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STUDY OF NANOSTRUCTURED NICKEL SULFIDE THIN FILMS FOR PHOTOVOLTAIC APPLICATIONS

V. B. SANAP[1*], B. H. PAWAR

[1]Yeshwantrao Chavan College, Sillod, Dist. Aurangabad (M.S.), India.

*Corresponding author email: vbsanap@rediffmail.com

Abstract: Nanocrystalline thin films of Nickel Sulfide have been prepared by a simple and inexpensive chemical bath deposition technique. Films have been prepared on glass substrate by varying the deposition parameters such as concentration of solution, deposition time, temperature, etc. XRD, SEM, UV-VIS analysis of as-deposited nickel sulfide thin films have been carried out and the results are discussed in detail. The as-deposited film shows cubic structure with good crystallinity. The optical study reveals the good quality nanocrystalline films with energy band gap of 1.39 eV useful for optoelectronic applications.

Keywords: Nickel sulfide, chemical bath deposition, thin films.

1. INTRODUCTION

Thin-film technologies are being developed as a means of substantially reducing the cost of photovoltaic (PV). This can be achieved by the selection of proper and inexpensive material, amount of material used and processing methods. Nickel sulfide belongs to VIII–VI compound semiconductor materials. Nickel sulfide films have a number of applications in various devices such as solar selective coatings, solar cells, photoconductors, sensors, IR detectors, as an electrode in photoelectrochemical storage device etc. [1,2]

A variety of methods, including electrodeposition, SILAR [3], pulsed laser ablation [4], metal-organic chemical vapour deposition [5] thermal and photochemical chemical vapour deposition [6] can be used for the preparation of nickel sulphide thin films. Out of this chemical bath deposition technique has become more popular in recent decades, especially for thin film deposition, due to its numerous advantages. It is easy, inexpensive and convenient method for large area preparation of thin films, at close to room temperature. Also films can be deposited on different kinds, shapes and sizes of substrates [7-9].

In this work, good quality thin films of nickel sulfide were prepared and the influences of deposition parameters, such as deposition time, temperature, pH and concentration of solution on the properties of thin films were studied. This reported data is very useful for many scientific, technological and industrial applications in the field of optoelectronic devices, especially solar cells.

2. EXPERIMENTAL DETAILS

All chemicals used in the experiments were of the highest purity grade available. Solutions of varying concentration of nickel sulfate and thiourea prepared in double distilled water is used for deposition of nickel sulfide films. pH was adjusted by adding ammonia solution slowly in the prepared solution. The solution was stirred and transferred to another container containing substrate. The resulting solution was kept at 70±2ºC for different deposition time. Commercial soda lime glass slides were used as substrate for the deposition. Cleaning of substrate is important in deposition of thin films, cleaning steps and growth procedure is reported elsewhere [10-12].

The crystallographic structure of films was analyzed with a diffractometer (EXPERT-PRO) by using Cu-Kα lines (λ= 1.542Å).The average grain size in the deposited films was obtained from a Debye-Scherrer's formula. Surface morphology was examined by JEOL model JSM-6400 scanning electron microscope (SEM). Optical properties were measured at room temperature by using Perklin-Elmer UV-VIS lambda-35 spectrometer, at normal incidence of light in the wavelength range 200-1000nm.

3. Results and Discussion

3.1 Structural and Morphological Properties

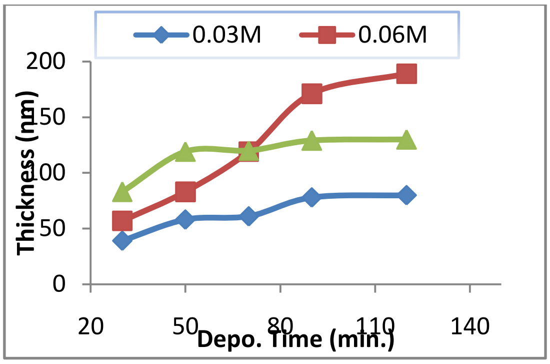

Fig. 1 *Variation of film thickness with deposition time for different concentration.*

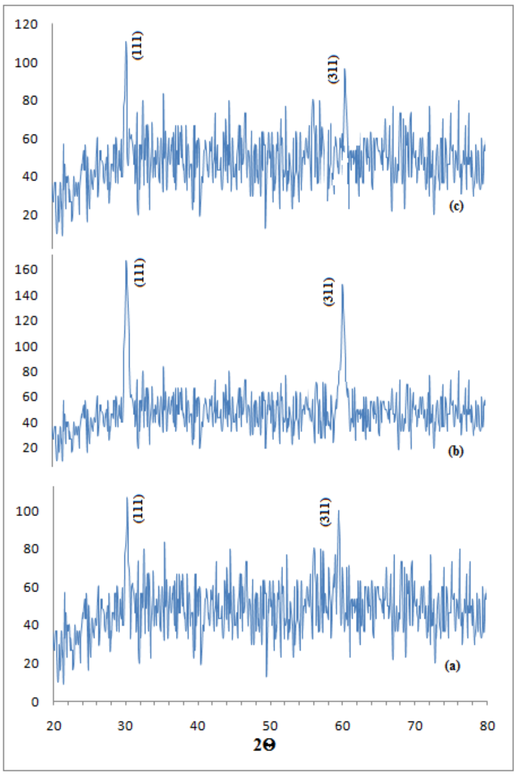

Fig. 2 *XRD pattern of nickel sulfide films for different concentrations (a) 0.03M (b) 0.06M (c) 0.1M*

Fig. 1 shows the variation of film thickness with deposition time for different concentration of deposition solution. It is observed that the film thickness linearly increased with deposition time for 0.06M solution. Where as for lower and higher concentration it is saturated after 70 min. Nickel sulfide films prepared using 0.06M solution shows well crystalline films with uniform deposition over the substrate.

