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Low temperature growth of metastable cubic CdSe nanocrystals and their photoluminescence properties

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ABSTRACT

Metastable cubic CdSe nanocrystals have been synthesized via solution growth technique along the temperature range 55–95 °C. The as-synthesized nanocrystals have been characterized using X-ray diffraction (XRD), transmission electron microscopy (TEM) and energy dispersive X-ray (EDX). The results indicated that metastable cubic CdSe with the lattice constant $a=0.609$ nm is formed. This cubic structure was found preserved at all temperatures growth. HRTEM measurement confirmed the good crystallinity cubic phase of the CdSe NCs with lattice constant $a=0.61$ nm. The EDX measurement indicated the presence of Cd and Se only with atomic ratio of Cd Se is 0.56:0.44. The optical absorption as a function of the wavelength for the prepared CdSe nanocrystals at different temperatures is investigated. The results indicated the formation of CdSe nanocrystals and their size corresponding to the regime of spatial exciton confinement. The photoluminescence emission intensity for as-synthesized CdSe nanocrystals at different reaction temperatures depicted that at low temperature (55 °C) the emission peak intensity of the CdSe QDs was much larger than the absorption edge, indicating the presence of surface trap-state emissions. These surface crystal defects reduced with the increase in the reaction temperature.

1. Introduction

Semiconductor quanta dots (QDs) have attracted broad attention in recent years because of their bright, photostable fluorescence, broad excitation spectrum and narrow size-controlled emission, which allows multi-color imaging [1–3]. Among them, cadmium selenide (CdSe) QDs have become one of the most extensively studied fluorescent semiconductor nanocrystals due to their suitable and tunable band gap throughout the visible spectrum [4,5].

The properties of QDs are strongly influenced not only by the composition and structure of the matrix, but also by the preparation technique. There exist many techniques that have been applied to synthesize CdSe quantum dot such as single molecule precursor route, solvothermal route and sonochemical route [6–8]. These techniques require a very high temperature besides the use of expensive and toxic chemicals. Synthesis directly in water has been considered to be an alternative approach for circumventing the above-mentioned disadvantages [9–11].

Recently, great efforts have been employed to focus on the synthesis of CdSe QDs directly using water-based route [12–14]. The advantages of this method include the low-cost, green, fast, low temperature required for processing, the possibility of controlling particle morphology, the good crystalline and mass-production of CdSe NCs with the desired quality. All CdSe QDs produced at low temperature in aqueous phase have a cubic structure [15,16].

In this work, we describe a simple method to prepare monodispersed CdSe QDs from a molecular precursor using water as solvent. While there have been many reports on the synthesis of CdSe nanoparticles in water [17–20], as far as we know, this is the first report of preparing CdSe QDs in aqueous solution directly from a single molecular precursor. Our approach produces water-soluble QDs in relatively high yields, the particle size and its emitting color can be tuned easily by changing the feed ratio between capping agent and the precursor. The QDs prepared are fairly uniform in size, without the need of size-sorting such as for those carried out in some earlier reports on water-soluble preparations [21–25].

2. Experimental

Nanocrystals of CdSe were prepared by chemical method and all the chemicals used were of analytical grade. Cadmium chloride ($CdCl_2 \cdot 5H_2O$) was used as the cadmium source and sodium selenosulfate (Na_2SeSO_3) was chosen as the selenium source.

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