Solution-processed quasi-two-dimensional perovskite light-emitting diodes using organic small molecular electron transporting layer

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Abstract
In this paper, all-solution-processed LEDs using quasi-two-dimensional perovskites with organic small molecular electron transporting materials (ETMs) are successfully fabricated. The obtained LEDs exhibit high efficiency and narrow emission (FWHM = 22 nm), in which the one with TPBi as ETMs record a peak current efficiency and maximum brightness of 11.9 cd/A and 3 × 10^3 cd/m^2 respectively.

1. Introduction

Beneficial to their intriguing optoelectronic properties, metal halide perovskites (MHPs) are recently emerging as a promising candidate for a series of applications such as solar cells, light-emitting diodes (LEDs), photodetectors, and lasers. In particular, due to their high photoluminescence quantum yield (PLQY), facile color tunability, solution processability, and sharp emission, perovskite light-emitting diodes (PeLEDs) have attracted significant attention[1-2].

Generally, for a high efficiency, the devices of light-emitting diodes based on MHPs adopt multilayer thin-film structure, in which electron or hole transporting materials were subtly inserted between MHPs and cathode or anode. 2,2',2''-(1,3,5-benzinetriyl)-*tris*(1-phenyl-1-*H*-benzimiazole) (TPBi) and 2,9-dimethyl-4,7-biphenyl-1,10-phenanthroline (BCP), which are two commonly used commercial ETMs since of their high electron mobility (10^{-4} to 10^{-3} cm^2 V^{-1} s^{-1}), deep LUMO (~ –2.7, –3.0 eV) and HOMO (–6.2 eV, –6.4 eV) energy levels, are widely used in optoelectronic devices such as OLEDs and QLEDs. However, TPBi and BCP are generally thermally evaporated during device fabrication, which not only requires expensive equipment, but also inevitably accompanies serious material waste and quite complicated fabrication process. Therefore, a substantial increase in cost is generated. On the contrary, with almost no waste of materials, low equipment dependence and simple fabrication process, solution processing is commonly recognized as an efficient solution for industrial production. Therefore, since the hole transporting layer and perovskite layer are usually fabricated via solution process, development of solution process as well for ETMs, is of great significance for the practical applications of PeLEDs and other perovskite optoelectronic devices.

2. Results and Disscussions

In this work, $PEA_2(FAPbBr_3)_2PbBr_4$ is applied as the emitting layer for quasi-2D perovskite LEDs, where PEA and FA are phenylethylammonium ($C_6H_5C_2H_4NH_3^+$) and formamidinium ($HC(NH_2)_2^+$), respectively. As can be seen from Fig. 1 (a), the solution-processed film shows consecutive and full coverage, along with brilliant green emission. Then, PeLED devices were fabricated with a device structure shown in Fig. 1 (b), in which the HTMs, ETMs and perovskite layers are all formed via solution process. Both two devices taking TPBi and BCP as ETMs gave strong luminescence with narrow bandwidth, in which the one with TPBi as ETMs record a peak current efficiency and maximum brightness of 11.9 cd/A and 3 × 10^3 cd/m^2 respectively [Fig. 1 (c) and (d)].

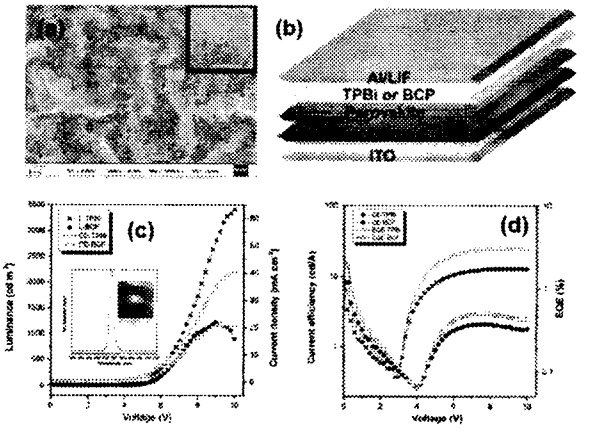

Figure 1a: Top-view SEM image of the perovskite layer, Inset: Photoluminescence photo of the perovskite film

Figure 1b: Device structure of the PeLEDs

Figure 1c: *J-V-L* characteristics

Figure 1d: *CE-V-EQE* curves of the PeLEDs. Inset: EL spectra of PeLEDs and electroluminescence photo of PeLED

3. References

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