J. of Korean Oil Chemists' Soc.,
Vol. 18, No. 1. March, 2001. 7~11

White-Light-Emitting Materials for Organic Electroluminescent Devices

Duck-Young Kim, Oh-Kwan Kwon, Hyuck-Joo Kwon, Young-Kwan Kim, Byoung-Chung Sohn and Yun-Kyoung Ha*

Dept. of Chem. Eng., Hong-Ik Univ., 72-1, Sangsu-Dong, Mapo-Gu, Seoul 121-791 Korea;
**Dept. of Science, Hong-Ik Univ., 72-1, Sangsu-Dong, Mapo-Gu, Seoul 121-791, Korea*
(Received November 23, 2000 ; Accepted March, 6, 2001)

Abstract : White emission is important for applying organic EL devices to full-color flat panel display and backlight for liquid crystal display. In order to obtain white emission, the use of a light-emitting material which shows the white emission by itself is advantageous for these applications because of its high reliability and productivity. A chelate-metal complex such as zinc bis(2-(2-hydroxyphenyl) benzothiazolate) ($Zn(BTZ)_2$ was known to emit white light with a broad electroluminescence. In this study, the electroluminescent characteristics of $Be(BTZ)_2$ and $Mg(BTZ)_2$, as well as $Zn(BTZ)_2$ were investigated using organic electroluminescent devices with the structure of ITO/TPD/ $Be(BTZ)_2$, $Mg(BTZ)_2$, or $Zn(BTZ)_2$ /Al. It was found that the device containing $Be(BTZ)_2$ showed the highest power efficiency.

Keywords : Electroluminescent, $Be(BTZ)_2$, $Zn(BTZ)_2$, white emission

1. INTRODUCTION

Organic electroluminescent devices(OLEDs) are popular for their potential applications in large-area, flat-panel, and high-luminance full-color displays, utilizing low driving voltage, either as back-lighting sources or directly emitters in emissive displays[1-8]. Tang and Vanslyke were the first to report on the high-performance EL devices composed of a vacuum-sublimed double-layer dye film(emissive and hole-transport layers)[1]. Since then, various multi-layered structure devices, fluorescent dyes, and electrode materials have been studied to improve the efficiency and stability of the devices[3-7].

White emission is important for applying organic EL devices to full-color flat panel display and back-light for liquid crystal display. In the full color flat display, white emission is necessary to realize full coloring in combination with a color filter. The features of this system, which combines white emission with a color filter, are low cost an easy manufacturing progress and good reliability. When RGB-emitting materials are simultaneously used, it is

difficult to control the intensity of each RGB peak for obtaining white emission. Thus, the reproducibility of the white emission is poor, and multi-layer device structures are also complicated. However, if a white emitting material producing white emission by itself was used, the reproducibility of the white emission would be excellent and the device structure would be simple because there would be no need to control the RGB intensity, and a two layer device structure could be employed. The condition for such a white emitting material is that it must have a broad photoluminescence spectrum with a peak wavelength in the bluish-white and greenish-white region, where this must be a broad spectrum including the RGB components.

In this study, the electroluminescent characteristics of $Be(BTZ)_2$ and $Mg(BTZ)_2$, as well as $Zn(BTZ)_2$ were investigated using organic electroluminescent devices with the structure of ITO/TPD/ $Be(BTZ)_2$, or $Mg(BTZ)_2$, or $Zn(BTZ)_2$ /Al. The luminance of the devices using various metal complexes with the same ligand, BTZ were compared and discussed.

