Electronic supplementary information

Shifting the light emitting component from core to shell: an effective approach to improve the efficiency of the light-emitting diodes based on multi-junctional quantum materials

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Structural characterization of ZnCdS/CdSe/CdZnSeS/ZnS QDQWs

Fig. S1 gives the results obtained from a HRTEM (JEOL-2010F) equipped with an EDS. From the atomic line profiles in Fig. S1 b and c we could see that Cd atoms are concentrated in the central region. It can be estimated that the size of the ZnCdS core is about 3.5 nm. It also shows that the line profile of S atoms has three peaks, a central peak and two shoulders. The central peak matches the core of ZnCdS and the shoulder peaks are in agreement with the shell of CdZnSeS/ZnS. Also, the line profile of Se atoms shows two peaks which only match the CdSe/CdZnSeS shell. Therefore, the thickness of the CdSe/CdZnSeS/ZnS shell could be estimated to be around 0.4/0.8/0.3 nm.

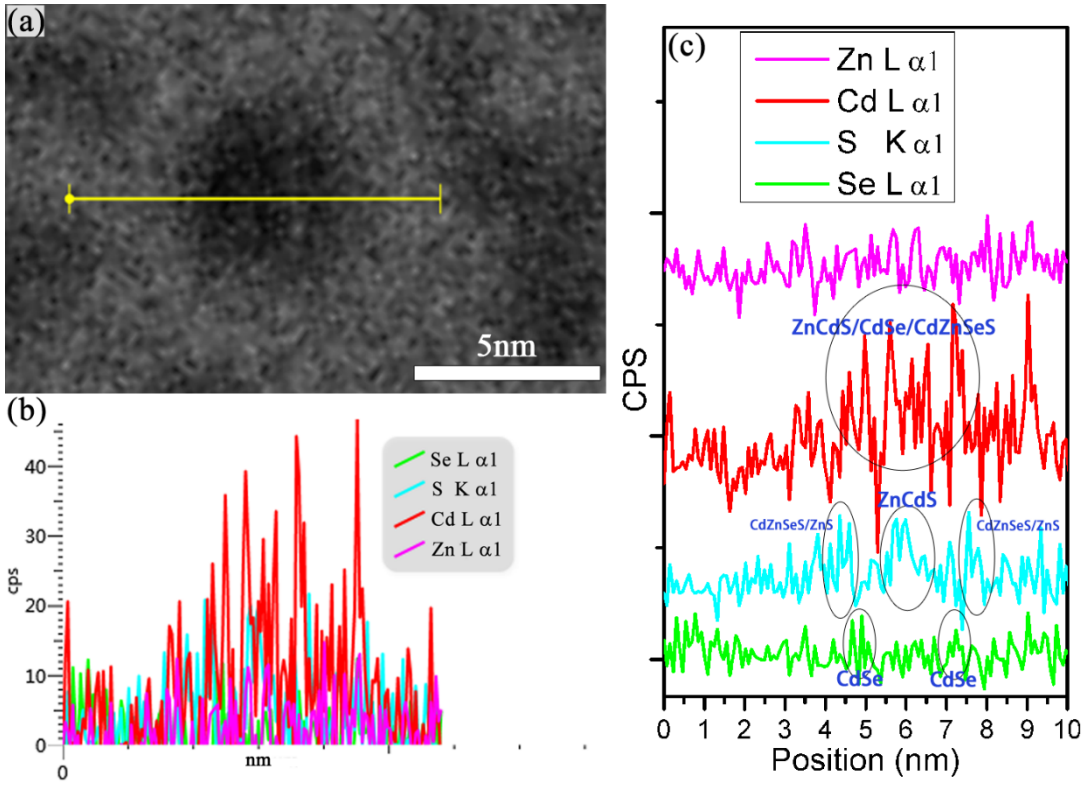

Fig. S1 Structural characterization of ZnCdS/CdSe/CdZnSeS/ZnS QDQWs (a) TEM image of a QDQW structure. (b) Atomic line profiles of the QDQW. (c) Atomic line profiles of Zn, Cd, S, and Se of the QDQW.

Synthesis and characterizations of the ZnO quantum dots

Zinc acetate (2.95 g) was firstly dissolved in 125 mL methanol at 60 ˚C. Then a solution of KOH (23 mmol) in 65 mL methanol was titrated into the zinc acetate solution under vigorous stirring. After 2 h and 15 min, the nanoparticles precipitated with the removal of the heater and stirrer, and the solution became turbid. Then the precipitate was collected by a centrifugation step and washed twice by 50 mL methanol. Finally, the precipitate was dissolved in 10 mL chlorobenzene. The solution which was almost transparent could be kept in room temperature for more than 2 weeks.

Fig. S2 shows the transmission electron microscopic (TEM) image of the prepared ZnO quantum dots. Though the particles show somewhat aggregation due to the high concentration of the solution for preparing the TEM samples, the size of the quantum dots could be gauged as around 5 nm, particularly from the HRTEM image shown as the inset. The inset presents a clear crystal lattice of a series of quantum dots, indicating that the resultant has a good crystalline quality. The absorbance spectrum of the ZnO solution is given in Fig. S3, where an optical absorbance onset at around 400 nm could be distinctly observed, consistent with the reported values [1]. The PL spectrum of the ZnO quantum dots is displayed as the red curve in Fig. S3. In comparison with the high intensity of PL signal from CdSe/CdSeZnSeS/ZnS, the PL signal from ZnO quantum dots could be ignorable, indicating that for the real LED devices, the emitting contribution from ZnO could also be ignored. The main function of the ZnO layer is transporting the electrons to the light emitting layer.

