

High-efficiency blue and white phosphorescent organic light-emitting devices [☆]

Shizuo Tokito ^{a,*}, Toshimitsu Tsuzuki ^a, Fumio Sato ^a, Toshiki Iijima ^b

^a *NHK Science and Technical Research Laboratories, 1-10-11 Kinuta, Setagaya-ku, Tokyo 157-8510, Japan*

^b *Tokyo University of Science, 1-3 Kagurazaka, Shinjuku-ku, Tokyo 162-8610, Japan*

Received 30 August 2003; accepted 7 November 2003

Available online 9 June 2004

Abstract

We have significantly improved the efficiency of blue and white phosphorescence from organic light-emitting devices (OLEDs) based on phosphorescent iridium complexes. To improve the emission efficiency, 4,4'-Bis(9-carbazolyl)-2,2'-Dimethyl-biphenyl (CDBP), which has a high triplet energy, was used as the carrier-transporting host for the emissive layer. The blue phosphorescent OLED exhibited a maximum external quantum efficiency of 10.4%, which corresponds to a current efficiency of 20.4 cd/A. This result can be explained as due to the efficient confinement of triplet energy on blue phosphorescent molecules, which is consistent with the results of transient photoluminescence experiments. The white phosphorescent OLED with greenish-blue and red emissive layers exhibited a maximum external quantum efficiency of 12% and a luminous efficiency of 18 cd/A. This is primarily attributed to the improvement of greenish-blue emission efficiency as well as the emission efficiency of the blue phosphorescent OLED.

© 2004 Elsevier B.V. All rights reserved.

PACS: 85.60.Jb; 42.70.Jk; 73.61.Ph

Keywords: Organic light-emitting device; Phosphorescence; Triplet energy; Quantum efficiency

1. Introduction

Blue emission in organic light-emitting devices (OLEDs) is important in full-color flat-panel displays because blue is one of the three primary colors [1,2]. White light emission from OLEDs is also of interest because it can be used for full-color flat-panel displays with color filters and as an alternative lighting source [2]. The combination of white light emission and color filters should simplify the fabrication process for fine-pixel large-screen displays [3]. To accelerate the commercialization of OLEDs, though, improved blue and white emission efficiency are needed. A Princeton University group has demonstrated a way to break through the efficiency limitation by using certain organic materials which emit intense phosphorescence from triplet states at room temperature [4,5].

The phosphorescent materials used were iridium (Ir) and platinum (Pt) complexes with organic ligands, and they were doped as an emissive guest into a charge-transport host material of the emissive layer [6]. The phosphorescence from the device can be understood in terms of the energy transfer from both the singlet and triplet states of the host molecules to the triplet states of the phosphorescent guest molecules and/or by direct excitation of the phosphorescent guest molecules followed by charge trapping. The devices using phosphorescent materials already showed a high external quantum efficiency of over 5% in green, red, blue, and white light emission [5,7,8]. In particular, the efficiency of the green-emission device was almost 20%, implying 100% internal quantum efficiency [9,10]. However, the quantum efficiency of the blue emission device was only 5.7% and that for the white-emission device was just 5.2% [7,11]. Iridium(III)bis[(4,6-di-fluorophenyl)-pyridinato-N,C^{2'}]picolinate (FIrpic) was used as the blue phosphorescent guest and 4,4'-Bis(9-carbazolyl)-2,2'-biphenyl (CBP) was used as the host in these devices. The energy difference of the triplet energies of the host and guest materials was

[☆] Original version presented at the 4th International Conference on Electroluminescence of Molecular Materials and Related Phenomena (ICEL4), 27–30 August 2003, Cheju Island, Korea.

* Corresponding author.

E-mail address: tokito.s-eu@nhk.or.jp (S. Tokito).

discussed by Baldo et al. and they pointed out that higher triplet energy is preferable to achieve efficient blue phosphorescence of the guest molecules [12]. Triplet energy of CBP is lower than that of FIrpic, which indicates that higher efficiency cannot be attained from this host and guest combination.

In this paper, we present an improvement of emission efficiency of FIrpic-based blue OLED by using a new host material with a high triplet energy of 3.0 eV. This material is 4,4'-Bis(9-carbazolyl)-2,2'-dimethyl-biphenyl (CDBP) which is a derivative of CBP. The blue phosphorescent OLED exhibited an external quantum efficiency of 10.4%, which is much higher than the previously reported values [13]. We also demonstrate high-efficiency white phosphorescent OLEDs with greenish-blue and red emissive layers. A greenish-blue phosphorescent material, bis[2-(3,5-bis(trifluoromethyl)phenyl)pyridinato-N,C^{2'}]iridium(III)picolinate ((CF₃ppy)₂Ir(pic)), was used for the greenish-blue emissive layer. The well-known red phosphorescent material, bis[2-(2'-benzo[4,5-a]thienyl)pyridinato-N,C^{3'}]iridium(III)acetylacetonate((btp)₂Ir(acac)), was used for the red emissive layer [14]. To enhance the greenish-blue emission, CDBP was used as the host of each emissive layer. The phosphorescent devices exhibited Commission Internationale de l'Eclairage (CIE) coordinates of (0.35, 0.36), and an external quantum efficiency of 12%.

