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Structural and Electrical Studies of Boric Acid Doped Cadmium Oxide Thin Film by JNSP Technique for Optoelectronic Applications

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Abstract: The present work deals with preparation and characterization of boric acid (b) dopped cdo thin films by the jet nebulizer spray pyrolysis technique at optimized temperature 450°C. Boric acid doped cdo thin films were prepared by jet nebulizer spray pyrolysis technique with different wt% of boric acid (x=0, 0.5,2.5, 4). The xrd pattern of various weight percentage boric acid dopped cdo thin films show the polycrystalline nature with cubic structure. At room temperature, the electrical conductivity of the prepared films increases with 4Wt% of 2.32x10-3 S/cm. The plot of voltage versus current as a function of temperature (RT-30°C) indicates the ohmic behavior of the films. Moreover, significant optoelectronic applications are cadmium oxide dopped with boric acid thin films at room temperature electrical resistivity is in the order of 101Ω cm which is low enough to be a good supercapacitor electrode material.

Keywords: Thin films, Optoelectronic applications, JNSP technique.

Introduction

In today's highly competitive technological world, any modern technology's success is necessary in order to achieve. For the past few decades, semiconductor technology and memory chips have been the primary focus for any industry's progress and a nation's development in science and technology. New semiconductor materials and processing techniques in bulk and thin film preparation are required as semiconductor technology advances.[1-2]

The first evaporated thin films were probably the deposits which faraday obtained in 1857, when he exploded metal wires in an inert atmosphere. The possibility of depositing thin metal films in a vacuum by joule heating of platinum wires was discovered by nahrword (1887) for the purpose of measuring refractive indices of metal films. Because of their potential value and scientific curiosity, thin solid films have been extensively studied for over one and a half century [maissel and glang 1970]. The engineering of thin film is complicated by the fact that their physics in some cases is not well understood. Thus, knowledge and determination of the nature, functions and new properties of thin films can be used for the development of new technologies for future applications.

Thin film solar cells form a competitor for the single crystal and polycrystalline silicon solar cells because of the availability of cheaper raw materials as well as processing costs. Thin films have attracted great attention in recent years for their potential use in dynamic rams and multi-chip modules (mcm) due to their high dielectric constant and relatively low leakage current. Most of the thin film applications deal with the development of devices in semiconductor industries like transistors, displays, micro electro–mechanical systems (mems), planar waveguides (for optical component integration), non-volatile memory and optical components, coatings for anti-glare, anode and cathode materials (batteries, capacitors and / or super capacitors) [3-6]. The optical industry has been using thin film coatings in components like lenses, prisms, filters, reflectors or mirrors. According to experts, the lack of understanding of industrial requirements is considered as a bottleneck for all materials being researched. This is especially relevant because thin films are a part of material system and should be integrated with other systems. Thus, for all of them, there's plenty of room for improvement and development of thin film device applications.[7]

Large varieties of deposition processes are available for thin film fabrication. Basically, thin film deposition technologies are either physical methods or chemical methods. Some of them are evaporation, sputtering, spray pyrolysis, chemical vapor deposition, solution growth, electroless deposition and electrodeposition. Of these techniques spray pyrolysis, chemical vapor deposition, solution growth and electrodeposition are some of the chemical deposition techniques which are particularly attractive for large area devices and also relatively cheap.[8-9]

The dissertation deals with preparation and characterization of boric acid (b) dopped cdo thin films by the jet nebulizer spray pyrolysis technique at optimized temperature 450°c. The coated thin films were analyzed to understand the structural, surface morphology, optical studies for boric acid dopped cdo films. From the obtained results we are concluding that obtained b dopped cdo thin films are suitable for various application such as solar cells, light emitting diodes, photo diodes and many other optoelectronic devices.

