New phosphorescent host material: Tetrameric Zinc(II) Cluster

Hyung-Sup Lee, Ae-Kyong. Jeon and Kyu-Wang Lee
Department of Chemistry, Myongji University, Yongin, Korea
E-mail : kyuwlee@mju.ac.kr
Sung Joo Lee[1]
[1]Smartech Inc. O-San, Korea

Abstract

Doping a small amount of a phosphorescent dye into an organic light-emitting diodes(OLED) can lead to a significant improvement in the device properties. The fluorescent host materials like TAZ, CBP have been used, but have a problem of rapid decay of efficiency at high current densities. To alleviate this problem, phosphorescent host was introduced. The whole configuration of OELD fabricated was ITO/a-NPD(50nm)/Zn cluster:Ir(ppy)$_3$(30nm)/BCP(10nm)/Alq$_3$(20nm) /Al:Li. The OLED showed high luminance (> 50,000 cd/m^2) and external efficiency(5.7%). At higher current densities, rapid decay of external quantum efficiency or host emission, which was frequently observed in the fluorescent host system, were not observed.

1. Introduction

One of the useful approach to improve efficiencies in the OLED is that using phosphorescent dye doped host system in the emitting layer. In the previous report on these, 7.5 % of external quantum efficiencies are reported in Ir(ppy)$_3$ doped CBP.[1] But these phosphorescent guest-fluorescent host system show rapid decay of efficiency at high current densities, because of triplet-triplet annihilation and saturation of emissive phosphorescent dopants at high triplet exciton population contribute to the decrease.[3-4] These two effects are both affected by the decay lifetime of dopant. If the decay lifetime difference between the host and dopant exciton is reduced, either by using a shorter lived dopant or a longer lived host, it is possible to reduce the extent of the saturation of the dopant triplet emissive sites.

In this research, we used tetranuclear Zinc(II) cluster(Zn$_4$O(AID)$_6$(AID=7-azaindolate)) as a new candidate for phosphorescent host. The zinc cluster is blue phosphorescent (centered at 430nm) materials that show excellent stability in atmosphere and obtained from simple preparations.[2]

For green phosphorescent emission, we used Ir(ppy)$_3$ as a dopant. The whole configuration of OELD fabricated was ITO/α-NPD(50nm)/Zn cluster:Ir(ppy)$_3$(30nm)/BCP(10nm)/Alq$_3$(20nm) /Al:Li.

2. Experimental

Cleaned indium tin oxide(ITO)-coated glass with a sheet resistance of 15Ω/sq was used as the substrate and anode. The ITO-coated glass

was treated with O_2 plasma before being loaded into the deposition chamber. The organic films were deposited onto ITO-coated glass. We used α-NPD as a hole transport material, Alq_3 as a electron transport material and BCP as hole block material. The rate of deposition was typically 1-2Å/s. The active emitting layers of the devices were prepared by codeposition of the host and dopant materials evaporated from separate resistive heating boat. The cathode, consisting of a 1,500Å thick, 99.5:0.5 Al:Li alloy, was deposited and the rate of deposition was 5-10Å/s. The emitting areas of the diode were about $0.3\times0.3cm^2$.

The luminance of the EL cell was measured with spectrocolorimeter(Photoresearch PR-650) and I-V characteristics were measured by source measurement unit(Keithly 236).

