Transparent organic light-emitting devices with CsCl passivation layer

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Abstract

We have developed the transparent passivation layer for transparent organic light-emitting devices (TOLEDs) using CsCl layer. The CsCl passivation layer improves the optical transmittance of Ca/Ag double layer which have used as a semitransparent cathode, resulting in substantial increase of the luminance by the enhanced light extraction out of the cathode surface of the TOLEDs.

1. Introduction

As a new transparent concept display, OLED realized by having emissions from both direction of anode and cathode electrodes. And this type of display is expected to be useful in car windshield, architectural windows and eyewear[1, 2]. The passivation layers on these semitransparent metal cathode stacks have been reported to improve the performance of top emission devices since these layers enhance the extraction of the generated lights in the devices[3]. These passivation layers could reduce the device failures resulting from very thin metal cathodes because the layers could be a buffer during the encapsulation process with transparent glass sheets.

We have developed the new transparent CsCl passivation layer on the transparent cathode Ca/Ag double layer by the thermal evaporation process which results in no damage on composing organic layers[4, 5].

2. Experimental

The glass (5 cm × 5 cm) substrates were ultrasonically cleaned in acetone and rinsed in deionized water and subsequently dried in flowing nitrogen gas. The ITO films were patterned by photolithography process and wet etching. And the ITO anode patterns were pre-treated by oxygen plasma sputtering at 150W for 5 min before depositing organics layers. Transparent organic light-emitting devices (TOLEDs) were fabricated as follows (Fig. 1).

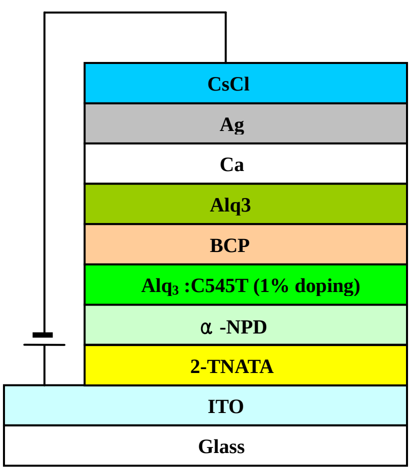


Fig 1. Cross sectional structure of our TOLED with CsCl passivation layer.

Devices with a structure of ITO/2-TNATA (15 nm)/ NPB (35 nm)/Alq3:C545T (1%, 35 nm)/BCP (5 nm)/ Alq_3 (5 nm)/ Ca (10 nm)/Ag (10 nm)/with or without CsCl were fabricated by high vacuum (10^{-7} Pa) thermal evaporation. 4,4_tris[2-naphthyl(phenyl)amino]triphenylamine(2-TNATA), 4,4-bis[N-(1-naphtyl)-N-phenyl-amino]biphenyl (NPB), 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (BCP), 7-diphenyl-1,10-phenanthroline (BCP), tris-(8-hydroxyquinoline)aluminum (Alq_3), 2,9-dimethyl-4, are used as hole injection (HIL), hole-transport (HTL), hole blocking layer(HBL) and electron-transport (ETL) respectively. Tris-(8-hydroxyquinoline)aluminum (Alq_3) and 10-(2-Benzothiazolyl)-2,3,6,7-tetrahydro-1,1,7,7,-tetramethyl l-1H,5H,11H-[1] benzopyrano [6,7,8-ij]quinolizin-11-one (C545T) are used as emitting-layer. The 2-TNATA and NPB predominantly transport holes, while Alq_3 layer serves as an electron-transporting. The BCP hole-blocking and exciton confinement layer in the emitting region, where Alq_3 layer which was inserted between the cathode and BCP acts as EIL [6]. Ca and Ag layers were sequentially deposited with the thickness of 10 nm for the each layer after the deposition of organic layers. The CsCl layer was deposited for the passivation of devices before encapsulation with transparent glass sheets. Optical transmittance was measured using a spectrophotometer (JASCO V-560) with a normal incidence of monochromatic light at the sample surface side. We measured voltage-current density, luminance, spectrum and efficiency. The current voltage characteristic and brightness were measured with an experimental set up essentially consisting of a Kethley 2400 source meter and CS100 spectroradiometer.

