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Redistribution of carriers in OEL devices by inserting a thin charge-carrier blocking layer

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Abstract

By inserting a thin Gd(AcA)$_3$phen layer in the electroluminescent devices ITO/Alq/Al and ITO/TPD/Eu(DBM)$_3$phen/Alq/Al, the quantum efficiency is increased in both devices and the emission color of the second device is changed. These results are supposed to be due to the carrier-blocking effect of the thin Gd(AcA)$_3$phen layer which changes the distribution of electrons and holes in the devices. © 1997 Elsevier Science S.A.

Keywords: Organic devices; Electroluminescence; Gd(AcA)$_3$phen blocking layer

1. Introduction

Since 1987 when Tang and VanSlyke [1] developed thin-film organic electroluminescence (OEL), the OEL devices have attracted great interest [2,3]. During this period, many research groups have continued to study and improve the light-emitting characteristics. The use of an ETL (electron transport layer) and HTL (hole transport layer) in multilayer devices greatly improves the condition of carrier injection and confinement of the carrier in the emitting layer (EML). In other words, the carrier distribution of the multilayer devices is more suitable for the generation of the exciton, so that the luminescent efficiencies are remarkably increased.

In this paper, we demonstrate another method which can change the carrier distribution of the EL devices and results in improving the efficiency and in changing the emission zone.

2. Experimental

Fig. 1 shows the molecular structures of the materials used in this study. The OEL device is fabricated by the conventional vacuum deposition method. The film thickness is controlled by an LTC-2 thin film controller. The TPD layer is controlled at 70 nm and the Eu(DBM)$_3$phen layer is 60 nm.

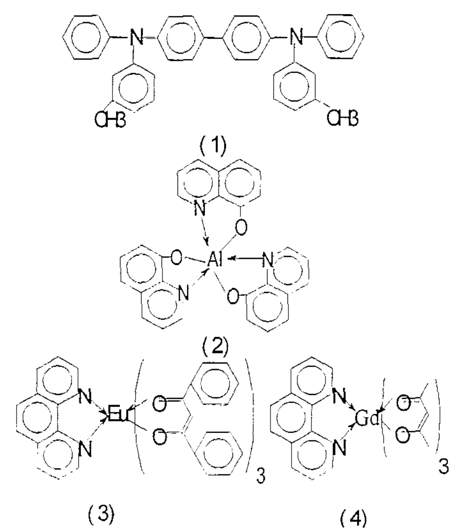

Fig. 1. Molecular structures: (1) TPD, (2) Alq, (3) Eu(DBM)$_3$phen, (4) Gd(AcA)$_3$phen.

In both devices, the Alq layer is controlled at 80 nm and the Gd(AcA)$_3$phen layer is kept at 10 nm. Finally, a 100 nm Al layer is deposited. The luminescent area is controlled by the Al layer of 3×3 mm.

3. Results and discussion

The Gd complex Gd(AcA)$_3$phen has no fluorescence and has poor carrier-transporting properties as compared with

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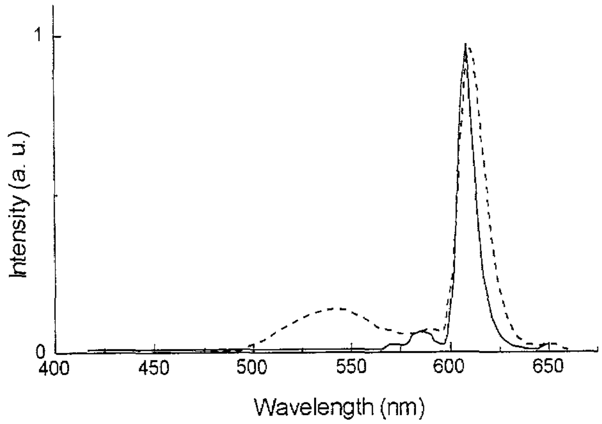

Fig. 2. Change of EL spectrum after inserting the Gd(AcA)$_3$phen layer: EL device without the Gd(AcA)$_3$phen layer (solid line); EL device with the Gd(AcA)$_3$phen layer (dotted line).

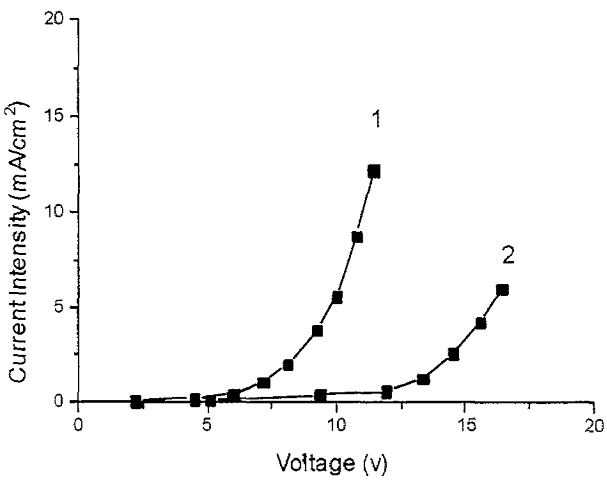

Fig. 3. I–V characteristics of the devices: (1) ITO/Alq/Gd(AcA)$_3$phen/Alq/Al; (2) ITO/TPD/Eu(DBM)$_3$phen/Alq/Gd(AcA)$_3$phen/Alq/Al.

