Ceramics International 42 (2016) 11822–11826

Contents lists available at ScienceDirect

Ceramics International

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

Sodium dodecyl sulfate-assisted SILAR synthesis of nanostructured cadmium oxide films

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ARTICLE INFO

Article history:
Received 28 March 2016
Received in revised form
19 April 2016
Accepted 19 April 2016
Available online 20 April 2016

Keywords:
CdO film
Surfactant
SDS
Nanostructure

ABSTRACT

Nanostructured CdO films were prepared on glass substrates by a surfactant – sodium dodecyl sulfate (SDS) – assisted SILAR technique. The influence of SDS concentrations of the growth solution on the structural, morphological and optical properties of the films was investigated and discussed. From the metallurgical microscope and scanning electron microscope images, it was seen that the surface morphology of the films are significantly enhanced by SDS addition. XRD investigations confirmed that the films have good crystallinity levels and are grown preferentially in (111) and (200) orientations. UV–vis. spectroscopy investigations showed that the bandgap and transmittance values of the films are affected dramatically by SDS concentrations.

1. Introduction

Transparent conducting oxides materials (TCOs) have been widely investigated due to their significant physical properties and applications in semiconductor based device technology [1–4]. Among various TCO materials, cadmium oxide (CdO) is an important n-type semiconductor material with a direct bandgap of approximately 2.5 eV [5]. Due to its high carrier concentration, good optical transparency in the visible spectral region and extraordinary luminescence characteristics, CdO is commonly used in several applications such as photodiodes, phototransistors, photovoltaic solar cells, smart windows and flat panel displays [6–9,10].

A number of physical and chemical deposition methods such as chemical vapor deposition [11], chemical bath deposition (CBD) [12], thermal evaporation [13], sputtering [14], sol–gel [15], spray pyrolysis [16], pulse laser deposition [17], successive ionic layer adsorption and reaction (SILAR) [18] methods have been developed for the preparation of nanostructured CdO films. Among them, SILAR is a relatively new liquid phase chemical deposition method, which enables layer-by-layer growth at low temperature at atmospheric pressure. It is also a cost-effective method and suitable for large area depositions [19].

Physical properties of solution-based thin films can be adjusted by supplement of surfactants. Generally, surfactants are used in aqueous solution growth techniques to adjust the surface morphology, crystalline structure and particle size. The entity of surfactant in the growth solution can decrease the surface tension and energy [20]. Sodium dodecyl sulfate (SDS) is an organic additive surfactant material that can be added to the CdO growth solutions in suitable levels by which it may cause regulations on the primary physical properties.

The purpose of this research is to investigate the changes in the surface morphology, optical and micro-structural properties with respect to different SDS concentrations in the growth solutions. The results exhibited that SDS played an important role in the surface morphology and micro-structural properties of CdO films.

2. Experimental methods

2.1. Growth of nanostructured CdO films

For the deposition of CdO films, 0.1 M cadmium acetate solutions were prepared with $Cd(CH_3COO)_2 \cdot H_2O$ and varied amounts of sodium dodecyl sulfate in 100 ml double distilled water (18.2 MΩ cm). The pH value of the solution was adjusted to ~12.0 by adding aqueous ammonia. The deposition was carried out at about 85 °C. For the growth of CdO films, the following steps were performed: first, pre-cleaned glass substrates were dipped vertically into the solution containing cadmium precursor and SDS for

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http://dx.doi.org/10.1016/j.ceramint.2016.04.103
0272-8842/

20 s in which cadmium ions are adsorbed on the substrates surfaces. Second, the substrates were dipped into deionized water for 20 s to remove weakly adsorbed ions. By repeating SILAR cycle 18 times, nearly uniform and white $Cd(OH)_2$ films were obtained. In order to convert $Cd(OH)_2$ into CdO, the films were annealed at 300 °C for 45 min in air atmosphere. The white colors of the as deposited films were changed to brown after annealing process.

2.2. Characterization of the materials

Crystal structure was determined by a Panalytical Empyrean X-ray diffractometer in the range of $2\Theta = 30-80°$. Surface morphology was characterized by a metallurgical microscope (Nikon Eclipse MA100) and a scanning electron microscope (Jeol JEM-2100F). UV–visible absorption spectra of the CdO films were obtained with a UV–vis. spectrometer (Thermo Scientific Genesys 10S UV–vis.) in the spectral range of 190–1100 nm at room temperature.

3. Results

3.1. Metallurgical microscope (MM) images

The performance of metal oxide nanostructures strongly depends on the surface morphology. For example, the change in surface roughness of the films leads to a change in the efficiency of photovoltaic solar cells [21,22]. Modification in the surface morphology of CdO films via SDS addition to the growth solutions were studied by a MM. Fig. 1(a–d) demonstrate the MM images of CdO films with increasing SDS concentrations of 0, 0.1, 0.2 and 0.4 M %, respectively. Fig. 1(a) shows bigger dimensions of dark and bright regions which reveals high porosity and non-homogenous distribution of clusters on the surface. On the other hand, Fig. 1(b–d) images exhibit that the surface homogeneity was enhanced with increasing SDS addition. It is attributed to the decrease in the porosity density of the film surfaces with increasing SDS concentrations.

