

Emission zone in organic light-emitting diodes(OLEDs)

Sokwon Noh, Sung-Taek Lim, Dong-Myung Shin
Department of Chemical Engineering, Hong-Ik University, SEOUL, 121-791, KOREA

Abstract

Organic light-emitting diodes(OLEDs) are constructed using multilayer organic thin films. The hole-transport layer is PVK and the emitting material is rubrene and Alq₃. The emitting layer is doped with rubrene partially. As the partially-doped layer migrate from the interface PVK/emitting layer, the emission peak of rubrene decrease and diminish. By comparing with the previous reports, we propose the zero-field hole injection barrier at ITO/PVK interface and hole-trapping effect of rubrene in host materials as predominant factor to determine the emission zone.

Introduction

The mechanism for molecular organic light-emitting diodes(OLEDs) have been the subject of interest to develop materials useful for multicolored, flat-panel displays. Doping of fluorescent dyes into the electron transport/emitting layer has been shown to be effective in improving the device efficiency of molecular OLEDs[1,2]. The emission mechanism in the dye-doped double-layered diodes comprised of an aromatic diamine as a hole transporter, tris-(8-hydroxyquinoline) aluminum(III)(Alq₃) as the host and a laser dye(DCM1) as the dopant has been studied in great details[3]. In this report, Tang and co-workers has showed that the recombination and emission zones were established near the diamine/Alq₃ interface and reported the width of zones, 200Å in electron-transporting layer. More recently Murata and co-workers demonstrated an wide emission zone, 200 Å in hole-transporting layer[4]. They have proposed a mechanism in which the dopants act as an electron hopping site and a hole trap in the host materials, N,N'-diphenyl-N,N'-bis(3-methylphenyl)1,1'-biphenyl-4,4'-diamine(TPD). On the other hand, Tang *et al.* [3] suggested that the exciton diffusion coefficient and its lifetime in the emitter layer governed the emission zone. In his equations, the mobility of hole transporting layer(HTL) was not considered.

In this report, we located the emission zone of OLED and compared that with previous reports. OLEDs were prepared by doping emitting-layer with highly fluorescent rebrene using high vacuum deposition techniques. To investigate the dependence on the carrier mobility of emission zone, Poly(N-vinylcarbazole)(PVK) was used instead of conventional HTL, TPD.

Experiment

The chemical structures of the organic materials used in the experiment are shown in Figure 1. TPD, Alq₃ and rubrene were purchased from Aldrich Chemical Co. and PVK from Kanto. All materials were deposited as received without further purification. Aluminum (Aldrich Chemical Co., 99.9 % purity) was used as the cathode materials. Indium tin oxide (ITO) was used as the transparent anode with a sheet resistance of 20Ω /square and a thickness of 300nm. PVK was layered via spin-cast technique in thickness of 540 Å from a *p*-chlorobenzene solution. Alq₃ and rubrene were thermally evaporated under 5.0 x 10⁻⁶ torr or less. The rubrene-doped Alq₃ were layered with the ratio of 1:1 in thickness and the thickness was monitored with quartz crystal microbalances. Figure 2 shows schematic features

