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Research paper

Synthesis of 4-aminothiophenol functionalized quantum dots to sensitize silver nanowires and its application for solar cells

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ABSTRACT

A novel strategy for synthesizing a quantum dot (QD)-sensitized silver nanowire (AgNW) nanocomposite has been reported. 4-aminothiophenol (PATP) functionalized quantum dots (QDs-PATP) were prepared using the thiol (—SH) end of PATP molecules strongly bound to the surface of QDs via a ligand exchange technique. AgNWs could bind to the remaining amino group (—NH_2) of PATP via self-assembly techniques, and quantum dot-sensitized silver nanowires were then formed. The nanocomposite is denoted as QDs-PATP@AgNWs. The photovoltaic properties of a quantum dot-sensitized solar cell (QDSSC) based on QDs-PATP@AgNWs were investigated. Under AM 1.5 illumination, the QDSSC reached a peak conversion efficiency of 3.34%. This finding suggests that QDs-PATP@AgNWs had potential applications as a photoanode for QDSSC.

1. Introduction

Energy crises and environmental pollution have become common problems faced by all countries throughout the world [1,2]. The development and utilization of solar energy have a very important role in solving the energy crisis and the development of a low-carbon economy [3,4]. At present, there are many disadvantages of solar energy, such as the high energy consumption and low photoelectric conversion efficiency of solar cells. Hence, finding more effective methods or strategies has become a major issue in the fields of materials physics, photovoltaic devices and energy science.

The new generation of solar cells-quantum dot-sensitized solar cells (QDSSCs) [5–7] has aroused widespread concern in the scientific community because the photovoltaic conversion efficiency of QDSSC may exceed the Shockley and Queisser limit [8,9] of 44% [10]. So far, a major challenge for improving the performance of QDSSC has been inhibiting electronic recombination [11–13]. Therefore, scientists have chosen TiO_2 [14–17], CNTs [18,19] and other materials as a bridge to provide an electronic pathway from QDs to the electrode. In particular, nanowires have arisen as a superior candidate over other materials due to their unique optical properties [20,21], plasmonic effects [22,23], electrical properties [24,25] and mechanical properties [26–28]. Tang et al. prepared a ZnO nanowire array, used chemical bath deposition to deposit QDs and then assembled a battery whose photoelectric conversion efficiency was only 0.34% [29]. Compared with the ZnO nanowire, AgNWs exhibit much lower resistivity [30,31], so synthesizing a QD-sensitized silver nanowire nanocomposite and appraising its QDSSC properties are meaningful tasks. However, the chemically inert surface of QDs [32] has restricted the connection of AgNWs, and the efficiency of transferring electrons has hardly been enhanced. For this reason, strengthening the interaction between AgNWs and QDs is a prerequisite for fabricating QDSSCs with higher power conversion efficiencies.

In this work, a connecting molecule with a conjugated electron cloud (P-π) is selected, which is 4-aminothiophenol (PATP). The thiol (—SH) of PATP can strongly bond to the surface of QDs [33], and then AgNWs can bind to the remaining amino group (—NH_2) of PATP via self-assembly techniques [34]. This achieves a chemical link between QDs and AgNWs. Thus, a quantum dot-sensitized silver nanowire (QDs-PATP@AgNWs) nanocomposite is formed (as illustrated in Fig. 1) [35]. The benzene ring in the QDs-PATP@AgNWs provides a conjugated electron cloud passageway for electron transport and makes the photoelectron effectively transmit to the silver nanowires. The conversion efficiency of QDSSC based on QDs-PATP@AgNWs is increased.

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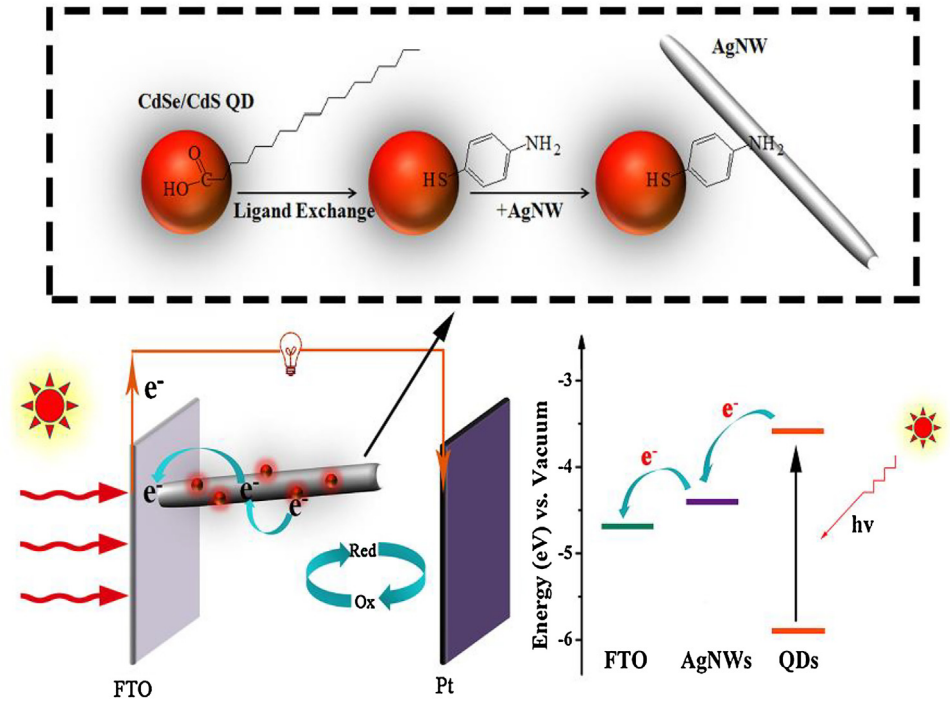

