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Organic electroluminescent devices using terbium chelates as the emitting layers

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Abstract

Electroluminescent (EL) devices using a ternary terbium complex [Tb(AcA)$_3$phen] as emitter have been fabricated. When polyvinylcarbazole is used as the hole-transporting layer (HTL), luminance of 210 cd m^{-2} with pure Tb^{3+} EL emissions from the devices is achieved.

Keywords: Organic electroluminescent devices; Terbium chelates

1. Introduction

The emission spectra of organic electroluminescence (OEL) with fluorescent dyes generally have a large bandwidth (100–200 nm), and the dull luminescent colours are not well suited for actual multicolour display applications. Kido et al. have already reported rare earth RE(III) ion emissions in OEL devices, but there have been few reports on Tb^{3+} green emission in EL devices [1,2].

In this study we shall further investigate the EL properties of OEL devices in which ternary Tb chelate is used as an emitter layer (EML), and low molecular or polymer compounds are used as the hole-transporting layer (HTL) i.e., ITO/organic polymer or low molecular compound/ternary Tb chelate/Al, in order to obtain a pure green EL emission from Tb^{3+} with higher EL luminance.

2. Experimental

Fig. 1 shows the cell configuration and molecular structure of the materials used. The EML is Tb(AcA)$_3$phen-[Tb(acetylacetonato)$_3$(monophenanthroline)]. The HTL is the polymer PVK (polyvinylcarbazole) or TPD (a dimine derivative) which are well-known HTL materials [2,3]. Tb(AcA)$_3$phen was vacuum deposited onto the PVK or TPD layer and the thickness of the Tb chelate is 50 nm. The PVK and TPD films with thicknesses of 150 and 40 nm were fabricated by spin-coating and by means of vacuum deposition, respectively. The luminance was determined by a 198A1 Luminance Meter at room temperature.

3. Results and discussion

Fig. 2 shows EL emission and photoluminescent (PL) spectra of the ITO/TPD/Tb(AcA)$_3$phen/Al device. It is seen that the EL spectrum consisted of sharp emission bands overlapped on a broad band at 580 nm, which differed from the PL spectrum of the Tb chelate films. It was also found that when the HTL was T-pd (tetraphenyldiamine without two methyls), a blue band and the green emission of Tb^{3+}, which alternates on a broad band, appear in the EL spectrum [3]. Kido et al. also observed a similar phenomenon in their device [ITO/TPD(400 Å)/Tb(AcA)$_3$phen/Mg:Ag], and their possible explanation was that the broad band may originate from the phenanthroline or an exciplex between a decomposed product and TPD [2]. However, when the PVK polymer was used as the HTL, pure line-like spectra from the Tb(III) ions and a luminance of 210 cd m^{-2} at 16 V for the OEL device were achieved, and the EL spectra are the same as for the PL (see PL spectrum in Fig. 2(b)). It is presumably

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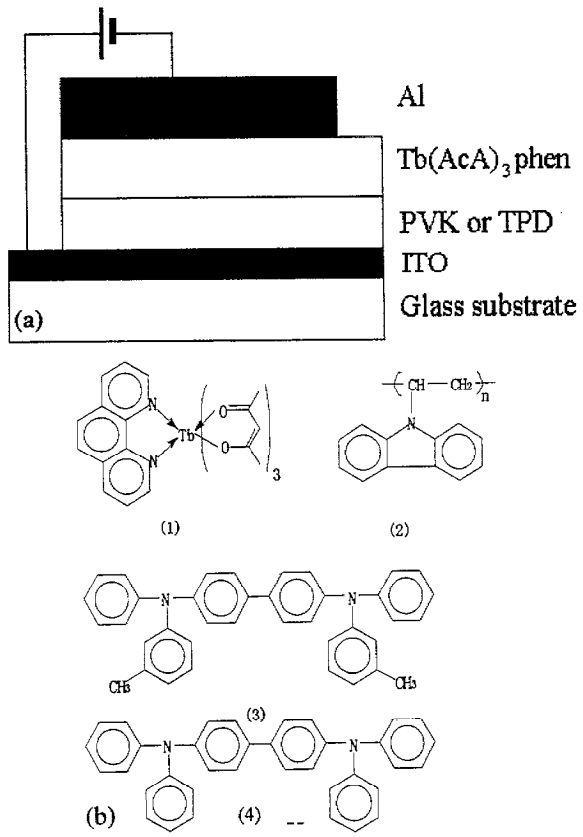

