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White light emission from OEL devices based on organic dysprosium-complex

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Abstract

Trivalent dysprosium ion (Dy^{3+}) complex with a structure of Dy(acetylacetonato)$_3$phenanthroline (Dy(AcA)$_3$phen) was synthesized and used as an emitting material in organic electroluminescence (OEL) devices from which a white light emission was observed. A double-layer OEL device with a structure of PVK (100 nm)/Dy-complex (70 nm) was fabricated. The white emission consisted of a yellow band (~580 nm) and a blue emission band (~480 nm) corresponding to the $^4F_{9/2} \rightarrow {}^6H_{13/2}$ transition and $^4F_{9/2} \rightarrow {}^6H_{15/2}$ transition of Dy^{3+} ion in the complex, respectively.

Keywords: Dysprosium; OEL devices; Electroluminescence

1. Introduction

Since Tang et al. demonstrated efficient thin-film electroluminescence (EL) devices driven by a low DC voltage, OEL diodes [1,2] have been studied by many researchers in order to realize various types of emission characteristics, for instance, white light emission [3], variable color emission [4,5], sharp spectrum emission [6,7]. Although rare-earth (RE) ion complexes, especially β-diketonate complexes of trivalent europium and terbium ions, are currently of great interest for the development of OEL emitting materials because of their line-like EL spectra [8–10], other RE ions with abundant luminescent characteristic were rarely studied for OEL purposes. Given two significant emitting bands (blue and yellow) of Dy^{3+} ion in visible spectral range, we considered the suitability of organic Dy-complex for realizing white light emission. In this study, our objective is to develop a new kind of OEL device in which white emission is generated from a Dy-complex acting as the emitting layer.

2. Experiments

Poly(*N*-vinylcarbazole) (PVK) was employed as hole transporting material. Dy(acetylacetonato)$_3$phenanthroline (Dy(AcA)$_3$phen) acted as an emitting material. Both of them were synthesized in our laboratory according to the conventional method. The materials and cell structure are shown in Fig. 1. After chloroform solution of PVK was spin-coated onto an indium-tin-oxide (ITO) glass substrate, emitting layer (70 nm) and metal cathode (200 nm) were deposited successively by thermal evaporation method in vacuum chamber under 1×10^{-4} Pa. The cathode was a Mg:Ag alloy with an atomic ratio of about 10:1, which was formed by co-evaporation method. The thickness of PVK film is about 100 nm. The photoluminescence (PL) spectrum of Dy(AcA)$_3$phen solid and EL spectra of the device were measured by a Hitachi 4000 fluorescence spectrophotometer. The brightness is measured by a 1980A spot photometer. Both measurements were conducted under ambient atmosphere at room temperature.

3. Results and discussion

As shown in Fig. 2, EL spectrum (solid line) of the device is quite similar to PL spectrum (dot line; excitation

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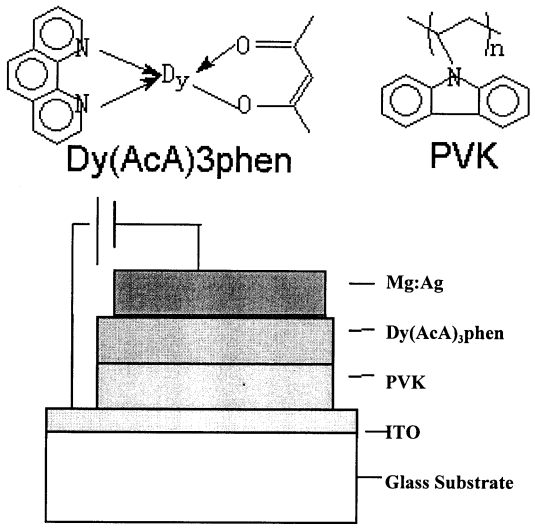

Fig. 1. The formula of the materials used and the cell structure.

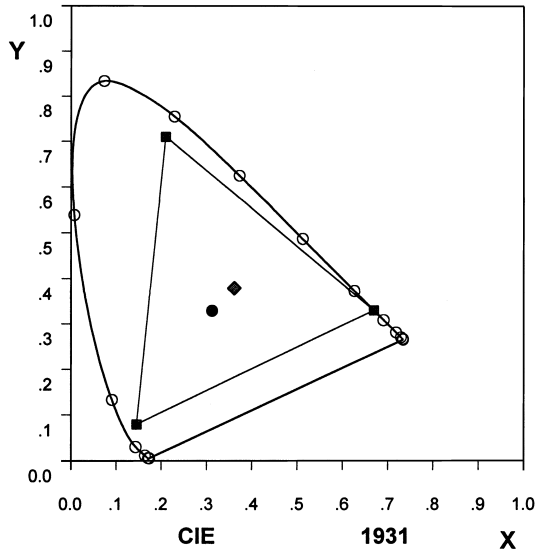

Fig. 3. Calculated values of the EL emission spectrum (rhombus) and the standard white (circular dot) in the chromaticity diagram coordinates of CIE.

