Supporting Information

Full Solution-Processed Heavy-Metal-Free Mini-QLEDs for Flexible Display Application

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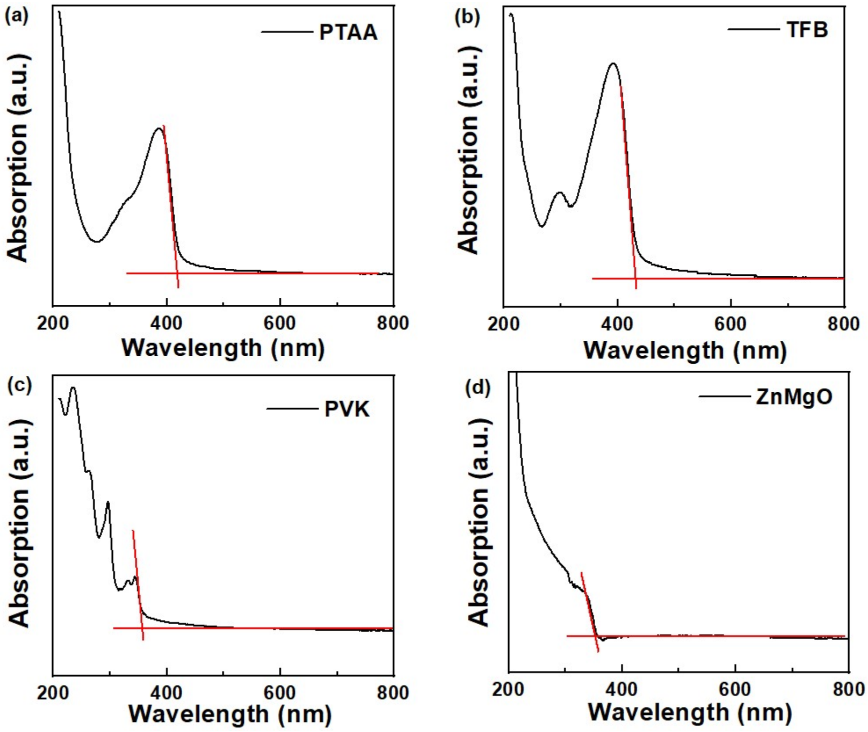

Figure S1The UV absorption spectra of HTLs of (a) PTAA; (b) TFB; (c) PVK and ETL of ZnMgO.

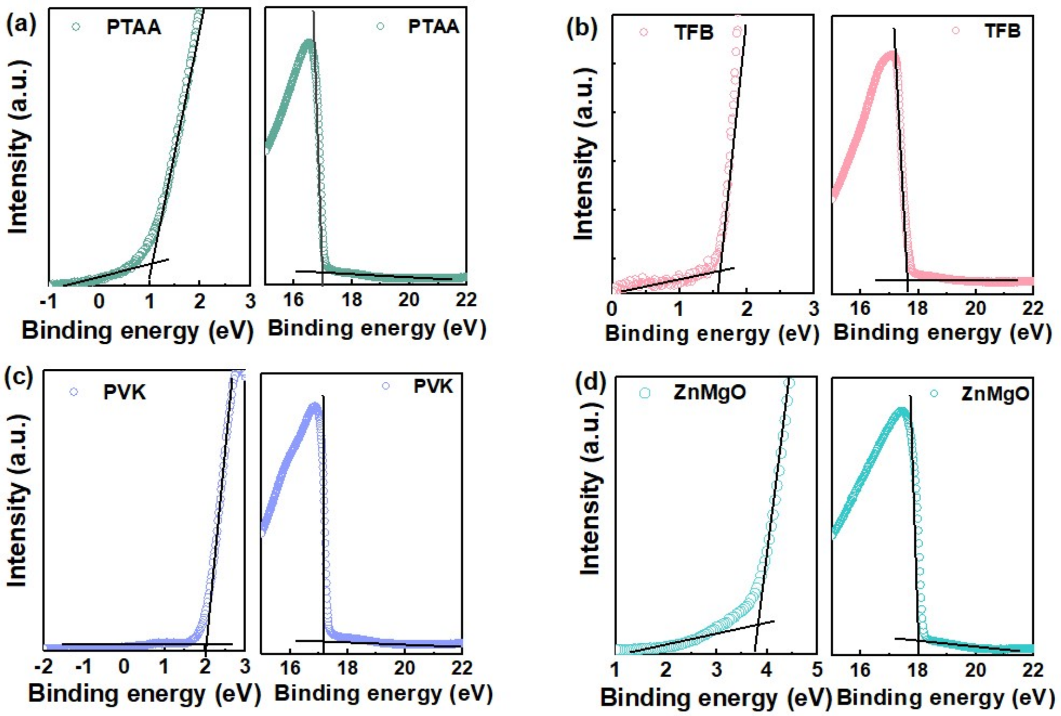

Figure S2 Ultraviolet photoelectron spectroscopy (UPS) of HTLs and an ETL. (a) PTAA; (b) TFB; (c) PVK and (d) ZnMgO.

