

Electronic Supplementary Information (ESI)

Extremely High External Quantum Efficiency of Inverted Organic Light-Emitting Diodes with Low Operation Voltage and Reduced Efficiency Roll-Off by Using Sulfide-Based Double Electron Injection Layers

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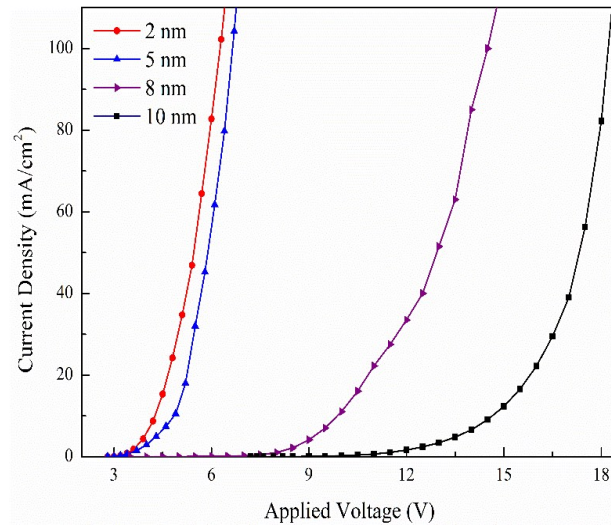


Figure S1 Current density-voltage characteristics of IOLEDs with various thicknesses of ZnS EIL.

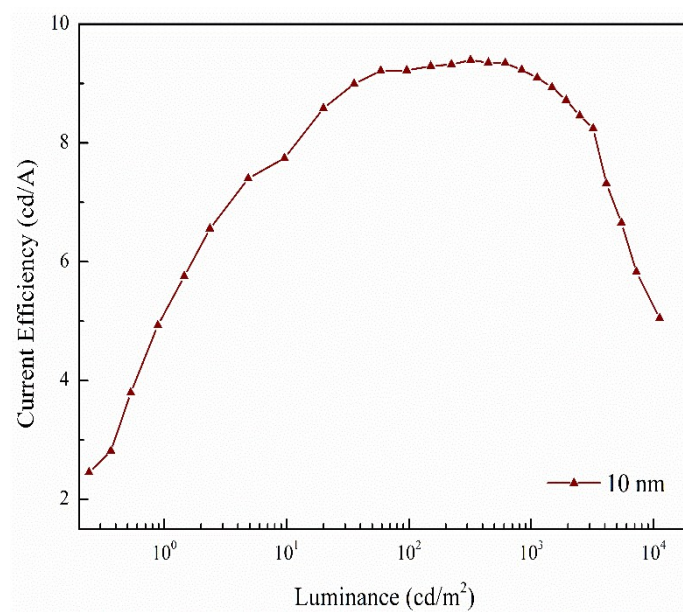


Figure S2 Luminance efficiency-luminance curve for the Device D with 10 nm ZnS film.

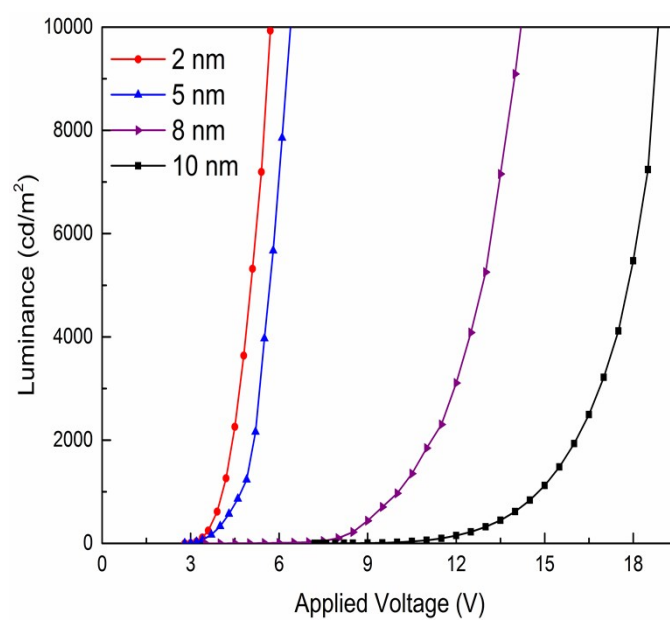
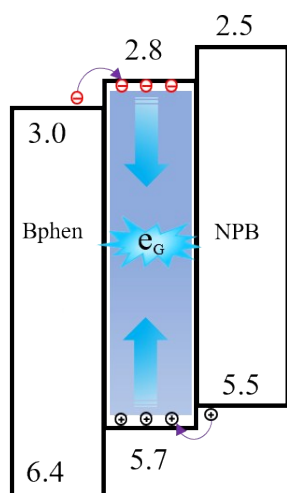


