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Electronic Supplementary Information (ESI)

Localized Surface Plasmon-Enhanced Blue Electroluminescent Device Based on ZnSeTe Quantum Dots and AuAg Nanoparticles

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Finite-difference time-domain (FDTD) simulations

Firstly, we used total field scattered field (TFSF) source to calculate the plasmonic absorption spectra of AuAg nanoparticles (NPs) through Lumerical FDTD Solutions software. The absorption monitor was placed around the AuAg NPs within the TFSF source zone, while the scattering monitor was placed outside. Since the incident fields are subtracted from the total fields outside the TFSF zone, scattered fields are subtracted from the incident light consequently, the remaining was considered as absorbed light by AuAg NPs. To calculate the electric field distribution near AuAg NPs, a TFSF source of 460 nm was used as an excitation source to represent the photoluminescence (PL) of ZnSeTe blue QD. The incident light propagates along the z direction with polarization along the x axis. The intensity of electric field near AuAg NPs was calculated in x-y plane. Perfectly matched layer (PML) boundary conditions were used the simulation with the grid size of 0.5 nm. Values of n,k for refractive index was imported from Rioux et al. to set optical properties of 10 nm sized $Au_{0.5}Ag_{0.5}$ NPs in FDTD simulation.[1]

Synthesis of ZnSeTe/ZnSe/ZnSeS/ZnS core/multishell QDs

ZnSeTe/ZnSe/ZnSeS/ZnS core/multishell QDs were synthesized via a wet colloidal one-pot technique. Typically, 2 mmol of Zn acetate, 2 ml of oleic acid (OA), and 15 mL of 1-octadecene (ODE) were placed inside a three-neck flask along with a magnetic stirrer. The flask was then purged with N_2 gas and heated to 300°C. Meanwhile, Se and Te stock solutions were prepared by dissolving 1 mmol of Se in 0.5 mL of diphenylphosphine (DPP) and 0.02 mmol of Te in 0.5 ml of trioctylphosphine (TOP). These anionic stock solutions were sequentially introduced into the flask. The reaction temperature was maintained at 300°C for 1 h for the growth of ZnSeTe cores. After that, ZnSe inner shelling proceeded by co-injecting Zn and Se stock solutions into the core crude solution at 300°C and holding the reaction at that temperature for 1 h. Zn and

Se stock solutions above were prepared beforehand by dissolving 1.2 mmol of Zn acetate in 2 ml of OA and 1 mL of ODE and 1.2 mmol of Se dissolved in 1 mL of TOP, respectively. Subsequently, to form ZnSeS intermediate shell, the same Zn stock solution as above and SeS stock solution (0.6 mmol of Se and 0.6 mmol of S in 1 ml of TOP) were swiftly added at 300°C and the reaction was kept at that temperature for 30 min. For ZnS outer shelling, the identical Zn and S (1.2 mmol of S in 1 mL of TOP) stock solutions were injected and reacted at 300°C for 30 min. Lastly, 1.2 mmol of Zn stearate dissolved in 4 mL of ODE was further injected at 230°C and the reaction was continued for 30 min, followed by the injection of 1 mL of 1-octanethiol (OTT) and reaction at that temperature for 30 min. The resulting ZnSeTe/ZnSe/ZnSeS/ZnS core/multishell QDs were precipitated with a mixture of hexane and acetone and re-dispersed in hexane for further use.

Synthesis of Ag and Au NPs

To synthesize Ag NPs, a mixture of 6 mL of ODE and 4 mL of OLA in a 3-neck flask was heated to 160^{o}C under N_2 gas flow. When the temperature of this mixture reached 160^{o}C, 1 mL of Ag stock solution (prepared by dissolving 0.225 mmol of Ag acetate in mixture of 1 mL of ODE and 1 mL of OLA) was injected. After 30 min of reaction, 1 mL of OA was injected and the reaction temperature reacted for 30 min and finally quenched. In the case of Au NPs, 1 mL of Au stock solution (prepared by dissolving 0.225 mmol of Au chloride trihydrate in a mixture of 1.5 mL of ODE and 0.5 mL of OLA) was injected instead, while other reaction details remained unchanged.