2. EXPERIMENTAL

The author used TPD as a hole- transport material, $Be(BTZ)_2$, $Mg(BTZ)_2$, or $Zn(BTZ)_2$ as emitting materials. They used the double-layer OLED (TPD/ $Be(BTZ)_2$, $Mg(BTZ)_2$, or $Zn(BTZ)_2$ by means of a vacuum-deposition method. The organic EL devices were consisted of 40nm-thick hole-transport layer and 60 nm-thick emitting layer, where these layers were prepared by the vacuum evaporation method. The vacuum pressure was maintained in the range of 10-6 Torr during the whole deposition. The ITO coated glass substrates with a sheet resistance of 15 Ω/□ (sheet resistance) was used, which were donated by Samsung Corning Co. Ltd. The UV/visible absorption spectrum of Be(BTZ)2, Mg(BTZ)2, or Zn(BTZ)2 was obtained using a Hewlett Packard 8425A spectrometer. Photoluminescence(PL) and Electroluminescence(EL) spectra were obtained using a Perkin Elmer LS50B in the air. The current density-voltage (J-V) characteristics and luminance of organic LEDs were measured with Keithley 238 electrometer and Minolta chromameter CS100, respectively. Molecular structures of BTZ metal complexes, and TPD used in this study were shown in Fig. 1.

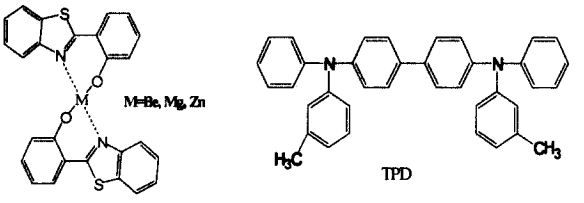
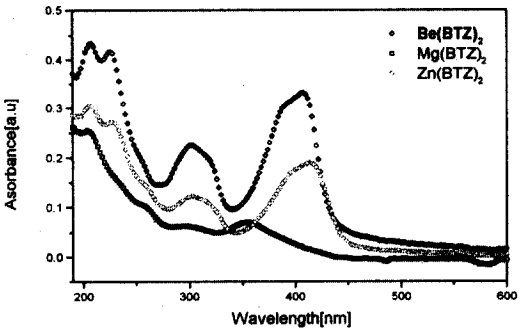


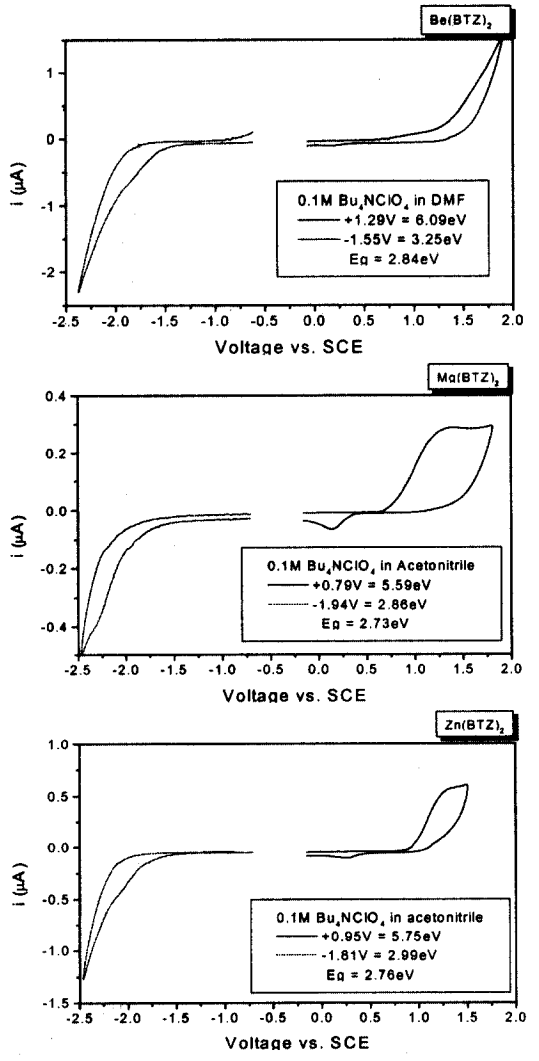
Fig.1. Chemical structures of the BTZ metal complexes and TPD.

