Structural and Optical Properties of Sol-Gel Derived Dip-Coated CdO Thin Film

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ABSTRACT

In this paper CdO thin film has been prepared by sol-gel dip-coating method on glass substrate. The film was characterized by X-Ray diffraction, UV-Visible spectroscopy and photoluminescence spectroscopy for structural and optical properties of CdO thin film. The XRD pattern shows that film is polycrystalline in nature and has a cubical structure with orientation along (111) plane. The diffuse reflectance spectra for the film is studied in wavelength range 400-800 nm. The direct energy band gap of 2.50 eV is found for the film using modified Kubelka-Munk function. Photoluminescence spectra shows one sharp peak at 540 nm due to oxygen vacancy of cadmium oxide.

Keywords: Sol-gel dip coating, Thin film, Band gap, CdO

1. INTRODUCTION

In the last few years, CdO thin films have gained considerable attention because of its unique structural, optical and electrical properties. CdO is a II - VI group n-type semiconductor [1]. It is a semiconductor with a rock salt crystal structure and having a large energy band gap ranging from 2.2 to 2.8 eV. Cadmium oxide has high electrical conductivity and high transmission coefficient in the visible region along with the average refractive index. Its unique properties make it useful for various applications like solar cells, phototransistors, transparent electrodes, photodiodes, photovoltaic cell, IR detectors and anti-reflection coatings, and many more [2-7].

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CdO thin film have been prepared by many techniques like spray pyrolysis [8], pulsed laser deposition [9], sol-gel [10-11], DC magnetron sputtering [12-13], chemical bath deposition [14], SILAR [15], thermal evaporation [16], chemical vapour deposition [17], RF magnetron [18], screen printing [19] etc. Some of these methods are very expensive and need extra attention. Sol-gel dip-coating method has been used in this paper because it has many advantages like low cost, easy fabrication of large area films, good homogeneity, easy to control the composition, easy coating process on large shaped substrates.

In the present work CdO thin film is prepared by sol-gel dip-coating method and investigated for its structural and optical properties for using them in practical applications.

2. EXPERIMENTAL DETAILS

2.1. Synthesis

Sol-gel dip coating method has been used for the preparation of the CdO thin film. 20 ml ethylene glycol was used to dissolve Cadmium acetate (AR-grade) with constant stirring for 45 minutes and monoethylamine (MEA) (10 ml) is added drop wise to the solution. Here, ethylene glycol is used as a solvent and monoethylamine is used as a stabilizer. The solution is prepared at room temperature. The final solution was stirred with magnetic stirrer at a constant temperature of 80°C for 2 hours to yield a homogeneous and clean solution. The pH of the solution was maintained at 7.5 during gel formation. Glass substrate was cleaned with soap solution and then by distilled water and then finally cleaned with acetone before dip coating.

The clean glass substrate was dipped into the solution vertically at a speed of 120 mm/min. After dip coating the film was dried at 100°C for 20 minutes in the oven and this procedure was repeated for 9 to 10 times, and finally the coated glass substrate was subjected to the annealing process at 500°C temperature for 10 minutes to combust the undesired organic materials and to stabilize the film.

2.2. Characterization

For the study of XRD pattern of thin film, Rigaku (ULTIMA-IV) diffractometer was used in the 2θ range of 25° – 60°. Diffuse reflectance spectra for CdO thin film was recorded by UV-Visible Spectrophotometer (U-3900, Model No. 2116-010) in the wavelength range 400-800 nm. The energy band gap of the CdO thin film was calculated by using modified Kubelka-Munk function. PL spectra was used to analyze the emission characteristics of CdO thin film. The thickness of the film was measured by using a gavimetric weight difference method, and it is found to be of the order of 10⁻⁸ meter.

3. RESULTS AND DISCUSSION

3.1. Structural analysis

The XRD pattern for dip-coated CdO thin film is shown in Figure 1. Three peaks are obtained corresponding to (111), (200), (220) planes as shown in Figure 1. The d-values for CdO calculated using Bragg’s equation were compared with JCPDS card no. 75-0594 for the confirmation of the structure of film material. This comparison confirms the cubic structure for prepared CdO film. It is also observed that the prepared film is strongly oriented in the (111)
direction. Average crystalline size for the film was calculated using Debye – Scherrer formula as [20]:

\[ D = \frac{0.94 \lambda}{\beta \cos \theta} \]

where: 
- \( D \) = Average crystalline size of the particle.
- \( \lambda \) = Wavelength of the X-Ray diffraction.
- \( \beta \) = Full width half maxima (FWHM).
- \( \theta \) = Diffraction angle.

In present study the estimated crystallite size of CdO film was 28nm.

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3. 2. Optical analysis

Energy band gap of CdO thin film was studied through the diffuse reflectance spectra in 400-800 nm wavelength range. Figure 2. Shows the diffuse reflectance spectra of CdO thin film. Diffuse reflectance spectra is an useful tool for studying energy band gap of the materials. To calculate the energy band gap for the film, a graph between modified Kubelka-Munk function \([F(R)hv]^2\) versus photon energy \((hv)\) is plotted. The extrapolation of linear part of this graph gives the value of energy band gap for the film. The modified Kubelka-Munk function can be expressed as:

\[ [F(R)hv] = A(hv - E_g)^{1/2} \]
where: $F(R) = \frac{(1-R)^2}{2R}$ is the Kubelka – Munk function [21], $R$ is the absolute reflectance and $A$ is constant. Figure 3. Shows the graph between modified Kubelka function $[F(R)h\nu]^2$ versus photon energy ($h\nu$). The value of energy band gap estimated from this graph is found to be 2.50 eV for CdO film, which agrees well with the reported values [22].

Figure 2. Diffuse reflectance spectra of CdO thin film.

Figure 3. Plot of $[F(R)h\nu]^2$ versus photon energy ($h\nu$) for CdO thin film.
Refractive index is an important parameter for the fabrication of devices. Figure 4. Shows the variation of refractive index with photon energy ($h\nu$). The refractive index initially increases with photon energy up to 2.12 eV and then decreases. This result is consistent with the result reported earlier [23]. The refractive index for the prepared CdO film is calculated by the relation [24]:

$$n = \left[ \frac{1 + R^{1/2}}{1 - R^{1/2}} \right]$$

where: $R$ is reflectance.

![Graph](image)

**Figure 4.** Variation of refractive index with photon energy of CdO thin film.

### 3.3. Photoluminescence analysis

Optical quality of CdO thin film was determined by using photoluminescence spectroscopy. Figure 5 shows the PL spectra of prepared CdO thin film at room temperature. This spectra shows a sharp peak in the visible range at 540 nm which may be due to oxygen vacancy of CdO as recombination of photogenerated hole occurs with an electron in conduction band. Similar peaks in PL spectrum of CdO have been reported earlier [25]. A rough estimation of energy band gap can also be made from photoluminescence spectra of the CdO film given in Figure 5, by employing the formula:

$$E_g = \frac{1240}{\lambda}$$

The energy band gap estimated from PL spectra corresponding to wavelength 540 nm is found to be 2.29 eV, which is slightly lower than the band gap calculated using Kubelka-Munk function.
4. CONCLUSION

A simple and low cost sol-gel derived dip – coating method was used for synthesis of CdO thin film. XRD pattern confirm that CdO thin film was polycrystalline in nature. The energy band of CdO thin film was found to be 2.50 eV. PL measurement shows that CdO thin film has strong luminescence character. The results obtained in this work are suitable for device application.

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References


Figure 5. Potoluminescence spectra of CdO thin film.


