Materials Letters 126 (2014) 119–122

Contents lists available at ScienceDirect

Materials Letters

journal homepage: www.elsevier.com/locate/matlet

Structural, optical and magnetic properties of cobalt and aluminum codoped CdS nanoparticles

G. Giribabu [a], G. Murali [b], D. Amaranatha Reddy [c], S. Sambasivam [d], R.P. Vijayalakshmi [b,*]

[a] Department of Physics, P.V.K.N. Govt. Degree College, Chittoor, A.P., India
[b] Department of Physics, Sri Venkateswara University, Tirupati, India
[c] Department of Chemistry and Chemical Institute for Functional materials, Pusan National University, Busan 609-735, South korea
[d] Department of Physics, Pukyong National University, Busan 608-737, South Korea

ARTICLE INFO

Article history:
Received 30 January 2014
Accepted 7 April 2014
Available online 16 April 2014

Keywords:
Nanoparticles
Codoping
Crystal structure
Magnetic materials

ABSTRACT

We are the first to report a systematic study on the structural, optical and magnetic properties of cobalt and aluminum codoped CdS nanoparticles synthesized by simple co precipitation method. XRD patterns confirm the formation of single phase cubic structure for all the compositions. From diffuse reflectance spectra (DRS), three characteristic reflectance minima peaks present for all samples at 686, 729 and 750 nm associated with d–d transitions $^4A_2(F) \rightarrow 3/2U^1$, $^4A_2(F) \rightarrow E^{11}$ and $^4A_2(F) \rightarrow 5/2U^1$ confirm the substitution of Cd^{2+} ion by Co^{2+} ion in CdS. Blueshift of absorption edge with the incorporation of Al into CdS:Co nanoparticles is the evidence for the substitution of Cd^{2+} ion by Al^{3+} ion. Bandgap widening observed with increasing Al content can be explained by Burstein–Moss effect. Photoluminescence spectra revealed the transition of defect related green emission into near band edge blue emission by aluminium codoping, which can be attributed to the reduction of defect levels. In the present study, $Cd_{0.96-x}Co_{0.04}Al_xS$ nanoparticles system is found to be capable of retaining a part of room temperature ferromagnetic (RTFM) portion even at $x=0.07$.

1. Introduction

Dilute magnetic semiconductors (DMS) are attracting the interest of the research community as they can accommodate both charge and spin degrees of freedom in to a single material. DMS materials have their potential technological applications in the areas such as spintronics (spin valve transistors, spin light emitting diodes, and non volatile storage and logic devices), magneto optics, medicine, quantum computing, lasers and solar cells [1–4]. Much attention has been paid to transition metal doped wide bandgap semiconductors (II–VI and III–V). CdS is one of the wide bandgap II–VI semiconductors with wide range of applications like photo resistors, X-ray detectors, panchromatic hybrid-sensitized solar cells, hetero junction light emitting diodes, high-performance photocatalysts, gas detectors and bio sensors [5–10]. We have reported a systematic study on the structural, optical and magnetic properties of cobalt doped CdS nanoparticles (NPs) [11] and observed well defined RTFM hysteresis loop for 4% Co concentration. Recently we have also reported the effect of Mn codoping on the optical and magnetic properties of CdS:Co DMS NPs [12]. Optical and magnetic properties of these semiconducting DMS NPs can be tuned better by codoping more than one metal in to the host lattice. In order to study the effect of Al^{3+} codoping on CdS:Co DMS NPs, in this paper we are reporting structural, optical and magnetic properties of $Cd_{0.96-x}Co_{0.04}Al_xS$ nanoparticles by simple chemical co precipitation method.

2. Experimental

$Cd_{0.96-x}Co_{0.04}Al_xS$ ($x=0$, 0.01, 0.03, 0.05 and 0.07) nanoparticles capped with 2-mercaptoethanol were synthesized by simple co precipitation method. All chemicals ($Cd(CH_3COO)_2 \cdot 2H_2O$, $Co(CH_3COO)_2 \cdot 4H_2O$, $Al(NO_3)_3 \cdot 9H_2O$ and Na_2S) used in the present study are of AR grade and used without further purification. The synthesis procedure and various characterization techniques used are similar to those which we have already described in our earlier published article [11].

3. Results and discussion

Structural studies: X-ray diffraction patterns of $Cd_{0.96-x}Co_{0.04}Al_xS$ nanoparticles are shown in Fig. 1(a). Two broad peaks

* Corresponding author. Tel.: +91 877 2260211.
E-mail address: vijayaraguru@gmail.com (R.P. Vijayalakshmi).

http://dx.doi.org/10.1016/j.matlet.2014.04.044
0167-577X/© 2014 Elsevier B.V. All rights reserved.

