Study of Organic Light Emitting Devices with Bis(2-phenylbenzothiazolato)(acetylacetonate) iridium - doped Hole Transport Layer

R.Tomova1,a,b, P. Ivanov1,2, P. Petrova1, S.Stanimirov2, I.Petkov2
1Institute of optical materials and technologies „Acad. J. Malinowski“, Bulgarian Academy of Sciences, Acad. G. Bonchev str. bl. 109, 1113 Sofia, Bulgaria
2 Laboratory of Organic Photochemistry, Faculty of Chemistry and Pharmacy, University of Sofia,1 James Bauчерий blvd., 1164 Sofia, Bulgaria

Abstract

We demonstrate white organic light-emitting devices (WOLEDs) by doping a yellow-emitting iridium complex bis(2-phenylbenzothiazolato)(acetyl-acetonate)iridium(III) (Ir(bt)2acac), into a hole-transporting layer of N,N’-bis(3-methylphenyl)-N,N’-diphenylbenzidine (TPD) incorporated in poly(N-vinylcarbazole) (PVK) matrix. Bis(8-hydroxy-2-methylquinoline)-(4-phenylphenoxy)aluminum (BAlq) and bis(2-(2-hydroxyphenyl) benzothiazolate)zinc (Zn(btz)2) were used as electroluminescent and electron-transporting materials. It was found that OLED with 2.5 wt % Ir(bt)2acac irradiated a white light which CIE coordinates changed from bluish-white (0.28, 0.30) at 8 V, to yellowish-white (0.35, 0.40) at 20 V.

Keyword: WOLEDs, Ir(bt)2acac, BAlq, Zn(btz)2

1. INTRODUCTION

WOLEDs have attracted great attention due to their potential applications such as full color displays, backlight units, and general illuminant light sources. In particular, phosphorescent WOLEDs are promising due to their high efficiency by harvesting both singlet and triplet excitons. An important breakthrough is phosphorescent light emitting diodes (PHOLEDs) with the use of the heavy metal complexes, particularly iridium complexes. Cheng et al.[1] have synthesized and characterized a series of iridium(iii) complexes with substituted 2-phenylbenzothiazoles as the cyclometalated ligands and showed that the electroluminescent (EL) efficiency and emissive colors of OLEDs based on it could be finely tuned by suitable modification of the substituents on ligands.

2. EXPERIMENTAL AND RESULTS

In this study the influence of doping of HTL of OLED structure: PET/ITO/HTL/EL/ETL/M with yellow dopant Ir(bt)2acac on the device performance was investigated. In the structure ITO was a transparent anode of In2O3:SnO2, and M - a metallic Al cathode. Devices with area 1cm2 were prepared on al polyethylene terephthalate (PET) substrates coated with ITO (40 Ω/sq). The doped HTL of PVK:TPD (30 nm) film was formed by spin-coating and layers of BAlq (40 nm), Zn(btz)2 (35 nm) and Al cathode (80 nm) were thermal evaporated in vacuum better than 10^-4 Pa at rates 0.2 - 0.5 nm/s. Zn(btz)2 and Ir(bt)2acac were synthesized in Laboratory of Organic Photochemistry Faculty of Chemistry and Pharmacy, University of Sofia “St. Kl. Ohridski”.

All measurements were performed at room temperature and under ambient atmosphere, without any encapsulation. The photoluminescence (PL) and the electroluminescence (EL) spectra were obtained by Ocean Optics HR2000+ spectrometer.

Fig.1. shows the optical absorption spectrum of Ir(bt)2acac and PL spectra of Ir(bt)2acac, PVK and TPD in CH2Cl2 solution at photoexcitation with PX-2 Pulsed Xenon Lamp UV (220-750 nm).

The Ir(bt)2acac emitted a greenish yellow light with a peak at 557 nm and shoulder at 597 nm. The PVK and TPD emitted a blue light with peaks at 367 and 414 nm. It can be expected that the efficient Förster energy transfer would be possible from PVK and TPD to Ir(bt)2acac since 1MLCT and 3MLCT absorption spectra of Ir(bt)2acac has broader spectral overlap with fluorescence spectra of PVK from 330 to 450 nm and of TPD from 390 to 450 nm. Efficient Dexter energy transfer is also possible from phosphorescence of PVK and TPD to 3MLCT absorption of Ir(bt)2acac (493 nm).

