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Facile preparation of Ag_2S nanoparticles with broad photoelectric response region

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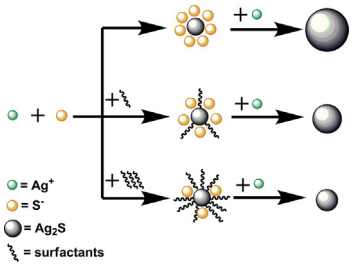
HIGHLIGHTS

- We report a simple one-step hydrothermal synthesis on Ag_2S nanoparticles.
- The photoelectric properties of the Ag_2S nanoparticles were studied.
- A mechanism for the nucleation and growth of Ag_2S NPs was proposed.
- The concentration of surfactants impacts the grain diameter and the photoelectric properties.

GRAPHICAL ABSTRACT

Ag_2S nanoparticles (NPs) are prepared by a simple one-step hydrothermal synthesis. Various particle diameters of Ag_2S NPs are obtained under different concentrations of surfactants. A mechanism for the nucleation and growth of Ag_2S NPs under the influence of surfactants is proposed. X-ray powder diffraction (XRD), scanning electron microscopy (SEM) and UV–vis absorption spectroscopy are used to characterize the obtained product. In order to investigate the photoelectric properties of the Ag_2S NPs, surface photovoltage (SPV) technique was studied. The Ag_2S NPs perform intense photoelectric response in the range of NIR and visible region, which could be applied in photoelectric detector.



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ABSTRACT

In this paper, Ag_2S nanoparticles (NPs) are prepared by a simple one-step hydrothermal synthesis. Various particle diameters of Ag_2S NPs are obtained under different concentrations of surfactants. A mechanism for the nucleation and growth of Ag_2S NPs under the influence of surfactants is proposed. X-ray powder diffraction (XRD), scanning electron microscopy (SEM) and UV–vis absorption spectroscopy are used to characterize the obtained product. In order to investigate the photoelectric properties of the Ag_2S NPs, surface photovoltage (SPV) technique was studied. The Ag_2S NPs perform intense photoelectric response in the range of NIR and visible region, which could be applied in photoelectric detector.

1. Introduction

With the development of photoelectric detection technology, the semiconductor photoelectric detector with high efficiency and accuracy is applied abroad [1]. Based on region of photoelectric response, the detectors are distinguished into ultraviolet photoelectric detector, visible light photoelectric detector and infrared photoelectric detector. At this stage, silicon prove to be the core of visible light photoelectric detector, possessing excellent photoelectric properties in the region of visible light [2]. The core component of NIR and infrared photoelectric detectors upon most occasions consist of elements in long period. In the available reports, the solid solution HgCdTe made with HgTe and CdTe [3,4], InMnAs [5], InGaAs [6], Ge/Si heterojunction [2] have already been put into

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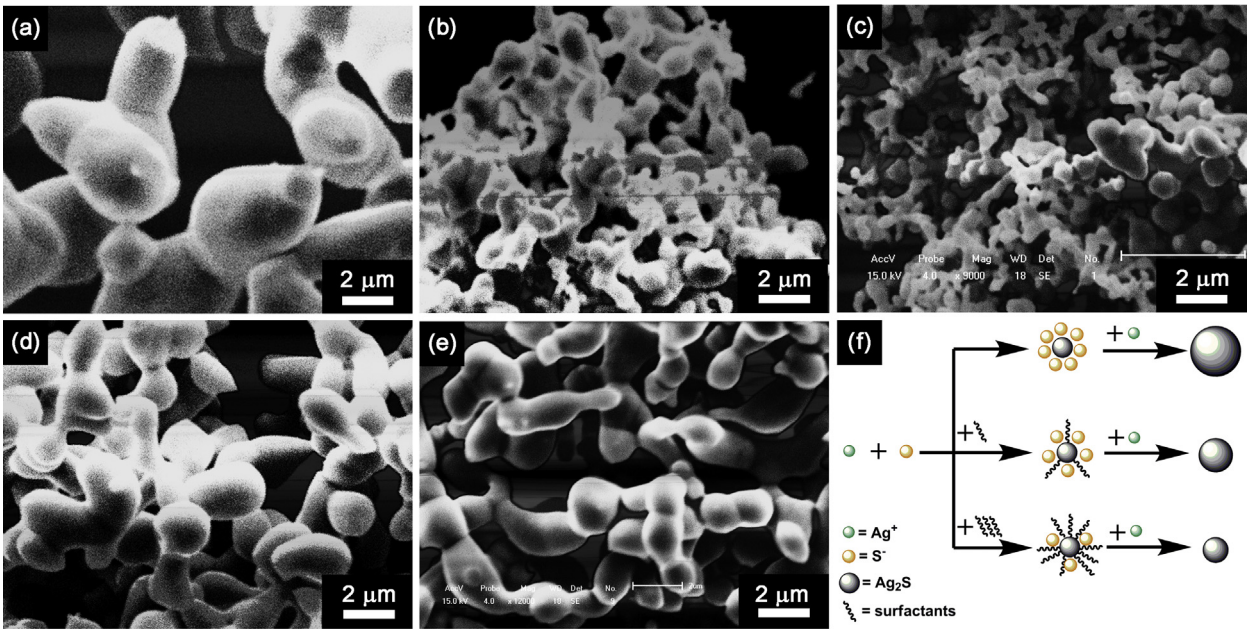