3. RESULTS AND DISCUSSION

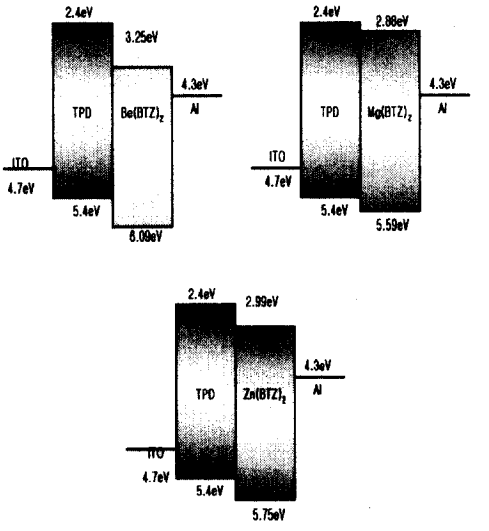
It was found that the UV/Visible absorption spectrum was almost the same, but the intensity of edge peak of UV/Visible absorption spectrum had differences, which seems to be due to the different metal. The UV/Visible absorption spectra and CV data of the BTZ metal complexes are shown in Fig. 2.



(a) The UV/Visible absorption spectra of the BTZ metal complexes



(b) Cyclic Voltamogram of the BTZ metal complexes



(c) Device energy level of BTZ metal complexes

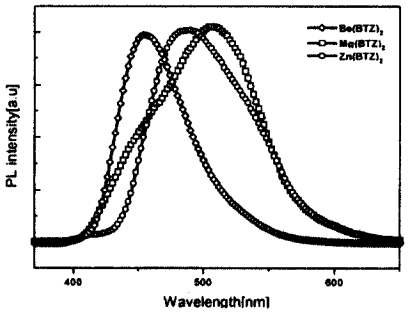
Fig. 2. (a) The UV/Visible absorption spectra, (b) CV data of the BTZ metal complexes and (c) Device energy level of BTZ metal complexes.

Electrochemical measurements were performed using cyclic voltammetry at room temperature and constant scan rate 100~20 mV/sec in 0.1M tetrabutlyammonium perchlorate (Bu_4NClO_4) with acetonitrile or DMF. The voltammograms measured for BTZ metal complexes are shown in Fig. 2 (b). We find that the BTZ metal complexes films can be both irreversibly oxidized and reduced. The oxidation onset potential and the reduction onset potential of $Be(BTZ)_2$ is measured to be +1.29V and -1.55V about the SCE electrode which yields IP = 6.09eV, EA = 3.25eV and Eg = 2.84eV in 0.1M Bu_4NClO_4 with DMF at 50 mV/sec. The oxidation onset potential and the reduction onset potential of $Mg(BTZ)_2$ are measured to be +0.79V and -2.86V about the SCE electrode which yields IP = 5.59eV, EA = 2.86eV and Eg = 2.73eV in 0.1M Bu_4NClO_4 with Acetonitrile at 50 mV/sec. The oxidation onset potential and the reduction

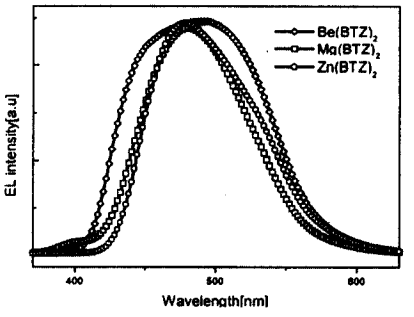
onset potential of $Zn(BTZ)_2$ are measured to be +0.95V and -1.81V about the SCE electrode which yields IP = 5.75eV, EA = 2.99eV and Eg = 2.76eV in 0.1M Bu_4NClO_4 with Acetonitrile at 50 mV/sec.

The PL spectra of the various BTZ metal complexes are shown in Fig. 3 (a). It was found in this Fig. 2 (a) that the PL spectra of the various BTZ metal complexes showed the broad peak at the wavelength from 400 to 600nm, which was almost in the same rank of the peak wavelengths of other metal complexes known as white-light emitting materials.