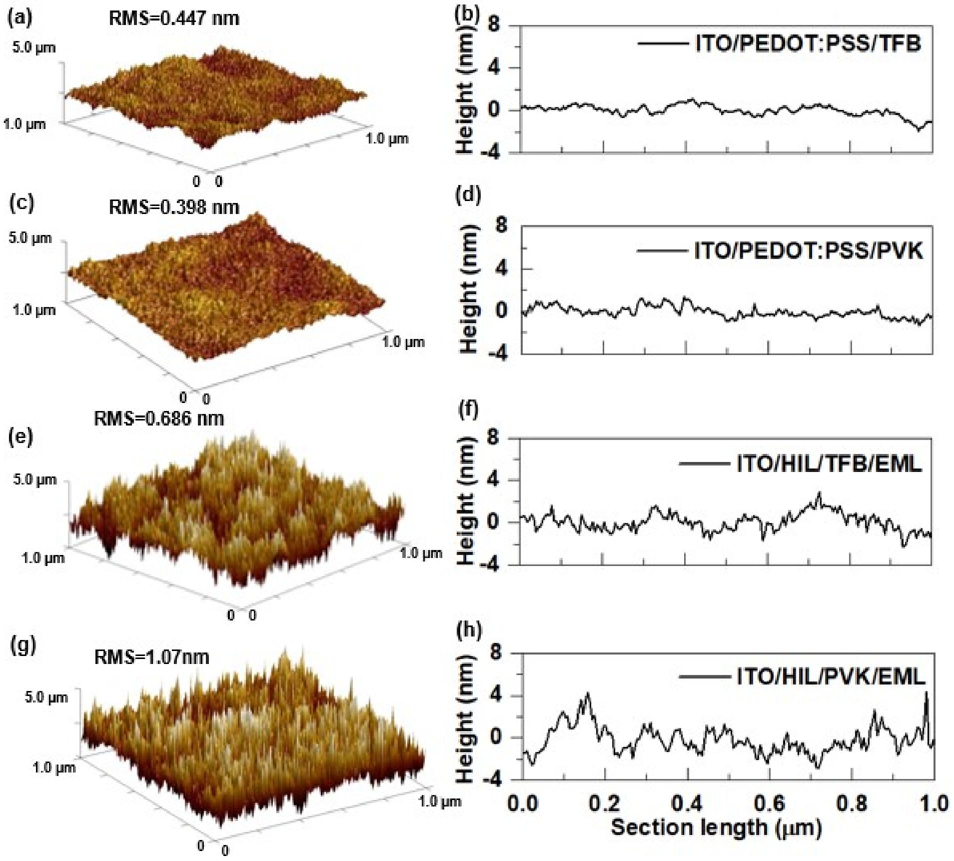

Figure S3 Morphology characterization of QDs thin films on different substrates by AFM. AFM images and corresponding line scan of different structures (a), (b) ITO/HIL/TFB; (c), (d) ITO/HIL/PVK; (e), (f) ITO/PEDOT:PSS/TFB/QDs; (g), (h) ITO/PEDOT:PSS/PVK/QDs.

