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Analysis of various solvent effects to Quantum Dots for Bilayer Quantum Dot Light-Emitting Diodes

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ABSTRACT

Bilayer color-tunable quantum dot light-emitting diodes (QD-LED) are required color modulation layer (CML) between two QD emission layers (EMLs). In this research, various organic solvents for CML are evaluated. Chlorobenzene showed minimum damage on the QD layer, consistent device performance, and wide color-tuning range.

1 INTRODUCTION

Conventional RGB sub-pixel layout for displays has low geometric fill factor, which show limitations in application for high resolution and efficiency improvement. Color-tunable pixel, which can reproduce various colors with a single pixel, can be an innovative approach to improve the fill factor issue.[1] The bilayered emission layer (EML) structure is already studied for white EL devices.[2] Moreover billayered EML structure is one of method to implement the color-tunable pixels. However, a simple bilayer structure exhibit limited color-tuning range. Thus, color-modulation layer (CML) insertion between EMLs is essential to control the carrier concentration through bilayer EML. CML materials are usually dissolved in organic solvent for solution process. Here, a process issue occurs as organic solvents can damage the previous QD layer. In this research, we analyze the effects of various organic solvents on the QD layer and suggest the most suitable solvent that minimize the damage.

2 EXPERIMENT

The bilayer QD-LED is following structure. Indium Tin Oxide(ITO)/ poly(3,4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT:PSS)/ poly(9-vinylcarbazole) (PVK)/ green QD (CdSe@ZnS)/ organic solvents/ red QD (CdSe@ZnS)/ Zinc Oxide(ZnO)/ Al. Whole layer except ITO and Al is processed by solution spin coating process. PVK is dissolve in chlorobenzene as 1.0wt% concentration. Green and red QD is dissolve in toluene as 10mg/ml concentration. ZnO nanoparticle is dispersed in butanol as 160mg/ml concentration. Evaluated organic solvents are toluene, chlorobenzene, o-dichlorobenzene, and n-octane. Aluminum is deposited 100nm by thermal evaporation method.

3 RESULTS

Without solvent process between bilayer EML showed green to greenish-yellow color shift range. Turn-on voltage, highest EQE, and highest luminance is 6V, 2.14%, 13816 cd/m^2, respectively. Toluene and n-octane case showed similar color shift range compare to w/o solvent case. Concretely, color range of n-octane is little bit green shifted rather than toluene. Turn-on voltage, highest EQE, and highest luminance of toluene is 5V, 3.7%, 9320 cd/m^2, respectively. In case of n-octane 6.5V, 1%, and 6500 cd/m^2, respectively. However, chlorobenzene and o-dichlorobenzene have different color shift range. Chlorobenzene showed red to yellow color shift range. O-dichlorobenzene also started deep red but ended orange. Device characteristics of chlorobenzene and o-dichlorobenzene were analogous value. Specifically, turn-on voltage of two solvent are 4V and 3.5V. Highest EQE was 0.52% and 0.50%. Highest luminance was also 842 cd/m^2 and 860 cd/m^2.

4 DISCUSSION

Most suitable organic solvents for CML materials must take less damage previous QD layer and have good wettability to next QD layer. Toluene and n-octane showed similar color shift range to w/o solvent case. That means toluene and n-octane take less damage previous QD layer. But toluene and n-octane have different device characteristic. Compare to all solvent, toluene showed best device characteristics. In case of chlorobenzene and o-dichlorobenzene, color range of both solvents is shifted to red. It suggests two solvents take severe damage green QD layer. Also, device characteristics of two solvents were dramatically deteriorated. Overall, toluene is

suitable organic solvent for CML. N-octane also can be alternative option.

5 CONCLUSIONS

In this research, we analyze various solvents to find suitable solvent for CML which take less damage previous layer and has good wettability next layer. Toluene was confirmed most suitable solvent among evaluated solvents. In case of CML material which does not dissolve in aromatic organic solvent such as toluene, n-octane can be alternative solvent.

REFERENCES

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[2] J. H. Kim, et al, “Fabrication of a white electroluminescent device based on bilayered yellow and blue quantum dots”, Nanoscale, 7(12), 5363-5370 (2015).

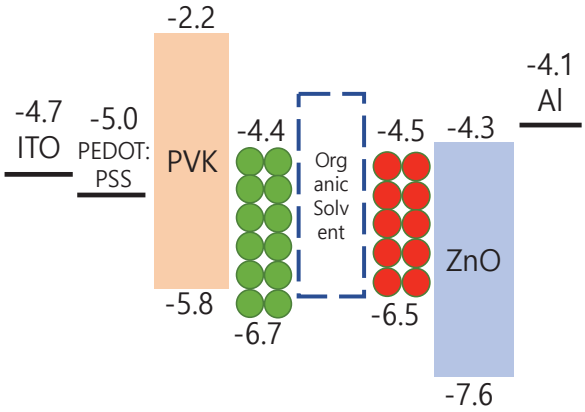

Fig. 1 Energy level diagram of bilayer EML QD-LED

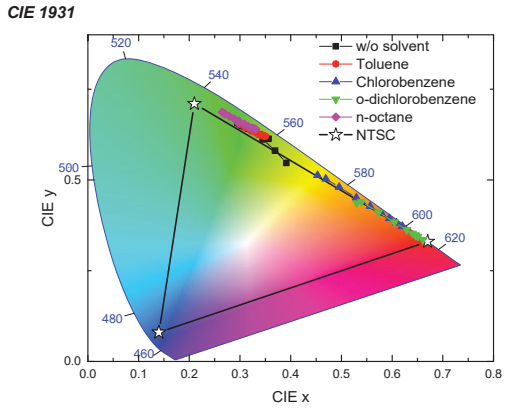

Fig. 2 Color range of evaluated solvents using CIE 1931

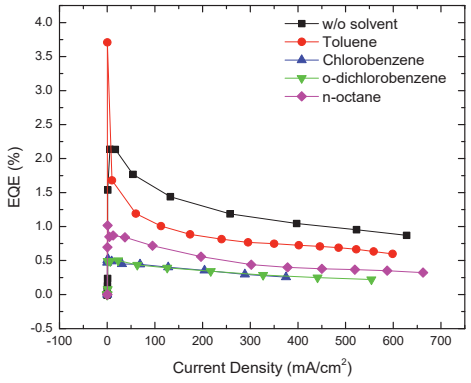

Fig. 3 EQE versus current density

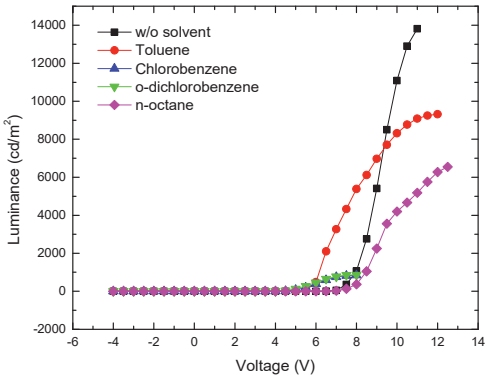

Fig. 4 Luminance versus voltage