wavelength, 350 nm) of Dy-complex solid. The three emission bands located at 478, 580 and 670 nm correspond to $^4F_{9/2} \rightarrow {}^6H_{15/2}$, $^4F_{9/2} \rightarrow {}^6H_{13/2}$ and $^4F_{9/2} \rightarrow {}^6H_{11/2}$ transition of Dy^{3+} ion, respectively. Commission Internationale De L'Eclairoge (CIE) color coordinates of the output spectrum of the devices at 15 V are $x = 0.3519$ and $y = 0.3785$. In Fig. 2, it was noticed that, due to some unclear reasons, the three main bands of EL spectrum shifted towards longer wavelength and possessed broader bandwidth compared with those of PL spectrum. A broad weak band ranging from 400 to 640 nm appeared in the EL spectrum. Probably it can be attributed to the exciplex formed between the ligands of Dy-complex and PVK under forward bias.

As we expected, the white light emission is considerably stable. That is, the emission spectrum of devices is independent of the drive voltage. Although there is a little distance between standard white light and output from the device (see Fig. 3), we still have chances to improve it. By modulating coordinate environment of Dy^{3+} ion, the ratio of the two intense peaks could be modified. In other words, increasing the hypersensitive $^4F_{9/2} \rightarrow {}^6H_{15/2}$ transition or decreasing $^4F_{9/2} \rightarrow {}^6H_{13/2}$ transition can realize more suitable white light emission from Dy complexes.

I–V and *B–V* (*B* represents brightness of the devices) curves of the device are shown in Fig. 4. The current density and luminescence intensity is much lower than those of conventional OEL devices, which can provide larger injection current and more brilliant emission. It is an urgent problem that the poor stability of RE complexes prevents OEL devices from large current injection. The weak emission is also due to inefficient energy transfer from triplet states of ligands to Dy^{3+} ion. This problem can be solved by choosing more suitable ligands.

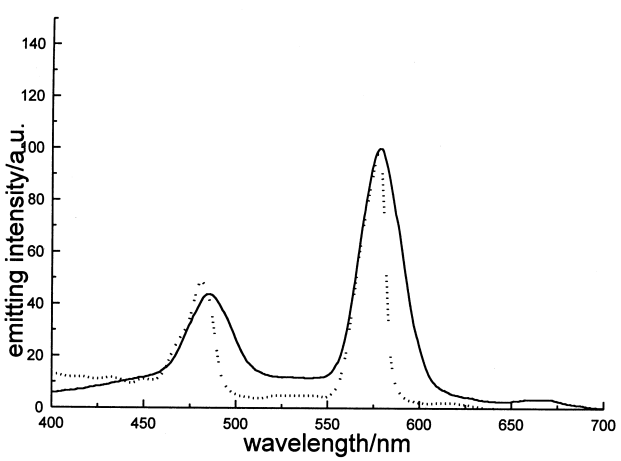

Fig. 2. PL spectrum of the Dy-complex (dotted line) and EL spectrum (solid line) of the device.

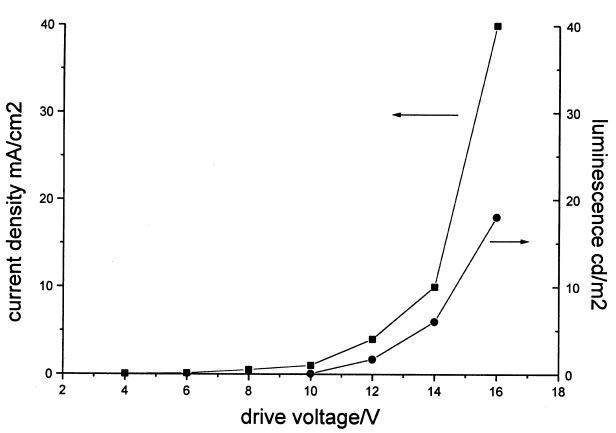

Fig. 4. *I–V* (square dot) and *B–V* (circle dot) curves of the device.

4. Conclusion

In summary, a Dy-complex was synthesized and used for an OEL device. From the double-layer device, a white emission consisting of two emitting bands of Dy^{3+} ion was obtained. The white light emission is independent of drive voltage. Choosing ligands to increase luminescence is the next step of our work.

Acknowledgements

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