Available online at www.sciencedirect.com
SCIENCE DIRECT®
Solar Energy Materials & Solar Cells 90 (2006) 704–712
Solar Energy Materials & Solar Cells
www.elsevier.com/locate/solmat

Photoluminescence studies of CdS thin films annealed in $CdCl_2$ atmosphere

J. Aguilar-Hernández*, J. Sastré-Hernández, R. Mendoza-Pérez, G. Contreras-Puente, M. Cárdenas-García, J. Ortiz-López

Escuela Superior de Física y Matemáticas, Instituto Politécnico Nacional, Edificio No. 9 U.P.A.L.M. Lindavista C.P. 07738, México D.F.

Available online 23 May 2005

Abstract

We have grown CdS films by the Close Spaced Vapor Transport technique under specific conditions: substrate temperature (T_s): 450 °C, source temperature (T_{so}): 725 °C, argon pressure in the chamber (P_{Ar}): 100, 200 and 500 mT, deposition time (t_d): 100 s. The films were studied by measuring the luminescence properties at different temperatures in the range 10–300 K. The room-temperature PL spectrum of the as-grown CdS films showed a very broad band centered at 2.26 eV and a shoulder in the low-energy side at 1.80 eV. After $CdCl_2$ thermal annealing at 300 K, the spectrum showed better PL characteristics: a strong band in the low-energy side at 1.67 eV and a band in the high-energy side at 2.47 eV. The analysis at lower temperatures showed that the high-energy band becomes most intense and shifts to higher energies reaching a value of 2.54 eV, very close to the energy band gap at 10 K. The low-energy band becomes broader and centered around 1.9 eV. Analysis of the PL intensity as a function of temperature in an Arrhenius representation, allows applying a theoretical model for the quenching of the PL intensity.

Keywords: CdS; Photoluminescence; Exciton band; $CdCl_2$; Temperature dependence

*Corresponding author. Tel.: +52 57296139; fax: +52 55862957.
E-mail address: jaguilar@esfm.ipn.mx (J. Aguilar-Hernández).

doi:10.1016/j.solmat.2005.04.007

1. Introduction

Over the years, CdS thin films have been intensively investigated, mainly due to their application in large-area electronics devices such as thin-film field-effect transistors and solar cells [1–6]. Among several n-type semiconductor materials, it has been observed that CdS is the most promising heterojunction partner for the well-known polycrystalline photovoltaic materials CdTe and $CuIn(Ga)Se_2$ (CIGS). In both cases, a CdS layer is used as the large band gap n-type window material. In these devices, light penetrates the CdS layer and is absorbed in the p-type semiconductor close to the p–n junction. Thin films of CdS can be grown with different techniques such as Close Spaced Vapour Transport (CSVT), Chemical Bath Deposition (CBD), Sputtering, Laser Ablation (LA) and Spray Pyrolysis (SP). Among these techniques, the CSVT technique offers several advantages with respect to other film processing techniques. For example, in the case of solar cells, the CSVT provides the required electrical, structural, optical and morphological properties of the films in order to obtain good photovoltaic response [7]. Moreover, the CSVT technique guarantees good physical properties, like good crystalline quality of the films. CdS obtained by the CBD, LA or SP-techniques, exhibit a typical grain size in the 10–80 nm range, while larger grain sizes, up to 100 μm, can be obtained by the CSVT technique. Large grain size is often desirable in order to improve the electrical properties of the films. On the other hand, the electronic transport in polycrystalline semiconductors is often limited by scattering at the grain boundary depletion layers; but it is controlled by the bulk properties of the crystallites under a particular level of illumination. This means that it is important to know the crystalline quality of the films as a function of the grain size.

The crystalline quality of the semiconductor film can be analyzed by means of photoluminescence (PL), which is a very sensitive and non-destructive optical technique. PL studies of as-grown and annealed CdS films have been reported in the temperature range 10–200 K [8]. In this work, we report temperature dependence measurements of PL on CdS films prepared by the CSVT technique. The PL measurements were carried out in the range 10–300 K. These measurements allowed us to study the PL emission band associated with the band-to-band recombination as well as other light emission processes originating from specific point defects in this material.

2. Experimental

The experimental CSVT setup for the growth of CdS films has been fully described before [8]. Glass slides with a buffer layer of tin oxide were used as substrates. The Ar-gas pressure in the growth chamber ranged between 100 and 500 mTorr, whereas the substrate (T_{su}) as well as the source (T_{so}) temperatures were fixed at 450 and 725 °C, respectively. Thermal annealing of the films was carried out in $CdCl_2$ vapor at 400 °C for 30 min in the same CSVT system [8]. The criteria for selecting these parameters was based on the efficiency of the CdTe/CdS solar cells fabricated using