Alq. In this study, it was inserted into the middle of the Alq layer and serves as a carrier-blocking layer.

At first, we insert the thin Gd(AcA)$_3$phen layer (10 nm) into the middle of the Alq layer in the EL ITO/Alq/Al device. Two times higher luminance is obtained at the same current compared with the device which has no Gd(AcA)$_3$phen layer. However, the external quantum efficiency of this device is still on the order of 0.1% because of the unbalanced carrier injection in this device.

In the same way, when the thin Gd-complex layer is inserted into the Alq layer in the structure ITO/TPD/Eu(DBM)$_3$phen/Alq/Al, it is found that the emitting color and luminance of the device significantly change. The quantum efficiency of the device is increased from 0.6 to 1.0%. The device without a Gd(AcA)$_3$phen layer emits red light which is the characteristic emission of Eu^{3+} of the Eu(DBM)$_3$phen layer. After inserting the Gd(AcA)$_3$phen layer, the luminance of the device becomes about twice as high at the same current and the emitting color becomes yellow. In this case, a part of the emission originates from Alq. Fig. 2 shows the changes in the EL spectrum after inserting the thin Gd(AcA)$_3$phen layer.

It should be noted there is no distinct increase of drive voltage after inserting the Gd(AcA)$_3$phen layer in both devices. Fig. 3 shows the I–V characteristics of the devices.

The increases of efficiencies in both devices and the change of the color in the second device are supposed to be due to the carrier-blocking effect of the thin Gd(AcA)$_3$phen layer which changes the distribution of electrons and holes in the devices. Fig. 4 is a schematic diagram showing the changes of carrier distribution after inserting the carrier-blocking layer. In the single-layered ITO/Alq/Al device, electrons and holes are homogeneously distributed within the Alq layer. In the triple-layered ITO/TPD/Eu(DBM)$_3$phen/Alq/Al device it can be assumed that electrons and holes are mainly

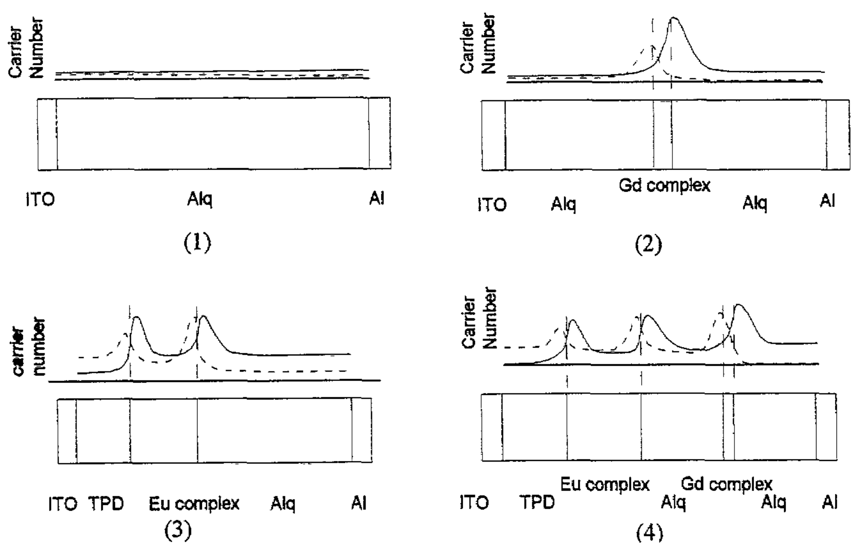

Fig. 4. Schematic diagram showing the distribution of electrons (solid line) and holes (dotted line) in each device: (1) ITO/Alq/Al, (2) ITO/Alq/Gd(AcA)$_3$phen/Alq/Al, (3) ITO/TPD/Eu(DBM)$_3$phen/Alq/Al, (4) ITO/TPD/Eu(DBM)$_3$phen/Alq/Gd(AcA)$_3$phen/Alq/Al.

collected at the boundary of the Eu(DBM)$_3$phen layer and Alq layer or the boundary of the Eu(DBM)$_3$phen layer and TPD layer [3,4]. After inserting the thin Gd(AcA)$_3$phen layer, because of the carrier-blocking effect, a large number of electrons and holes gather near both sides of the Gd(AcA)$_3$phen layer. The chance for electrons and holes to recombine is greatly increased here. Thus, a large number of excitons is generated in this narrow region and this results in the increase of efficiency in both devices and the emission of Alq in the second device.

4. Conclusions

The carrier-blocking layer acts as a 'trap' and large numbers of electrons and holes gather near both sides of it. If the layer is thin enough, large numbers of excitons can be recombined in this region. By this method, one can increase the efficiency and change the emissive region of the OEL devices.

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References

[1] C.W. Tang and S.A. VanSlyke, Appl. Phys. Lett., 51 (1987) 913.
[2] C. Adachi, S. Takito, T. Tsutsui and S. Saito, Jpn. Appl. Phys., 27 (1988) 269.
[3] C.W. Tang, S.A. VanSlyke and C.H. Chen, J. Appl. Phys., 65 (1989) 3610.
[4] E.-I. Aminaka, T. Tsutsui and S. Saito, J. Appl. Phys., 79 (1996) 8808.