Supplemental information

Enhanced mobility in PbS quantum dot films via PbSe quantum dot mixing for optoelectronic applications

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Detailed Description of Experimental Procedures:

All chemicals are purchased from Sigma company without further purification.

PbS quantum dot synthesis: PbS quantum dots were synthesized by hot injection using following the preparations. First, 0.9 g PbO (99.99%), 2.8 g OA (90%) and 15 g ODE were loaded in a 100 ml three-neck flask to form colorless and transparent solution under vacuum, while stirring and heating at 90 °C for 5 h. Then 280 µl hexamethyldisilathiane (TMS) in degassed ODE was injected into Pb source at 85 °C. The heating mantle was removed and the colloidal flask was cooled naturally to room temperature. The as-synthesized PbS quantum dots were purified 3 times consecutively by precipitation and redispersed in hexane with a concentration of 30 mg/ml for use.

PbSe quantum dot synthesis: First, 0.512 g CdO, 3.14 g OA and 25 g ODE were loaded in a 100 ml three-neck and degassed at 100 °C for 30 min. Then this solution was heated at 250 °C for 60 min under nitrogen

protection to become transparent Cd precursor solution. 0.315 g Se powder was dispersed in 5 ml ODE by sonication. Then this Se precursor was injected into Cd precursor at 200 ^{o}C, naturally cooled to 175 °C and then quickly cooled to room temperature using water bath. The synthesized CdS quantum dots were purified three times by precipitation and dispersed in 5 ml ODE for cation ion exchange. After this, 1.25 g $PbCl_2$ and 15 ml oleylamine were loaded in a three-neck flask and pumped at 140 °C to form Pb source. Then CdS quantum dots in ODE were injected into Pb source and kept reaction for 3 min to form PbSe quantum dots. Finally, the synthesized PbSe quantum dots were isolated 3 times following the recipe and dispersed in hexane with a concentration of 30 mg/ml for use.

PbS and PbSe quantum dot mixing: the desired amount of PbSe QD solution was added into PbS solution to form mixed QD solution.

Preparation of ZnO precursor solution: 1 g zinc acetate, 0.3 g mono-ethanolamine and 15 g 2-methoxylethanol was added in a 20 ml vial to form uniform solution under stirring and heating at 70 °C for 24 h. The obtained solution was filtered for use.

Device fabrication: The patterned ITO glasses were cleaned using detergent, acetone, isopropanol. Two layers of ZnO film were deposited and annealed in air ambient condition on patterned ITO glasses using sol-gel spin-coating method following the recipe.[1] Five samples of QDs were spin-coated onto the ZnO films, then treated with 10 mM PbI_2 DMF solution and rinsed with acetonitrile by soaking. This procedure was repeated 6 times to yield 200 nm thick QDs layers. Two layers of pure PbS QDs with 50 nm thickness were spin-coated onto the QD layer and treated with PbI_2 then with 1,2-ethanedithiols (EDT) as hole transport layer in solar cell. Approximately 100 nm thick gold electrodes were deposited by thermal evaporation. The active area is 0.09 cm^2. For fabrication of photodetector, the QDs solution was spin-coated on glass substrates, then treated with 10 um/mol PbI_2 DMF solution and rinsed with acetonitrile. This procedure was repeated 4 times using identical process of solar cell fabrication to yield 100 nm QDs film; gold interdigitated electrodes were thermally evaporated and finally 10 mg/ml PMMA toluene solution was spin-coated onto deposited QDs film to prevent the incursion of moisture and oxygen from the air. Field

effect transistors were fabricated by spin-coating QDs onto SiO_2/Si substrates with pre-patterned interdigitated gold electrodes.

Characterization: The PL spectra of perovskite NCs were measured at room temperature by a homemade laser PL spectroscopy system using a different wavelength laser (CrystaLaser, Model BLC-050-405) as the excitation source. The absorption spectra of the solution-based samples were measured by Perkin Elmer Lambda1050 UV–vis–NIR spectrophotometer in ambient conditions. XPS measurements were carried out with a Genesis system (EDAX Inc.). The current density–voltage (J-V) characteristics of these devices were measured using Keithley 2400 (I-V) digital source meter under a simulated AM 1.5G solar irradiation at 100 mW/cm^2 (Newport, AAA solar simulator, 94023A-U). X-ray photoelectron spectroscopy (XPS) measurement was carried out with a Genesis system (EDAX Inc.). TEM measurements were carried out using a Tecnai G2 20U-TWIN. Photodetector performances were measured using a probe station connected to an Agilent B1500A semiconductor characterization system. The device was further covered with an aluminum cap to provide optical and electromagnetic shielding during the photodetector measurements. Illumination was generated from 760 nm light emitting diodes (LEDs) controlled by a functional generator (Agilent 33210A). Light intensity was calibrated using a silicon photodetector (Newport 818-UV). Time-resolved PL spectroscopy (TRPL) were carried out on the finished device at room temperature by using a Hamamatsu single-photon counting system and a solid state laser with excitation power of about 100 mW. The laser pulse width was 130 fs, and the repetition rate was 76 MHz. The excitation wavelength for both PL and TRPL measurements is 800 nm.