Figure S3 Luminance-voltage characteristics of IOLEDs with various thicknesses of ZnS EIL.

At low voltage,
Excitons would generate on the **guest**.



At high voltage,
Excitons would generate on the **host**.

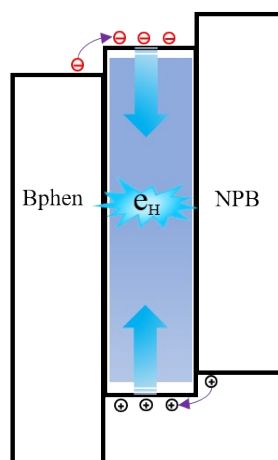


Figure S4 The energy-level diagram in the blue OLED with the EML composed of DSA-ph-doped ADN.

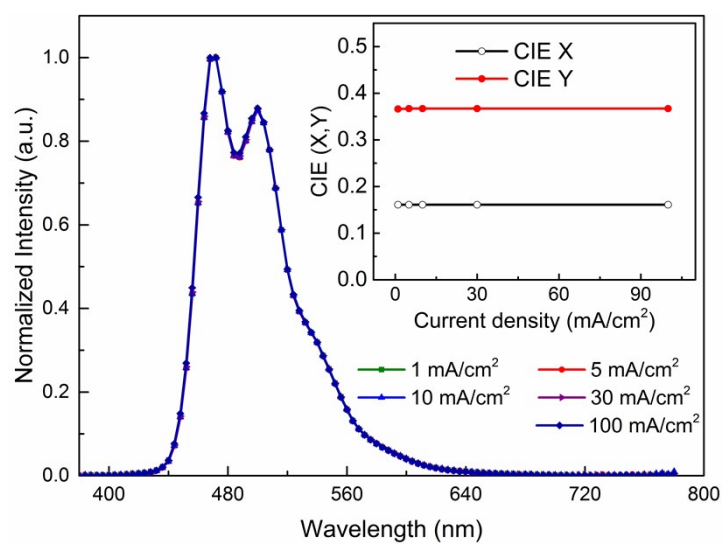


Figure S5 The normalized EL spectra of Device A at various current densities. The inset shows CIE colour coordinate migration of Device A.

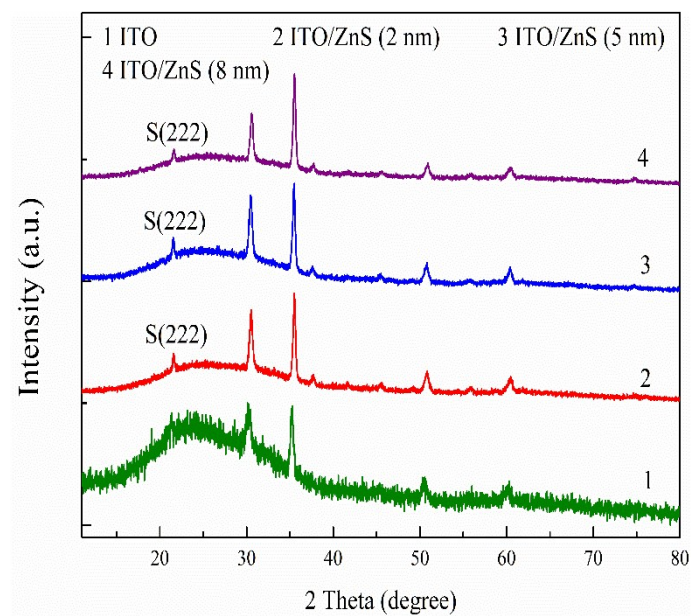


Figure S6 XRD patterns of the bare ITO, ITO/ZnS (2 nm), ITO/ZnS (5 nm) and ITO/ZnS (8 nm).

