Improvement of QD-LED Performance through reducing leakage current via alleviating Polymer entanglement of mixture for hole transport layer

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ABSTRACT

To take advantages two polymer materials for hole transport layer, it blended in solvent with optimized ratio. However, polymer-entanglement occurs when polymers are dissolved in solvent. It makes the surface rough, which causes leakage current. We introduce to decrease polymer-entanglement. It can decrease leakage current, then improve the QD-LED performance.

1 INTRODUCTION

Quantum-dot light-emitting diode (QD-LED) is a promising light source for future displays because of several advantages, such as high color purity and cost-effective fabrication using the solution process. However, the low power efficiency feature in QD-LEDs is a bottleneck for actual display applications.[1] One of the main causes for the low device efficiency is the charge imbalance in the QD layer. This is because QDs have a deep highest occupied molecular orbital (HOMO) level, resulting the hole injection relatively more difficult than the electron injection. The charge imbalance in the QD layer leads to the non-radiative Auger recombination, which degrade the device performances.[2] Therefore, efficient hole transport to the QD layer is essential to improve the device efficiency.

In other research, it is reported that perovskite QD-LED using poly(9-vinylcarbazole)(PVK) and Poly(N,N'-bis-4-butylphenyl-N,N'-bisphenyl)benzidine(Poly-TPD) mixture has high performance than pristine one.[3] When the two materials were dissolved in a vial at once in solvent with stirring 24 hours, polymer-entanglement occurs. It makes surface rough, which causes to increase leakage current.[4] So it is necessary to decrease polymer-entanglement because the leakage current degrades device performance.

To overcome this problem, two solutes are separately dissolved in a solvent, and then the mixture is blended at solution state. This mixture decreases phase separation. It makes surface smooth, which contributed to the improvement of QD-LED device performance than conventional method.

2 EXPERIMENT

The conventional QD-LED is following structure. Indium-Tin-Oxide(ITO)/poly(3,4ethylenedioxythiophene)polystyrenesulfonate (PEDOT:PSS)/HTL/GreenQD(CdSe@ZnS)/Zinc Oxide(ZnO)/Al. Whole layer except ITO and Al is processed by solution spin coating process. HTL is composed of PVK, Poly-TPD, PVK and Poly-TPD mixtures. The pure PVK and Poly-TPD is dissolve in chlorobenzene as 0.5wt% concentration. PVK and Poly-TPD mixtures are dissolved in chlorobenzene as 0.5wt% with different way. One is a method of dissolving two materials in a vial at once in a solvent by stirring 24 hours (the method name as solute). Another is a method of dissolving the two materials separately in different vials by stirring 24 hours and then mixing them in a solution state (the name as solution). Green-QD is dissolve in toluene as 10mg/ml concentration. ZnO nanoparticle is dispersed in butanol as 80mg/ml concentration. Aluminum is deposited 100nm by thermal evaporation method.

3 RESULTS

QD-LED using the pure PVK as HTL has high turn-on voltage, but the others have lower turn-on voltage about 2V. Although the device using PVK has high current efficiency, it has low power efficiency characteristics because it has high turn-on voltage. QD-LEDs using PVK and Poly-TPD mixture are almost same turn-on voltage. However, solution method has high current efficiency. It leads to have high power efficiency. In the region before the threshold voltage, solute method has high leakage current. Also, in the region after the threshold voltage, it relatively high current flows than solution method. When measured with Atomic Force Microscopy (AFM), the solute method has high surface roughness. Solute method has 2.454nm root mean square roughness (R_q). Solution method has 0.956nm R_q.

4 DISCUSSION

QD-LED using PVK and Poly-TPD mixture as HTL can improve power efficiency than QD-LED using PVK or Poly-TPD. Polymer-entanglement relatively more occurs when the mixture is used in solute method. Phase-separation is observed in AFM image. It is considered that polymer-entanglement is the main cause of roughening the surface. The surface roughness causes leakage current. The solute method shows a large leakage current below the threshold voltage. In other word, due to rough surface, it can make leakage current, reducing the efficiency of the QD-LED device. When PVK and Poly-TPD mixture is used in solution method, it less likely to form polymer-entanglement, thus leakage current is less than solute method.

5 CONCLUSIONS

In this research, we analyze to blend two polymer materials with different method. Polymer-entanglement is key problem to degrade device performance when two polymer materials are mixed in solvent. Solution method is effective to blend different polymers. It can effectively take two polymer materials advantage. Therefore, it is possible to improve QD-LED device performance more efficiently.