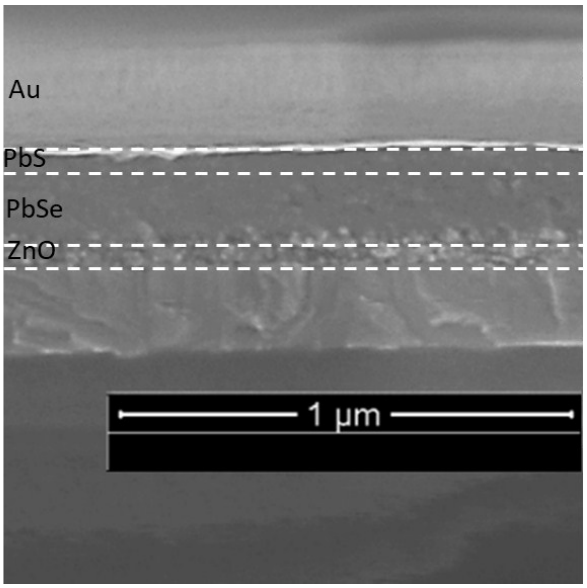

Figure S1. Scanning electronic microscopy image of complete device of 5% PbSe mixing solar cell

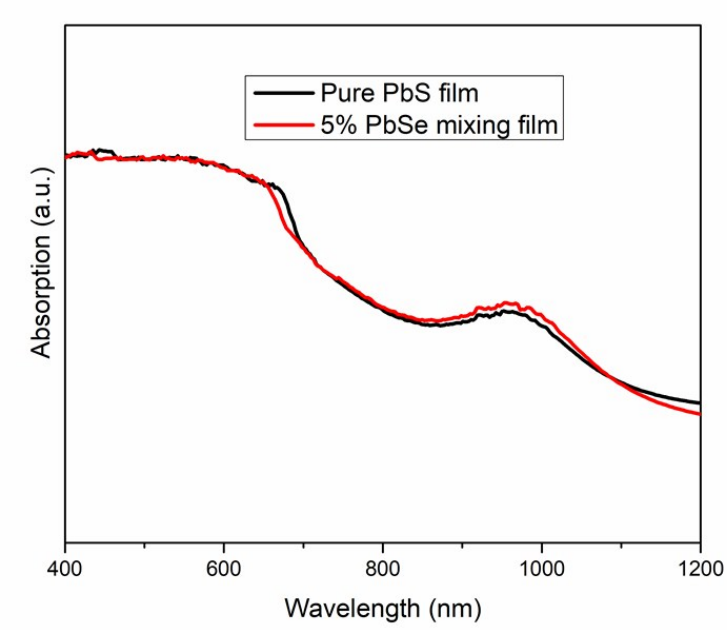

Figure S2. The UV-VIS absorption curves of pure PbS and 5% PbSe mixed films.

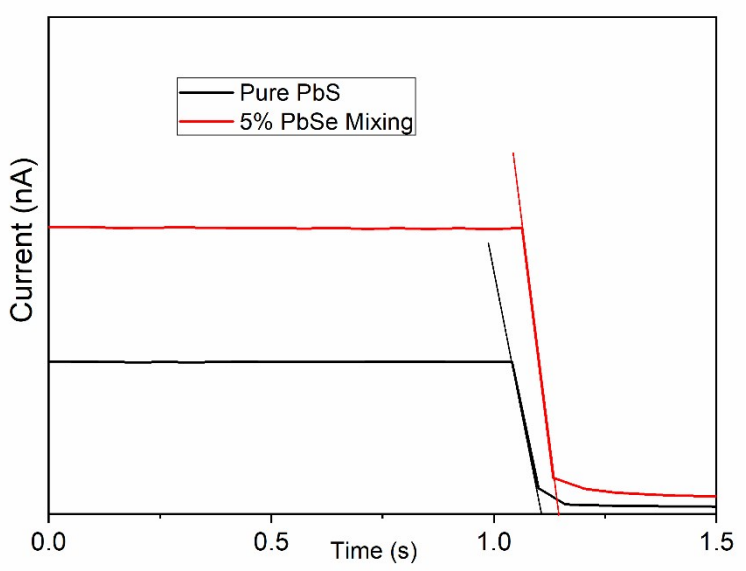

Figure S3, the temporal response curves of two kinds of photodetectors.

Table S1. Detailed characteristics of our photodetectors and reported photodetectors.

performance	**Detectivity**	**responsivity**	**Ip/Id**
Pure PbS	23.0 x 10^9 Jones	1.2 mA/W	20
5% PbSe Mixing	27.6 x 10^9 Jones	1.9 mA/W	24
Reference[2]	21.0 x 10^9 Jones	1.5 mA/W	4.4
Reference[3]	8.9 x 10^9 Jones	1.6 mA/W	11.9

SI References

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