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SUPPORTING INFORMATION

Inverted Quantum-dot Light-Emitting Diode with Solution-Processed Aluminum-Zinc-Oxide as Cathode Buffer

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1. Material characterization of Quantum Dot solution.

In this work, we used quantum dot solution of triple shell (core-shell-shell) structure, purchased from QD Solution in Korea. As shown in Fig. S1(a) and (b), the QD film coated by drop-cast has the optical band gap of 1.90 eV and photoluminance (PL) peak at 628 nm with full-width at half-maximum (FWHM) of 33 nm.

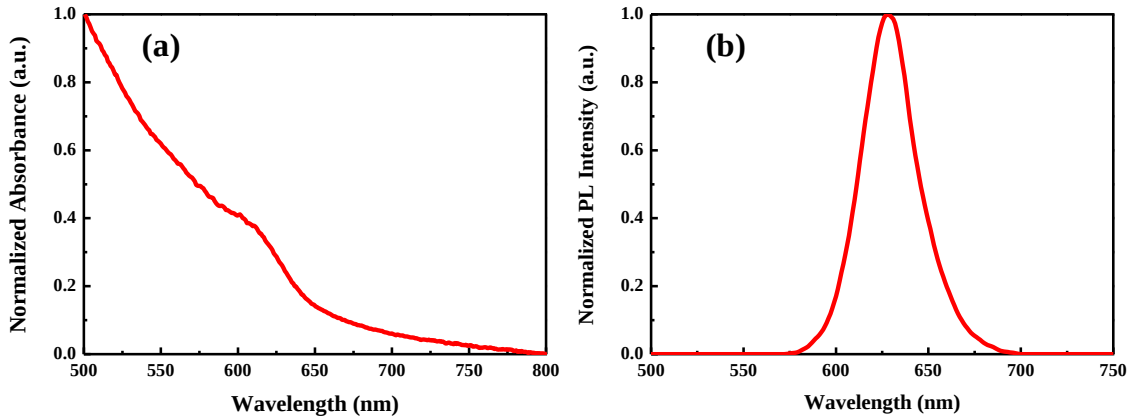

Figure S1. (a) Optical band-gap of quantum dot film formed by drop-cast and (b) normalized PL intensity for the quantum dot solution.

2. Optimization of NPD/HAT-CN layer thickness

In this work, we optimized the layer thicknesses of NPD and HAT-CN and found that device with 20 nm of NPD and 20 nm of HAT-CN show the best performance. The Figure S2 shows the device characteristics of (a) Log current density-voltage, (b) luminance-voltage, (c) current efficiency–luminescence and (d) power efficiency –luminescence for the QLED's using 20, 30 and 40 nm each for both NPD and HAT-CN. From Fig. S2, it is clear that 20 nm device exhibits the best performance. In this experiment the thickness of AZO was fixed to 33 nm. More detail data are shown in Table S1.

