

Short Communication

CdZnO Coated Thin Films: Application for Energy Conversion Devices

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Wide band gap semiconductors have appeared as promising materials suitable for high temperature high frequency high power operations in electronics as well as optoelectronic devices because of their exceptional material characteristics. More specially CdO and ZnO films possess an outstanding ability to materialize short wavelength light emitting devices due to their large band gap energy. CdO and ZnO films are widely used for optoelectronic applications in the short wave length visible-light region especially for laser diodes (LDs) and light emitting diodes (LEDs). In this paper we report structural, optical and electrical properties of wide band gap CdZnO thin film prepared by spray-pyrolysis on glass substrate. Characterization of the samples was carried out with UV-spectroscopy, X-ray diffraction (XRD), scanning electron microscope (SEM), Raman spectroscopy and four-probe measurements. The XRD pattern exhibited a mixture of cadmium oxide cubic and hexagonal ZnO phases. Surface morphology of sample was identified from SEM micrograph as porous surface. Raman spectra exhibit the strong E2 (High) phonon peak in addition to other multiphonon peaks. Optical absorption spectroscopy and DC conductivity measurements give the optical band gap of 2.87 eV and semiconductor nature with activation energy of 0.33 eV.

Keywords: TCO, XRD, UV-visible, Conductivity, Spray pyrolysis.

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1. INTRODUCTION

The cost effective transparent cadmium doped zinc oxide conductor thin films find applications in the field of optoelectronic devices as efficient energy conversion material in thin film solar cells and light emitting diodes [1-3]. Among the TCO semiconductors, ZnO and CdO semiconductors are technically essential because of their high electrical conductivity due to moderate electron mobility, high carrier concentration and transparency in the visible range of electromagnetic spectrum [4]. These two metal oxide semiconductors have been broadly investigated by researchers in pure and doped forms. In modern optoelectronic devices, modulation of band gap in the material is important for making it attractive for its application as buffer layers on solar cells. Therefore, modulation of these two unique materials will allow us to realize expected band gap and intermediate optical and electrical properties of CdZnO [5]. Thus, CdZnO composition with higher Cd content has gained more attention in the scientific field, especially for making laser diodes and solar cells, where the band gap engineering is necessary [6].

In this paper, we report various characterizations of CdZnO composite thin films prepared by spray pyrolysis method. The method is scalable, very simple and economical. Use of low cost, high throughput equipment, low material wastage, and high uniformity over large area make this a truly efficient deposition method.

2. EXPERIMENTAL TECHNIQUE

Cadmium acetate and zinc acetate salts were mixed with deionised water for solution. This solution was

sprayed onto the heated glass substrates held at constant temperature of 450°C [7].

3. RESULTS AND DISCUSSION

Zn doped CdO oxide thin film was deposited on glass substrate at 450°C by using spray pyrolysis technique. The structural, surface morphological, optical and electrical characterizations of the deposited films were investigated.

The XRD patterns of the CdZnO thin film deposited on glass substrate at 450°C are shown in Fig. 1.

It is seen that the film is polycrystalline in nature with double phase, having cubic and wurtzite crystal structures along with a strong orientation (111) plane.

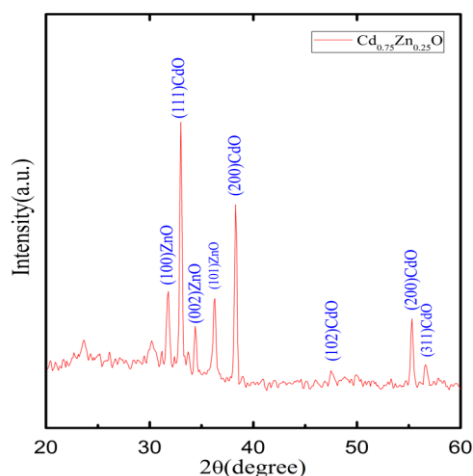


Fig. 1 – XRD pattern of CdZnO thin film

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All the diffraction peaks are well matched with the JCPDS card no. s (05-0640: CdO) and (36-1451: ZnO). Useful information that characterizes the growth is extracted from the XRD measurements. These include the lattice parameter values ' a ' and ' c ' calculated in the range of 3.253 Å and 5.221 Å. The average crystallite size (D) from the most intense peak (111) is 35 nm and has been calculated using the Scherrer equation:

$$D = \frac{0.94\lambda}{\beta \cos\theta}, \quad (1)$$

where λ , β , and θ are the X-ray wavelength (1.54 Å), the full width at half maximum (FWHM) in radians, and the diffraction angle.

Raman spectroscopy technique has been used to study the vibrational, rotational, and other low-frequency characteristics. Raman spectrum shows a strong sharp peak at 431 cm^{-1} assigned to $[E_2(H)]$. This signifies ZnO hexagonal wurtzite structure with broadness due to higher Cd content. It has been observed that appearance of lower peaks reflects the presence of induced stress that is caused by structural disorder in the film due to replacement of Cd^{2+} with Zn^{2+} in the host CdO matrix [8, 9]. The characteristics of Raman spectra are in good agreement with the XRD results and are depicted in Fig. 2.