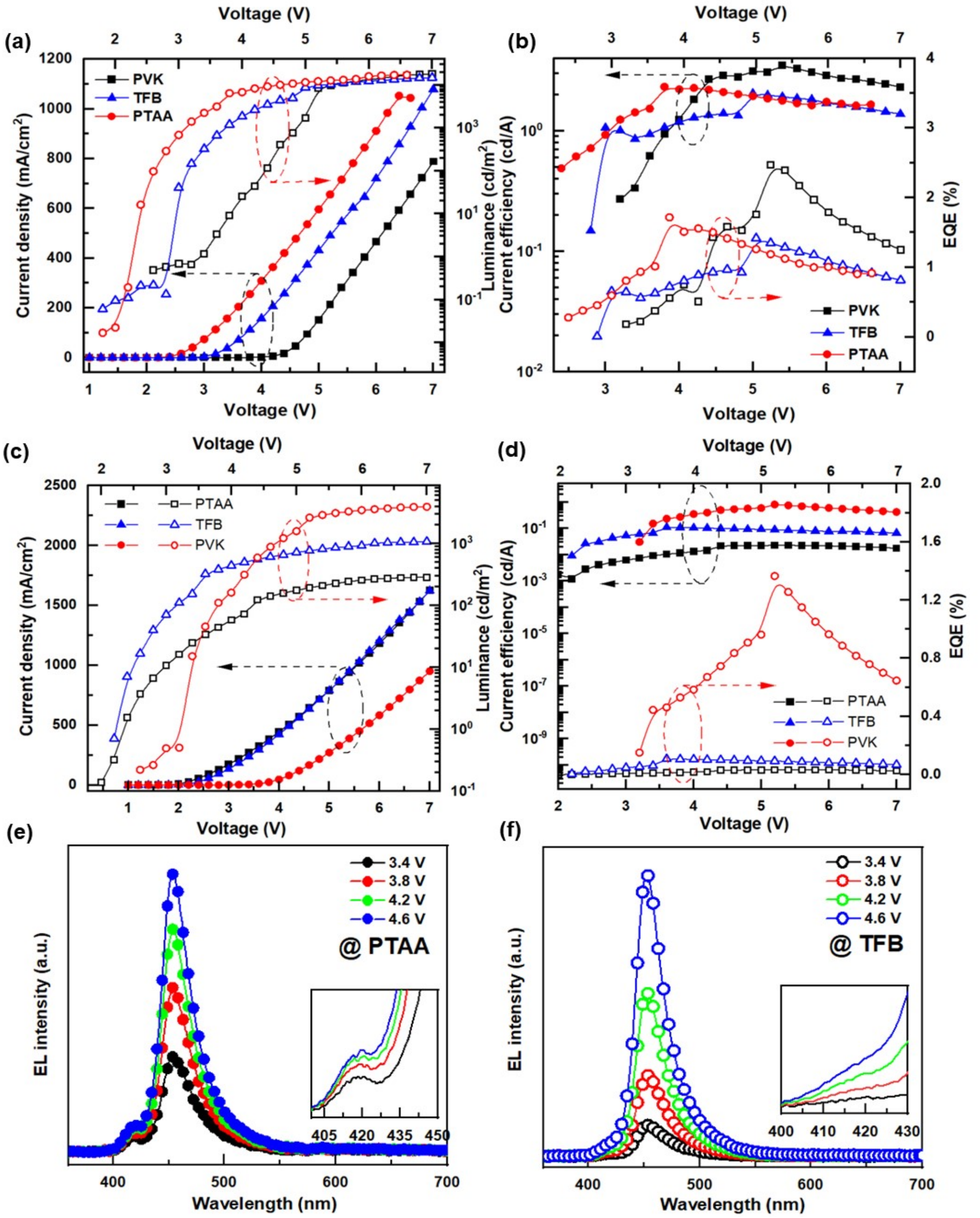

Figure S4 EL performance of QLEDs with different HTLs of PTAA, TFB, and PVK. QLEDs based on QDs (473 nm): (a) Current density-voltage-luminance (*J-V-L*); (b) Current efficiency-voltage-EQE (*CE-V-EQE*). QLEDs based on QDs (452 nm): (a) *J-V-L*; (b) *CE-V-EQE*; Under different driving voltages, EL spectra of QLEDs based on HTL of PTAA (e) and TFB (f).

As shown in Figure S4(a)-(b), PVK-based sky-blue QLEDs exhibit the smallest current density, the biggest turn-on voltage, and the biggest CE and EQE, indicating the PVK-based QLEDs exhibit the biggest power consumption among the three different HTLs based QLEDs, which is primarily attributed to that PVK is with a low HOMO (-5.86 eV), forming a big hole transport barrier (0.66 eV) at the interface of PEDOT: PSS/PVK. Meanwhile, PVK has low hole mobility (2.5×10^{-6} $cm^2/V\cdot s$). Therefore, the hole transport performance is extremely low in PVK-based QLEDs, leading to an imbalance of hole-electron injection during device operation, due to ZnMgO with high electron mobility (2.15×10^{-4} $cm^2V^{-1}s^{-1}$～0.95×10^{-4} $cm^2V^{-1}s^{-1}$). Besides, compared with PVK, PTAA and TFB have high HOMOs, which reduces the hole transport barrier at the interface of HIL/HTLs. Simultaneously, their hole mobility (PTAA～1.0×10^{-3} $cm^2V^{-1}s^{-1}$, TFB～1.0×10^{-2} $cm^2V^{-1}s^{-1}$) is higher than that of PVK, respectively. Hence, compared with PVK-based QLEDs, both PTAA and TFB-based QLEDs exhibit low turn-on voltages and high brightness in the low voltage range from 1 V- 5 V. Obviously, in the two QLEDs based on PTAA and TFB, PTAA-based QLEDs exhibit a smaller turn-on voltage and higher brightness, attributed to dominant factor of the hole transport interface barrier, which means PTAA based QLEDs have an advantage of low power consumption. Therefore, PTAA is selected as the optimal HTL for the sky blue QLEDs.