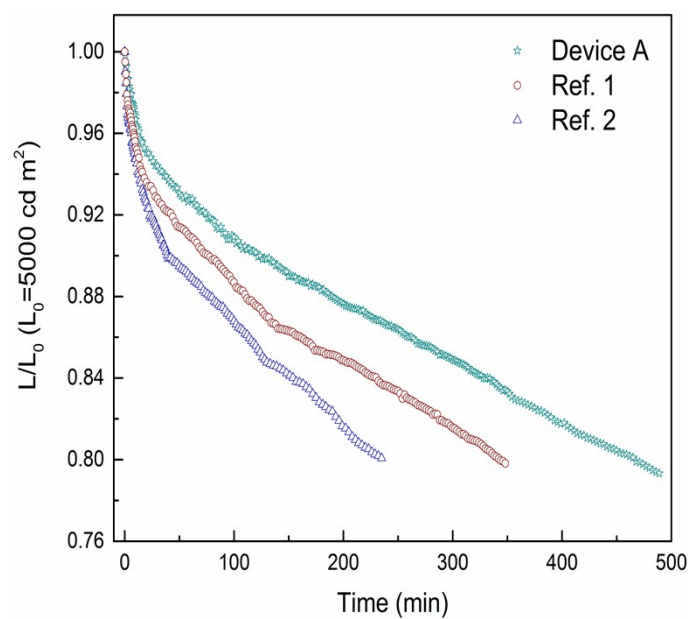


Figure S7 Time evolution of the normalized luminance, L , of Devices A, Ref. 1 and Ref. 2 in dry-nitrogen ($<0.1 \text{ ppm H}_2\text{O}$ and O_2) atmospheres at the initial luminance of $L_0 = 3,000 \text{ cd m}^{-2}$.

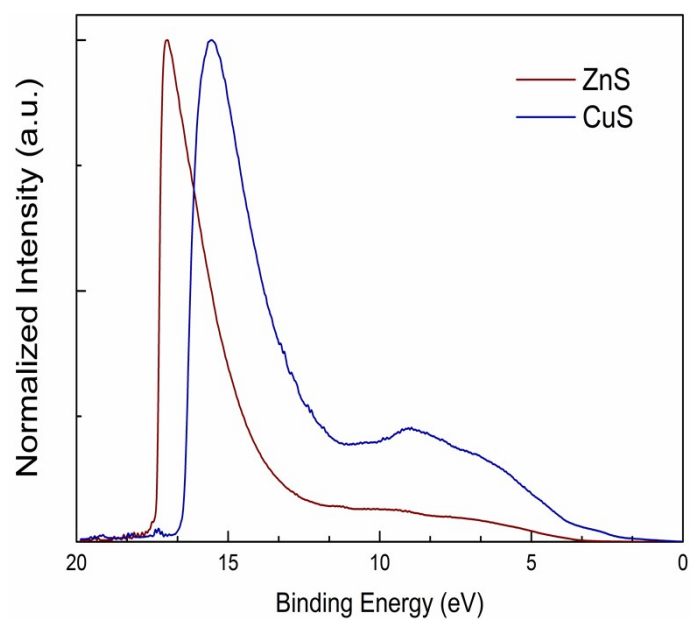


Figure S8 The ultraviolet photoelectron spectroscopy (UPS) spectra of ZnS and CuS.