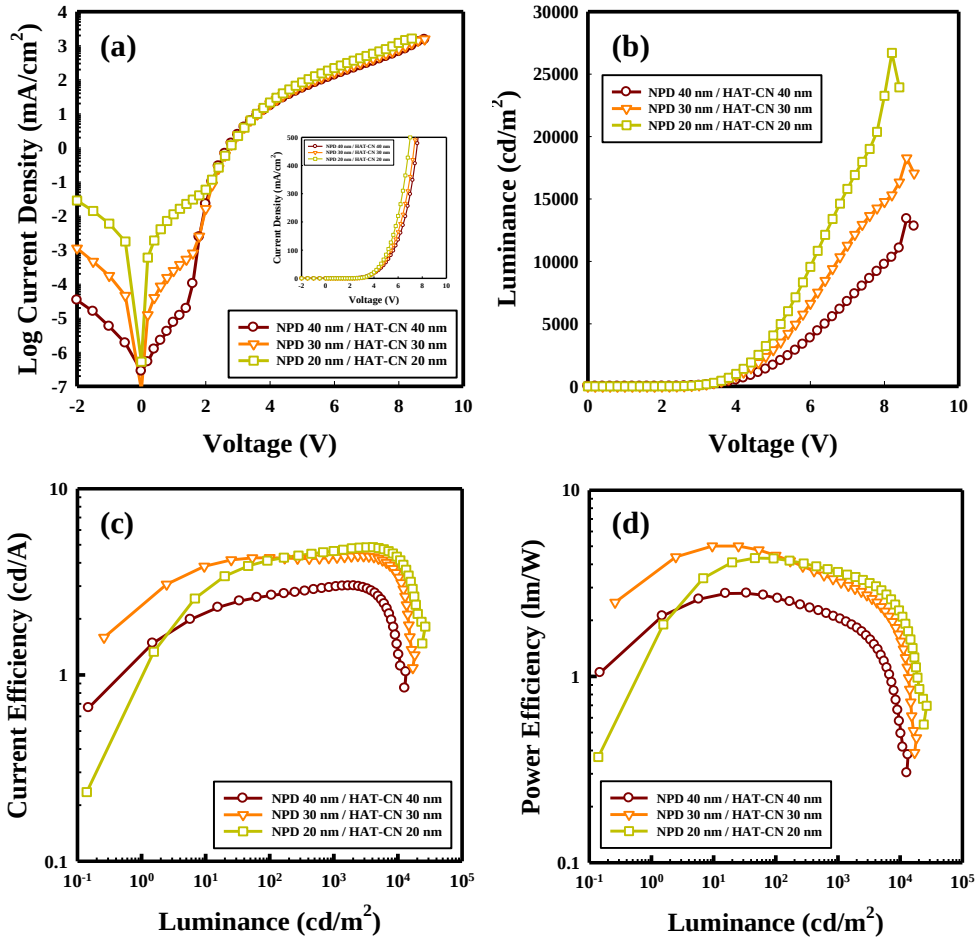

Figure S2. Device characteristics of the QLEDs with various NPD and HAT-CN layer thicknesses. (a) Log current density-voltage (inset: current density-voltage in linear scale), (b) luminance-voltage, (c) current efficiency-luminance, (d) power efficiency-luminance. (A 30% AZO film with ~33 nm was used as ETL).

Table S1. A device characteristic of the QLED's with the variation of NPD and HAT-CN thicknesses. The AZO layer with ~ 33 nm was used as ETL.

NPD/HAT-CN thickness (nm)	**V_T (V)**	**V_D (V)**	**C/E_{max} (cd/A)**	**P/E_{max} (lm/W)**	**L_{max} (cd/m^2)**	**@ 1,000 cd/m^2**	
						C/E (cd/A)	P/E (lm/W)
40/40	1.93	3.17	3.01	2.80	13,410	2.96	2.06
30/30	1.88	3.00	4.36	5.01	18,280	4.26	3.26
20/20	1.94	3.02	4.86	4.32	26,700	4.63	3.64

3. Emission spectra for QLED

Figure S3 shows the EL peak in our device. We could see the only QD peaks at around 640 nm at various brightnesses.

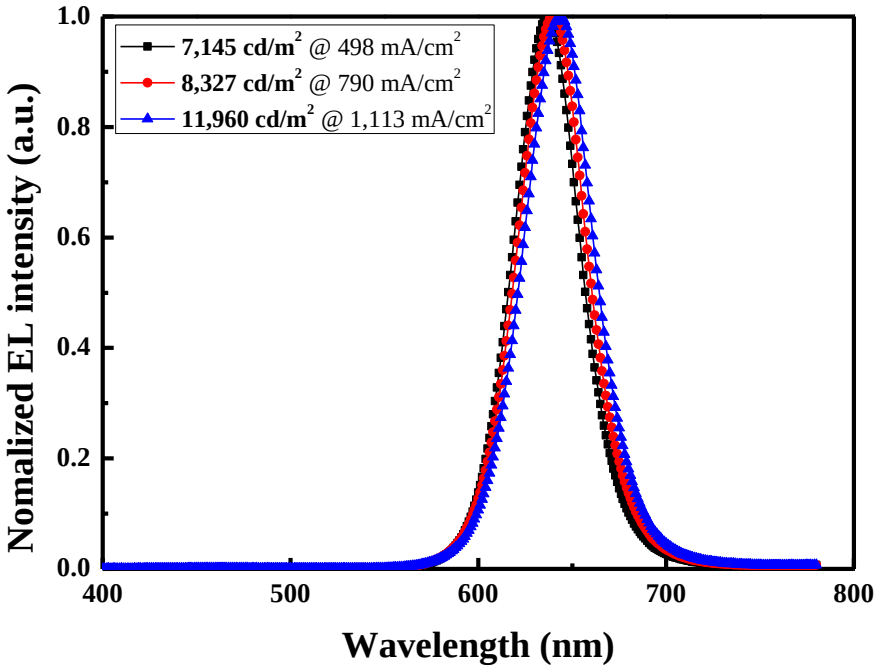

Figure S3. Normalized EL intensity in linear scale for the QLED.