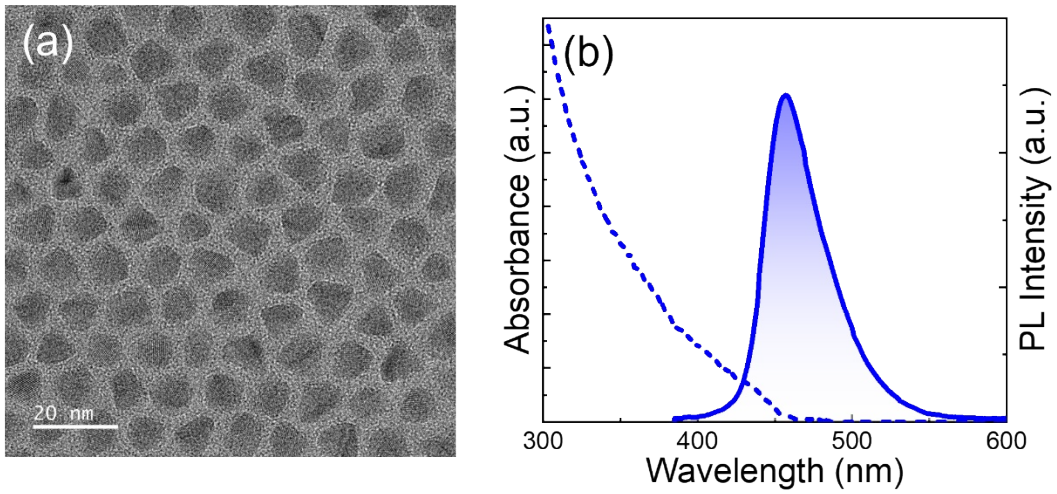

Fig. S1 (a) TEM image (scale bar: 20 nm) and (b) absorption and PL spectra of blue ZnSeTe QDs.