Fig. 1. Schematic and energy band diagram of the fabricated solar cell.

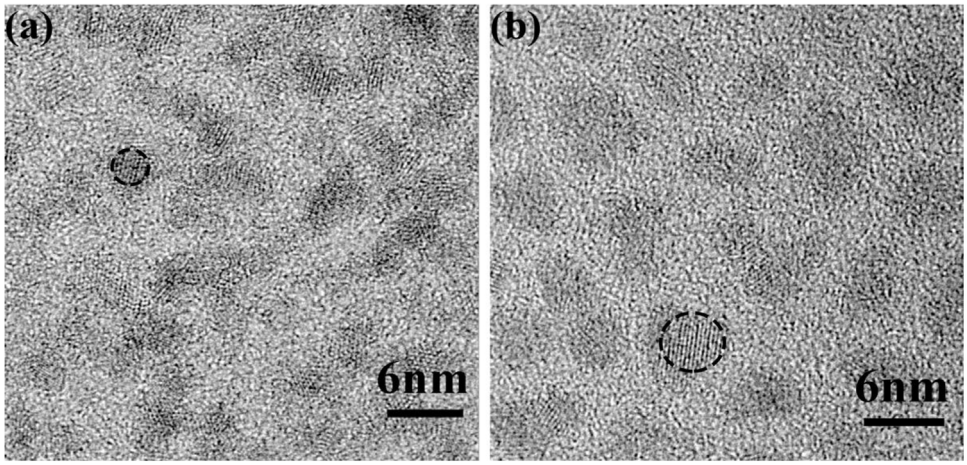

Fig. 2. HR-TEM images of CdSe QDs (a) and CdSe/CdS core/shell QDs (b).

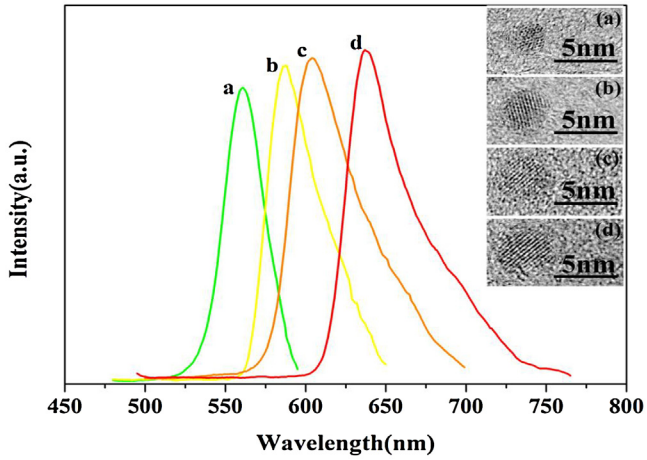

Fig. 3. FL spectra and HR-TEM images of CdSe/CdS QDs with increasing CdS capping times to 5 (a), 10 (b), 15 (c) and 20 min (d).

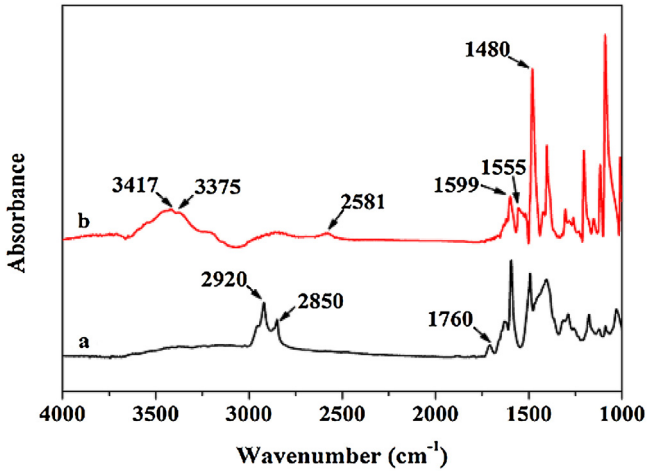

Fig. 4. FT-IR spectra of (a) OA, (b) PTAP capped CdSe/CdS core/shell QDs.