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SUPPORTING INFORMATION

Inverted Quantum-dot Light Emitting Diodes with Cesium Carbonate doped Aluminum-Zinc-Oxide as Cathode Buffer Layer for High Brightness

By *Hyo-Min Kim*, *Abd. Rashid bin Mohd Yusoff*, *Jun-Ho Youn*, and *Jin Jang**

Department of Information Display and Advanced Display Research Center,
Kyung Hee University, 26 Kyungheedae-ro, Dongdaemun-gu, Seoul, Korea
[*] E-mail: jjang@khu.ac.kr

1. Material characterization of Quantum Dot solution.

In this work, we used quantum dot solution of triple shell (core-shell-shell), purchased from Nano Square.INC in Korea. As shown in Figure S1 (a) and (b), the QD film coated by drop-cast has the optical band gap of 1.90 eV and QD solution exhibits photoluminance (PL) peak at 634 nm with full-width at half-maximum (FWHM) of 35 nm.

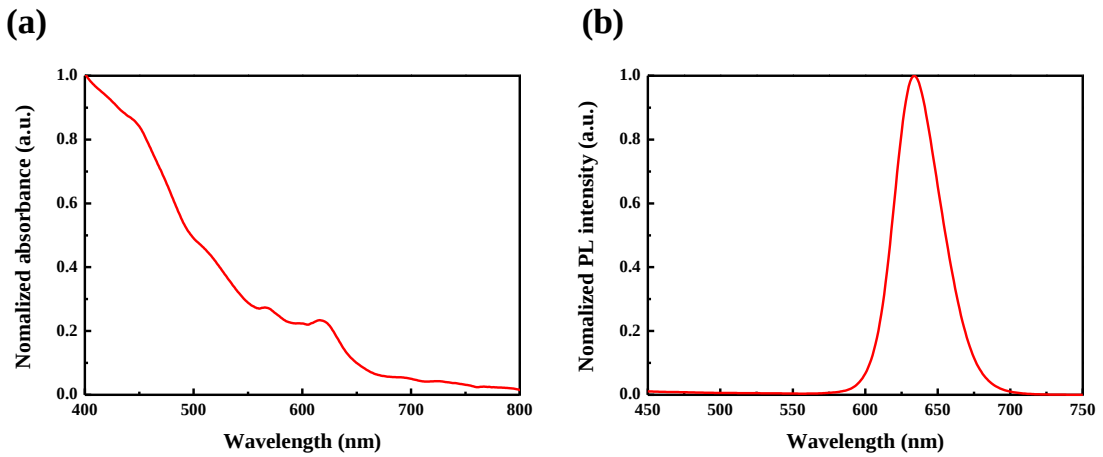

Figure S1. (a) Absorbance of quantum dot film coated by drop-cast and (b) normalized PL intensity for the quantum dot solution.

2. Comparison between ZnO and AZO as ETL in QLEDs.

In this work we optimized Al concentration in ZnO as ETL and it is found that the device with AZO as ETL has better EL performance than ZnO-based device. As can be seen in Figure S2, AZO-based device (30% Al) has the maximum luminance of 9,949 cd/m^2, current efficiency of and power efficiency of, 5.78 cd/A, and power efficiency of 7.12 lm/W. The details are shown in Table S2.