Experimental Procedure

Materials

Analytical grade cadmium acetate(c4h6cdo4), boric acid(h3bo3) was used for the film preparation. Pureand boric acid doped cdo films deposited at substrate temperature 450°c through jet nebulizer spray pyrolysis (jnsp) technique. An optical glass slides (75 x 25 x 1 mm^3) was used as substrates. The substrates were cleaned using distilled water and various organic solvents[10-11]. Also, it is cleaned by ultrasonic method. The solution was prepared by dissolving cadmium acetate of 0.1 m in 10 ml of de-ionized water and the solution was stirred for one hour using a magnetic stirrer and then h3bo3was added. Boric acid is taken in different weight % with respect to taken cadmium acetate in grams (i.e 0.5% 2.5%,4%). The stirring was continued for one hour to get clear and homogeneous spray solution. The prepared solution was sprayed on the surface ultrasonically cleaned glass substrates kept at the optimized temperature 450°c. Films prepared by this method have uniform thickness and well adherent with the substrate. The optimized preparative parameters for pure and boric (b) doped cdo thin films are listed in table 1.

Preparation of boric acid doped cdo thin films techniques

A clean substrate is pre-requisite for the formation of any film. It is necessary to remove contaminants without damage to the substrate. The procedure for cleaning the glass substrates includes the following steps. The soda lime glass substrates of 0.1 mm thickness are washed with soap solution and deionized water for the film deposition. The cleaned substrates are ultrasonically cleaned for 20 mins and again immerged in isopropyl alcohol and heated up to boiling for 15 mins and dried then it is used for film fabrication.[12]

In recent literature shows, among transparent conducting oxide (tco) films, the cadmium oxide (cdo) film has attracted considerable attention because of their low resistivity and high transparency in the visible spectrum. The majority of known tco materials are n-type semiconductors where defects such as oxygen vacancies, impurity substitutions and interstitials donor electrons to the conduction band providing charge carriers for the flow of electric current. The increasing use of transparent conductors in various optoelectronic devices, heterojunction solar cells and heat mirror prompted interest in electro-optical applications of thin films.

CdO is a degenerate semiconductor with wide band gap that varies from 2.2 to 2.9 ev with increasing carrier density. It shows high n-type conductivity due to the presence of interstitial cd atoms and oxygen vacancies which both act as donors. The success of this work may lead to the development of cheaper conductive materials, photo diode and solar cells.

Table 1 optimized preparative parameters of boric acid doped cdo films

Parameters	Values
Deposition rate substrate temperature (°c) deposition time (minutes) nozzle to substrate distance Carrier gas pressure	0.5 ml/minutes450°c 15 minutes 6 cm 2.5 kg/m^2

Results and discussion

XRD Analysis

The boric acid doped CdO thin films were deposited on a glass substrate using jet nebulizer spray pyrolysis technique. Thin films of 0.5%b+ CdO, 2.5%b+ CdO and 4%b+ CdO were prepared, further it is utilized for various structural, optical, surface morphological studies and compared with pure CdO thin film.

Fig. 1 shows the xrd pattern of boric acid dopped CdO thin films characterized by x- ray diffraction analysis. The xrd pattern of JCPDS card no (05:0640) well matched boric acid dopped CdO shows the polycrystalline nature with cubic structure and is oriented through (111) direction[13]. The lack of grains is oriented through (111), (200), (220), (311) and (222) directions. The intensity of (111) plane is increased with the value of x. In x= 2.5 the intensity of the peaks is reduced and the grains are oriented through (222) plane only. At x=4 the intensity of the (111) is high and other peaks which represents the of calculated from the Debye-Scherrer formula

$$D=k\lambda/(\beta \cos\theta) \quad (1)$$

$$\varepsilon=\beta \cos\theta/4 \quad (2)$$

$$\delta=1/D^2 \quad (3)$$

$$SF=[(2\pi^2)/[45(3 \tan\theta)]^{(1/2)}]\beta \quad (4)$$

Where, k is the shape factor (0.94), λ is the wavelength of cu kα (x-ray) (1.5406å), β is the full width at the half maximum and θis the diffraction angle. The calculated fig (2) shows the grain size of boric acid dopped cdo thin films with different x values. The grain size of the prepared films is increased up to x=2.5 and then decreased slightly, for x=0.5the grain size increases. The grain size of the prepared films is increased up to x=4 and then decreased slightly, for x= 2.5 the grain increases. The decreases of grain size may be due to the same composition of boric acid different wt% of the prepared films. Then x=4 shows the interconnected fibber with some grain with average size of 365 nm due to presents of boric acid different wt% concentration in the prepared films.