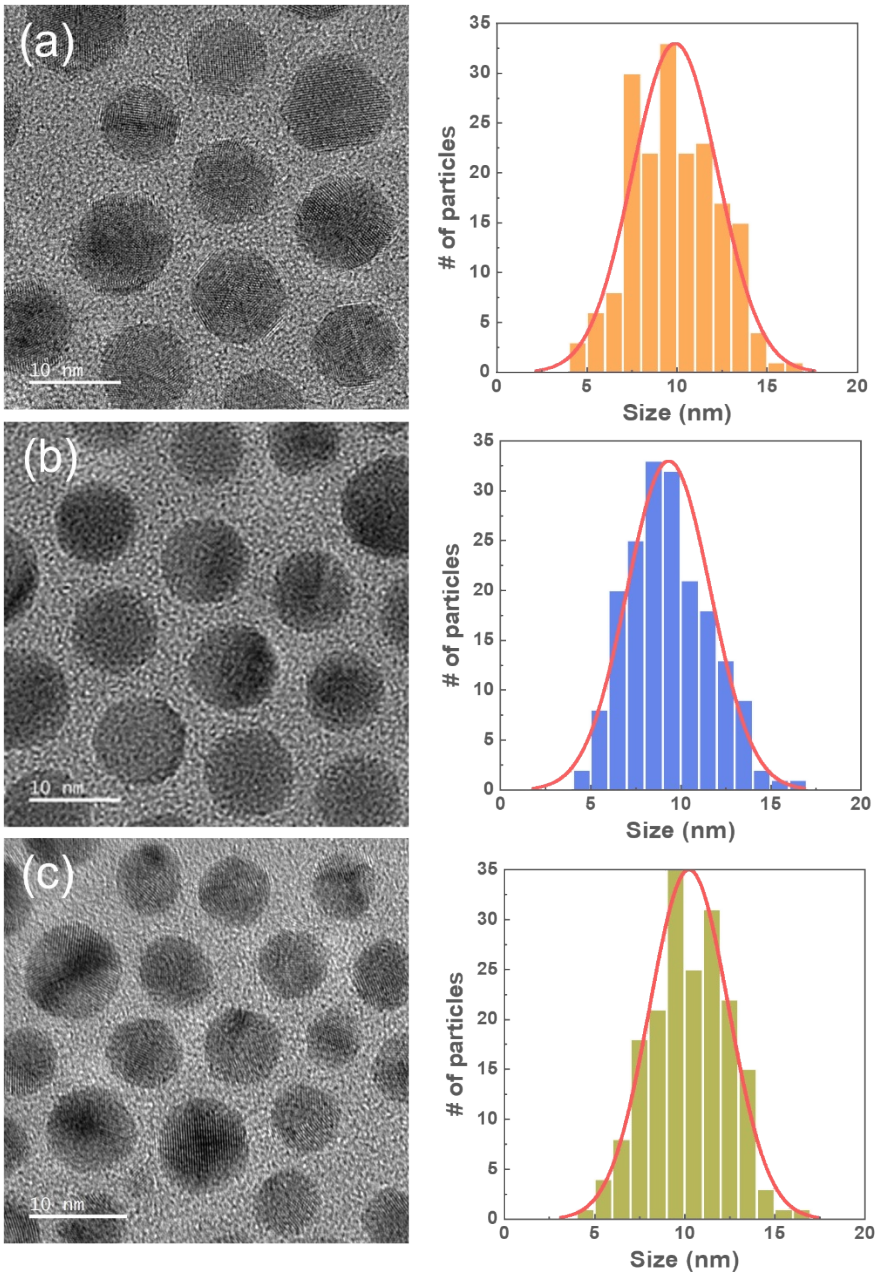

Fig. S2 TEM images (scale bar: 10 nm) and size distribution histograms of (a) Ag, (b) $Au_{0.5}Ag_{0.5}$ and (c) Au NPs.