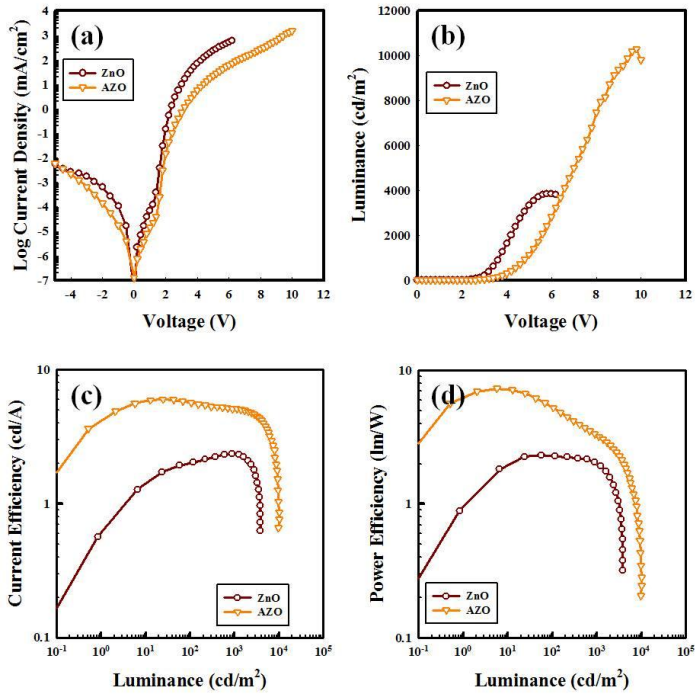

Figure S2. Device characteristics of the QLEDs using ZnO and AZO layers as ETL. (a) Log current density-voltage, (b) luminance-voltage, (c) current efficiency-luminance, and (d) power efficiency-luminance. (ZnO and AZO layers are ~45 nm layers).

Table S2. Device characteristics of the inverted QLEDs using ZnO and AZO layer as ETL.

ETL	V_T (V)	V_D (V)	C/E (cd/A)	P/E (lm/W)	L_{max} (cd/m^2)	@ 1,000 cd/m^2 C/E (cd/A)	@ 1,000 cd/m^2 P/E (lm/W)
ZnO	1.82	2.73	2.55	2.61	3,969	2.54	2.18
AZO(30% Al)	1.82	3.31	5.78	7.12	9,949	5.01	3.24

3. X-ray Photoelectron Spectroscopy (XPS) for AZO and AZO:Cs_2CO_3 layer

Figure S3 (a) shows the binding energy peak at 73.40 eV for AZO, which is due to Al_2O_3 (Al $2p_{3/2}$). Also, the AZO:Cs_2CO_3 has binding energies at 74.66 and 76.56 eV corresponding to Al_2O_3 (Al $2p_{3/2}$) and Cs/Al (Cs 4d), respectively. It is found that Cs/Al peak can be seen when AZO is blended with Cs_2CO_3. Figure S3 (b) shows the binding energy peaks at 1,020.94 and 1,021.57 eV, which are due to the presence of AZO and AZO:Cs_2CO_3, respectively. Both peaks are due to ZnO (Zn $2p_{3/2}$). As can be seen in Figure S3, Al_2O_3 peak intensity increases and ZnO peak decreases by blending with Cs_2CO_3 in AZO.

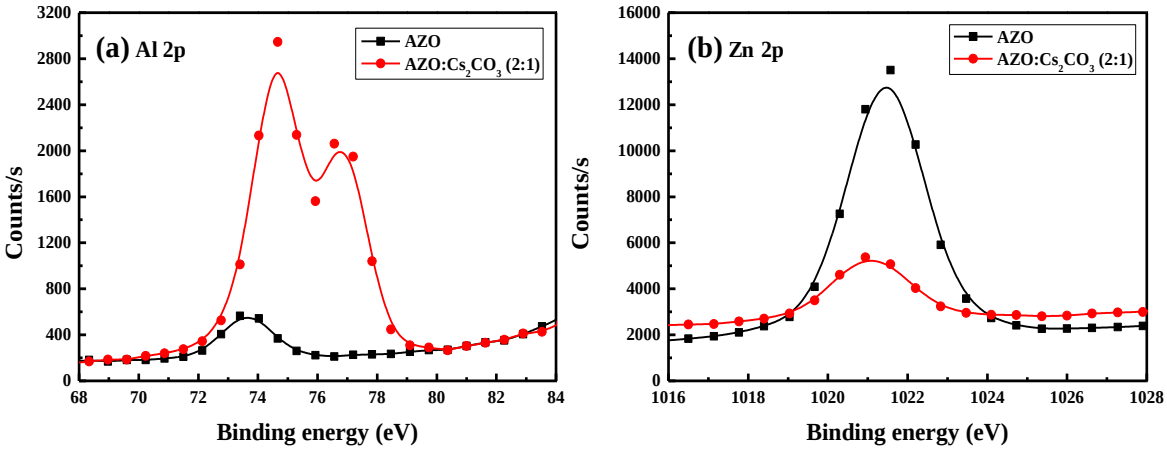

Figure S3. XPS data of AZO and AZO:Cs_2CO_3 layers (symbol : experimental and line : fitted). Binding energy peaks in (a) Al 2p and (b) Zn 2p core levels.