

Influence on Structural, Optical & Solid State Properties of Nickel Doped Cadmium Sulfide Thin Films

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ABSTRACT- Nanocrystalline Cd_{1-x}Ni_xS thin films were prepared at 70±2°C by a simple and inexpensive chemical bath deposition (CBD) technique. These films have been deposited on commercial glass substrate for various nickel concentrations (i.e. x= 0, 0.3, 0.5, 0.7, 1). The effect of nickel content (x value) on structural, morphological, optical and solid state properties have been studied. The as-deposited films were characterized using X-ray diffractometer (X-PERT PRO), SEM and UV-VIS spectrophotometer. The obtained film shows good crystallinity with hexagonal structure. The average grain size estimated is 4.22nm. The values of energy bandgap, optical and solid state constants have been evaluated for varying Ni content for the study of various optoelectronic applications.

KEYWORDS: CdNiS, chemical bath deposition, thin films.

I. INTRODUCTION

In last few years, considerable interest has been shown in the synthesis of semiconducting nanocrystalline thin films for optoelectronic applications. Nanostructured materials based on II-VI group compounds have long been known to be suitable materials for photovoltaic device applications because of their high optical absorption coefficients [1]. The synthesis of ternary metal chalcogenides of group II-VI semiconductors in nanocrystalline form has been a rapidly growing area of research due to their important non-linear optical properties, luminescent properties, quantum confinement effect and other important chemical and physical properties.

Doped semiconductor nano-materials have attracted research interests in the recent years. These materials exhibit novel size dependent properties. Thus they are under active consideration as potential candidates for various optoelectronic applications. Nickel doped cadmium sulfide (Cd_{1-x}Ni_xS) have properties in between CdS and NiS. CdNiS films have low resistivity in light and also have high transmittance in the visible region [2].

II. LITERATURE SURVEY

Addition of Ni to the most widely used CdS buffer layer material enhances the electronic and optical properties of optoelectronic devices. From the analysis, due to high bandgap Cd_{1-x}Ni_xS films were found to possess favorable properties for solar and industrial applications such as antireflection coating in the solar collectors [3-4], solar control coatings, warming coatings as well as solar absorber layer of a solar cell [5]. Keeping these aspects in view, more attention is being given in producing good quality CdNiS thin films for comprehensive structural, optical studies and their various applications.

Cd_{1-x}Ni_xS thin film have been prepared using various techniques such as, spray pyrolysis, sputtering, electro deposition, vacuum evaporation, chemical vapour deposition, chemical bath deposition (CBD), etc. Among these techniques, chemical bath deposition is simple, cost effective which yields uniform, adherent, stable and hard nanocrystalline films with good reproducibility as compared to the others for large-area solar cell fabrication [6-9]. In this study, we were prepared the Cd_{1-x}Ni_xS thin films for varying Ni content by simple CBD technique. The effects of Ni content on structural, morphological and some optical, solid state properties have been investigated.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Vol. 7, Issue 11, November 2018

III. EXPERIMENTAL DETAILS

The $Cd_{1-x}Ni_xS$ thin films were prepared by CBD technique on commercial glass slide for various nickel concentration ($x= 0, 0.3, 0.5, 0.7, 1$). The starting materials used were $CdCl_2$ (1M) as a Cd^{2+} ion source, $NiCl_2$ ($x= 0, 0.3, 0.5, 0.7, 1M$) as Ni^{2+} ion source, thiourea (1M) as an S^{2-} ion source. An alkaline solution of ammonia was used to adjust pH of the reaction mixture. All the chemicals used were of Analytical Reagent grade. The process involving a controllable chemical reaction at a low rate, by adjusting the pH value and temperature of the working solution allows maintaining the stoichiometry constant for any ratio of anions and cations. The experimental arrangement consists of a special substrate holder which is attached to a motor having a constant speed of 60 r.p.m. The temperature of chemical bath was adjusted with a hot plate and temperature controller ($72\pm 2^\circ C$), while magnetic stirrer is applied to promote ion-by-ion heterogeneous growth on the substrate. The $Cd_{1-x}Ni_xS$ samples were prepared on carefully cleaned glass substrates. Cleaning of substrate is important in deposition of thin films, cleaning steps and growth procedure is reported elsewhere [10-11]. As-deposited thin films were rinsed with distilled water and allowed to dry in air.

The grown films were characterized by (XPRT-PRO) X-ray diffractometer using $Cu-K\alpha$ radiation with wavelength, 1.5418\AA for the study of crystallographic structure. The thickness of thin film was measured by the weight difference method at room temperature. The average grain size in the deposited films was obtained from a Debye-Scherrer formula. Surface morphology was examined by JEOL model JSM-6400 scanning electron microscope (SEM). Optical properties were measured at room temperature by using Perkin-Elmer UV-VIS lambda-35 spectrometer in the wavelength range 300-1100nm.