3. Results and Discussion

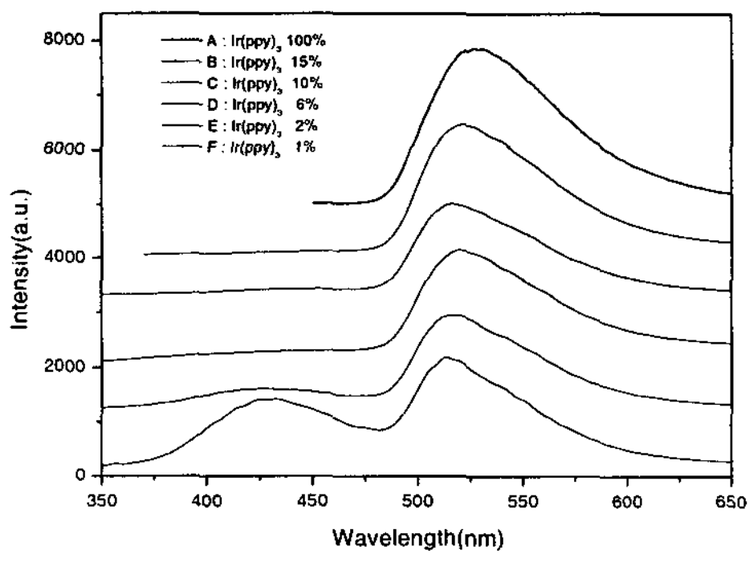
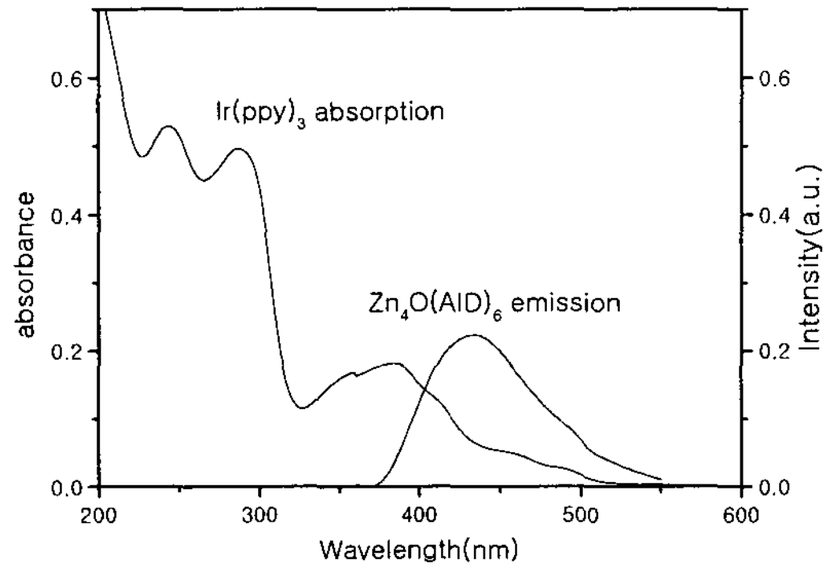
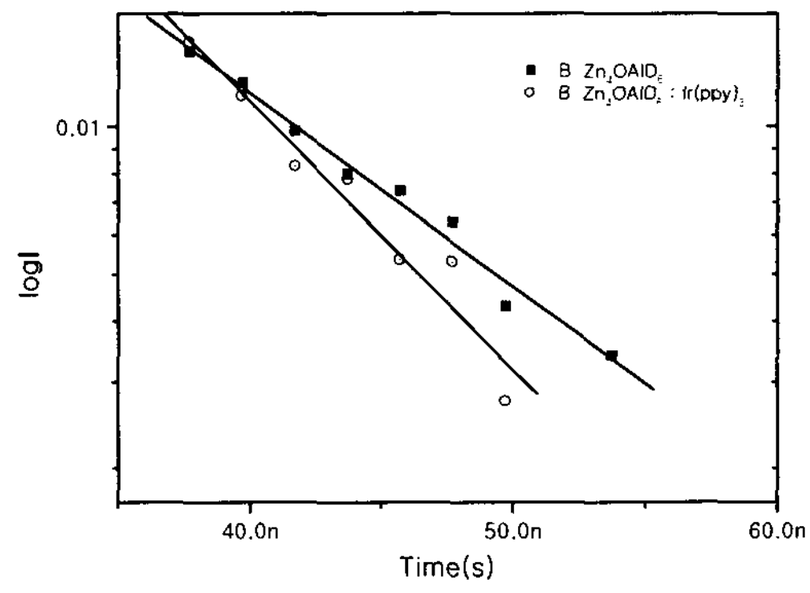


Figure 1. Photoluminescence spectra of doped films through doping concentrations

PL spectra of doped films were shown in fig.1. When $Ir(ppy)_3$ was doped below 6% of doped concentration of $Ir(ppy)_3$, dual emission from host and guest was observed. But in case of the doping concentration over 6%, emission from guest($Ir(ppy)_3$) was only observed. That means complete energy transfer is achieved above 6%.



(a)



(b)

Figure 2. The evidence of energy transfer mechanism

(a) Overlap between Zn cluster emission and $Ir(ppy)_3$ absorption

(b) Decay lifetime of $Zn_4O(AID)_6$ and $Zn_4O(AID)_6$:$Ir(ppy)_3$ films at 430nm

The rate of Förster energy transfer is proportional to the Förster radius(R_0) for energy transfer. The R_0 from Zn cluster to $Ir(ppy)_3$ was affected by the overlap between host emission

and dopant absorption. And the value was calculated to be 27 Å which is similar with CBP system(29 Å). If Dexter energy transfer occur, the host decay lifetime decrease. Because lower energy dopant will effectively quench the host triplet, the host decay lifetime of doped film was shorter than Zn cluster film.(Fig. 2(b)) Both Förster and Dexter energy transfer mechanisms are operative for this system.

Table 1. Doping concentration of $Ir(ppy)_3$ vs power efficiency

Doping Concentration (%)	5	10	12	20
Power Efficiency (cd/A)	5.3	9.3	17.2	7.0

In the devices, the turn-on was observed at 4.5 V. Optimized doping concentration of $Ir(ppy)_3$ was 12% in this device performance (Table 1.) and this value is twice than that of CBP-$Ir(ppy)_3$ system.[1] This indicates facile energy transfer between host and dopant so that we can minimize the triplet annihilation and saturation problems found at high doping concentrations of $Ir(ppy)_3$.

