Electronic Supplementary Information (ESI)

Bright Inverted Quantum-Dot Light-Emitting Diodes By Simplified All-Solution Processing

Cleaning of ITO glass substrates

First, the pre- patterned ITO substrates were cleaned through immersion and sonication for 15 min in different solvents: 1) detergent solution of Hellmanex III (2% v/v) in milli-Q water; 2) milli-Q water; 3) isopropyl alcohol (IPA): acetone (1:1); and 4) ethanol. After drying by N_2 blowing, the substrates were heated up to 140 °C for 10 minutes over a hot plate, to evaporate any solvent residue. This was followed by plasma–cleaning for 10 min, inside a PLASMA ETCH chamber.

Fabrication of the inverted QLEDs by all-solution processing

The ZnO NPs were synthesized applying some modifications to the precipitation method reported by Mashford et al. (2013)[1]. Then, a solution of ZnO:Cs_2CO_3 was prepared by mixing the as-prepared ZnO NPs dispersion (in IPA-MeOH) and a solution 7 mg/mL of Cs_2CO_3 in 2-methoxyethanol, using a volume ratio of 1:4. The resulting solution was heated up to 120 °C, filtered (0.2 μm pore size) and spin-coated at 2000 rpm for 38 s onto the pre-cleaned ITO substrate. Next, a solution of CdSe QDs in chlorobenzene (CB), with optical density of 0.336 ($\lambda_{ext} = 365\ nm$), was filtered (0.2 μm pore size) and spin-coated at 2000 rpm for 38 s onto the ZnO: Cs_2CO_3 layer. CdSe-ZnS-CdZnS core-shell-shell QDs were synthesized by organometallic route using hot injection of the precursors [2]. After deposition, the edge of the substrate was cleaned using a cotton swab wet with methanol, and the devices were annealed over a hot plate at 150°C for 5 min. Previous reports have shown that annealing the QD layer at high temperatures may improve the preservation of the QD layer. Subsequently, the HTL was deposited by dynamic spin-coating of a poly-TPD solution 1.0 wt %. in ortho-dichlorobenzene (ODCB). The solution was dripped during the first low-speed cycle, 500 rpm for 10 s, and then the speed was increased up to 2000 rpm and kept for 60 s. After poly-TPD deposition the device was annealed at 160 °C for 10 min. It is worth noting, that dynamic spin-coating of poly-TPD led to significant reduction of solvent infiltration into the QD underlayer, eliminating the coffee-ring effect observed when using static spin-coating. To evaluate the best conditions for deposition of the HIL, we prepared devices from 3 different PEDOT:PSS solutions : the pristine PEDOT:PSS solution (Clevios AI 4083), a PEDOT:PSS : IPA (1:1 v/v) solution and a PEDOT:PSS : Triton X-100 (500:1 v/v) solution. All the PEDOT:PSS solutions were filtered (0.45 μm pore size) to remove any

agglomerate and spin-coated at 4000 rpm for 60 s, followed by baking at 110 °C for 10 min. Finally, the 100 nm thick Al electrodes were deposited by thermal evaporation in high vacuum (10^{-6} mbar) at a rate of ~ 2 A/s. All the devices were encapsulated before characterization outside the glove-box.

Characterization

The characteristic curves *J-L-V* of the QLEDs were measured using a Bo-Test source meter, and the luminance was calibrated with a Konica Minolta LS-110 meter. The electroluminescence spectrum of the QLEDs was measured using an optical fiber spectrometer (Ocean Optics USB 2000) in the normal direction. The contact angle images were taken with a standard goniometer model 250-00-115 from Ramé-Hart, inc. The optical microscopy images were taken using a microscope Olympus BX51. The work function of the PEDOT:PSS films was measured by ultraviolet photoelectron spectroscopy (UPS) in an ultra-high vacuum (UHV) chamber with a base pressure of $1x10^{-10}$ mbar and at room temperature. A helium discharge lamp (Specs GmbH, UVS 300) together with a UV monochromator (Specs GmbH, TMM 304) was employed as He-I (21.22 eV) source. A high-resolution hemispherical analyzer (Specs GmbH, Phoibos 150) was used for photoelectron detection. The overall energy resolution is estimated to 80 meV at room temperature (295 K) for UPS measurements. Sample work functions were obtained by recording the secondary electron cut-off (SECO) at normal electron emission with a bias potential of U= −3 V applied to the samples.

