Novel Three-Color Polymer Light-Emitting Devices for Passive-Matrix Flat Panel Displays

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With polymer-based organic LED's, patterning of the polymer to achieve color is a critical issue. A locally dye-doped polymer film is attractive for realization of multi-color devices on a single substrate. Different dyes may be locally added either by ink-jet-printing[1,2] or by masked dye diffusion[3] onto a previously spin-coated polymer film to get R,G,B subpixels. However, high leakage and low efficiency of these single-layer doped polymer LEDs limit their applications in passive matrix displays[4]. Both of these problems can be solved by adding an electron transport layer (ETL) over the polymer layer after dyes have been applied. The ETL Alq suppresses hole tunneling to reduce reverse leakage current, moves the cathode away from the emissive dyes to reduce cathode-quenching of the excitons via dipole interaction, and balances electron and hole transport to raise efficiency. However, due to the low exciton energy in the Alq ($E_{exciton}$=2.3eV), excitons formed in the polymer layer will migrate to the Alq layer, so that the dye in the polymer does not control the emission color (Figure 1,2(a)). In this paper, we introduce a thin exciton blocking layer (EBL) between the doped-polymer layer and the ETL, to confine the excitons within the polymer layer, yet still allow electrons to pass through, so that multi-color polymer-based devices can be realized (Figure 2(b)). The fabricated red, green, blue polymer LEDs using this novel tri-layer structure have higher efficiency and reverse leakage current two orders of magnitude lower than the single-layer devices.

The devices (Figure 2(b)) begin with a 100 nm thick polymer blend layer using poly(9-vinylcarbazole) (PVK) as a hole transport polymer, 2-(4-biphenylyl)-5-(4-tert-butyl-phenyl)-1,3,4,-oxidiazole (PBD) as an electron transport molecule and fluorescence dye (Nile red for red devices, Coumarin 6 for green devices, Bimane for blue devices) as an emission material, which is deposited on top of ITO layer by spin coating. A thin 6 nm 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (BCP) layer as an exciton blocking layer (E_g=3.6eV) and a 40 nm thick 8-hydroxyquinoline aluminum (Alq) layer as an electron transport layer are deposited continuously by thermal evaporation. At last a 150 nm thick Mg:Ag (10:1)/Ag layer is deposited as the OLED cathode.

Figure 3 shows the electroluminescence spectra of the fabricated blue, green, and red tri-layer devices, with peak wavelengths of 436 nm, 500 nm and 590 nm respectively. Compared with the single-layer devices, there is negligible increase in operation voltage from the extra layers (Figure 4). The rectification ratio of the tri-layer devices, defined as the ratio of forward current to reverse current at the same bias, is improved drastically: For a bias of ±10V, the rectification ratio for the blue device is increased from 1.5e4 to 2.4e6; for the green device from 1.3e3 to 1.3e6; for the red device from 7.4e3 to 8.7e5. In addition to the high rectification ratio, the tri-layer devices have higher efficiencies than the single-layer devices (Table 1). In conclusion, we demonstrated three-color organic light-emitting devices with very high rectification ratio and improved quantum efficiency. The fabricated devices are well suited for full-color passive matrix OLED displays. Further research is being done in fabricating a full-color passive matrix display using these novel devices.

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3. F. Pschenitzka and J. C. Sturm, *Appl. Phys. Lett.*, **74**, 1913 (1999)
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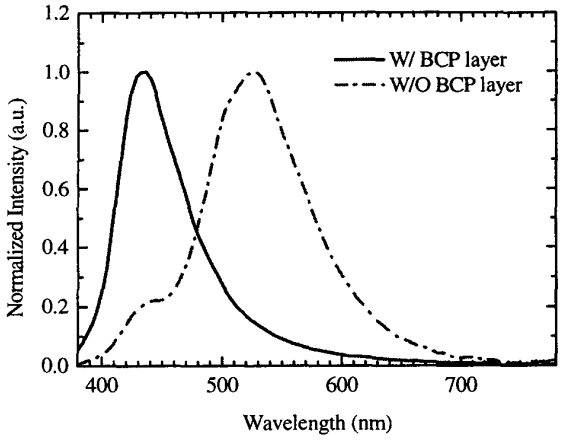

Figure 1. Spectra of the blue devices with and without exciton blocking layer BCP: without the BCP layer, Alq emission (peak @ 524nm, green) dominates; with the BCP layer, only Bimane emission (peak @ 436nm, blue) remains.