IV. RESULTS AND DISCUSSIONS

1. Structural & Morphological properties

Figure 1 shows the XRD pattern of $Cd_{1-x}Ni_xS$ films for Ni content $x=0.5$. A comparison of the peak position (2 θ values) of the JCPDS XRD spectra data suggests that the as-deposited films have hexagonal structure. The 2 θ value of 24.54° ($d= 3.6179\text{\AA}$) and 28.72° ($d = 3.0998\text{\AA}$) correspond to the diffraction lines produced by (100) and (101) planes respectively [12].

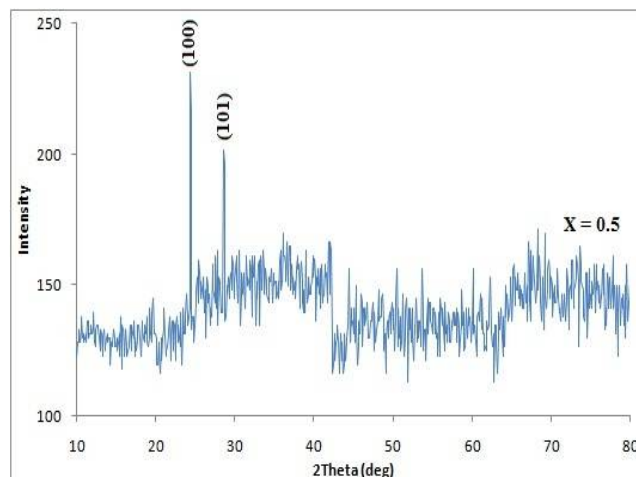


Fig.1 XRD pattern of $Cd_{1-x}Ni_xS$ films for $x = 0.5$

The grain sizes (g) has been estimated from the XRD pattern using Debye-Scherrer's relation [10-11,13],

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$$g = K\lambda / \beta \cos\theta \quad (1)$$

Where,

K = constant taken to be 0.94, λ = wavelength of X-ray used (1.542Å), β = FWHM of the peak and θ = Bragg's angle.

The calculated average grain size of the film is about 4.22 nm.



Fig. 2 SEM of Cd_{1-x}Ni_xS films at x = 0.5

The SEM micrograph shows smoother and more uniform films (Figure 2). It is observed that the average grain size obtained from XRD matches with SEM and is about 4.22 nm.

2. Optical & Solid State properties

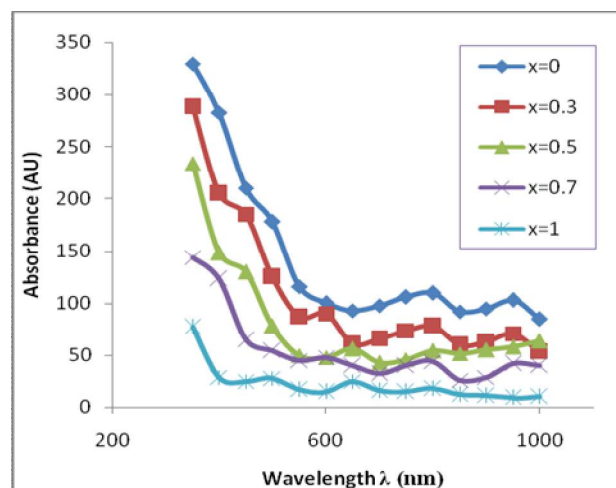


Fig. 3 Spectral absorbance of Cd_{1-x}Ni_xS films for x=0 to x=1

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Figure 3 shows the plot of spectral absorbance of $Cd_{1-x}Ni_xS$ thin films for varying Ni content. From the plot, it is observed that the absorbance of $Cd_{1-x}Ni_xS$ thin film decreases as the content of nickel in the film increases. This high absorbing material is used for window coating, since it is capable of absorbing the harmful UV radiations and leaving the inside surface cool. It acts as convectional air-conditioner.

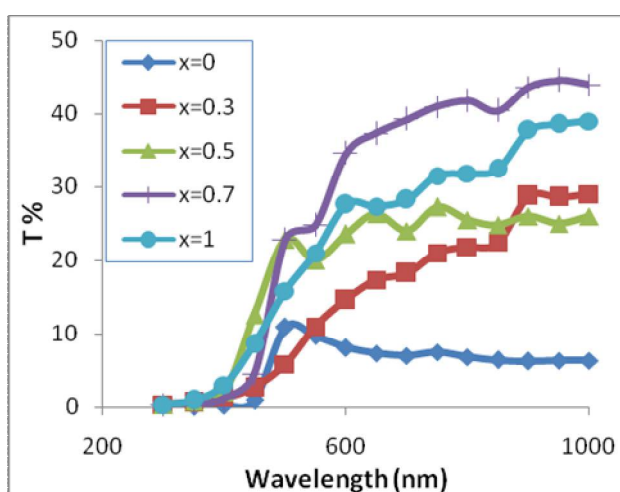


Fig. 4 Spectral transmittance of $Cd_{1-x}Ni_xS$ films for $x=0$ to $x=1$

Figure 4 shows the plot of spectral transmittance of $Cd_{1-x}Ni_xS$ thin film grown. From the plot it is observed that $CdNiS$ thin film has a high transmittance value in near infrared region (NIR) region whereas it is almost 0% in UV region. Plot shows, the value of transmittance for the deposited film increases as the Ni concentration increases. This makes the films suitable in the construction of poultry farms because it allows much infrared radiation to warm the chicks.