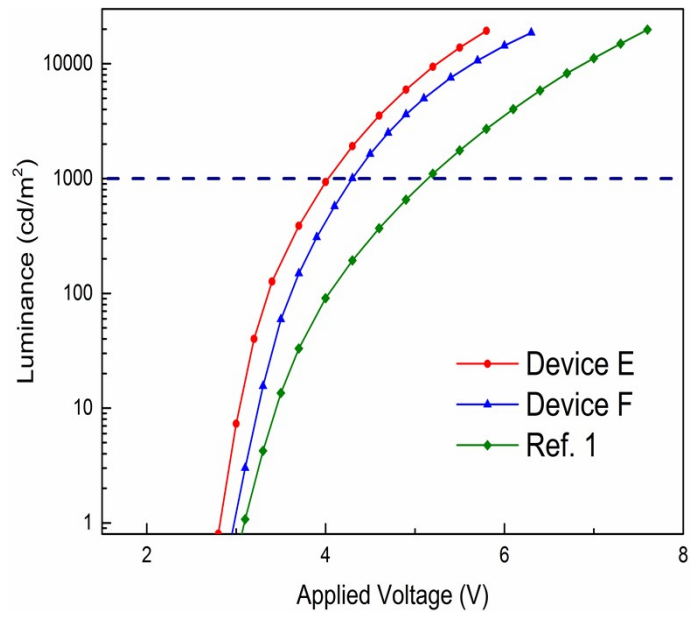


Figure S9 Luminance-voltage curve for Devices E, F and Ref. 1.

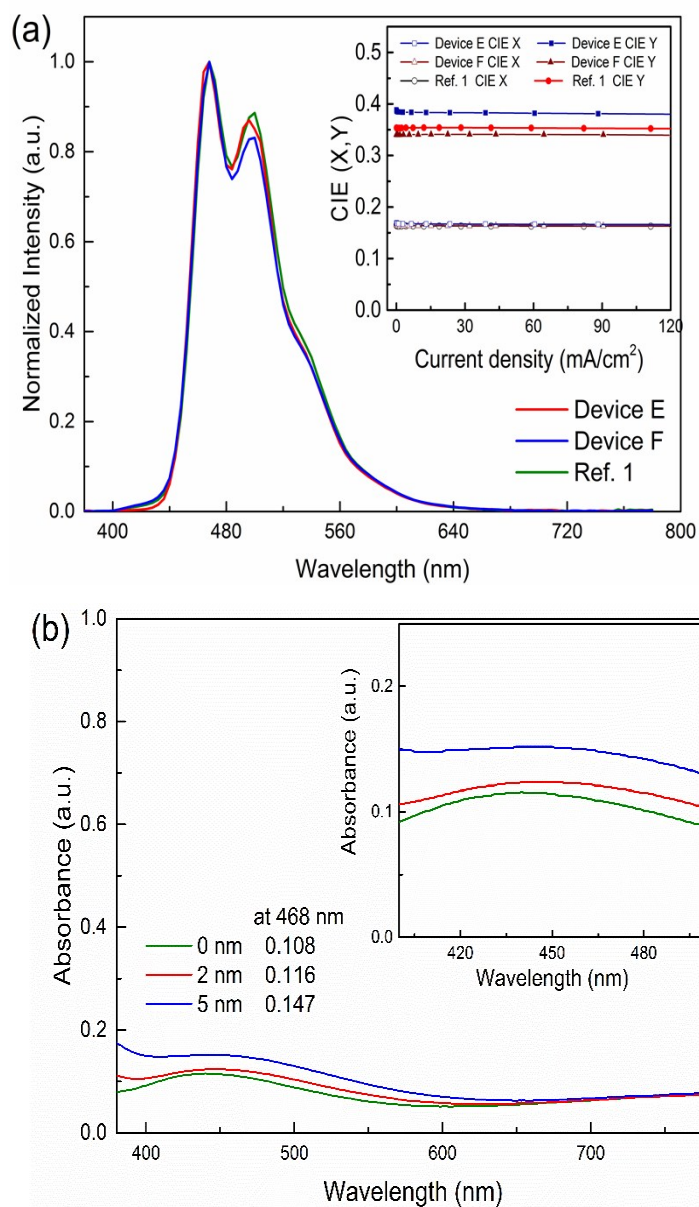


Figure S10 (a) The EL spectra of reference device and Devices E, F under the luminance of 1000 cd m⁻². Inset shows CIE colour coordinates as function of current density. (b) Absorbance spectra of CuS thin films with various deposition thickness on ITO glass. Inset shows magnified transmittance band edge between 400 and 500 nm.

