RESEARCH ARTICLE

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Structural and Electrical Studies of NixSn1-xO$_2$ Sn Dopped Nickel Oxide Thin Film by Jet Nebulizer Spray Pyrolysis Technique for Photodiode and Solar Cell Applications

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Abstract: The dissertation deals with preparation and characterization of $Ni_xSn_{1-x}O_2$ thin films by the jet nebulizer spray pyrolysis technique at optimized temperature 450°C with Ni dopants. The films were analysed to understand the structural, surface morphology, optical and electrical studies for $Ni_xSn_{1-x}O_2$ thin. Moreover, in the case of transparent oxide films, the thickness increases linearly with time of spray. Also, the growth of thin films is temperature dependent. At low temperatures, the growth rate is controlled by activated processes, such as adsorption, surface diffusion chemical reaction and desorption. However, at high temperatures, the activated processes occur so fast and the molecules do not dam up on the substrate. Growth rate also depends on the size of the droplets, because the decomposition of droplet is temperature dependent. If the droplet size is large, the heat absorbed from the surroundings will not be sufficient to vaporize entirely the solvent on the way to the substrate and adversely affect the kinetics of the reaction. The XRD Pattern of $Ni_xSn1\text{-}_xO_2$ shows the polycrystalline nature with orthorhombic structure and is oriented through (021) direction. The grain size of the prepared films is increased up to x=0.2 and then decreased slightly, for x= 0.8 the grain increases. The conductivity of $Ni_xSn1\text{-}_xO_2$(x=0) at room temperature is 2.8×10^{-4}s/cm and the other compositions (x=0.2, 0.4, 0.8) show the decrease of conductivity to 2.4×10^{-6}s/cm. The maximum transmittance (~75%) shows in IR region and ~70%of transmittance in the visible region at x=0.4. The band gap value of $Ni_xSn1\text{-}_xO_2$ films is 2.96, 2.98 and 3.0 ev for x=0.8 0.2 and 0.4 respectively. It can be used for diode and solar cell applications due to the higher transmittance and decreases of band gap energy.

Keywords: Solar Cells, Thin films, JNSP Technique, Photodiode

1. Introduction

In the fast-growing technological world, the success of any modern technology is possible only through achievement. Progress on any industry and development of a nation in science and technology for the past few decades has been based on semiconductor technology and semiconductor devices. The advancement in semiconductor technology necessitates to develop new semiconductor materials and new processing techniques both in bulk and thin film preparation. Semiconductor technology is used in widespread fields, particularly in photovoltaic field which has been identified as one of most important areas, that requires the focus of much attention, considering the ever-increasing energy requirements of the future. Among the various forms of photovoltaic devices, those based on semiconductor thin films have paved the way for the economical and efficient solar cell devices assuring the promising ways of meeting the ever-increasing energy demand [1-3].

The continuously growing field of optoelectronic application also increases the demand of semiconducting materials with specific properties and there is a great demand for high speed and high functional semiconductor devices. This is very important for the future growth of solid-state electronic industry. Thin film as a two-dimensional system is of great importance to many real-world problems. The term 'thin film' not only implies a layer of solid material but also a liquid and a gaseous phase. A 'thin film' may be arbitrarily defined as a layer (solid or liquid) having a thickness varying from a few Å to about 10 μm. 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 [4,6]. 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 is plenty of room for improvement and development of thin film device applications.

There is a fierce worldwide competition in applications related with semiconductor. In earlier days, scientific interest in thin solid films was centred on antireflection coatings for lenses, multilayer interference filters, automobile head lights and decorative coatings, ceramics and sun glasses, front surface mirrors etc. [5& 7]. The present world faces severe energy crisis due to the repeated mining of fossil fuels. The consumption of non-renewable energy causes huge damage to the environment, therefore an alternative form of energy to meet the present day's requirement is renewable energy sources. Solar energy stands out as a viable source of clean and limitless energy and it is the readily available source of energy [8-10]. The paper deals with preparation and characterization of $Ni_xSn_{1-x}O_2$ thin films by the nebulizer spray pyrolysis technique at optimized temperature 450°C with Ni dopants. The films were analysed to

understand the structural, surface morphology, optical and electrical studies for $Ni_xSn_{1-x}O_2$ thin. From the obtained results we are concluding that obtained $NixSn1-xO_2$ thin films are suitable for various application such as gas sensors, solar cells, light emitting diodes, photo diodes, photo detectors and many other optoelectronic devices.

