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A study on the characteristics of OLEDs using Ir complex for blue phosphorescence ☆

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Abstract

Several iridium-based complexes were investigated as phosphorescent dopants. They achieved about 100% internal quantum efficiency, due to utilization of both singlet and triplet excitons in the radiative processes. We have fabricated phosphorescent OLEDs with 8% $Ir(ppz)_3$ as a triplet emissive dopant in various host materials. CBP, which has an efficiency of 0.20 cd/A, is the best host material. Furthermore, we synthesized metal-organic phosphor complexes based on Ir with different ligands as to $(Im)_2Ir(acac)$, $(Im\text{-}R)_2Ir(acac)$, and $Ir(ppz)_2(acac)$.

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1. Introduction

Organic light-emitting diodes (OLEDs) have been actively researched because of their application to flat panel displays. Many efforts have been focused on the improvement of emission capability by developing highly efficient materials or device structures.

Phosphorescence is a way to overcome the limit of internal quantum efficiency, since phosphorescent materials can generate emission from both triplet and singlet excitons. Phosphor complexes based on heavy metal showed the characteristic of strong spin–orbit coupling. Thus, the internal quantum efficiency can reach nearly 100% [1–8]. These materials emit via the triplet metal-to-ligand charge transfer (MLCT) transition.

However, phosphorescence still has some problems in the realization of blue light-emitting devices. In this study, an OLED with $Ir(ppz)_3$ doped in various host materials was fabricated and the electro-optical characteristics induced by various host materials were confirmed [9]. OLEDs with $(Im)_2Ir(acac)$ and $(Im\text{-}R)_2Ir(acac)$ as other blue phosphors were investigated in order to measure their electro-optical characteristics. Finally, we also synthesized and searched metal-organic phosphor complexes based on Ir with ligands such as $Ir(pbpz)_3$ [2].

2. Experiments

To compare EL spectra of $Ir(ppz)_3$ doped in various hosts, host materials such as CBP, mCP, tCP and BCP were used. The host materials mCP, CBP and tCP are

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shown in Fig. 1. In the manufacturing process, ITO as the bottom electrode was sonicated by acetone, methanol, isopropyl alcohol and distilled water to remove impurities. The organic materials and Al were evaporated thermally at a base pressure of 5×10^{-7} Torr. The OLEDs were evaporated with a rate of 0.5–1 Å/s for organic materials and 6–10 Å/s for metal. The device structure is ITO/NPB (40 nm)/Host:Ir(ppz)$_3$ 8% (20 nm)/BCP (10 nm)/Alq (20 nm)/Liq (1 nm)/Al (150 nm). The area of the device is 3×3 mm^2.

In order to measure the radiative lifetime and confirm phosphorescence, transient PL measurements were performed on films of Ir(ppz)$_3$ doped in CBP. Current–voltage–light intensity of OLEDs were measured with a source measure unit (Keithley 236), an electrometer (Keithley 617), and a photodiode.

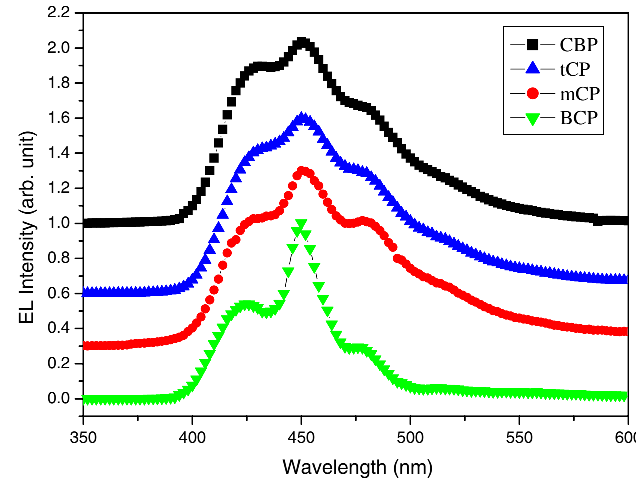

Fig. 2. EL intensity of devices with Ir(ppz)$_3$ doped in various hosts.