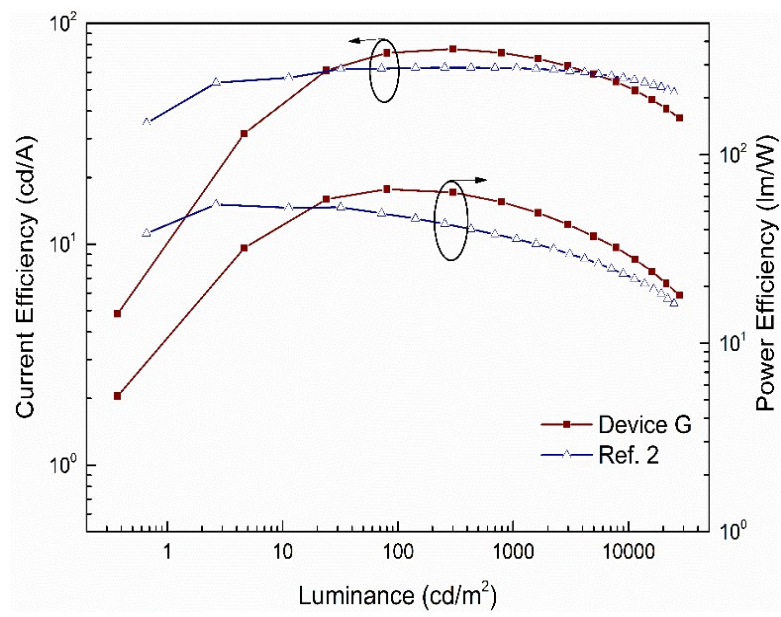


Figure S11 Current efficiency and power efficiency as a function of luminance for Device G and Ref. 2.

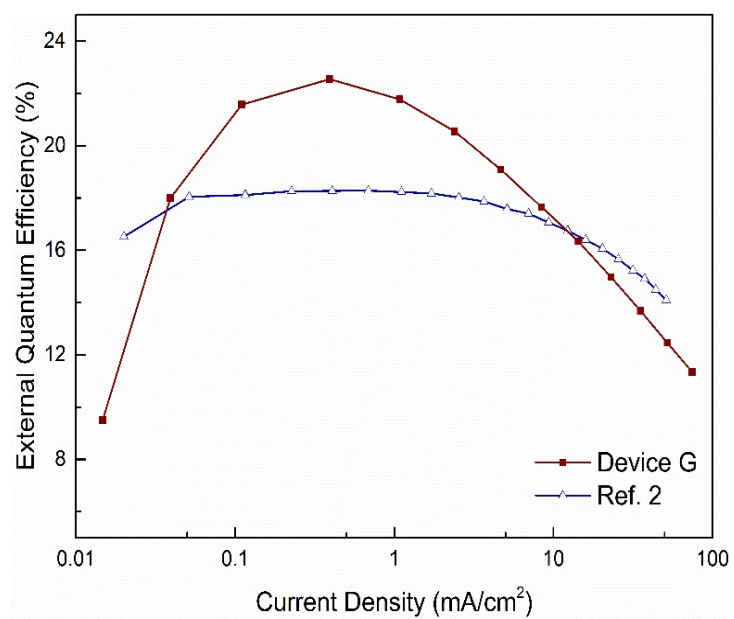


Figure S12 External quantum efficiency plotted against current density for Device G and Ref. 2.