Fig. 2 shows the XRD pattern of nickel sulfide thin films for different concentration of solution. The nickel sulfide film shows two dominant crystalline peaks (111) and (311). A comparison of the peak positions (2θ = 30.2° and 59.4°) of the JCPDS XRD spectra data for nickel sulfide suggests that the as-deposited films have cubic structure with the X-ray diffraction peaks corresponding to (111) and (311) peaks. XRD graph shows sharp peaks for lower concentration (0.06M) solution, may due to smooth surface with small grain size and high degree of homogeneity as compared with higher concentration (0.1M) solution.

The average grain size (g) has been obtained from the XRD patterns using Debye-Scherrer's formula [12-13],

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

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

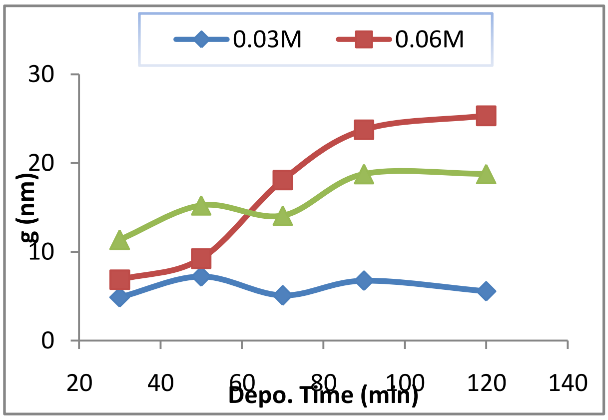

Fig. 3 *Variation of grain size with deposition time for different concentration*

The SEM micrograph shows smoother and more uniform films for 0.06M concentration. The grain size obtained from SEM matches with the grain size obtained by XRD. The lattice parameters of the cubic structured nickel sulfide film are 5.14 A°, well matched with standard data. The variation of film thickness and grain size with deposition time can be illustrated by Fig. 3.

3.2 Optical Properties

Fig. 4 shows the optical absorbance spectra of nickel sulfide thin film deposited for varying concentration of deposition solution. Both the film shows gradual decrease in absorbance with the increase in wavelength of radiation. The film prepared for 0.06M concentration shows better absorbance compared to that of the films prepared for higher concentration (0.1M). This higher absorbance may be due to the random deposition of nickel sulfide, all over the substarte surface.

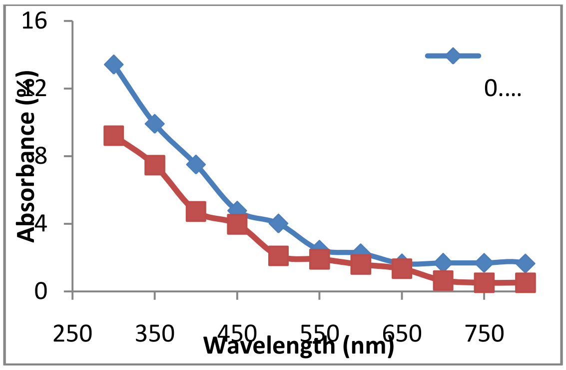

Fig. 4 *Optical absorbance of nickel sulfide thin films for different concentration.*

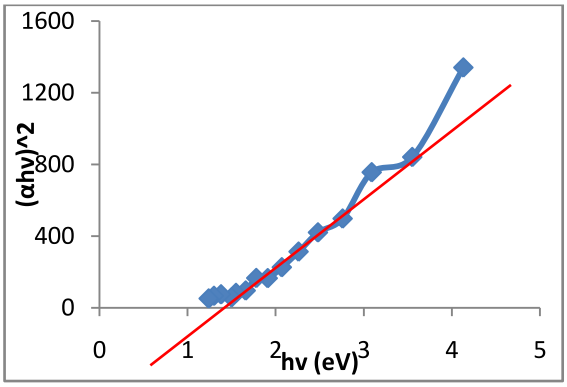

Fig. 5 *Plot of $(\alpha h\nu)^2$ versus hν for nickel sulfide thin films.*

From the absorbance data, the absorption co-efficient α was calculated using Lamberts law [14],

$$\ln (I_0/I_t) = 2.303\ A = \alpha\ d$$

Where, I_0 and I_t are the intensity of incident and transmitted light respectively. A the absorbance and d the film thickness.

The absorption co-efficient α was found to follow the relation, [15]

$$\alpha h\nu = A\,(h\nu - Eg)^{½}$$

The band gap Eg was determined from each film by plotting $(\alpha h\nu)^2$ versus hν and then extrapolating the straight line portion to the energy axis at α =0. The band gap energy Eg obtained is 1.39eV. (Fig. 5).

4. Conclusions

Nanocrystalline nickel sulfide thin films have been grown successfully by CBD technique. The films have been characterized using optical measurements as absorbance spectra, optical band gap energy as well as thickness, structure, surface morphology. It was observed that the deposition parameters such as deposition concentration, time, temperature, etc. could significantly change the crystallinity and morphology of the films. Results obtained from characterization shows obtained films are of good quality and suitable for optoelectronic applications.

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