3.2. Scanning electron microscopy images

Direct influence of surfactant SDS on the morphology of CdO films can be observed in their SEM micrographs. Fig. 2 shows the SEM surface morphologies of CdO films with SDS concentration of 0, 0.1, 0.2 and 0.4 M%. It is obvious that an increase in dimensions (length and width) of the CdO films is observed with addition of SDS into the growth solutions. Furthermore, the thickness of the particles is found to be decreased with SDS addition. The uniform particles shown in the SEM images imply improved crystalline quality. The improvement of average grain size leads to the decrease of total grain boundary fraction of nanostructured films, which affects the physical properties [23].

3.3. X-Ray diffraction results

The effects of SDS concentration on the crystalline structure and crystal phase of CdO films were investigated by XRD and the results are shown in Fig. 3. All the patterns can be indexed as cubic CdO structure (NaCl structure of a space group *Fm*3*m*) according to the JCPDS Card no: 005-0640. The largely sharp and narrow diffraction lines also imply that CdO particles have high crystallinity and purity. The surfactant addition in growth solutions improves

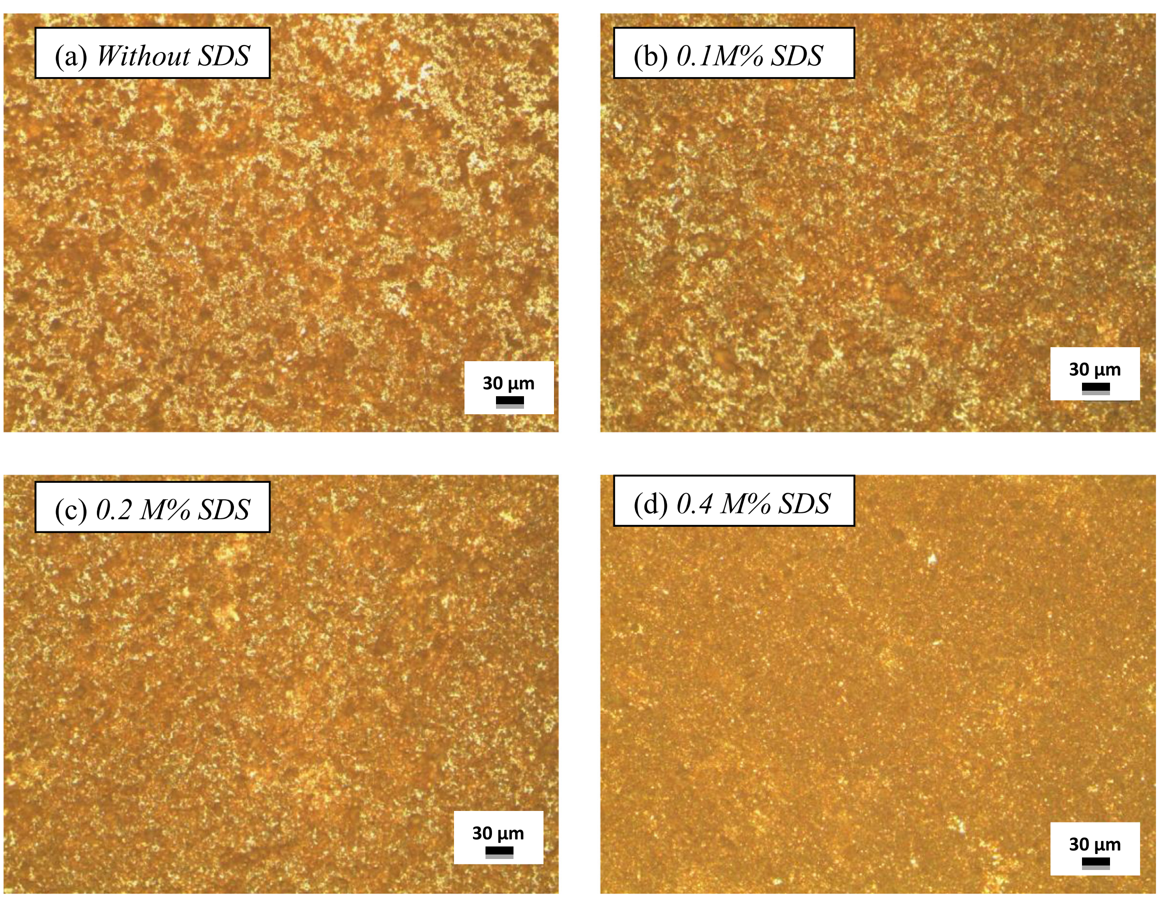

Fig. 1. Metallurgical microscope images of CdO films with varied values of SDS concentrations of (a) 0 (without SDS), (b) 0.1 M%, (c) 0.2 M% and (d) 0.4 M%.