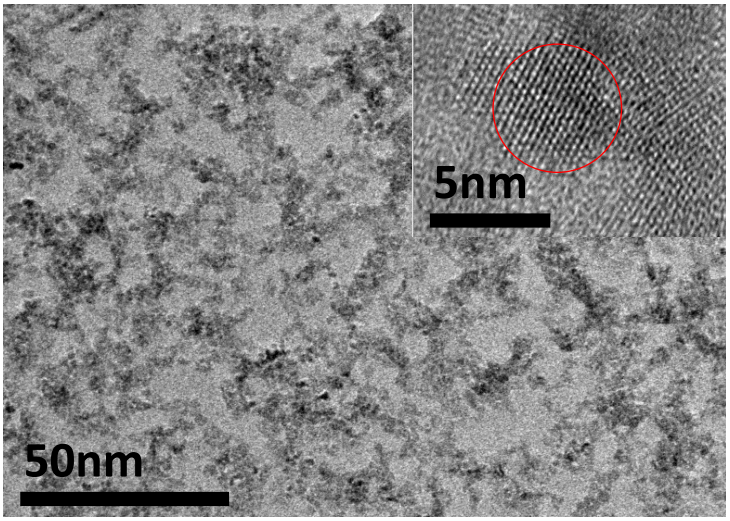

Fig. S2 TEM image of the prepared ZnO quantum dots.

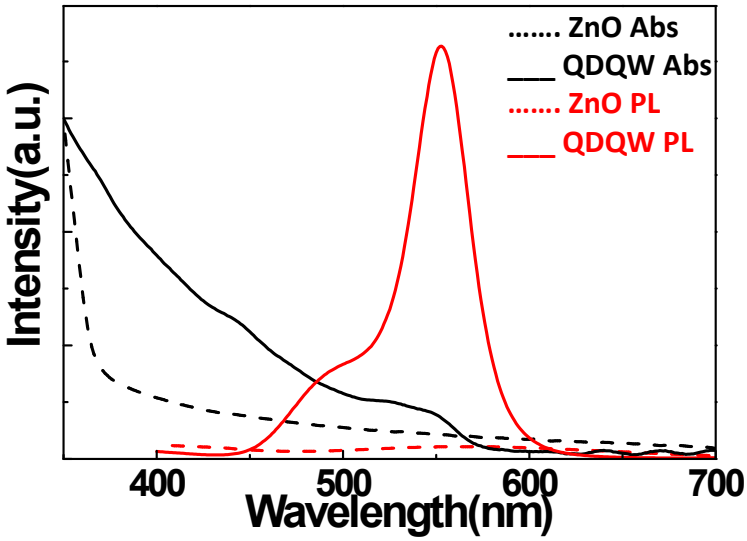

Fig. S3 Absorbance and photoluminescence spectra of the QDQW and ZnO solution.

Structural characterization of the LED devices

Fig. S4 presents the cross-sectional scanning electron microscopic image of the LED devices. Considering the exactly same parameters in fabricating the two sets of devices, the devices show the same structural feature. The thicknesses of the ZnO layer and the light emitting layer could be measured as 30 nm and 25 nm, from the image directly.

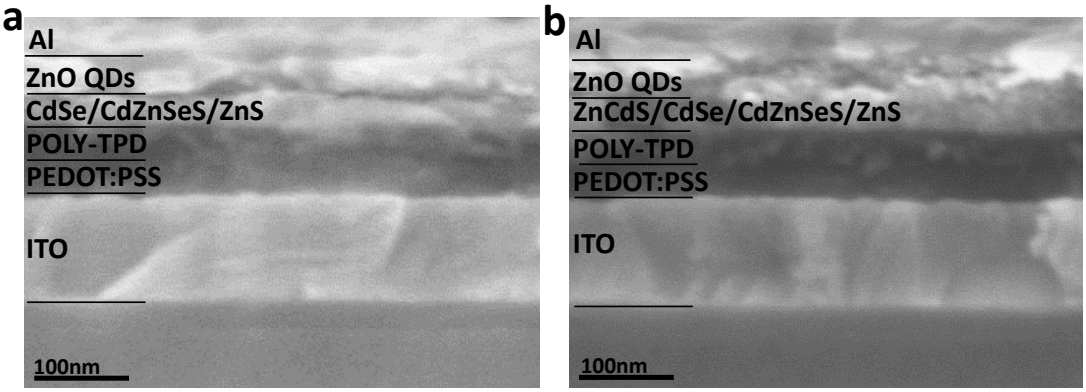

Fig. S4 Cross-sectional scanning electron microscopic image of the LED devices.

1. N. S. Pesika, K. J. Stebe and P. C. Searson, *Advanced Materials*, 2003, **15**, 1289-1291.