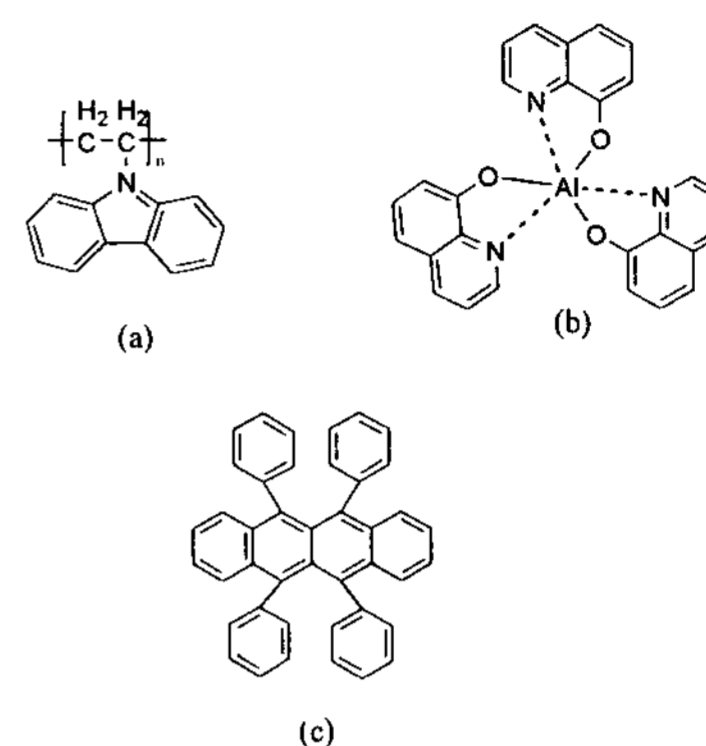


Fig. 1. The chemical structures of organic materials (a) PVK (b) Alq₃ (c) rubrene

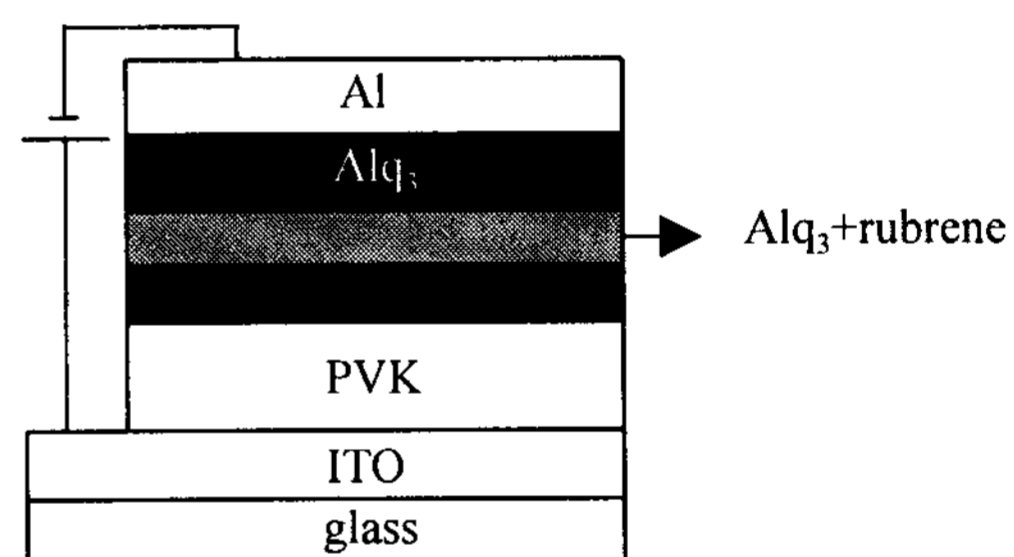


Fig. 2. Schematic features of OLED

of OLED fabricated in this study. The thickness of Alq₃ layer under rubrene-doped Alq₃ layer was varied from 0nm to 20nm in step of 5nm. And the thickness of total emitter layer was 600 Å. The electroluminescence(EL) spectra were measured with a LS50B, Perkin-Elmer and the current density-voltage(*J-V*) characteristics of the devices was obtained with Kiethley 236. All the measurements were carried out at room temperature.

Results and Discussions

Figure 3 shows the *J-V* characteristics of OLEDs. Because of poor reproducibility of spin-casting technique and top-surface morphology, electrical properties were observed somewhat different case to case. Figure 4 shows the EL spectra of OLEDs as a function of dye-doped layer location. As the distance from PVK/Alq₃ interface increased, the contribution of emission peak at 550nm to total emission spectra decreased. With the distance of 200 Å or more, the only emission peak of Alq₃ at 500nm was observed. The relative maximum emission peak at 550nm was