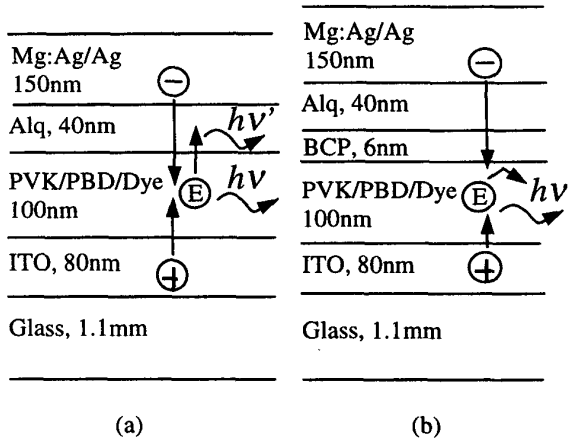

Figure 2. Schematic cross section of the OLEDs: (a) without EBL layer; (b) with EBL layer. Motion of the electrons, holes and excitons is shown.

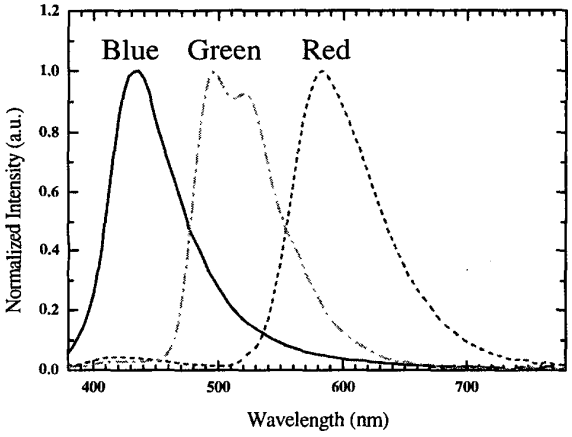

Figure 3. Electroluminescence spectra of the blue, green, and red tri-layer devices. Different emission colors depend on the corresponding dye dopants in the polymer layer: Blue: Bimane; Green: Coumarin 6; Red: Nile red

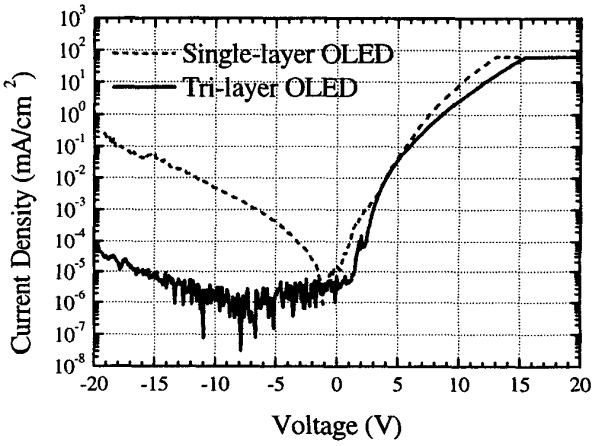

Figure 4. Typical I-V characteristics of the single-layer and tri-layer OLEDs

Table 1. Comparison of the single-layer and tri-layer devices

		Blue (Bimane)	Green (Coumarin 6)	Red (Nile red)
η_{ext} (%)	Single-layer	0.13%	0.70%	0.61%
	Tri-layer	0.34%	1.1%	0.95%
Rectification ratio @ ±10V	Single-layer	1.5e4	1.3e3	7.4e3
	Tri-layer	2.4e6	1.3e6	8.7e5