Fig. 1. The configuration (a) and the molecular structures of the materials (b) used in the study. (a) ITO/PVK/Al or TPD/Tb(AcA)$_3$phen/Al. (b) The structures of the materials used: (1) Tb(AcA)$_3$phen; (2) PVK; (3) TPD; (4) T-pd.

indicated that PVK gives a better carrier balance for exciton recombination in the Tb^{3+} chelate EML of the devices. The Tb^{3+} binary chelate, Tb(AcA)$_3$ [1], was also used as the EML in the devices in order to understand the formation of the broad band of the TPD or T-pd devices described above. No broad EL emission band, however, was determined, and the spectra are very similar to those of the PVK devices although the EL emission was considerably weaker. It is well known that the molecule should have a larger planar structure for the ternary chelate than for the binary Tb chelate. So we can consider that the broad EL band for the TPD or T-pd devices may be due to an exciplex or charge-transfer complex (ECT) formed at the interface between Tb(AcA)$_3$phen and TPD or T-pd [4,5], and the blue band should be due to the T-pd layer for the T-pd device. In addition, the devices with a PVK HTL probably possess much higher durability than TPD devices because crystallization is easily produced in TPD or T-pd films, as is well known [6]. It is noticed that there are only two films in our PVK–Tb^{3+} device, so the structure will simplify the fabrication processes for organic EL devices. The Tb(AcA)$_3$phen should have electron-transporting ability, otherwise no higher luminance can be observed if there is not another ETL material on the Tb(AcA)$_3$phen layer. The detailed ETL properties have been proved elsewhere [7].

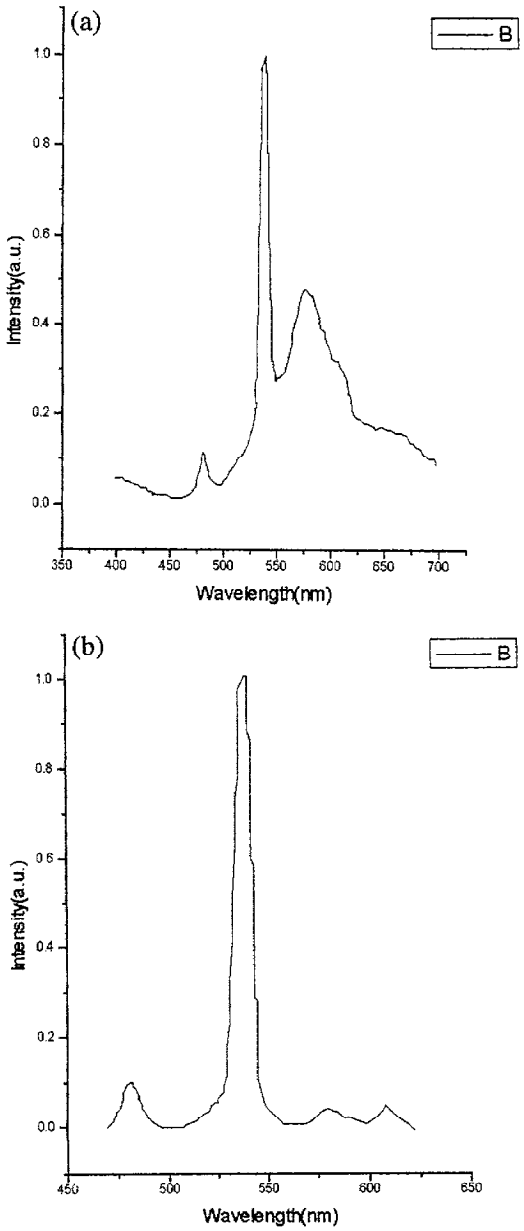

Fig. 2. (a) EL spectrum of the ITO/TPD/Tb(AcA)$_3$phen/Al device; (b) PL spectrum of the TPD/Tb(AcA)$_3$phen film deposited in vacuum.

4. Conclusions

In conclusion, when PVK and ternary Tb^{3+} chelate are used as HTL and EML materials, respectively, the device with dual-layer structure shows higher luminance, and when TPD or T-pd was used as the HTL pure green emissions from Tb^{3+} peaked at 545 nm cannot be obtained.

Acknowledgements

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