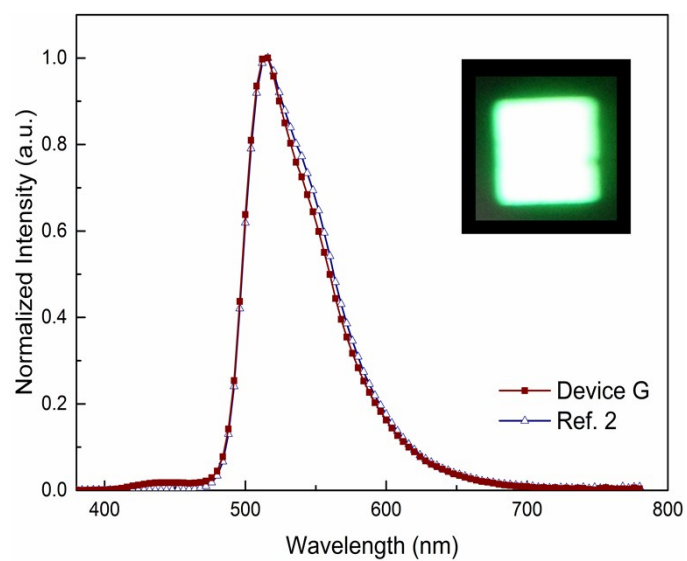


Figure S13 Normalized EL spectra of Device G and Ref. 2 at the luminance of 1000 cd m⁻². The inset shows photographs of the lighting images of the Device G.

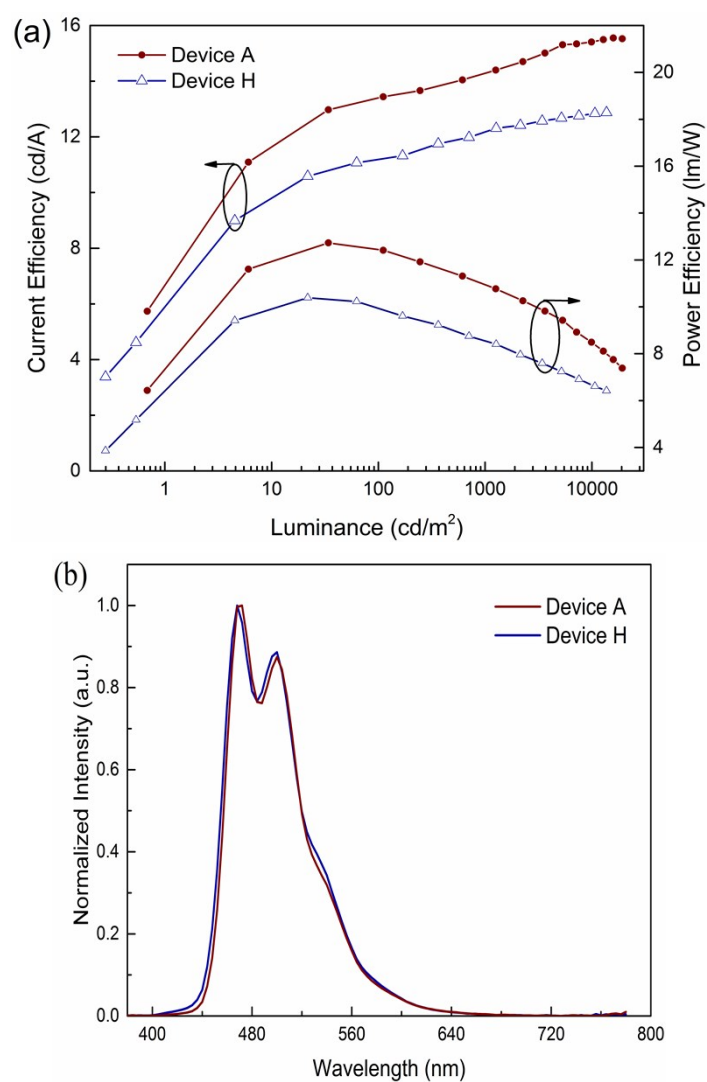


Figure S14 (a) Current efficiency and power efficiency as a function of luminance, and (b) Normalized EL spectra of Devices A and H.