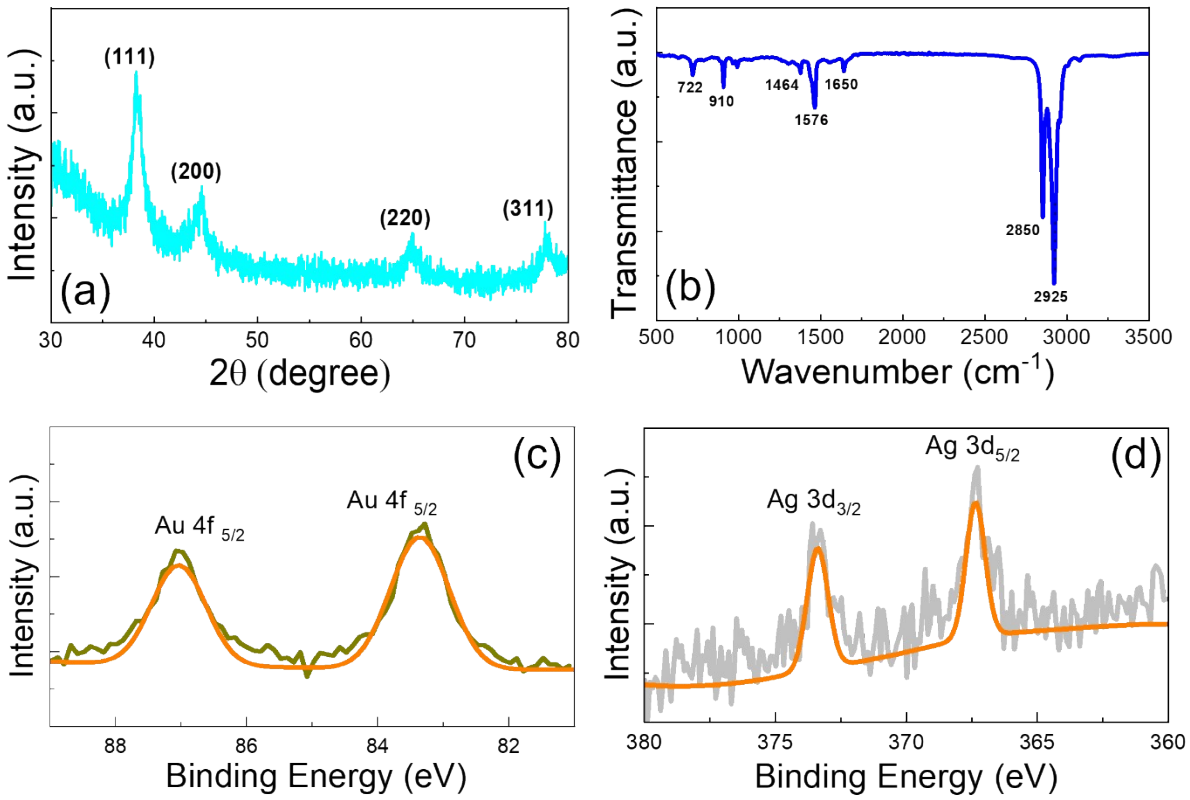

Fig. S3 (a) XRD pattern, (b) FT-IR spectrum, and high-resolution XPS scans of (c) Au and (d) Ag of $Au_{0.5}Ag_{0.5}$ NPs.

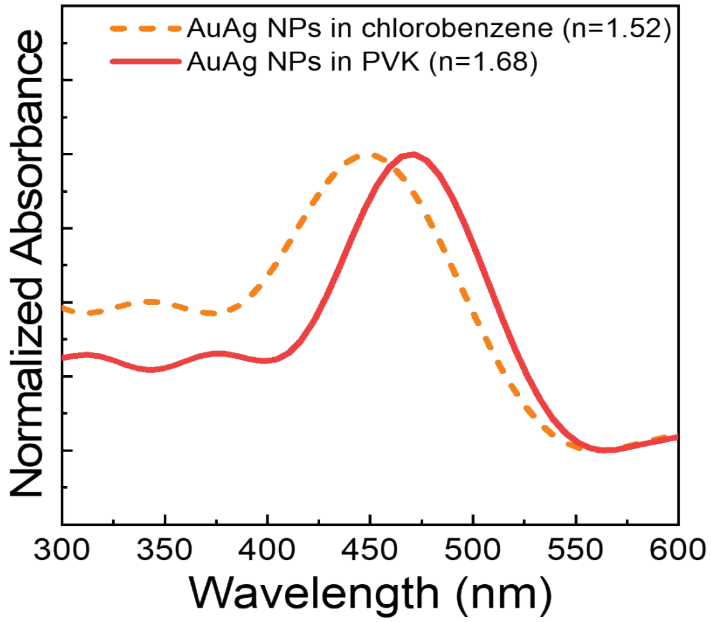

Fig. S4 FDTD-simulated absorption spectra of $Au_{0.5}Ag_{0.5}$ NPs with different surrounding media of chlorobenzene versus PVK.

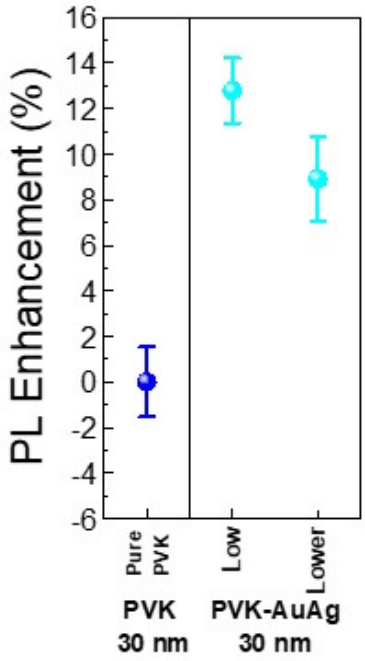

Fig. S5 Percent PL enhancements of QD films with low versus lower concentrations of AuAg NPs embedded in 30 nm PVK thicknesses (the error bars represent the standard deviation).