3. Results and discussion

We have fabricated transparent CsCl thin films by the thermal evaporation method. We have measured the transmittance with the encapsulated Ca (10 nm)/Ag (10 nm) and Ca (10 nm)/Ag (10 nm)/CsCl (100 nm) samples.

Figure 2 shows the transmittance of CsCl (100 nm), Ca (10 nm)/Ag (10 nm) double and Ca (10 nm)/Ag (10 nm)/CsCl (100 nm) triple layers. The transmittance of CsCl (100 nm) monolayer is 96 % at 550 nm. Ca (10 nm)/Ag (10 nm)/CsCl (100 nm) structure has higher transmittance than Ca (10 nm)/Ag (10 nm) without CsCl passivation layer, over the wavelength of 460 nm. Ca (10 nm)/Ag (10 nm) layer shows considerable drop of transmittance as the wavelength in the range of 400 ~ 900 nm.

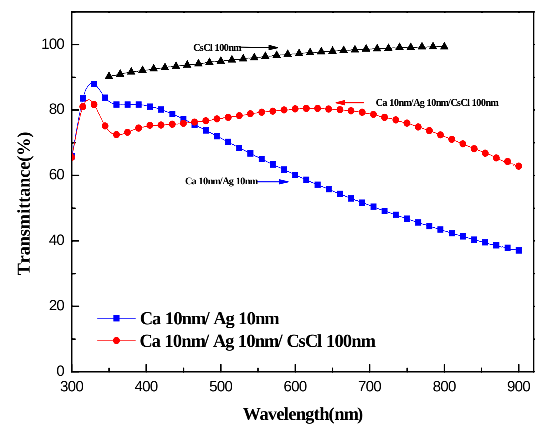


Fig. 2. Transmittance of CsCl (100nm), Ca(10 nm)/Ag(10 nm) ,and Ca(10 nm)/Ag(10 nm)/CsCl(100 nm) layers.

On the other hand, Ca (10 nm)/Ag (10 nm)/CsCl (100 nm) structure shows almost constant transmittance in the wavelength region of 460nm ~ 700nm. The CsCl can play a role to enhance the transmittance of semitransparent cathodes, resulting in improvement of extraction of the light emitting through out the device.

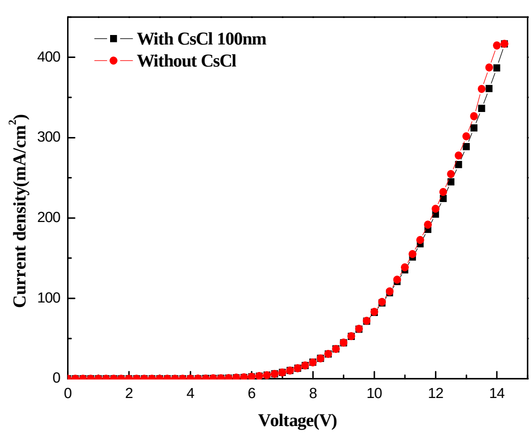
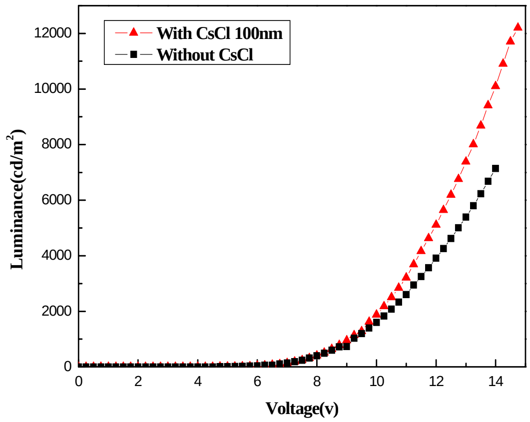


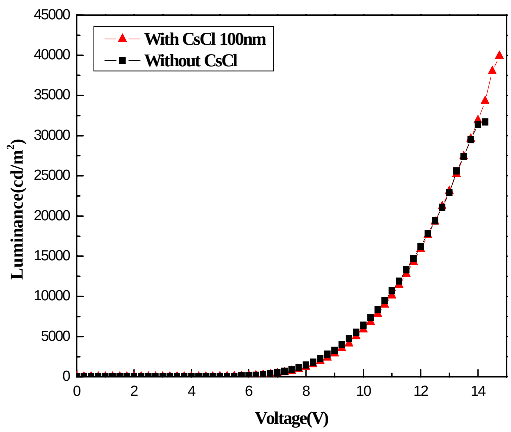
Fig.3. Current density vs. voltage curves of TOLEDs with and without CsCl passivation layer.