The EL spectra of the BTZ metal complexes as emitting materials are shown in Fig. 3 (b). $Be(BTZ)_2$ emitted greenish white light (x=0.275, y=0.368), $Mg(BTZ)_2$ emitted bluish green white light(x=0.247, y=0.366), and $Zn(BTZ)_2$ emitted greenish white light(x=0.261, y=0.393). It can be seen in Fig. 3 that the PL and EL spectra of these BTZ metal complexes show very broad spectra and the peak in the EL spectra of these metal complexes show a half-spectral bandwidth of more than 110nm. Fig. 4 (a) shows the dependence of the injection current on the applied voltage in three devices under the forward bias condition. The operating voltages of the BTZ metal complexes were similar to each other and found to be 7V. And the current density of the three devices was also almost the same each other. The luminance-voltage characteristics of all devices are shown in Fig. 3(b). It was found in this Fig. 4 (b) that the luminance of the devices containing $Be(BTZ)_2$ was higher than those of the devices containing $Mg(BTZ)_2$, and $Zn(BTZ)_2$.

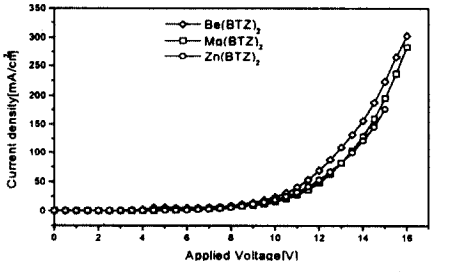


(a)

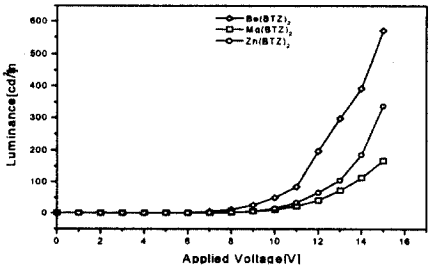


(b)

Fig. 3. (a) The PL spectra of the various BTZ metal complexes and (b) EL spectra of the BTZ metal complexes.



(a)



(b)

Fig. 4. (a) The current density-voltage (J-V) characteristics and (b) the luminance-voltage (L-V) characteristics of the BTZ metal complexes.

The power efficiency of the $Be(BTZ)_2$, $Mg(BTZ)_2$, $Zn(BTZ)_2$ was 0.054lm/W, 0.018lm/W and 0.040lm/W at the driving voltage of 15, respectively. The reason for the high power efficiency is that $Be(BTZ)_2$ seems to exhibit excellent electron transporting behavior in the device.
Because of energy battier height lower than other BTZ metal complexes.

4. CONCLUSIONS

The simple device with the structure of ITO/TPD/BTZ metal complexes/Al was prepared to evaluate the white-light emitting materials such as $Be(BTZ)_2$, $Mg(BTZ)_2$, and $Zn(BTZ)_2$. The power efficiency of the device using $Be(BTZ)_2$ as an emitting layer was the highest among the devices among other BTZ metal complexes. The other hand, energy barrier height of $Be(BTZ)_2$ lower than other BTZ metal complexes.

ACKNOWLEDGEMENTS

This work was fully supported by Hong-Ik University.

REFERENCES

1. Y. Hamada, T. Sano, M. Fujita, T. Fujii, Y. Nishio, and K. Shibata, *Jpn. J. Appl. Phys.* **32,** L511 (1993).
2. Y. Hamada, T. Sano, H. Fujii, Y. Nishio, H. Takahashi, and K. Shibata: *Jpn. J. Appl. Phys.* **35**, L1339-L1341 (1996).
3. R. H. Jordan, A. Dodabalapur, M. Strukelj, and T. M. Miller, *Appl. Phys. Lett.* **68 (9),** 26 (1996).
4. C. W. Tang and S. A. VanSlyke, *Appl. Phys. Lett.* **51**, 913 (1987).
5. J. Kido, K. Hongawa, K. Okuyama, and K. Nagai, *Appl. Phys. Lett.* **64**, 815 (1994).
6. N. Nakamura, S. Wakabayashi, K. Miyairi, and T. Fujii, *Chem. Lett.* 1744 (1994).
7. Y. Hamada, C. AdAchi, T. Tsutsui, and S. Saito, *Jpn. J. Appl. Phys.* **31**, 1812 (1992).
8. Y. Hamada, T. Sano, M. Fujita, T. Fujii, Y. Nishio, and K. Shibata, *Chem. Lett.* 905 (1993).