The maximum luminance of device was over 50,000 cd/m^2 and external quantum efficiency was 5.7 %(17 cd/A). The efficiency was lower than 7.2 % of CBP system, but both Zn cluster and CBP system shows similar values(17 cd/A) at 10 mA/cm^2 and Zn cluster system has slightly higher external quantum efficiency than CBP after the current density of 10 mA/cm^2.(Fig. 4)

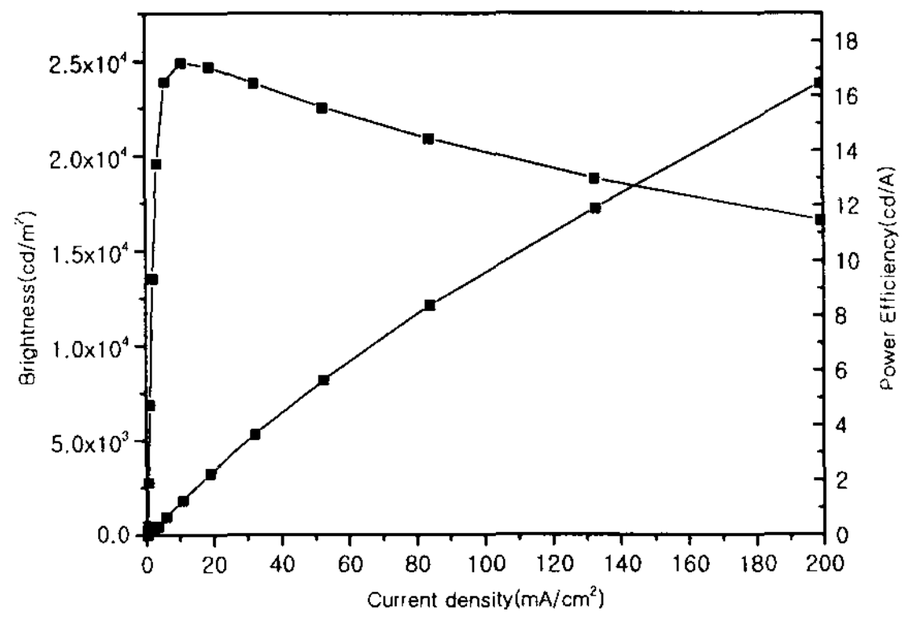


Figure 3. J-L characteristics and power efficiency of the device

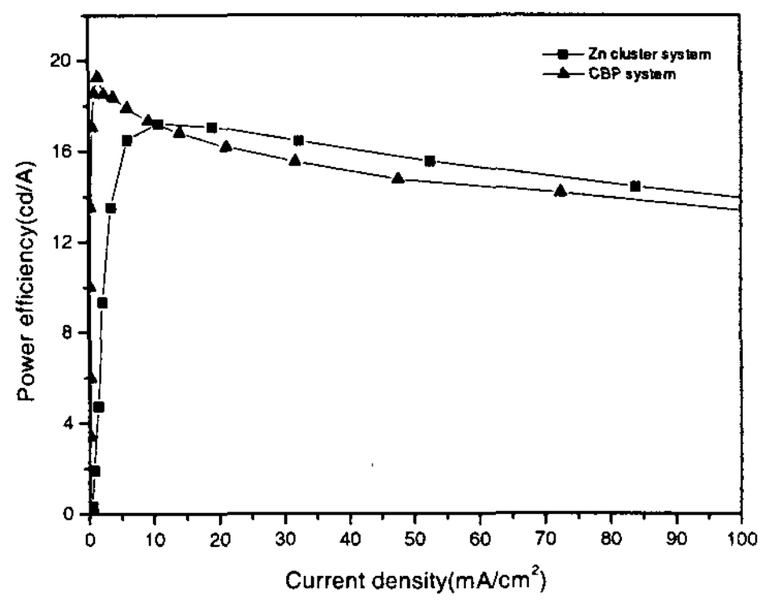


Figure 4. Compare with power efficiency Zn cluster and CBP system

At high current densities, rapid decay of external quantum efficiency or host emission which was reported in the fluorescent host system were not observed.[5] It means that the fluorescent host can be relaxed by non-radiative or radiative(host emission) decay before energy transfer to dopant at high current densities. The phosphorescent host that has a long triplet exciton decay lifetime compare to the fluorescent host can live during energy transfer to dopant.

The Zn cluster-Ir(ppy)$_3$ system shows good quantum efficiency especially at high current densities and color purity is increased.

4. References

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