Fig. 1. SEM images of Ag_2S NPs (a) without surfactants, (b) with 0.005 mol/L Glu, (c) with 0.0083 mol/L Glu, (d) with 0.0033 mol/L SDS, (e) with 0.0132 mol/L SDS, (f) the mechanism diagram of the growth process of Ag_2S NPs.

use in infrared detection field, and the limits of detection are from 800 nm to over 1000 nm [2–9]. But ability of detection of the detectors in the range of below 800 nm is limited. So the seeking for a semiconductor material with outstanding photoelectric properties and wide photoelectric region prepared by a safe and easy preparation method is necessary.

Silver sulfide (Ag_2S) is a direct, narrow-band gap semiconductor with good chemical stability and excellent optical limiting properties, as well as an unusual solid ionic conductor that operates at room temperature and conducts both electrons and ions [10]. The band gap of Ag_2S approximately equals to 1.0 eV [11]. So it has been widely applied in photoelectric device and solar cell [11–21]. When it comes to the preparation of Ag_2S, the reaction mechanisms that sulfur ions and silver ions take place chemical reaction with different surfactant have grown up. Li et al. utilize solvothermal processes to prepare Ag_2S nanowires with sulfur powder, $AgNO_3$ and octadecylamine (as a surfactant) [10]. The Ag_2S achieved by them bring out fine oxygen sensitivity in room temperature. The reaction process is complex as the octadecylamine need to be heating and melting to serve as a solvent. Dong et al. prepared cubic Ag_2S via hydrothermal method with CTAB as a surfactant [22]. Chin et al. employ hexadecylamine (HDA), octylamine (OA), ethylenediamine (EDA) and dioctylamine (DOA) as stabilizers to synthetize Ag_2S nanocrystal [23]. Many of the previous reports in which has a dramatic effect on adjusting the morphology of Ag_2S focus on the choice of stabilizers or surfactants, but the reaction condition and process to are complicated.

In this paper, a novel synthetic method of Ag_2S NPs prepared by a simple one-step hydrothermal synthesis s proposed, in order that the samples achieved by this way are provided with broad photoelectric region (including UV, visible light and NIR).

2. Experimental

2.1. Sample preparation

In our synthesis, an aqueous solution composed of 0.1 mol/L thiourea (Tu) and 0.033 mol/L $AgNO_3$ was used for preparation of the Ag_2S NPs, which was to give the final molar ratios of [Tu]:[$AgNO_3$] = 3:1 and the solution was stirred to form a clear one.

Subsequently, sample 1 was achieved by the following way: the above solution without any surfactants was stirred to form clear and the resulting mixture were sealed in 50 mL Teflon-lined stainless steel autoclaves and maintained at 180 °C for 4 h. After the solutions being allowed to cool to room temperature naturally, the black precipitates were collected by centrifugation and washed triple with distilled water and twice with anhydrous ethanol, then dried at 50 °C. Sample 2 and sample 3 were got by the way that the solution above were separately mixed with 0.005 mol/L glutathione (Glu) and 0.0033 mol/L sodium dodecyl sulfate (SDS), while the rest of the steps were the same as sample 1. The roles of Glu and SDS are both surfactants. By adjusting the initial concentration of Glu and SDS with the other conditions kept as constant (0.0083 mol/L Glu for sample 4 and 0.0132 mol/L SDS for sample 5), corresponding Ag_2S NPs could be prepared, respectively.

2.2. Characterization

The crystalline phase was determined by powder X-ray diffraction (XRD) with a Rigaku D/Max-2550 diffractometer using Cu Kα radiation (λ = 1.54056 Å) at 50 kV. The morphologies of Ag_2S were obtained by a scanning electron microscope (SEM, Shimadzu, SS-550). The UV-vis-NIR absorption spectra (Shimazu, UV-3600) were employed to measure the samples. The xenon lamp spectrum is recorded on a UV-vis spectrophotometer (Maya 2000 PRO, Ocean Optics)

2.3. Surface photovoltage measurements

The SPV spectroscopy measurement was carried out based on the lock-in amplifier. The measurement system consisted of a source of monochromatic light, a lock-in amplifier (SR830, Stanford Research Systems, Inc.) with a light chopper (SR540, Stanford Research Systems, Inc.), and a sample chamber. The conditions in the chamber were atmospheric pressure and ambient atmosphere during the measurements. Monochromatic light was provided by a 500 W xenon lamp and a monochromator (SBP500, Zolix). The