2. Experiments

Fig. 1 shows the molecular structures of the phosphorescent guest and host materials used in this study. We expected high triplet energy for the new host material, CDBP, because two phenyl carbazoles were decoupled by the steric hindrance caused by the two methyl groups. The CDBP was synthesized as follows [13]. Pd(OAc)₂ and (tert-Bu)₃P were stirred at 70 °C under nitrogen, then 4,4'-dibromo-2,2'-dimethyl-biphenyl, carbazole, tert-BuONa, and xylene were added and the mixture was refluxed for 5 h. Fluorinated Ir complex, (CF₃ppy)₂Ir(pic), was also synthesized in two steps using the standard procedures [15]. First, a cyclometalated Ir(III) m-chloro bridged dimer was synthesized by the reacting IrCl₃·nH₂O and 2-(3,5-bis(trifluoromethyl)phenyl)pyridine. Then, the dimer was reacted with picolinic acid sodium salt in 2-ethoxyethanol [14].

The triplet energies of the materials were measured from the highest energy peak of the phosphorescence spectra in methanol/ethanol solutions at 77 K. To investigate the energy transfer in the emissive layer, we also measured the transient photoluminescence decay in a CDBP thin film (50 nm) doped with 3% FIrpic and a CBP thin film (50 nm) doped with 3% FIrpic after laser pulse excitation with a 337-nm wavelength.

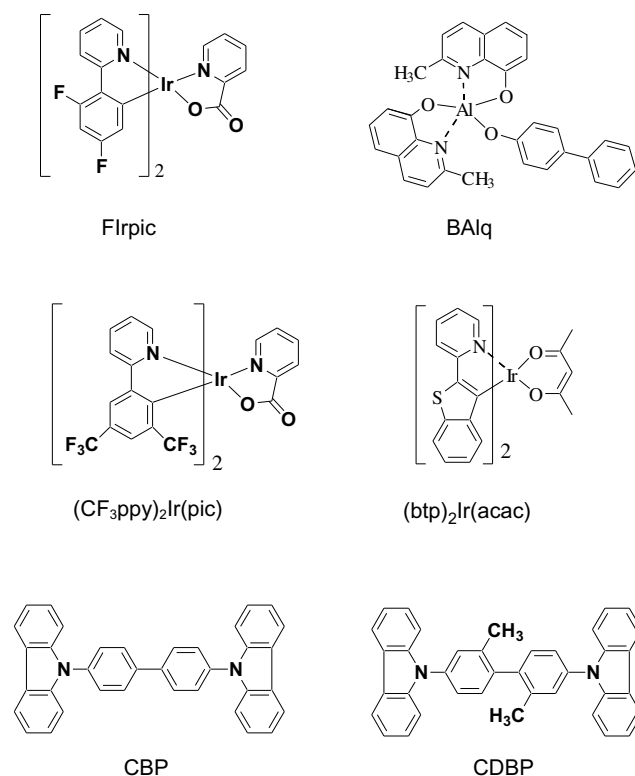


Fig. 1. Molecular structures of host and guest materials for emissive layer and hole blocking/electron transporting material.

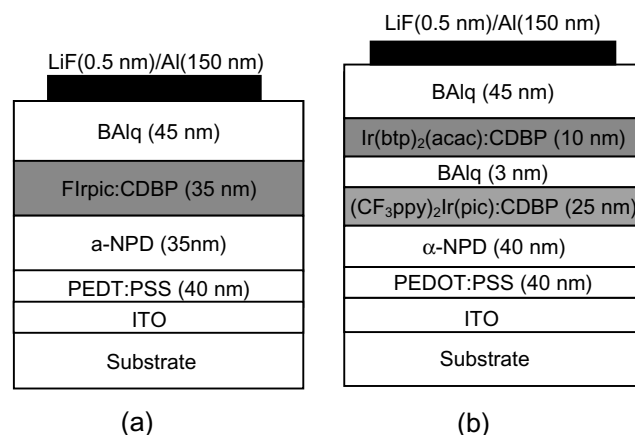


Fig. 2. Schematic structures of (a) FIrpic-based blue OLED and (b) white OLED with two emissive layers.

Fig. 2 shows the device structures of the blue and white phosphorescent OLEDs. A glass substrate coated with a 200-nm-thick indium-tin-oxide (ITO) layer with a sheet resistance of 10 Ω/□ was used at the substrate. Prior to fabricating the organic layers, the substrate was cleaned with ultra-purified water and organic solvents, and treated with a UV-ozone ambient. To reduce the possibility of electrical shorts within the device, poly(3,4-ethylenedioxythiophene)/poly(styrene sulfonic acid) (PEDOT:PSS) was spun onto the substrate from a water

Download English Version:

<https://daneshyari.com/en/article/10706829>

Download Persian Version:

<https://daneshyari.com/article/10706829>

[Daneshyari.com](https://daneshyari.com)