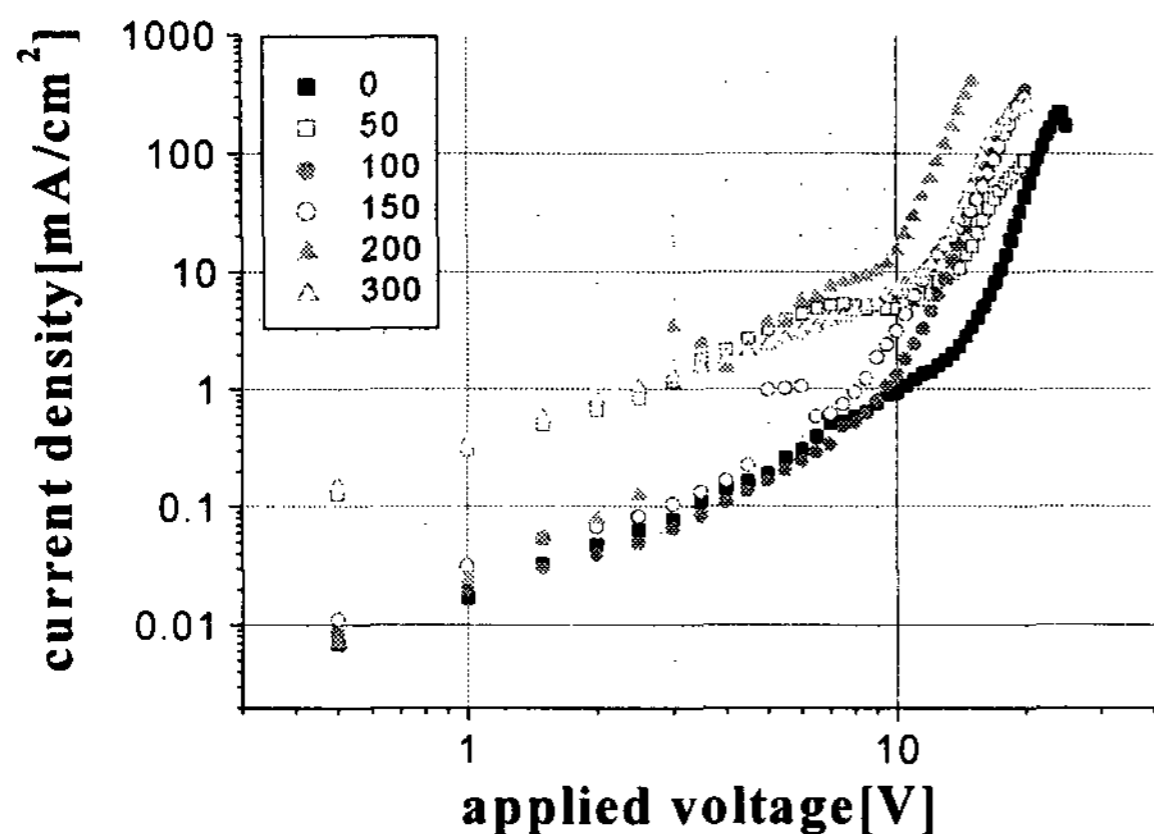


Fig. 3. J-V characteristics of OLEDs. The numbers in inset box indicate the thickness of Alq₃ layer between PVK and rubrene-doped Alq₃ layer.

observed when the dye-doped layer was located next to the interface. These results coincide with that of Tang *et al.* They showed the best fit to theoretical consideration was found for the exciton diffusion length of 200 Å for Alq₃[2].

The ionization potential(IP) of rubrene is 5.4eV[4], whereas Alq₃'s IP is in the range 5.6-5.8eV. Thus rubrene is expected to act as a hole trap in Alq₃, enhancing the probability for electron-hole recombination and creating highly fluorescent centers [5]. The hole mobility of TPD and PVK as reported are 10⁻³cm²/Vs and 10⁻⁶cm²/Vs [6] respectively. And zero-field IP of PVK is same to that of TPD as 5.8eV [4]. The same zero-field energy barrier at ITO/HTL interface and hole-trapping effect of rubrene in Alq₃ may be the predominant factor to determine the emission zone not the exciton diffusion length.

Moreover a narrow exciton diffusion length of TPD*, 50 Å, reported by Murata *et al.*, can be one of the evidence for the above argument. They also reported an wide emission zone, 200 Å, of OLED with a structure of ITO/TPD/rubrene-doped TPD/Alq₃/Mg:Ag[4]. These results may be one of the evidence that the hole-trapping effect is predominant factor to determine the emission zone in OLEDs.

Conclusion

We demonstrated that the emission zone in OLED, ITO/PVK/Alq₃/rubrene-doped Alq₃/Alq₃/Al. As the thickness of Alq₃ layer between PVK and rubrene-doped Alq₃ layer increased the emission peak of rubrene in total emission spectra decreased and finally diminished. We proposed zero-field injection energy barrier for holes and hole-trapping effect of rubrene in host materials as predominant factor to determine the recombination and emission zones.