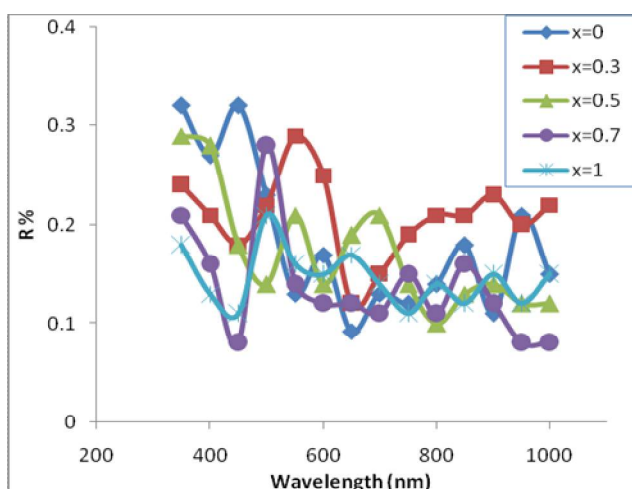


Fig. 5 Spectral reflectance of $Cd_{1-x}Ni_xS$ films for $x=0$ to $x=1$

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 7, Issue 11, November 2018

Figure 5 shows the plot of spectral reflectance of Cd_{1-x}Ni_xS thin film grown. From the plot, it is observed that the reflectance is low across the UV, visible and near IR regions. This makes the film suitable for anti-reflection thin films which when used, improves the efficiency of the solar collector plates.

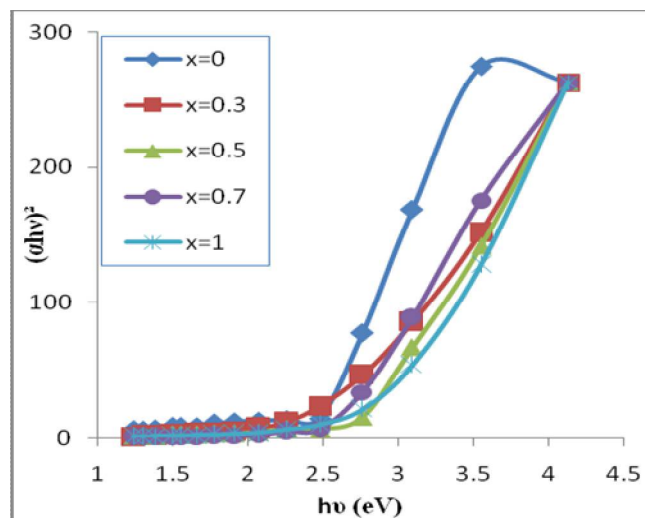


Fig. 6 Plot of $(\alpha h\nu)^2$ vs $h\nu$ for all Cd_{1-x}Ni_xS thin films.

The band gap energy was determined from absorbance data by plotting $(\alpha h\nu)^2$ versus $h\nu$ (figure 6) and then extrapolating the straight line portion to the energy axis at $\alpha=0$. The band gap energy E_g obtained for each Ni content is different. For higher Ni content ($x=1$) the band gap is 2.75 eV and for lower Ni content ($x=0$) it is 2.48 eV. The band gap of other films is intermediate.

Table 1. Optical & solid state constants of Cd_{1-x}Ni_xS thin films prepared at various Ni content ($x= 0$ to 1)

Ni content	Energy bandgap E_g (eV)	Average R.I. n	Extinction coefficient k	Dielectric constants		Optical conductivity $\sigma \times 10^{13} S^{-1}$
				ϵ_r	ϵ_i	
X=0	2.48	2.57	0.18	7.02	0.92	14.74
X=0.3	2.52	2.69	0.11	7.32	0.61	9.87
X=0.5	2.7	2.42	0.10	6.04	0.48	7.89
X=0.7	2.6	2.19	0.08	4.91	0.36	6.30
X=1	2.75	2.14	0.09	5.03	0.38	6.24

The optical and solid state constants of Cd_{1-x}Ni_xS films prepared at varying Ni content were evaluated. The observed optical and solid state constants such as refractive index (n), extinction coefficient (k), dielectric constants (ϵ_r, ϵ_i) as well as optical conductivity (σ) of the films were illustrated by table 1.

V. CONCLUSION

In this study, Cd_{1-x}Ni_xS nano-crystalline thin films have been grown successfully onto glass substrates using modified CBD technique. The structural, morphological, optical and solid state properties have been studied. The structural analysis indicates that the grown film has hexagonal crystalline structure with the average grain size of

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Visit: www.ijirset.com

Vol. 7, Issue 11, November 2018

4.22nm. The optical and solid state studies showed that the films have high absorbance in the UV region. This property makes the film for window coatings. The band gap energy obtained is in between 2.48eV and 2.72eV. The wider bandgap of the deposited films makes them suitable for optoelectronic devices, for instance window/absorber layer in solar cells.

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