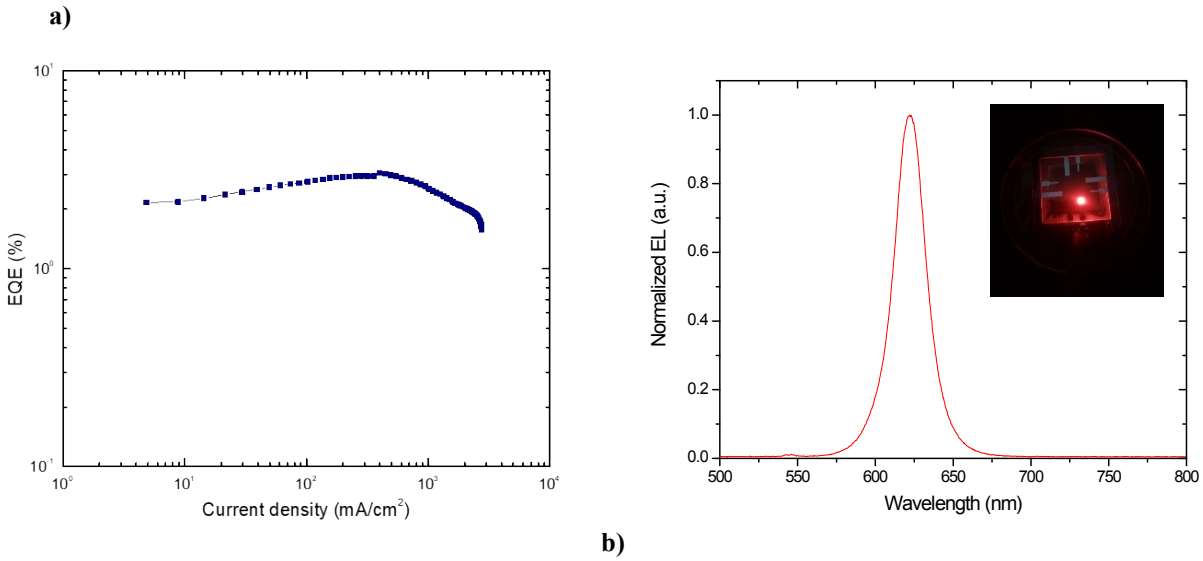

Fig. S1 a) External quantum efficiency–current density (EQE-J). b) Normalized EL spectrum of the QLED. Inset: photograph of the QLED under a voltage of 3.5 V.

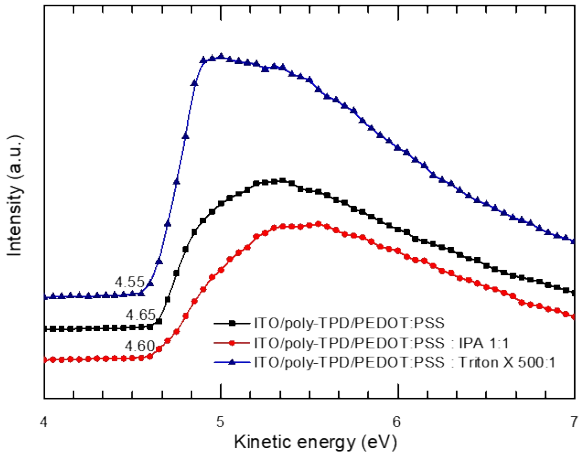

Fig. S2 UPS spectrum in the secondary electron region of the samples: ITO/poly-TPD/PEDOT:PSS, ITO/poly-TPD/PEDOT:PSS:IPA 1:1 and ITO/poly-TPD/PEDOT:PSS : Triton X 500:1.

Table S1. J-L-V characteristics of the QLEDs synthesized

	L_{max} (Cd/m^2)	$V_{turn-on}$ (V)	CE (cd/A) max	LPE (lm/W) max
Pristine PEDOT:PSS	6.37 (@ 10 V)	6.5	0.0002	0.000066
PEDOT:PSS : IPA (1:1)	76.86 (@ 10 V)	2.4	0.0011	0.000458
PEDOT:PSS : Triton X-100 (500:1)	75444 (@ 7.7 V)	1.8	4.9	4.26

References

1 B. Mashford, M. Stevenson, Z. Popovic, C. Hamilton, Z. Zhou, C. Breen, J. Steckel, V. Bulovic, M. Bawendi, S. Coe-Sullivan, and P. Kazlas, High-efficiency quantum-dot light-emitting devices with enhanced charge injection. *Nature Photonics,* 2013, **7**, 407-412.

2 Liu, W. H.; Breen, C.; International Patent Application Number: PCT/US2012/066140; Publication Number: WO2013/078245 A1.