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Synthesis of CdS nanoplates by PAA-assisted hydrothermal approach

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Abstract

Triangular and hexagonal CdS nanoplates, with average size about 100 nm and average thickness range from 10 to 30 nm, have been synthesized in the presence of poly (acrylic acid) (PAA) assisted hydrothermal process at 180 °C. The structural characteristics, morphology, and optical properties of the as-prepared CdS products were investigated. UV–vis spectroscopy measurement reveals that the products show a strong quantum size effect. Based on the experiment results, the possible formation mechanism of CdS nanoplates has been proposed.

Keywords: CdS; Hydrothermal; Nanoplates; Triangular; Hexagonal

1. Introduction

Nanomaterials, which have received wide recognition for their novel size- and shape-dependent properties, as well as their unique applications and special characteristics that differ from bulk crystals, have been extensively investigated for over decade [1–5]. In principle, the electronic and optical properties of semiconductor materials can be tuned by varying their shapes and sizes. Thus, the synthesis of inorganic nanocrystals of controlled size and shape are of special interest. The semiconductor CdS, which has been one of the most important II–VI group semiconductors with a direct band-gap of 2.42 eV at room temperature, has been investigated due to its extensive applications in photoelectric conversion in solar cells and light-emitting diodes and nanodevices [6–9]. In recent years, One-dimensional CdS nanostructural materials including nanowires, nanorods and nanotubes have been prepared by various physical and chemical solutions [10–13]. CdS of other morphologies such as hollow sphere, peanut shapes have been synthesized with different methods [14,15]. Although CdS nanostructures have been reported using various methods, to the best of our knowledge, there have been few reports about synthesizing triangular and hexagonal shape CdS nanoplates via organic-assisted hydrothermal method.

In the present work, we report the synthesis of triangular and hexagonal shape CdS nanoplates using a facile hydrothermal method, employing cadmium acetate ($Cd(CH_3COO)_2{\cdot}2H_2O$), thioacetamide (TAA, CH_3CSNH_2), poly (acrylic acid) (MW 9000, water solution, weight ratio, w/w=25%) as the starting reagents. The influence of the concentration of cadmium acetate on the shape and crystallization of CdS was investigated. The difference in the polarity of solvents also impacts the morphology of the products.

2. Experiment procedure

All of the chemical reagents used were of analytical grade and without further purification. The PAA was purchased from Polysciences, Inc. In a typical synthesis procedure, 0.144 g of thioacetamide and 1.106 g of poly (acrylic acid) were put into a glass beaker, which was filled with 60 mL distilled water under rigorous magnetic stirring at ambient temperature. After 30 min of further stirring, the mixture solutions were kept static for 24 h. Then about 0.426 g of cadmium acetate was dissolved in

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20 mL distilled water and dropped into the aforementioned mixture solution continuously stirring and resulted in a final solution. The cadmium acetate concentration was 0.02 mol·dm^{-3}. The final solution was transferred into Teflon-lined stainless steel autoclave, sealed and maintained at 180 °C for 24 h. Finally, The resulting deep-yellow solid products were centrifuged, washed with distilled water and ethanol several times to remove the ions and organic byproducts possibly remaining in the final product, followed by drying in oven at 60 °C for 20 h. The yellow powders were collected for characterization.

The obtained samples were characterized by X-ray powder diffraction (XRD) using a Bruker D8-ADVANCE X-ray powder diffractometer using Cu Kα radiation (λ=0.154178 nm) by step scanning with a step size of 0.02°. The morphology, structure of CdS was obtained from transmission electron microscopy (TEM). Fourier transform infrared (FTIR) absorption spectra were obtained with a NICOLET 510DX spectrometer. The UV–vis absorptions were recorded on Hp-6010 UV–vis spectrometer.

3. Results and discussion

The morphology and dimension of the products were examined by TEM, as shown in Fig. 1. Fig. 1a shows the TEM image of the as-prepared CdS nanoplates with an average size of 100 nm and the thickness of 7–10 nm when the cadmium acetate reaction concentration was 0.02 mol·dm^{-3}. The image reveals that a bulk of as-prepared CdS was consisted of lots of triangular and hexagonal nanoplates and some polyhedron. When the concentration of cadmium acetate, thioacetamide, poly (acrylic acid) was increased to 0.05 mol·dm^{-3}, 0.36 g, and 2.765 g, respectively, it is observed that the morphology of the CdS nanoplates have no evident change except that the thickness of triangular and hexagonal CdS nanoplates is increased to 20–30 nm, as shown in Fig. 1b and c. A selected area electron diffraction pattern was recorded from a single CdS nanoplate. The SAED pattern inserted in Fig. 1c indicates that the as-prepared CdS nanoplate is single crystal. Fig. 1d shows the representative XRD pattern of the products prepared by hydrothermal route. It is obvious that all the diffraction peaks can be indexed as cubic-phase structure CdS with cell constant a=0.419 nm,

