An Experimental Study to Improve the Performance of OLED Lighting Devices

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Organic light-emitting diode (OLED) lighting devices have great potential for the illumination market due to their thinness, high efficiency, tunable color and so on. Currently, the prices of OLEDs are still high because the cost of the production is mainly based on the vacuum deposition process. The solution-processed OLEDs appear to be quite attractive in terms of cost reduction. However, the performance of solution-processed OLEDs has not yet reached the market demands. The purpose of this study is to improve the efficiency and lifetime of OLED lighting devices.

An OLED lighting device has a multi-layered structure, including anode, hole injection layer (HIL), hole transportation layer (HTL), emissive layer (EML), electron transportation layer (ETL), electron injection layer (EIL) and cathode. In this study, green OLED devices with 0.25 cm^2 emissive area were fabricated. As shown in Figure 1, there are two OLED lighting device structures in the present study. The difference is that one of the materials used in the EML was separated from the EML and served as ETL. In this study, the anode was indium tin oxide (ITO), which was commonly used as transparent electrode. The HIL was poly(3,4-ethylenedioxythiophene):poly(styrene) (PEDOT:PSS) aqueous solution. The HTL material N4,N4'-di(naphthalen-1-yl)-N4,N4'-bis(4-vinylphenyl)biphenyl-4,4'-diamine (VNPB) was dissolved in toluene with solid content 1 wt.%. The EML contained four materials, including 2,6-bis(3-(9H-carbazol-9-yl)phenyl)pyridine (26DCzPPy), 4,4',4''-tris(carbazol-9-yl)triphenylamine (TcTa), tris[2-(p-tolyl)pyridine]iridium(III) ($Ir(mppy)_3$) and 2,2',2''-(1,3,5-benzinetriyl)-tris(1-phenyl-1-Hbenzimidazole) (TPBi), dissolving in chlorobenzene with solid content 2 wt.%. In the device of three-organic-layered structure shown in Figure 1(a), the HIL, HTL and EML were spin-coated on the ITO glass and annealed sequentially. In the device of four-organic-layered structure shown in Figure 1(b), the TPBi was separated from the EML and was vacuum deposited as the ETL. Then the EIL material lithium fluoride (LiF) and cathode metal aluminum (Al) were vacuum deposited under the pressure less than 5×10^{-6} torr.

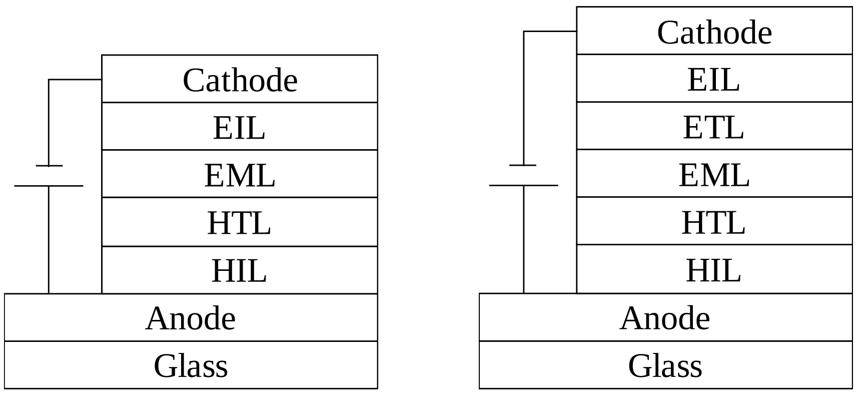

Figure 1. The OLED lighting device structures in the present study, (a) three-organic-layered structure and (b) four-organic-layered structure.

The efficiency and lifetime of the OLED lighting device were examined. The power efficiency at the luminance of 3000 cd/m^2 was set up as the basis for comparison. The lifetime was defined as the time that the luminance decreased to the half of initial brightness when operating with constant current.

In the three-organic-layered device, the preferable thicknesses of four functional layers were studied. An experiment based on Taguchi method was designed. Four factors including the thickness of the evaporated EIL and the spin speed of the wet-coated HIL, HTL and EML were studied. By controlling the thickness of each layer, carriers could recombine in the middle of EML more precisely, which would improve the efficiency and the lifetime of an OLED device. In addition, through the optimization of the EML materials and the annealing of the EML, the power efficiency was improved, and the lifetime with initial luminance of 3000 cd/m^2 was increased from less than 2 hours to more than 20 hours. The result could be attributed to the controlled carrier recombination zone, the balanced carrier injection, and the decreased residual solvent.

In the four-organic-layered device, the electron transporting material TPBi became a separate layer to prevent the holes from quenching at the interface between the EML and cathode. The power efficiency was further increased from 6 lm/W to more than 11 lm/W. The lifetime with initial luminance of 1000 cd/m^2 reached over 260 hours.

Reference

Tai, C.-T. (2016). *Analysis on Key Factors That Would Influence the Efficiency and Lifetime of Organic Light-Emitting Diode Lighting Devices* (Master thesis). National Tsing Hua University, Taiwan, R.O.C.