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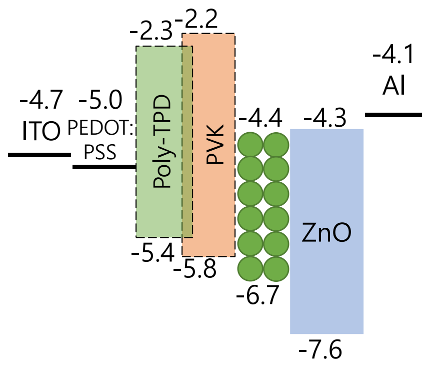

Fig. 1 Energy level diagram of QD-LED structure

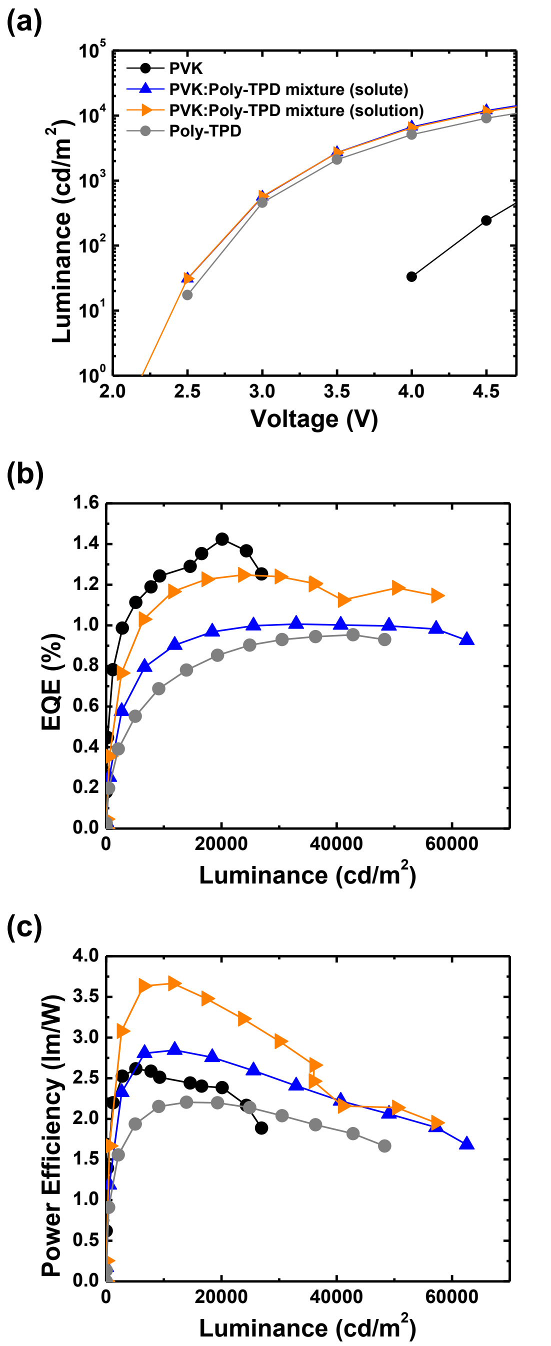

Fig. 2 (a) Luminance versus voltage (L-V log) (b) Current efficiency versus luminance (c) Power efficiency versus luminance of QD-LEDs

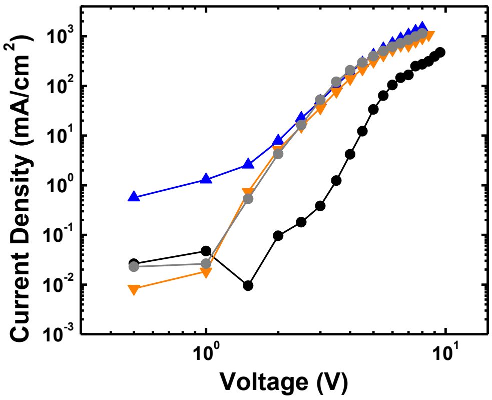

Fig. 3 Current density versus voltage (log-log)

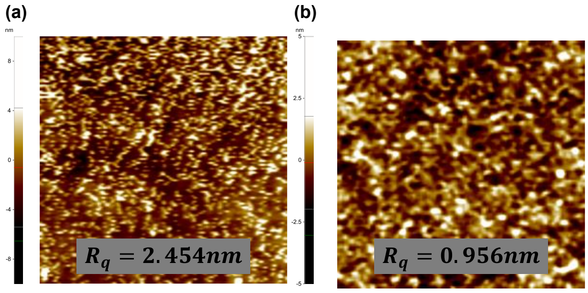

Fig. 4 The AFM images of different HTLs (a) PVK and Poly-TPD mixture with solute method (b) PVK and Poly-TPD mixture with solution method