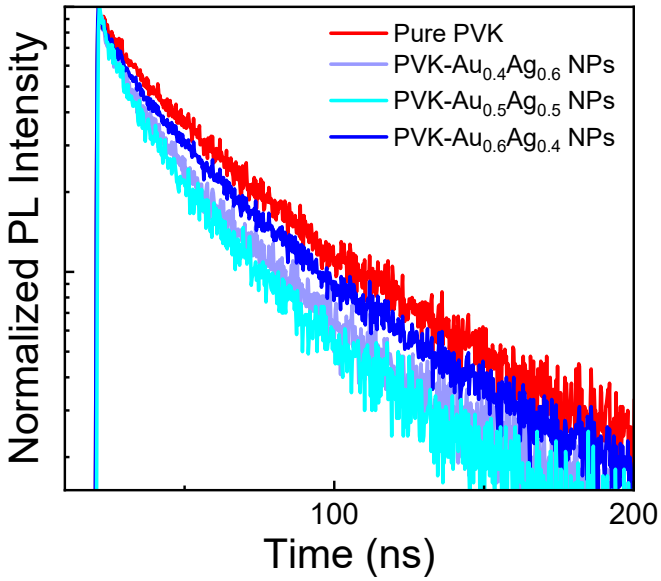

Fig. S6 Comparison of time-resolved PL decay profiles of QD films on PVK without versus with low concentrations of $Au_{0.4}Ag_{0.6}$, $Au_{0.5}Ag_{0.5}$, and $Au_{0.6}Ag_{0.4}$ NPs.