The PL spectra of spin coated pure and doped with Ir(bt)2acac PVK:TPD films are shown in Fig.2. It is seen that the blue emission at ~ 414 nm, attributed to PVK:TPD blend, reduces significantly with increasing of dopant concentration from 0 to 5 wt %, indicating that energy transfer from PVK and TPD to Ir(bt)2acac not only take

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*Fig.1. UV–visible absorption spectrum of Ir(bt)2acac and PL emission spectra of Ir(bt)2acac, PVK and TPD in CH2Cl2*

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*Fig.2. PL and EL spectra of PVK:TPD:Ir(bt)2acac films with varying concentration of Ir(bt)2acac dopant.***
place, but also increases with doping concentration and was completely brought to an end at 2.5 wt %.

![Fig.2. PL spectra of: a) of spin coated pure and doped with Ir(bt)\textsubscript{2}acac PVK:TPD films; neat BAlq, Zn(btz)\textsubscript{2} and consequent BAlq/Zn(btz)\textsubscript{2} thermal evaporated films.](image)

It was found that there was not essential differences between PL spectra of neat BAlq, Zn(btz)\textsubscript{2} and consequent BAlq/Zn(btz)\textsubscript{2} thermally evaporated films on a quartz glass (Fig.3).

![Fig.3.Normalized EL spectra of OLEDs at 16 V DC and its CIE coordinates at different concentrations of the dopant.](image)

In contrast to the PL spectra of the doped with iridium complex PVK films (Fig. 2.), any PVK-induced emission near ~400 nm, irrespective of the Ir(bt)\textsubscript{2}acac concentration, was not observed. The absence of major PVK related emission features has implied a charge trapping rather than an exciton transfer mechanism. The EL spectra of doped devices did not include any Zn(btz)\textsubscript{2} emission at 529 nm too and were basically the sum of the emissions of Ir(bt)\textsubscript{2}acac (at 560 nm) and BAlq (at 496 nm). With increasing Ir(bt)\textsubscript{2}acac concentration, the relative intensity of the greenish-blue emission (496 nm) decreased, while the yellow (560 nm) - increased and CIE coordinates of OLEDs shifted from blue (0.19, 0.30) at 0 wt % to yellow (0.42, 0.45) at 5 wt % of the dopant. It was found that OLED with 2.5 wt % Ir(bt)\textsubscript{2}acac irradiated a white light which intensity increased with increasing of applied voltages and CIE coordinates changed from bluish-white (0.28, 0.30) at 8 V, to yellowish-white (0.35, 0.40) at 20 V (Fig.4).

![Fig.4. EL intensity of the device with 2.5 % Ir(bt)\textsubscript{2}acac and its CIE coordinates at different bias voltages.](image)

All obtained results can be explained with shown in Fig.5. energy level diagram of studied device.

![Fig.5. Energy level diagram of studied device.](image)

According this diagram, observed yellow emission, except Förster or Dexter energy transfer from PVK:TPD blend to the dopant, is possible to appear as a result of the direct recombination of injected carriers at the Ir(bt)\textsubscript{2}acac sites, as the HOMO and LUMO levels of the dopant (−5.6 and −3.4 eV) are located within HOMO and LUMO level of the host blend material (−5.8 and −2.5 eV) electrons and holes. In undoped device excitons generate at the PVK:TPD/BAlq interface and recombine in the BAlq layer irradiating a blue light. Introduction of the dopant causes trapping of some carriers on Ir(bt)\textsubscript{2}acac HOMO and LUMO levels. The formed excited later decay radiatively emitting a red light. Increasing of dopant concentration or applied voltage leads to increasing of the light intensity and causes red shift of the CIE coordinates, because favor trapping of carriers in the dopant.

3. SUMMARY

It was established that the incorporation of Ir(bt)\textsubscript{2}acac in HTL of the investigated devices tunes the light emission thus allowing the successful development of WOLED

4. REFERENCES