Supporting information

In-Situ Assembly of Cu_xS Quantum-Dot into Thin Film: A Highly-Conductive P-Type Transparent Film

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Experimental details

Synthesis of Cu_xS QD film

Cu_xS QD thin films on quartz-glass and flexible PE substrates were synthesized in an aqueous solution at room temperature. Typically, 0.316 g $CuCl_2 \cdot 2H_2O$ was dissolved in a mixed solution of 50 ml of water and 3 ml of NH_4OH, and then 1.5 ml of triethanolamine (TEA) and 15 ml of 0.1 M thiourea (Tu) were added with stirring, respectively. Quartz-glass is surface-functionalized by self-assembled monolayers (SAMs) of 3-(trimethoxysilyl) propylamine (TMOSPA, Alfa Aesar, 96%), which were prepared by immersing the substrate into a 50:50 (v/v) solution of ethanol/water with 100 mM TMOSPA for 8 h. Surface of PE plastic substrate was modified by fumed sulfuric acid to form sulfonic groups. The surface-modified substrates were subsequently immersed into the aqueous precursor solution for 6 h at room temperature (~25 ^{o}C). Cu_xS film was formed based on the nucleation and growth of

cooper sulfide solid phases. The obtained film was carefully rinsed with deionized water and dried naturally.

Characterization

The elemental composition of the as-prepared Cu_xS thin film was determined by X-ray photoelectron spectroscopy (XPS) using nonmonochromatic Mg Kα X-rays as the excitation source and C1s as reference line. Morphologies of surface and cross-section of the Cu_xS film were characterized by field-emission scanning electron microscopy (FESEM; JSM 6700F, JEOL). High-resolution transmission electron microscope (HRTEM; JEM-2100F, JEOL) was used to determine the detailed crystalline structures. Optical transmittance study was carried out using a UV-Vis spectrometer in the wavelength range of 380~1100 nm. The Seebeck coefficient was calculated from the slope of the linear relation between ΔV and ΔT, where ΔV is the thermoelectromotive force and ΔT is the difference in temperature, measured by two Pt/Pt-Rh thermocouple attached to both ends of the surface of the prepared films. ΔT was built by heating one end using a film heater to generate temperature gradients. Dark electrical resistivity, carrier concentration and Hall mobility were measured by the dc four-point probe method in the van der Pauw configuration using a Hall measurement system (ACCENT HL5500).