2. Experimental Procedure

2.1 Materials

Analytical grade Nickel nitrate (Sigma Aldrich), Tin Chloride (Sn), Iron chloride (sigma Aldrich), Distilled water and various solvents like Ethanol and Isopropanol, Optical Glass slides (2X1 mm) was used as substrates.

2.2 Preparation Method

Analytical grade Nickel nitrate were used for the film preparation. Pure and Sn doped Ni thin films deposited at substrate temperature 350oC through Nebulizer Spray Pyrolysis (NSP) technique. The spray solution was prepared by dissolving 0.05 M Nickel nitrate in 30 ml of de-ionized water and the solution was stirred for 10 minutes using a magnetic stirrer. Similarly Tin Chloride (Sn) solution was prepared in the form of 2.5%, 5%, 7.5% and 10% (weight %) of 0.05 M Tin chloride. The stirring was continued for 30 min to get clear and homogeneous spray solution. The prepared solution was sprayed onto ultrasonically cleaned glass substrates kept at the optimized temperature 350oC [11-13&16-20]. Films prepared by this method have uniform thickness and well adherent with the substrate. The optimized preparative parameters for pure and Sn doped NixSn1-xO2 thin films are listed in Table .1.

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.

Table .1 Optimized preparative parameters of Sn doped $Ni_xSn_{1-x}O_2$ films

Deposition rate	0.5 ml/minutes
Substrate temperature (˚C)	350˚C
Deposition time (minutes)	10 minutes
Nozzle to substrate distance	5 cm
Carrier gas pressure	2.5 Kg/m2

3. Results and Discussion

3.1 Structural Analysis

Fig. 1 shows the XRD pattern of $Ni_xSn_{1-x}O_2$ thin films characterised by X-ray diffraction analysis. The XRD pattern of $Ni_xSn_{1-x}O_2$ shows the polycrystalline nature with orthorhombic structure and is oriented through (021) direction. The lack of grains is oriented through (116), (118), (227) and (112) directions. The intensity of (021) plane is increased with the value of x. In x= 0.4 the intensity of the peaks is reduced and the grains are oriented through (116) plane only [14-15]. At x=0.8 the intensity of the (021) is high and other peaks are diminished and a new peak is occurred at 2θ=40.4894 which represents the of$Ni_xSn_{1-x}O_2$is calculated from the Debye-Scherrer formula.

$$D = \frac{k\lambda}{\beta\cos\theta}$$

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 θ is the diffraction angle. The calculated fig (2) shows the grain size of $Ni_xSn_{1-x}O_2$thinfilms with different x values [21-24]. The grain size of the prepared films is increased up to x=0.2 and then decreased slightly, for x=0.8the grain size increases. The decreases of grain size may be due to the presence of the same composition of Ni and Sn concentration in the prepared films.