Electrical properties

The DC electrical resistivity and conductivity studies are carried out using Keithley electrometer 6517 B interfaced with two probe setups for the Boric acid dopped CdO thin films. The plot of voltage versus current as a function of temperature (RT-30°C) (Fig. 3) indicates the ohmic behavior of the films. The electrical resistivity and conductivity of the Boric acid dopped CdO film is calculated from the following formula.

$$\sigma = 1/\rho \qquad (1)$$

$$\rho = RA/l \qquad (2)$$

where, ρ is the resistivity, σ is the conductivity, R is the resistance, A is the cross-sectional area of the film and *l* is the inter-probe distance[14]. The resistivity of the Boric acid dopped CdO films decreases with the temperature and solution Wt%. (Fig. 4).

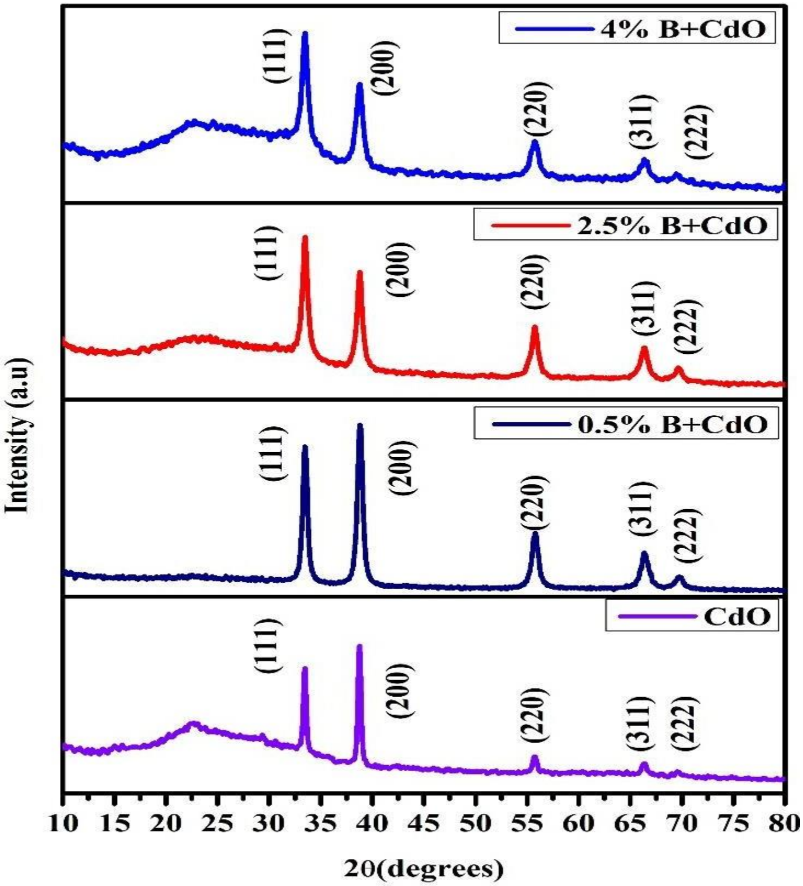

Figure 1 xrd pattern of boric acid dopped CdO thin films

Table 1 Calculated structural parameters of boric acid doped cdo thin films forvarious wt%.

