Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
Journal of Magnetism and Magnetic Materials 294 (2005) e77–e81
Journal of magnetism and magnetic materials
www.elsevier.com/locate/jmmm

Quantum dots of $Cd_{0.5}Mn_{0.5}Te$ semimagnetic semiconductor formed by the cold isostatic pressure method

O. Contreras[a,b], Ch. Power[a], M. Quintero[a], M. Morocoima[a], R. Tovar[a], E. Quintero[a], J. González[a,*], V. Muñoz-San José[c], J.M. Broto[d], E. Snoeck[e]

[a]*Departamento de Física, Facultad de Ciencias, Centro de Estudios de Semiconductores, Universidad de Los Andes, Mérida 5101, Venezuela*
[b]*Departamento de Física, Facultad de Ciencias, Universidad del Zulia, Maracaibo 4101, Venezuela*
[c]*Departamento de Física Aplicada, Edif. de Investigaciones 1, Universidad de Valencia, Burjassot, Spain*
[d]*SNCMP, Université Paul Sabatier, Toulouse, France*
[e]*Université Toulouse 3, CEMES, F-31062, Toulouse, France*

Available online 4 May 2005

Abstract

$Cd_{0.5}Mn_{0.5}Te$ is a semimagnetic semiconductor, which crystallizes in the zinc-blende structure (ZB) and exhibits a magnetic spin glass like transition at 21 K. Under pressure it shows a first-order phase transition around 2.6 GPa to the NaCl like structure. In this work, the pressure cycled method using a Paris–Edinburgh cell up to 8 GPa has been applied to $Cd_{0.5}Mn_{0.5}Te$ samples in order to obtain recovered nanocrystals. The nanoparticles have been characterized by EDX and electron microscopy. The X-ray and electron diffraction results confirmed the existence of nanocrystals in the ZB phase with an average size of 7 nm. Magnetization measurements made in the range of 2–300 K at low field show that the temperature of the magnetic transition decreases when the crystallites' size is reduced.

PACS: 64.70.Dv; 75.75.+a; 81.07.−b

Keywords: Nanocrystals; High pressures; Phase transitions; Magnetic properties

1. Introduction

The interest in semiconductors, which are spatially confined to a few tens of nanometers, has incremented in the latest years [1]. The quantum confinement modifies electronic properties and the spatial confinement modifies the vibrational properties. Three dimensionally confined electron–hole systems, well-known as quantum dots (QDs), have unusual optical properties that may lead to greatly improved optoelectronics devices. In particular colloidally prepared nanocrystals of

*Corresponding author. Tel.: +58 274240 332; fax: +58 274 2401286.
E-mail address: jesusg@ula.ve (J. González).

0304-8853/$ - see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.jmmm.2005.03.058

II–VI group (CdS, CdSe, and CdTe), or embedded in glassy oxides have received special attention [1]. One of the advantages of II–VI materials is that they can host magnetic ions (e.g., $Mn^{2}+$) which open the way for studying various spin-dependent phenomena in zero-dimensional geometries. It has recently been suggested that single paramagnetic or ferromagnetic QDs can be used for quantum computing applications, as well as for spin aligners and spin filters. It thus becomes important and timely to develop methods for fabricating magnetic QDs and for controlling their composition and size uniformity [2].

$Cd_{0.5}Mn_{0.5}Te$ is a semimagnetic semiconductor that crystallizes in the zinc-blende (ZB) structure and exhibits a magnetic phase transition spin glass like (SG) at 21 K [3,4]. Under pressure, bulk $Cd_{0.5}Mn_{0.5}Te$ is known to undergo a ZB to rock-salt phase transition about 2.6 GPa [5]. The transition is a first-order transition with a 20% decrease in unit cell volume and a change in coordination number from 4 to 6. We present here a novel and simple physical method for obtaining $Cd_{0.5}Mn_{0.5}Te$ nanocrystals using the pressure cycle method with the Paris–Edinburgh cell up to 8 GPa. The recovered nanocrystals in the cubic phase (ZB) were characterized by high-resolution transmission electron microscopy (HRTEM), electron diffraction (EDX), X-rays and magnetic measurements.

2. Experiment details

High pressure was generated using a large volume Paris–Edinburgh press, originally developed for neutron scattering experiments. A complete description can be found in Refs. [2,6]. The $Cd_{0.5}Mn_{0.5}Te$ samples in the ZB phase were compressed at pressures up to 3.5, 6.5 and 8 GPa (rock-salt phase) and taken back to ambient. The applying/removing the pressure was between 20 and 40 min depending on maximum applied pressure, and experimental measurements were made 6 months later. In order to obtain the crystallographic information and the average grain size of the QDs, X-ray measurements were made using an automated diffractometer. This information was confirmed by EDX and HRTEM. Details of high-resolution TEM experiment can be found in Ref. [8]. At low field, the magnetization as a function of temperature was measured using a SQUID magnetometer in the range 2–300 K.

3. Results and discussion

Fig. 1 shows X-ray diffraction patterns of $Cd_{0.5}Mn_{0.5}Te$ in the bulk and QDs. Only the ZB phase were identified. No other ordered or disordered (amorphous) phase could be identified. The diffraction patterns show broadening, that increases with increasing pressure in the cell where the QDs is formed.

The average crystallite size is given by the Debye–Scherrer equation [7]:

$$D = \frac{0.9 * \lambda}{\Delta\Gamma * \cos(\theta)}, \quad (1)$$

where λ is the X-ray wavelength (Å), θ is the Bragg angle and $\Delta\Gamma$ is the difference (rad) in the profile widths of broadened and standard sample (in our case, bulk sample). The nanoparticle sizes decrease linearly with increasing pressure as shown in the inset on Fig. 1.

Fig. 2(a) shows a high-resolution HRTEM micrograph of a QD of $Cd_{0.5}Mn_{0.5}Te$ formed at 8 GPa. These nanocrystals are nearly spherical with diameters of the order of 6.7 nm. The ZB structure is confirmed by electron diffraction patterns that cause the diffraction surfaces (1 1 1), (2 2 0), (3 1 1), (2 2 2), (4 0 0), (3 3 1), (4 2 2), and (3 3 3) of ZB structure, as observed in the Fig. 2(b) by EDX.

Fig. 3 shows the zero-field-cooling (ZFC) and field-cooling (FC) susceptibility χ curves as a function of the temperature T for the bulk as well as for various size of QDs samples, under an applied field of 100 G. At low temperature the ZFC–FC susceptibility exhibits an irreversible behavior $T_f = 21$ K both for bulk phase and nanocrystals. It is seen that, within the errors of the experimental measurements, a clear variation of the T_f values with QD size could not be found. Also, it is observed from Fig. 3 that, for $T < T_f$, the χ vs. T curves for the QDs are different from