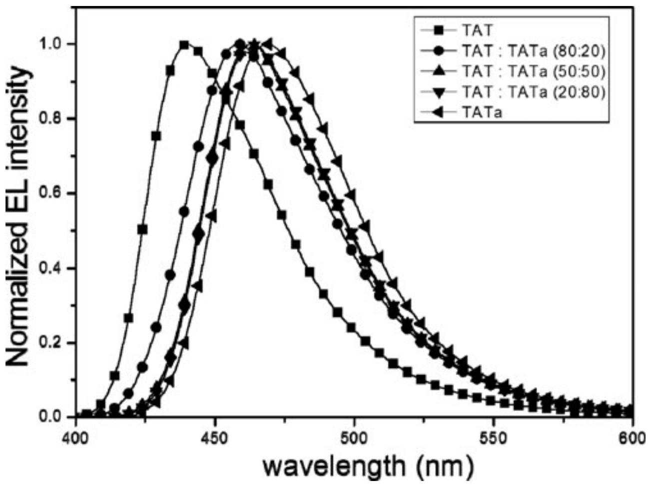


Figure 4. EL spectra of the fabricated devices.

Changing ratios of mixture from 100% TAT to 100% TATa, the devices show increasing I–V curves and decreasing turn-on voltage; hole carrier mobility of TATa can be increased than TAT because of donating effect of amine unit. Figure 4 shows the EL spectra of the five fabricated devices. For the systems with 100% TAT and 100% TATa, the maximum wavelength of EL was 441 nm and 469 nm, respectively. In general in OLED devices, when a doping agent is introduced into the EML at doping ratios, the EL spectrum could become asymmetrical or exhibits features of the doping agent's EL spectrum due to Föster energy transfer. In the system considered here, however, no doping effects were observed when TATa was co-deposited with TAT, regardless of the doping ratio. As the TATa content of the sample increases, the EL spectrum is gradually red-shifted. Changes of wavelength with varying the ratio of TAT to TATa can be useful in tuning the blue color.

The EL performances of the devices at a current density of 10 mA/cm^2 are summarized in Table 1. Multilayered non-doped OLED devices based on TAT or TATa showed luminance efficiencies of 3.4 cd/A and 7.4 cd/A at 10 mA/cm^2, respectively. Figure 5 shows the

Table 1. EL device performance of ITO / 2-TNATA(60 nm) / NPB(15 nm) / TAT : TATa = 100 : 0, 20 : 80, 50 : 50, 80 : 20, 0 :100 (30 nm) / TPBi (30 nm) / LiF(1 nm) / Al(200 nm) device, at 10 mA/cm^2

TAT : TATa	EL$_{max}$ (nm)	Voltage (V)	Turn-on [a](V)	L.E. [b](Cd/A)	P.E. [c](lm/W)	C.I.E. [d](x,y)
100 : 0	441	6.6	4.3	3.4	1.8	(0.148, 0.081)
80 : 20	458	6.5	3.9	4.4	2.4	(0.145, 0.143)
50 : 50	463	6.3	3.7	5.0	2.7	(0.143, 0.163)
20 : 80	463	6.2	3.5	4.9	2.6	(0.143, 0.169)
0 : 100	469	6.0	3.3	7.4	4.3	(0.139, 0.194)

[a] turn-on voltage measured at 1 cd/m^2 [b] L.E.: luminance efficiency, [c] P.E.: power efficiency, [d] C.I.E.: Commission Internationale de l'Eclairage

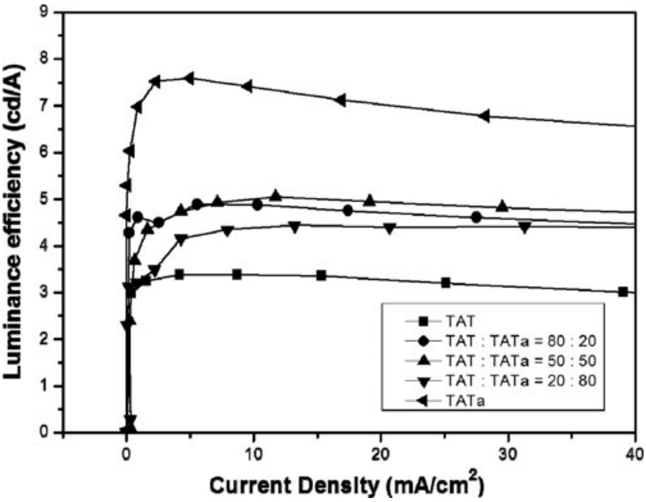


Figure 5. Luminance efficiency according to current density of the devices.

luminance efficiency vs current density. As TATa content of the device increases, the luminance efficiency increased up to a maximum of 7.4 cd/A in the device with 100% TATa. C.I.E. coordinate values were found to move from the deep blue area for the device with 100% TAT to the sky-blue area for the device with 100% TATa. These findings demonstrate that the EL efficiency and C.I.E. values can be tuned by varying the co-deposition ratio of TATa to TAT.

Conclusions

Five OLED devices with an emitting layer comprised of a co-deposited mixture of TAT and TATa were prepared and characterized. In the devices with 100% TAT and 100% TATa, the maximum wavelength of EL was 441 nm and 469 nm, respectively. Also, when TATa was co-deposited with TAT, no doping effects were observed for any of the doping ratios tested. As the TATa content increased, the EL spectrum was red shifted. In addition, the C.I.E. coordinates gradually shifted from deep-blue to sky-blue. The present findings thus show that EL efficiency and C.I.E. values can be gradually tuned by varying the co-deposition ratio of TATa to TAT.

Acknowledgment

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MEST) (No. 2012001846).

References

[1] Tang, C. W., & Van Slyke, S. A. (1987). *Appl. Phys. Lett.*, *51*, 913.
[2] Kim, S. K., Park, Y. I., Kang, I. N., Lee, J. H., & Park, J. W. (2007). *J. Mater. Chem.*, *17*, 4670.
[3] Kim, J. S., Heo, J., Kang, P., Kim, J. H., Jung, S. O., & Kwon, S. K. (2009). *Macromol. Res*, *17*, 91

[4] Park, H. T., Shin, D. C., Shin, S. C., Kim, J. H., Kwon, S. K., & Kim, Y. H. (2011). *Macromol. Res*, *19*, 965

[5] Choe, Y. S., S. Y. Park, Park, D. W., & Kim, W. H. (2006). *Macromol. Res*, *14*, 38.

[6] Kim, H. K., Cho, S. H., Oh, J. R., Lee, Y. H., Lee, J. H., Lee, J. G., Kim, S. K., Park, Y. I., Park, J. W., & Do, Y. R. (2010). *Organic Electronics*, *11*, 137.

[7] Tong, Q. X., Lai, S. L., Chan, M. Y., Zhou, Y. C., Kwong, H. L., Lee, C. S., & Lee, S. T. (2008). *Chem. Mater.*, *20*, 6310.

[8] Kim, S. K., Yang, B., Ma, Y. G., Lee, J. H., & Park, J. W. (2008). *J. Mater. Chem.*, *18*, 3376.

[9] Kim, S. K., Yang, B., Park, Y. I., Ma, Y. G., Lee, J. Y., Kim, H. J., & Park, J. W. (2009). *Organic Electronics*, *10*, 822.

[10] Kim, S. K., Oh, S. Y., & Park, J. W. (2008). *Thin Solid Films*, *517*, 1349.