For the pure blue-based QLEDs with different HTLs, PVK-based QLEDs still show the lowest current density, the highest turn-on voltage, and the biggest CE and EQE, as shown in Figure S4(c)-(d), which is explained as before. For PTAA and TFB-based QLEDs, though the turn-on voltages of the two QLEDs are smaller than that of PVK-based ones, the brightness of the PVK-based QLEDs can exceed those of TFB and PTAA-based QLEDs at the 3.6 V. Moreover, as shown in Figure S4(e)-(f), the parasitic emission occurs in TFB and PTAA-based QLEDs,[1] because a part of injected hole and electron radiatively recombine in the HTLs (PTAA and TFB), as shown in Figure S5, leading to generating EL peaks belonging to HTLs. It is unbeneficial to realize pure color luminescence. Thus, PVK is chosen as the matched HTL for pure blue QLEDs.

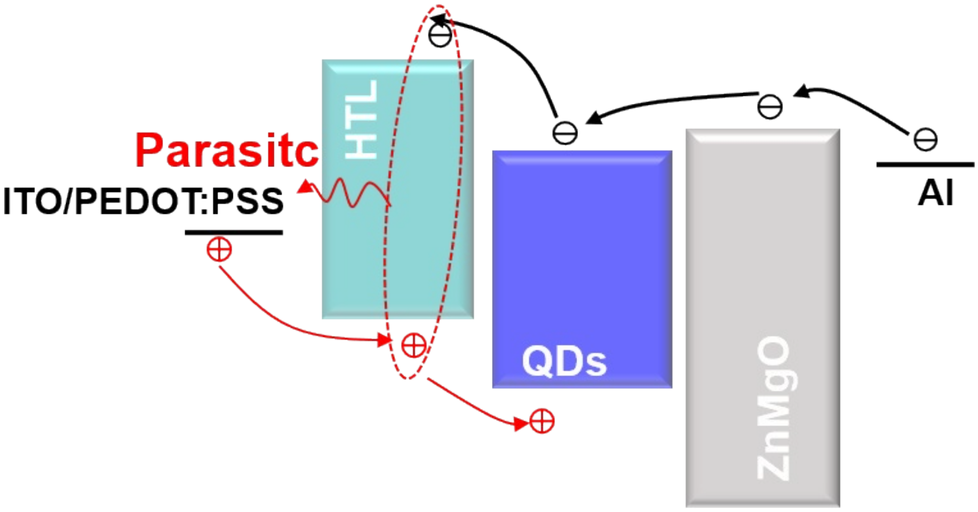

Figure S5 Illustration of the parasitic emission of QLEDs.