Molar concentration	Diffraction angle 2θ (°)	Interplanar distance d(a°)	FWHM Radians	Crystallite size (d) (nm) (x 10^{-9})	Micro strain (ε) (x 10^{-2})	Dislocation density (δ) (×10^{15} lines m^{-2})	Stacking fault (sf) (x 10^{-2})
Cdo	33.4234	2.6810	0.00467	31.02	0.11183	1.0391	0.28824
	38.7494	2.3238	0.00408	35.98	0.09639	0.7729	0.27818
	55.7047	1.6501	0.00700	22.39	0.15488	1.9933	0.64459
	66.4356	1.4072	0.00700	23.67	0.14655	1.7848	0.08060
	69.5201	1.3521	0.00140	120.05	0.02878	0.0068	0.01741
Cdo+b 0.5 %	33.4449	2.6793	0.00583	24.81	0.13981	1.6244	0.36055
	38.7807	2.3220	0.00642	22.90	0.15145	1.9061	0.43736
	55.7633	1.6485	0.01051	14.93	0.23225	4.4822	0.96787
	66.3175	1.4094	0.00467	35.49	0.09774	0.7939	0.53572
	69.7896	1.3476	0.00116	14.48	0.02394	0.0048	0.14621
Cdo+b 2.5%	33.4883	2.6759	0.00408	35.45	0.09785	0.7956	0.25257
	38.7802	2.3221	0.00350	41.99	0.08260	0.5669	0.23852
	55.7690	1.6483	0.00583	26.88	0.12904	1.3837	0.53783
	66.4202	1.4075	0.00817	20.28	0.17099	2.4296	0.94001
	69.6998	1.3491	0.00934	18.09	0.19167	3.0528	1.16691
Cdo+b 4%	33.5335	2.6724	0.00525	27.57	0.12579	1.3148	0.32500
	38.7944	2.3212	0.00817	17.99	0.19277	3.0879	0.55682

	55.8099	1.6472	0.01167	13.44	0.25799	5.5311	1.07633
	66.4913	1.4062	0.01167	14.20	0.24416	4.9537	1.34507
	69.5222	1.3521	0.01401	12.05	0.28780	6.8829	1.74197

