Optik 156 (2018) 43–48

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Original research article

Investigation on physical properties of polycrystalline nickel sulphide films grown by simple & economical screen-printing method

Vipin Kumar [a,*], D.K. Sharma [a], Kapil Sharma [a], D.K. Dwivedi [b]

[a] Department of Physics, Krishna Institute of Engg. & Technology, Ghaziabad, India
[b] Department of Physics, M.M.M University of Technology, Gorakhpur, India

ARTICLE INFO

Article history:
Received 24 August 2017
Accepted 27 October 2017

PACS:
78.20.Ci
78.50.Ge
78.66.-w
78.66.Hf

Keywords:
X-ray diffraction
Reflection spectra
Band gap
Electrical resistivity

ABSTRACT

Nickel sulphide (NiS) films offer a wide range of applications in solar cells, sensors, IR detectors and as an electrode in photoelectrochemical storage devices. In present investigation, nickel sulphide was synthesized by mechanical alloying and thick films were deposited on glass substrate by simple and economical screen-printing method followed by sintering process. The structural, morphological, elemental, optical and electrical properties of the prepared films were characterized using X-ray diffraction (XRD), field emission scanning electron microscopy (FE-SEM), energy dispersive x-ray analysis (EDAX), UV-VIS-NIR spectroscopy and DC electrical resistivity measurement. XRD studies revealed the polycrystalline nature of films, having hexagonal structure with preferential orientation of grains along (100) plane. The FE-SEM image indicates that the film bears compact surface morphology with nearly spherical clusters. The EDAX analysis confirms the presence of Ni and S elements in prepared films. The optical properties of the films were investigated through reflectance measurement. The films were found to have a direct energy band gap of around 0.56 eV. The DC electrical resistivity of films were measured in vacuum by two probe technique and was found to be of the order of 10^4 Ω cm. All these properties indicate the suitability of these films for device applications.

1. Introduction

Metal sulphide thin films have been studied extensively over last 30 years in view of their potential applications in semiconductor industry particularly in optoelectronics [1]. Among the metal sulphides, nickel sulphide (NiS) has its own significance in phase transition from low temperature antiferro-magnetic semiconductor to a high temperature paramagnetic metal [2]. Nickel sulphide (NiS) is a p-type semiconductor with a narrow band gap of about 0.5 eV and is most efficient electrochemically active materials due to its variety of applications such as lithium ion batteries, supercapacitors, photocatalytic H_2 generation and solar cells [3]. Due to existence of different phases and stoichiometry of nickel sulphide (e.g. Ni_3S_2, Ni_3S_4, Ni_9S_8, Ni_6S_5, Ni_7S_6, NiS_2 and NiS) make this material an important and challenging material to the scientists. In general NiS exists in two phases, viz hexagonal and rhombohedral [4]. Both phases exhibit variety of applications. In literature thin films of NiS have been deposited by variety of methods such as spray pyrolysis [5], chemical bath deposition (CBD)

* Corresponding author.
E-mail address: vipinkumar28@yahoo.co.in (V. Kumar).

https://doi.org/10.1016/j.ijleo.2017.10.169
0030-4026/

[6], hydrothermal [7], successive ionic layer adsorption and reaction (SILAR) [8], thermal evaporation [9], electro-deposition [10] and spin coating [11].

In present investigation, for the first time we report the deposition of nickel sulphide (NiS) films on glass substrate using an economically viable and non-vacuum based screen-printing method followed by sintering process. The optimum conditions for preparing good quality films were determined. The structural, morphological, optical and electrical properties of screen-printed nickel sulphide (NiS) films were carried out with an aim to utilize these films in optoelectronic device applications. Screen – printing is a simple, versatile and low cost deposition method for the preparation of polycrystalline films for large area deposition [12,13]. It can be applied to any surface, shape and size. The utilization of cost effective method for developing such materials would considerably enhance its industrial applications [14].

2. Experimental details

Nickel sulphide (NiS) powder was prepared by mixing AR grade nano powders of nickel and sulphur in elemental form with the help of agate mortar and pestle to allow nickel and sulphur to react completely. A thick paste was prepared by mixing thoroughly the fine powder of nickel sulphide with 10% wt. of nickel chloride hexahydrate ($NiCl_2{\cdot}6H_2O$) as an adhesive agent and an appropriate amount of ethylene glycol as a binder. The prepared paste was screen-printed on pre-cleaned glass substrates. The pre-cleaning were carried out by washing of glass slides by acetone and then by distilled water. The prepared films were dried on a hot plate at 100 °C for 2 h to avoid the cracks in the films. To stabilize the film and to remove the organic materials, the films were further sintered at 200 °C for 10 min in a muffle furnace. All the films were synthesized under the same experimental conditions to confirm the reproducibility of the results. Taylor Hobson (Taly step UK) instrument was used for film thickness measurement. The thickness of the films was found to be of the order of 4 μm. The sintered films were kept in a desscicator for 24 h in order to stabilize their behavior. The uniformity and adhesion of the films were better and no cracks were apparent. The X-ray diffraction pattern was recorded on Philips PW 1140/09 X-ray diffracto-meter in the 2θ range of 20°–70° using CuKα radiation of wavelength λ = 1.5418A∘. Field emission scanning electron microscope (FE-SEM) and EDAX were used for morphological and chemical composition analysis of films. The reflection spectra were recorded by Shimadzu UV-3600 plus spectrophotometer in range 1500–3000 nm. The dark DC electrical resistivity of films was measured by using standard two probe method.

3. Results and discussion

3.1. Structural studies

X-ray diffraction technique was used for crystallographic analysis of nickel sulphide films. An XRD spectra of screen-printed nickel sulphide film is shown in Fig. 1. It is clear from XRD spectra that the films have the high degree of crystallographic orientation. In XRD spectra higher intensity peaks at around 2θ = 30.06°, 34.53°, 45.80°, 53.51° reveals a hexagonal phase of nickel sulphide, which are consistent with the literature data of JCPDS card no.75-0613. These peaks could be assigned to the planes (100), (101), (102) and (110) respectively of hexagonal phase [15]. From XRD spectra, it is clear that nickel sulphide films are polycrystalline in nature having hexagonal lattice structure. No other phases were observed from XRD spectra. The lattice parameter a and c of hexagonal phase was calculated using the equation:

$$\frac{1}{d^2} = \frac{4}{3}\left(\frac{h^2+hk+k^2}{a^2}\right) + \frac{l^2}{c^2}$$

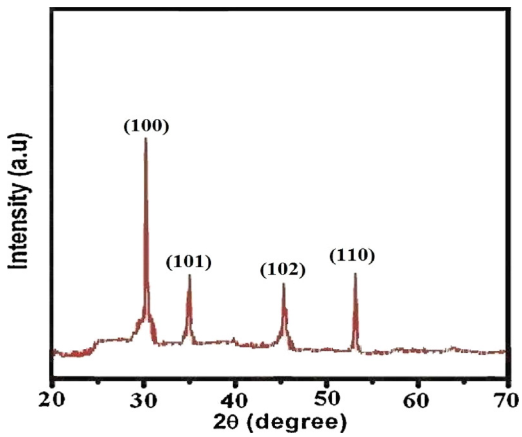

Fig. 1. XRD spectra of screen-printed nickel sulphide film.