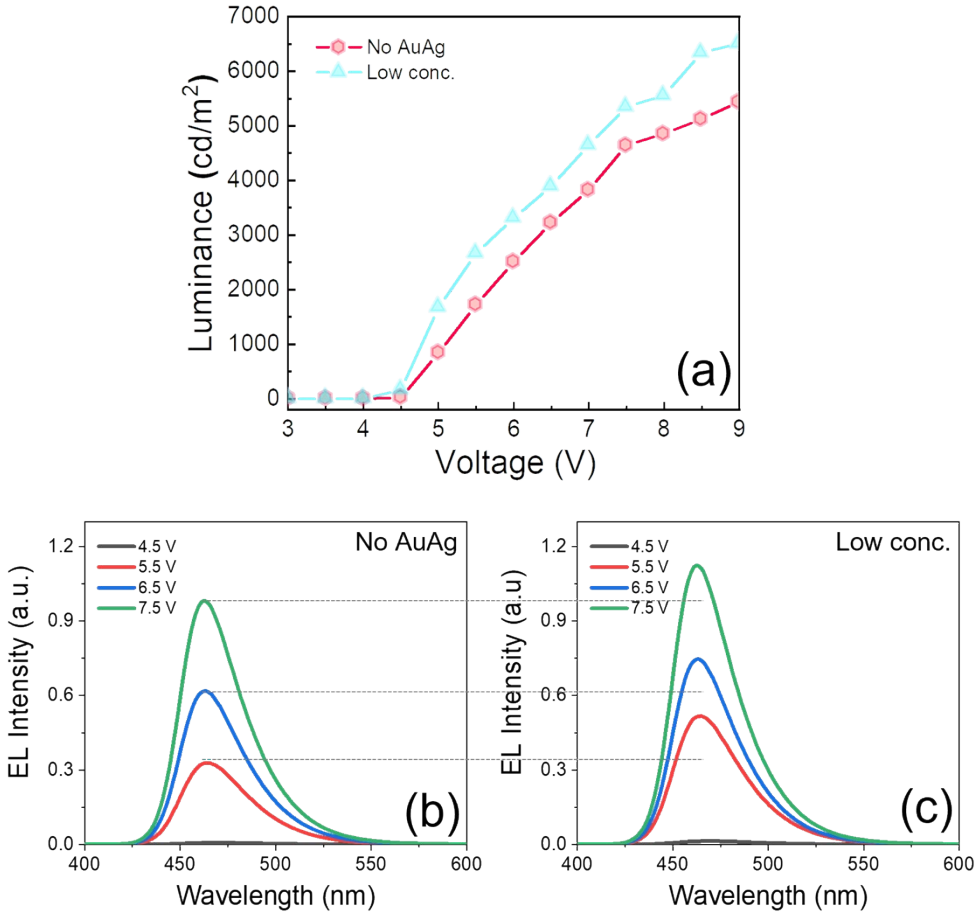

Fig. S7 (a) Variation of luminance as a function of voltage of blue QLEDs with no AuAg and a low concentration of AuAg NPs in PVK. Voltage-dependent, as-recorded EL spectral comparison of devices with (b) no AuAg and (c) a low concentration of AuAg NPs in PVK.

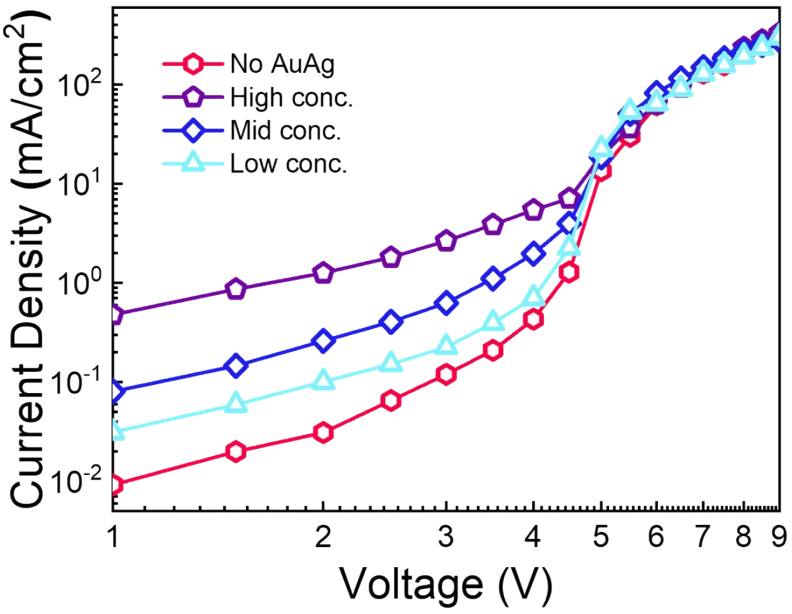

Fig. S8 Logarithmic plots of current density–voltage of blue QLEDs replotted from Fig. 5a.

Table S1 Triexponential fit parameters of time-resolved fluorescence spectra in Fig. 2b. Average lifetime of QD films were calculated using equation (1).

$$\tau = (\alpha_1\tau_1^{\ 2} + \alpha_2\tau_2^{\ 2} + \alpha_3\tau_3^{\ 2})/(\alpha_1\tau_1 + \alpha_2\tau_2 + \alpha_3\tau_3) \quad (1)$$

Film	α_1	τ_1	α_2	τ_2	α_3	τ_3	τ_{av}
w/o AuAg NPs	374.875	6.1244	413.863	21.837	117.696	57.8612	33.4
with AuAg NPs	357.522	3.0135	418.069	14.4088	112.655	43.8318	25.5

1 D. Rioux, S. Vallières, S. Besner, P. Muñoz, E. Mazur and M. Meunier, *Adv. Opt. Mater.*, 2014, **2**, 176–182.