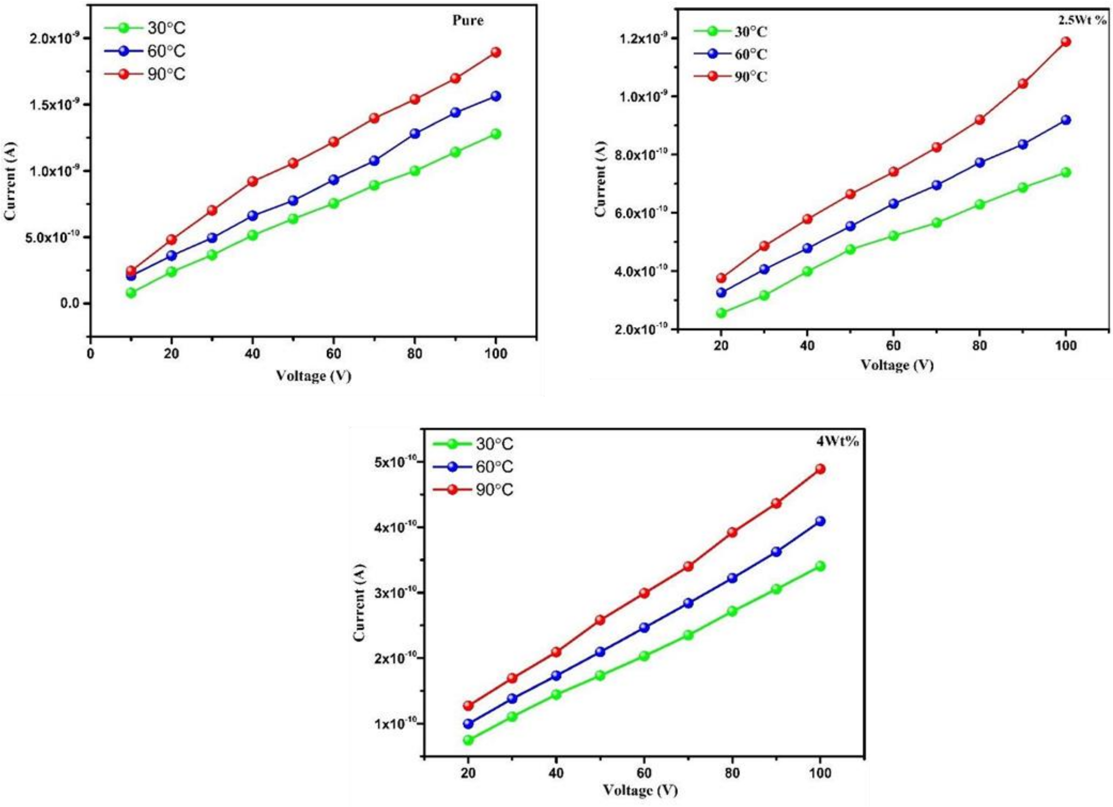

Figure 3 I-V Characteristics of Boric acid dopped CdO

The decrease in resistivity with temperature indicates the development of semiconducting nature in the prepared films. The room temperature electrical resistivity is in the order of 101Ω cm which is low enough to be a good supercapacitor electrode material.

P.S. Patil et al.and V.R. Shinde et al. have observed the electrical resistivity in the order of 102Ω cm and 103Ω cm respectively for spray-deposited Boric acid Dopped CdO thin films[15-16]. The nebulizer spray-deposited Boric acid Dopped CdO thin films have electrical resistivity better than already reported results.

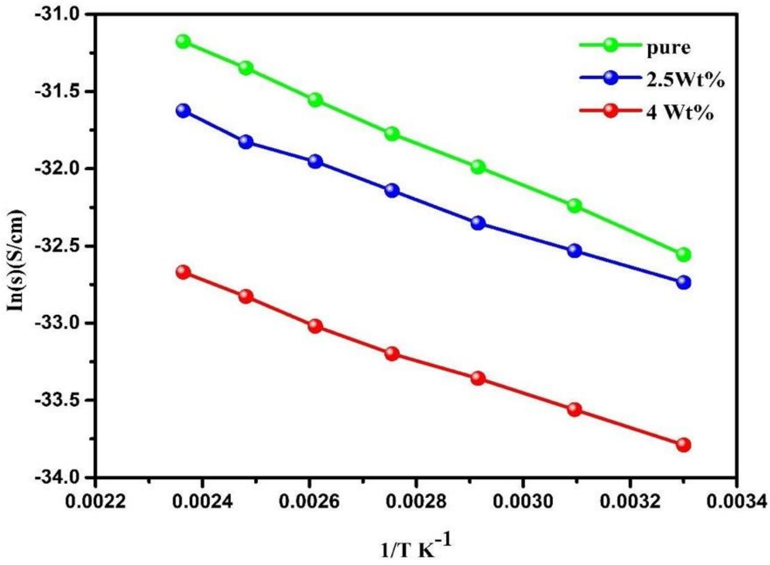

Figure 4 Conductivity of the B dopped CdO thin films with different Wt%

The room temperature conductivity (Fig. 5) values of the films prepared at pure and higher 4Wt% is 2.32 x 10^{-3} S/cm respectively[17]. The low crystallite size and the increased number of grains are responsible for the electrical conductivity increase in the cubic Boric acid dopped CdO thin films.

Conclusion

Boric acid doped cdo thin films were prepared by jet nebulizer spray pyrolysis technique with different wt% of boric acid (x=0, 0.5,2.5, 4). The xrd pattern of various weight percentage b dopped cdo thin films show the polycrystalline nature with cubic structure and is oriented through (111) direction. At room temperature, the electrical conductivity of the prepared films increases with 4Wt% from 2.32x10-3 S/cm. These investigations and the results confirm that the solution different 4Wt% strongly affects the properties of cubic structured cadmium oxide thin films. It has been concluded that, the Boric acid dopped CdO films is suitable for diode, photodetectors applications and the jet nebulizer spray pyrolysis technique is a proper method to prepare well supporter and good quality of films and different Wt% of Boric acid doping concentrations, which will made very useful for optoelectronic applications.

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