Figure 3 shows the current density - voltage curves of the TOLEDs with and without CsCl passivation layer. The current conduction characteristics of the devices are not changed with the CsCl passivation layer because the CsCl layer doesn't give any damages on underlying layers.

Figure 4 Luminance vs. voltage curves of (a) cathode side and (b) anode side of TOLEDs with and without CsCl passivation layer. In cathode side, the device with CsCl passivation layer shows higher luminance than unpassivated device.



(a)



(b)

Fig 4. Luminance vs. voltage curves of (a) cathode side and (b) anode side of TOLEDs with and without CsCl passivation layer.

Also, the device with CsCl passivation layer have better luminance than unpassivated device in anode side. These results indicate that CsCl passivation layer enhances the extraction of light emitting through out the surface side of the TOLED by the improvement of transparency in the visible region. Hence the current efficiency increases with CsCl layer as shown in Figure 5. Efficiency of both cathode and anode side with CsCl passion layer shows higher efficiency than unpassivated device.

Figure 6 shows the EL spectra of (a) cathode and (b) anode side of the TOLEDs doped with C545T . The EL spectra in the TOLEDs were measured by using Minolta CS100 spectroradiometer. The spectrum shows the main peak at 520 nm. Electroluminescence characteristics of the devices are not changed with the CsCl passivation layer of 100 nm.

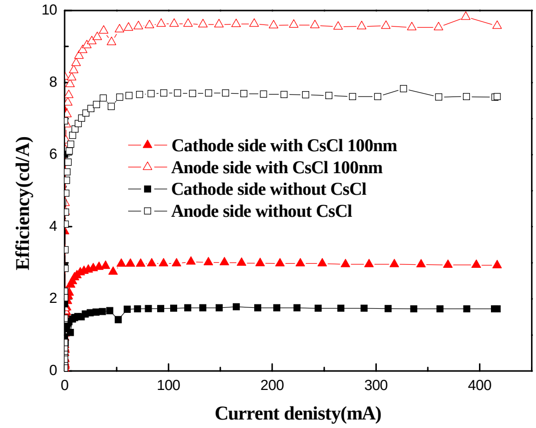
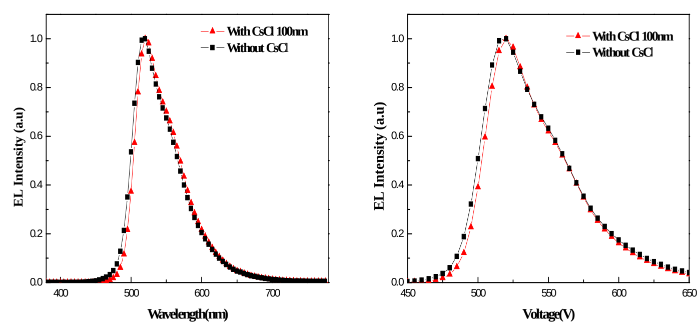


Fig 5. Current efficiency vs. current density of (a) cathode side and (b) anode side of TOLEDs with and without CsCl passivation layer.



(a) cathode side (b) anode side

Fig.6. (a) Normalized electroluminescence spectra of TOLEDs with and without CsCl passivation layer on the (a) cathode and (b) anode sides.

4. Summary

We have developed the transparent passivation layer for transparent organic light-emitting devices (TOLEDs) using CsCl layer. The CsCl passivation layer improves the optical transmittance of Ca/Ag double layer which have used as a semitransparent cathode. These results indicate that CsCl passivation layer enhances the extraction of light emitting through out the surface side of the TOLED by the improvement of transparency in the visible region.

The TOLEDs with CsCl passivation layer have better luminance and efficiency compared with the unpassived devices, which results from the enhancement of light extraction due to the CsCl layer.

5. References

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