References

- [1] Y. Hamada, T. Sano, K. Snibata, and K. Kuroki, *Jpn. J. Appl. Phys.*, **34**, L824(1995)
- [2] J. Kido, M. Kimura, and K. Nagai, *Science*, **267**, 1332(1995)
- [3] C.W. Tang, S.A. VanSlyke, and C.H. Chen, *J. Appl. Phys.*, **65**, 3610-3616(1989)
- [4] H. Murata, C.D. Merritt, and Z.H. Kafafi, *IEEE Journal of*

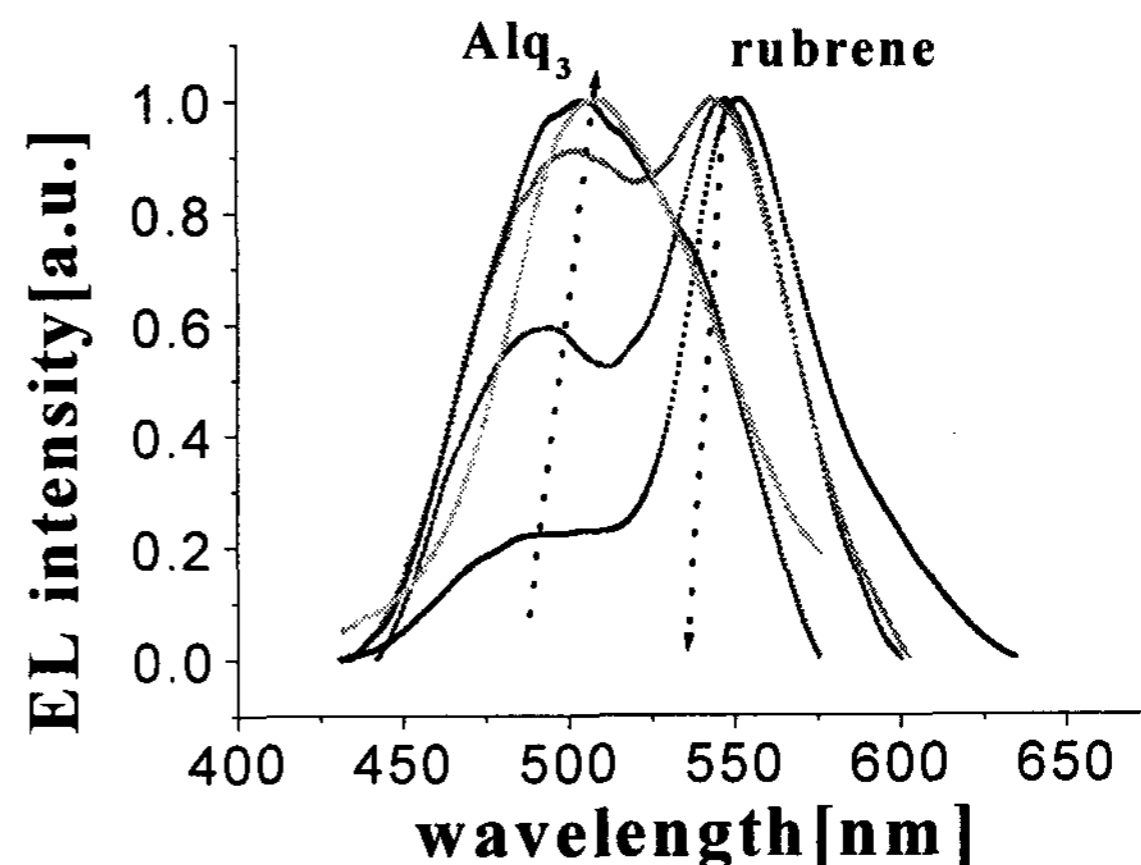


Fig. 4. EL spectra of OLEDs as function of thickness of Alq₃ layer between PVK and rubrene-doped Alq₃ layer. As the thickness increase the emission peak of rubrene decrease and diminish

selected topics in quantum electronics, **4**, 119-124(1998)

[5] D.J. Fatemi, H. Murata, C.D. Merritt, and Z.H. Kafafi, *Synthetic Metals*, **85**, 1225-1228(1997)

[6] M. Stolka, J.F. Yanus, and D.M. Pal, *J. Phys. Chem.*, **88**, 4707-4714(1984)