3. Results and discussion

3.1. Characteristics of blue phosphor Ir(ppz)$_3$ in various hosts

It is known that devices with Ir(ppz)$_3$ doped in a polymer film show an emission at 540 nm [10]. There is also a report that the CIE coordinates for the device were measured to be $x = 0.158$, $y = 0.139$ at 100 cd/m^2, which corresponds to pure blue, but in this study the film of it doped in a host showed different color characteristics. On comparing photoluminescence and electroluminescence of Ir(ppz)$_3$ doped in a host, near 450 nm an emission peak is similarly observed. This wavelength of Ir(ppz)$_3$ is the blue emission characteristic. Furthermore, all electroluminescence of Ir(ppz)$_3$ doped in various hosts appeared identically, as shown in Fig. 2. These emission spectra of the devices exhibited no emission from hosts. The reason for identical EL peaks was considered to be the emission from Ir(ppz)$_3$ regardless of different hosts. Transient PL measurements were performed on the film of Ir(ppz)$_3$ doped in CBP to confirm phosphorescence, as shown in Fig. 3. The radiative lifetime of Ir at $\lambda = 450$ nm was 218 ns, which is proof of phosphorescent emission originating from MLCT [11,12]. This long radiative lifetime is the major property of phosphorescence. In general, blue phosphorescent material was known to possess a short lifetime, due to emission degradation by oxygen at room temperature. However, Ir(ppz)$_3$ is observed with 230 ns lifetime, which is quite long. In order to utilize efficient energy transfer from host to dopant, the energy band gap of the host has to be larger than that of the phosphorescent material. In this study, CBP, mCP and tCP were used as hosts. The electrophosphorescent devices were fabricated with 8% Ir(ppz)$_3$ doped in these hosts [13,14]. *J–V–L* characteristics of OLEDs of Ir(ppz)$_3$ with various hosts are shown in Fig. 4. The OLEDs with CBP, tCP and mCP showed maximum luminous efficiencies of 0.20 cd/A, 0.08 cd/A, and 0.02 cd/A, respectively. When using CBP host, the OLEDs with Ir(ppz)$_3$ as blue phosphorescent material showed the best efficiency of 0.20 cd/A. In spite of the larger band gap of

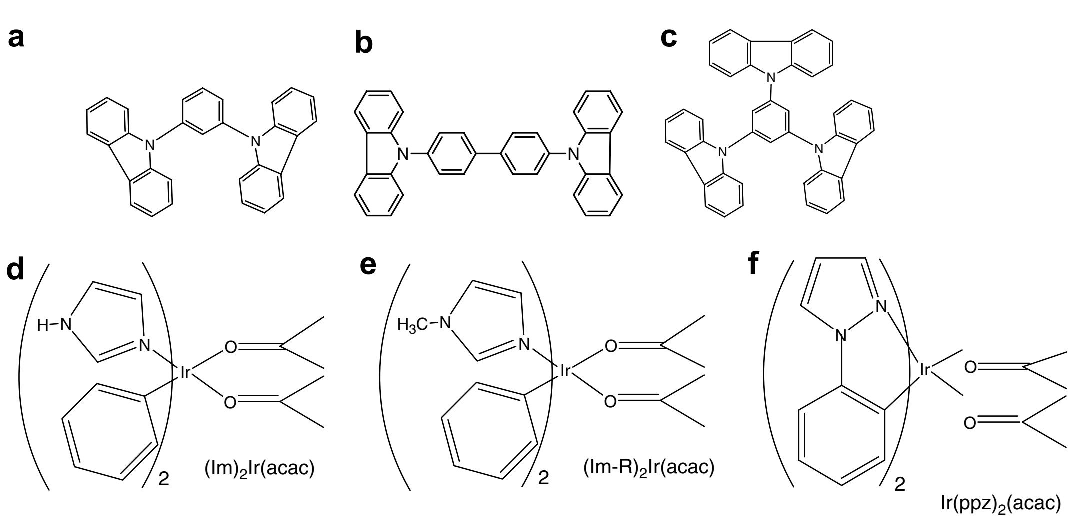

Fig. 1. Materials: (a) mCP; (b) CBP; (c) tCP; (d) (Im)$_2$Ir(acac); (e) (Im-R)$_2$Ir(acac); (f) Ir(ppz)$_2$(acac).