Electron Mobility Effect of Hole Transport Layer on OLED

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Abstract

In this article, we examine electron mobility effect of hole transport layer (HTL) on the spatial distribution of charge recombination and the performance of OLEDs using SETFOS. The recombination across the emissive layer is found to be much less as the mobility of electron is smaller.

1. Introduction

Organic light-emitting diodes (OLEDs) have a promising and highly attractive technology for high-quality displays and lighting. Whilst, device efficiency, performance and lifetime are always a crucial reliability issue before they can be adopted more extensively, especially for lighting purpose.1,2 These reliability issues in OLEDs are closely related to multiple device degradation factors, which can be further ascribed into intrinsic and extrinsic issues.3 A comprehensive model is presented for the quantitative analysis of the factors influencing the performance of OLEDs as a function of electron mobility. Here we propose a systematic approach to quantify the result based on electrical simulation, the cross-interface recombination distribution of electron mobility in the HTL at the EML interface, analyze the difference in the behavior of the device when HTL and EML layers are replaced by another host material with different properties and electron mobility.

2. Multi-layered OLED structure

2.1 Device structure

Fig. 1 shows the studied OLED device structures and their corresponding energy level diagrams. The device structure consisted of an indium tin oxide (ITO) as the anode layer, a 3 nm 1,4,5,8,9,11-hexaazatriphenylene hexacarbonitrile (HAT-CN) as a hole injection layer (HIL), a 40 nm layer of hole transporting layer (HTL), a 15 nm single emission layer (EML), a 40 nm 1,3,5-tris(N -phenylbenzimidazol-2-yl)benzene (TPBi) as electron transport layer (ETL), a 1 nm lithium fluoride (LiF) as electron injection layer (EIL), and a 100 nm aluminum as cathode. The employed light-emitting green dye was tris(2-phenylpyridine)iridium(III) (Ir(ppy)3). We employed three different materials for HTL 4,4’ cyclohexylidenebis[N,Nbis(4methylphenyl) benzenamin] (TAPC), N,N’-Di(1-naphthyl)-N,N’-diphenyl-(1,1’-biphenyl)-4,4’-diamine (NPB) and N,N,N’,N’-bis(1-naphthyl-N,N,N’-diphenyl-1,1’1,1’-biphenyl-4,4’,4’-diamine (α-NPD). The employed host material was 4,4-bis(carbazol-9-yl)biphenyl (CBP) and 4,4’,4”-tri(N-carbazolyl) triphenylamine (TCTA).

![Energy level diagrams of the OLED devices with HTL and EML host.](image)

Fig. 1 Schematic energy level diagrams of the OLED devices with HTL and EML host.

2.2. Recombination pattern

The recombination of the entering holes and electrons would mainly occur within the EML, but be dispersed near the two interfaces for the CBP-host composing device. While, it concentrates near the EML/ETL interface for the TCTA-host composing counterpart as shown in Fig 2(b). This may explain why the latter have a poorer device performance due to its narrower recombination zone and cross-interface area. Recombination pattern was observed for all the device structures, the order of
electron mobility of HTL is varied while the hole mobility is kept constant. At the higher electron mobility, the cross-interface recombination zone is found to be more quenched and has a large peak-area as shown if Fig 2(a). This could be explained as the variation in charge densities in the HTL/EML.

When the electron mobility of HTL increases, electron charge density in the EML decreases, which leads to a narrow recombination zone as shown in Fig. 3. This pattern suggests a better device performance, also when the electron mobility value is kept lower than the hole mobility in HTL, the recombination zones were found to be near the HTL/EML interface. This can be explained by better injection of excess electrons in HTL than ejection of holes by HTL. This leads to better recombination near the area of HTL.

Fig. 2(a) Effect of electron mobility of NPB layer on recombination distribution in CBP-host containing device, 2(b) Effect of electron mobility of NPD layer on recombination distribution in TCTA-host containing device.

3. Conclusions
The simulations outcome suggests that the optimum electron mobility of HTL achieve better device performance and expanded recombination curve implies a longer life time of the device. NPB show better recombination distribution and cross-interface area with host materials as compared to other HTL material due to its smaller electron mobility. The findings might help domain experts to carry out extensive studies to advance the understanding of lifetime issues of OLED devices and to devise new approaches to further enhance the device performance.

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References