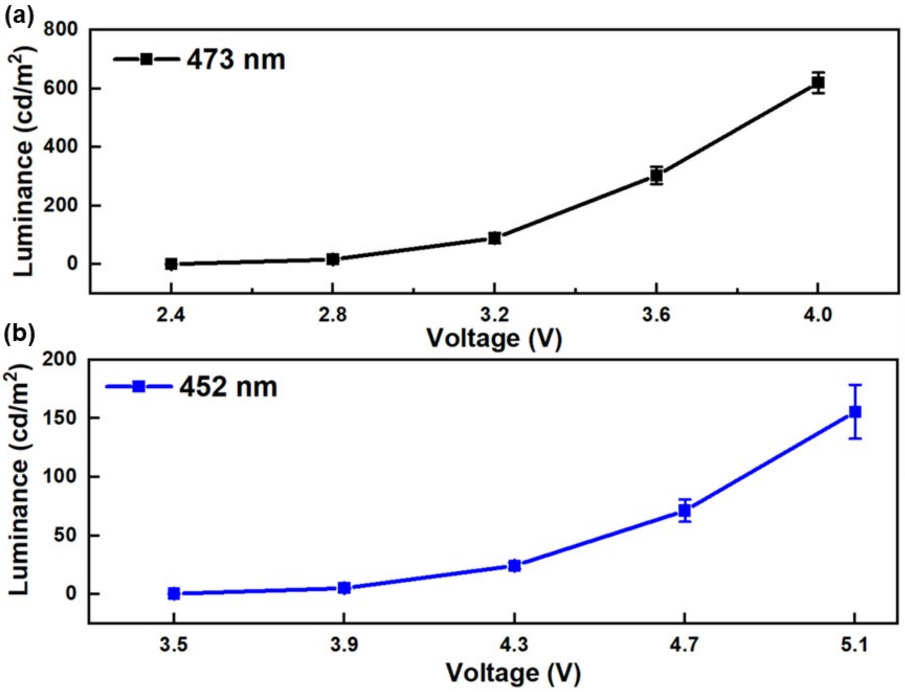

Figure S6 Luminance statistics of m-QLEDs fabricated (500×500 μm^2) at different voltages. Error bars represent standard deviation. (a) Sky pure m-QLEDs (EL peak at 473 nm); (b) Pure blue m-QLEDs (EL peak at 452 nm).

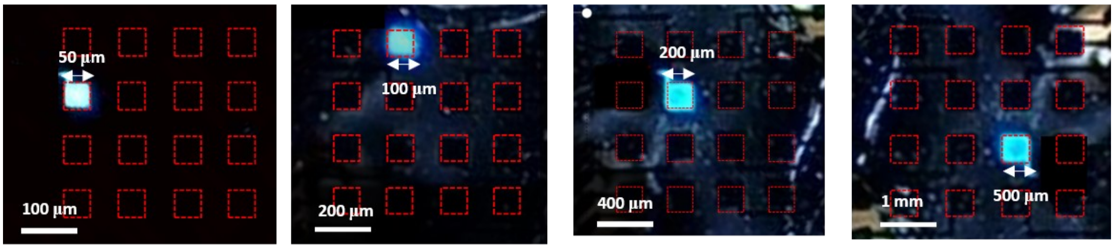

Figure S7 Real EL images of different size m-QLEDs.

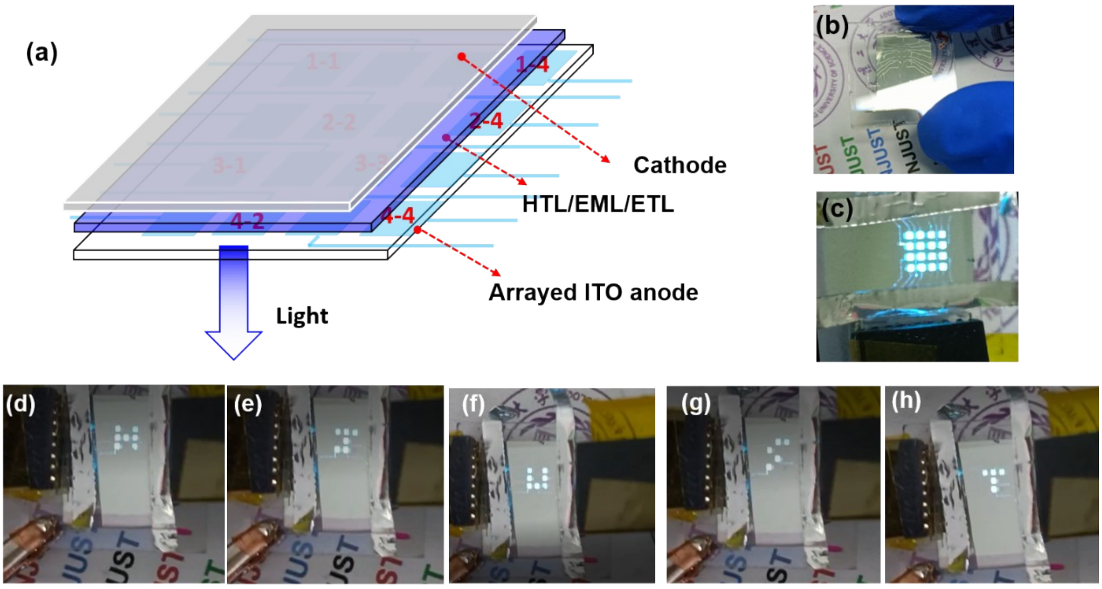

Figure S8 (a) The device architecture of PM-m-QLEDs by the anode array technology. (b) The real image of PM-m-QLEDs is based on arrayed ITO glass substrate without excitation. (c) The real emission images of PM-QLEDs under biases. (d)-(h) The EL pattern displays images of the letters "NJUST".

Reference:

1 Z. Wu, P. Liu, W. Zhang, K. Wang and X. W. Sun, *ACS Energy Lett.*, 2020, **5**, 1095–1106.