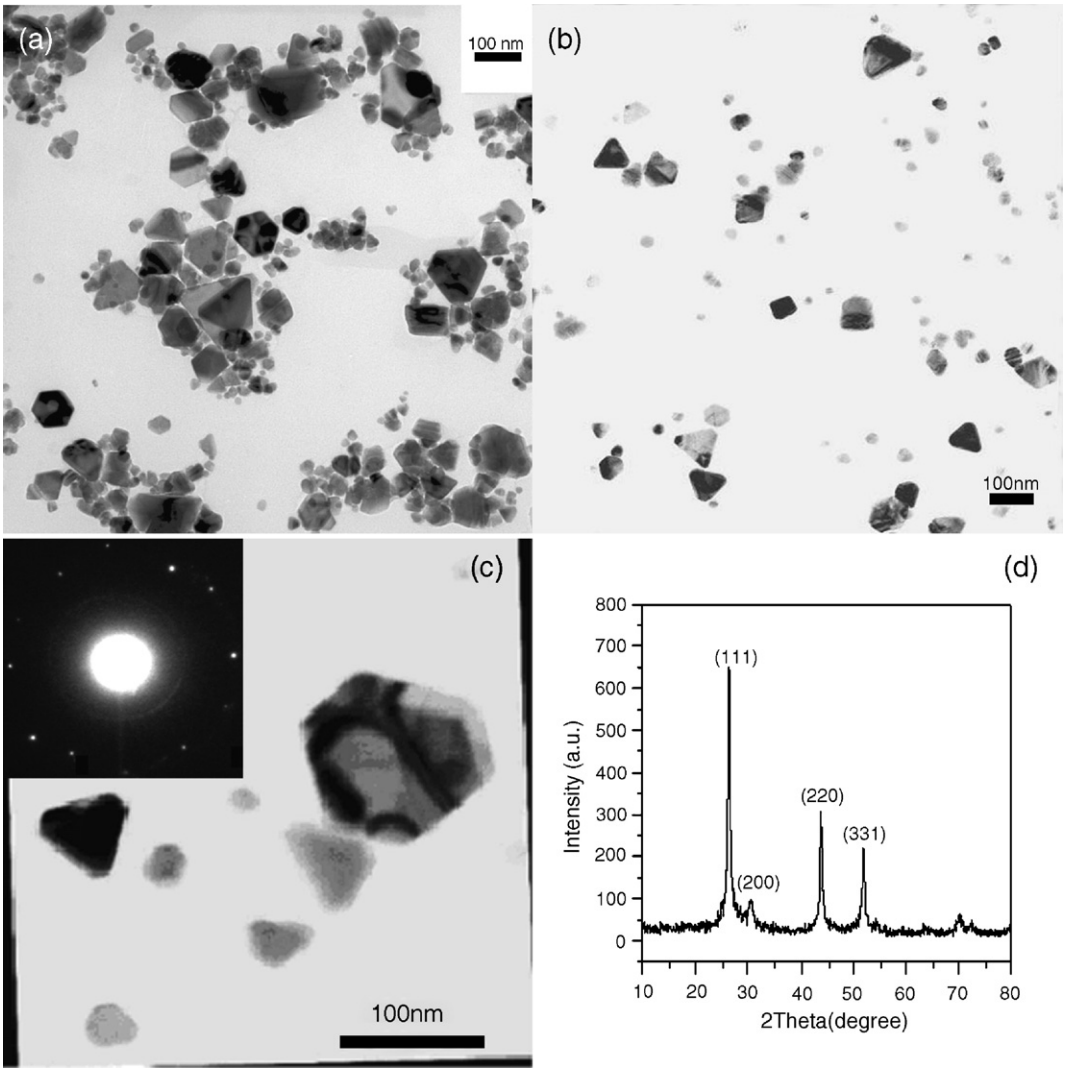

Fig. 1. TEM images of CdS nanoplates prepared in water under different cadmium acetate concentrations (a) 0.02 mol·dm^{-3}; (b) 0.05 mol·dm^{-3}; (c) TEM image of a single triangle and hexagonal CdS nanoplates under cadmium acetate 0.05 mol·dm^{-3}. The inset corresponds to the SAED pattern of the CdS nanoplates (d) XRD pattern of the product.