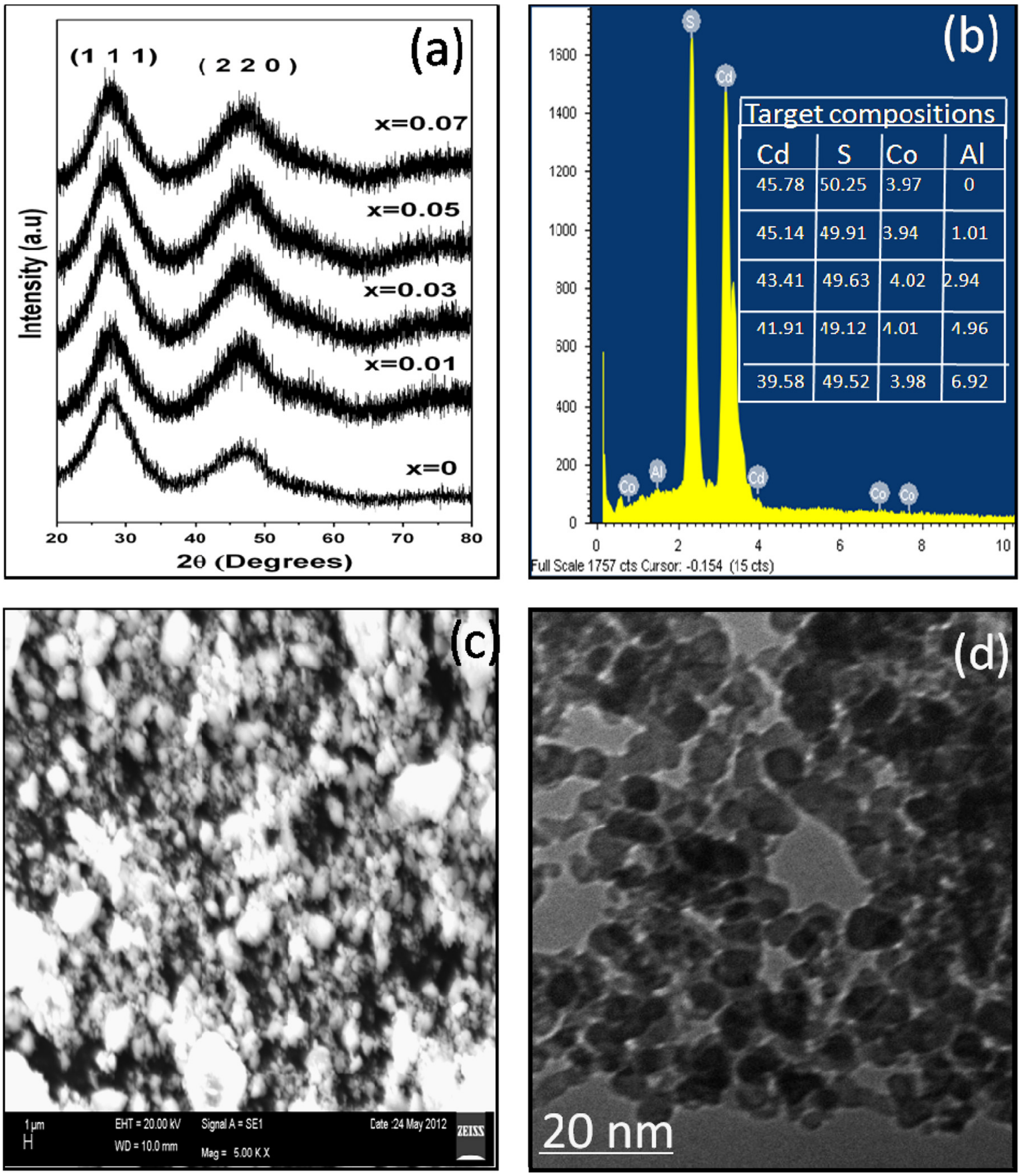

Fig. 1. (a) XRD pattern of $Cd_{0.96-x}Co_{0.04}Al_xS$ nanoparticles, (b) EDAX spectrum of $x=0.05$ (inset of the figure indicates the elemental composition of the synthesized samples), (c) SEM image of $x=0.05$, (d) TEM image of $x=0.05$.

observed for all the samples can be indexed to (1 1 1) and (2 2 0) planes of the cubic zincblende structure. No evidence for impurity phases are discerned within the detection limit of X-ray diffraction. XRD peak positions in the diffraction patterns are slightly shifted to higher 2θ values with increasing Al concentration, which can be attributed to the smaller ionic radii of Al^{3+} when compared to Cd^{2+}. This result supports the substitution of Cd^{2+} ion by the Al^{3+} ion in the as synthesized codoped CdS NPs. The average particle size is calculated using Scherrer formula [13] $D=0.89\lambda/\beta\cos\theta$. From the XRD studies, calculated diameters of the particles are found to be in the range 2 to 3 nm.

Fig. 1(b), shows the EDAX spectrum of $Cd_{0.96-x}Co_{0.04}Al_xS$ ($x=0.05$) nanoparticles. Target and estimated elemental compositions of the prepared nanoparticles are shown in the inset of Fig. 1(b). Elements Cd, S, Co and Al are found to be in a near stoichiometric ratio. EDAX analysis rules out the presence of impurities in the synthesized nanoparticles.

SEM micrograph and TEM image of 5% Al codoped sample are shown in Fig. 1(c) and (d), respectively. SEM micrograph shows the presence of agglomerated clusters of nanoparticles. Mono dispersed and nearly spherical shaped particles are observed from TEM image. From TEM analysis, estimated average crystallite size of the nanoparticles is found to be in the range 4 to 5 nm.

Optical studies: Diffuse reflectance spectra (DRS) of $Cd_{0.96-x}Co_{0.04}Al_xS$ NPs are shown in Fig. 2(a). Absorption edge for all the samples is blueshifted compared to bulk CdS (512 nm) and which is the direct evidence of quantum confinement associated with nanoscale regime of the present nanoparticles. Further, blueshift of absorption edge with increasing aluminum concentration indicates bandgap widening. This blueshift of absorption edge with