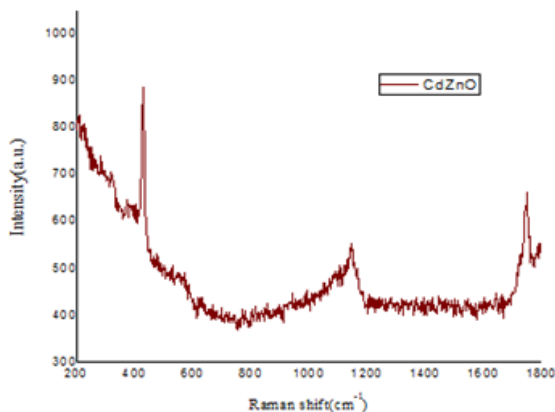


Fig. 2 – Raman spectra of CdZnO thin film

SEM image as shown in Fig. 3 reveals uniform surface with some porosity which confirms large surface-to-volume ratio that enhances the surface activity of the film, thereby leading to a higher degree of UV absorption being an important parameter for photovoltaic applications.

The absorption spectrum of CdZnO composite thin film recorded in the 400-1000 nm region is shown in Fig. 4. From this spectrum, energy band gap of ZnCdO sample is calculated by using the Planck relation as:

$$h\nu = \frac{1240}{\lambda_E}, \quad (2)$$

where h is the Planck constant and λ_E is the absorption edge.

Optical absorption measurements indicate that the material is a direct band-gap semiconductor with the energy gap of 2.87 eV.

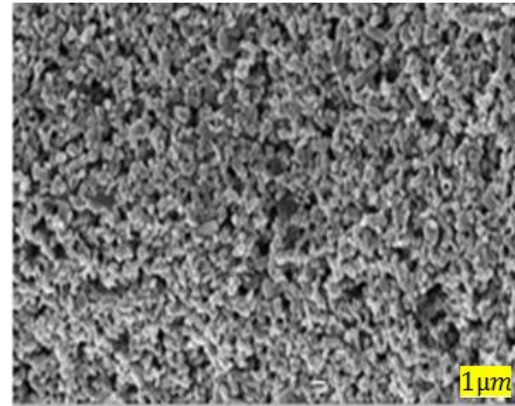


Fig. 3 – SEM image of CdZnO thin film

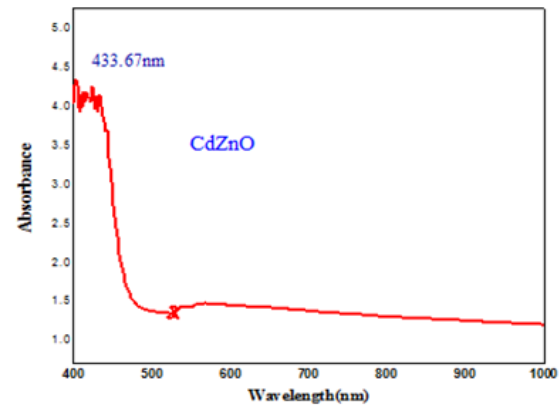


Fig. 4 – Absorbance spectrum of CdZnO thin film

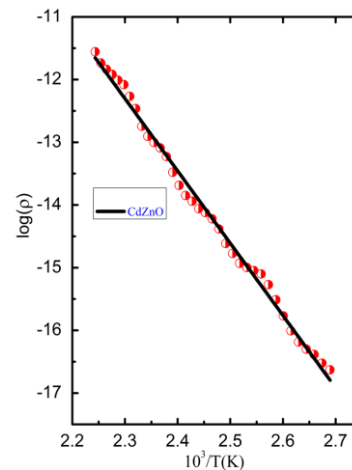


Fig. 5 – Linear fit of electric conductivity of CdZnO thin film

The electric conductivity measurement is important characterization for photovoltaic devices. The sample shows the semiconductor behavior because conductivity increases with increasing operating temperature due to the charges (electrons or holes) from one site to the other and is shown in Fig. 5. The charge carriers increase with temperature. As the activation energy of the sample comes out to be 0.33 eV, this is the thermal energy which is required to hop the carriers [10].

4. CONCLUSIONS

These studies successfully demonstrate the deposition of zinc doped cadmium oxide thin films by spray pyrolysis technique. To improve the performance as window layer in optoelectronic devices, we have used zinc as a dopant in CdO which reduced the resistivity of window layer of CdZnO thin films, because calculated parameters are suitable and the film quality allows them to be used in optoelectronic devices.

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Тонкі плівки CdZnO з покриттям: застосування для пристроїв перетворення енергії

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Широкозонні напівпровідники є перспективними матеріалами, придатними для високотемпературних, високочастотних, високоенергетичних операцій в електроніці, а також оптоелектронних пристроях через їх виняткові характеристики. Більш конкретно, на основі плівок CdO і ZnO можна реалізувати короткохвильові пристрої, що випромінюють світло, завдяки великій ширині забороненої зони. Плівки CdO і ZnO широко використовуються для оптоелектронних приладів в області короткохвильового видимого світла, особливо для лазерних діодів і світлодіодів. У даній роботі наведено структурні, оптичні та електричні властивості широкозонної тонкої плівки CdZnO, одержаної методом спреї-піролізу на скляній підкладці. Визначення характеристик зразків проводили за допомогою УФ-спектроскопії, рентгенівської дифракції, скануючого електронного мікроскопа, комбінаційної спектроскопії та чотиризондових вимірювань. На рентгенограмі виявлено суміш кубічної та гексагональної фаз оксиду кадмію. Морфологію поверхні зразка ідентифікували за допомогою скануючого електронного мікроскопа як пористу поверхню. Спектри комбінаційного розсіювання світла показують сильний фононний пік на додаток до інших багатофононних піків. Оптично-абсорбційна спектроскопія та вимірювання провідності постійного струму дають оптичну ширину забороненої зони 2.87 eV і напівпровідникову природу з енергією активації 0.33 eV.

Ключові слова: Прозорий провідний оксид, XRD, УФ-видимий діапазон, Провідність, Спреї-піроліз.