4. Optimization of AZO Layer Thickness

Figure S4 shows the device characteristics for the QLED's with various devices with 30% AZO layers with fixed NPD and HAT-CN layers as 30 nm each. As shown in the inset graph of Fig. S4(a), current density of a thicker (50 nm) AZO is smaller at the same voltage, however the luminance intensity is much improved until ~ 50 nm of AZO layer. Also, in Fig. S4(c), current efficiency at low luminance region is higher for AZO thinner layer device. Therefore, we used 30% AZO films with thickness of ~ 50 nm to obtain best performance. More detail data are shown in Table S2.

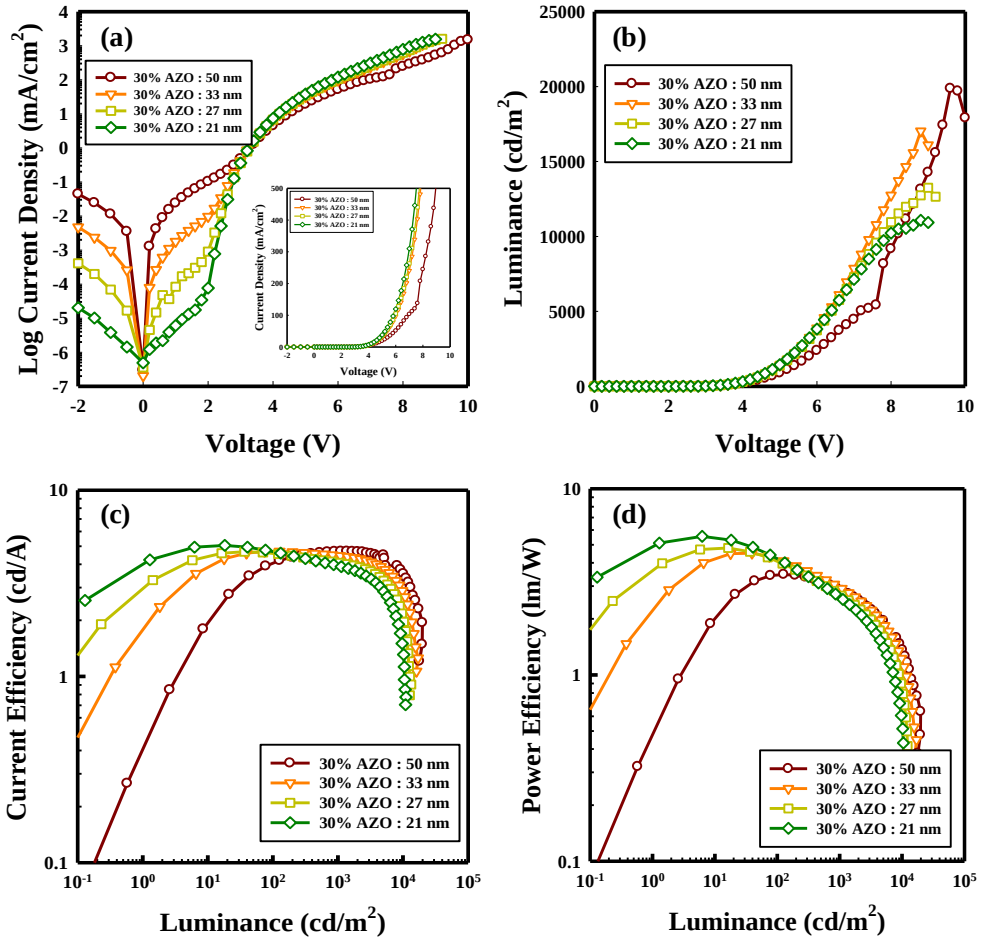

Figure S4. Device characteristics for the QLED with various 30% AZO layer thicknesses. (a) Log current density-voltage (inset: current density-voltage in linear scale), (b) luminance-voltage, (c) current efficiency-luminance and (d) power efficiency-luminance.

Table S2. Device characteristics with various 30% AZO thicknesses. NPD/HAT-CN layers with 30 nm/30 nm were used for HTL/HIL.

30% AZO thickness (nm)	**V_T (V)**	**V_D (V)**	**C/E_{max} (cd/A)**	**P/E_{max} (lm/W)**	**L_{max} (cd/m^2)**	**@ 1,000 cd/m^2**	
						C/E (cd/A)	P/E (lm/W)
50	2.40	3.69	4.70	3.46	19,870	4.69	2.89
33	2.23	3.50	4.69	4.51	17,030	4.46	2.96
27	2.28	3.52	4.67	4.80	13,250	4.09	2.71
21	2.35	3.48	5.06	5.55	11,080	3.93	2.63