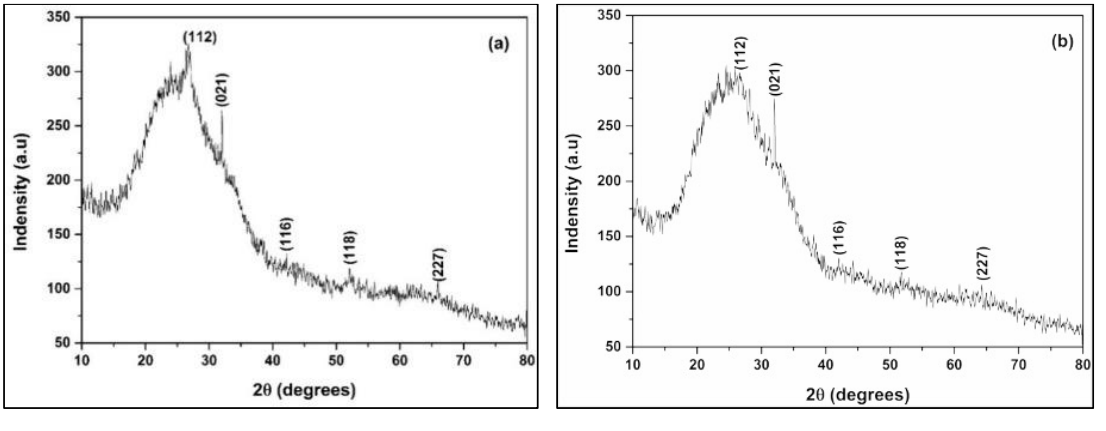

Fig.1 XRD pattern of NixSn1-xO2thin films with a) x= 0 b) x= 0.2

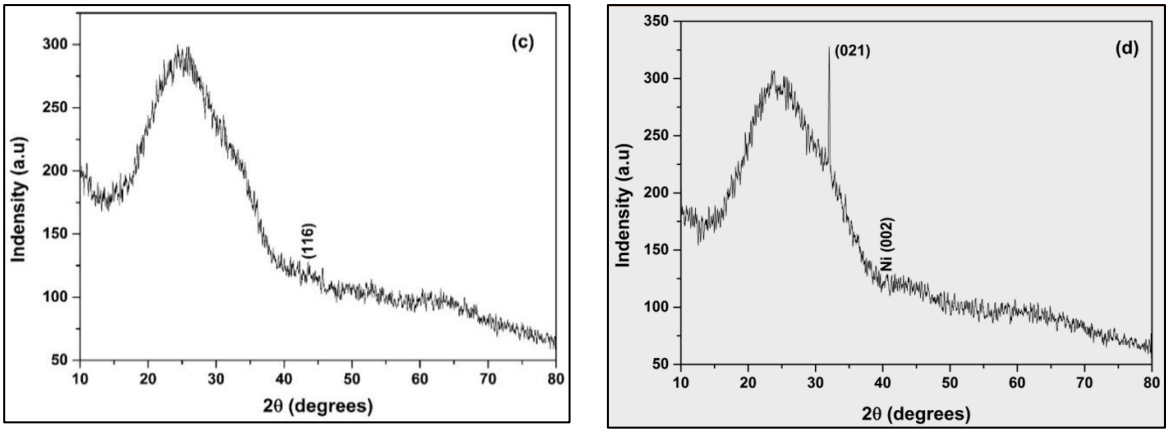

Fig.2 XRD pattern of $Ni_xSn_{1-x}O_2$thin films with c) x= 0.4 d) x= 0.8.

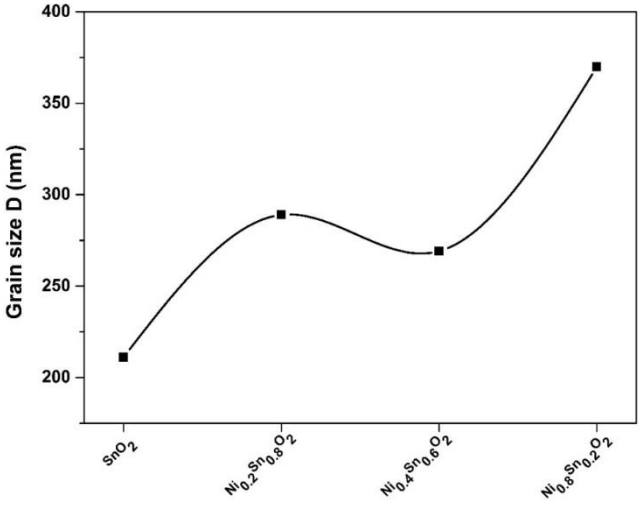

Fig. 3 Grain size of $Ni_xSn_{1-x}O_2$thin films

3.2 Electrical properties

The electrical conductivity of the Ni_x Sn_{1-x} O_2 films are carried out by using Keithley electrometer 6517 B interfaced with two probe setups. Fig. 4a&b shows the I-V characteristics of $Ni_xSn_{1-x}O_2$thin films performed by applying potential 10 to 100V [25-28]. It shows the ohmic behaviour of the prepared films. The electrical conductivity of the $Ni_xSn_{1-x}O_2$films is calculated from the following formula,

$$\sigma = \frac{1}{\rho} \quad (5)$$

$$\rho = \frac{RA}{l} \quad (6)$$

where, ρ is the resistivity R is the resistance, A is the cross-sectional area of the film and *l* is the inter probe distance.Fig.5 illustrates the electrical conductivity of $Ni_xSn_{1-x}O_2$thin films. The conductivity of $Ni_xSn_{1-x}O_2$ (x=0) at room temperature is $2.8x10^{-4}$ S/cm and the other compositions (x=0.2,0.4,0.8) show the decrease of conductivity to $2.4x10^{-6}$S/cm[29-30&27]. It may be due to the increase of Ni concentration.

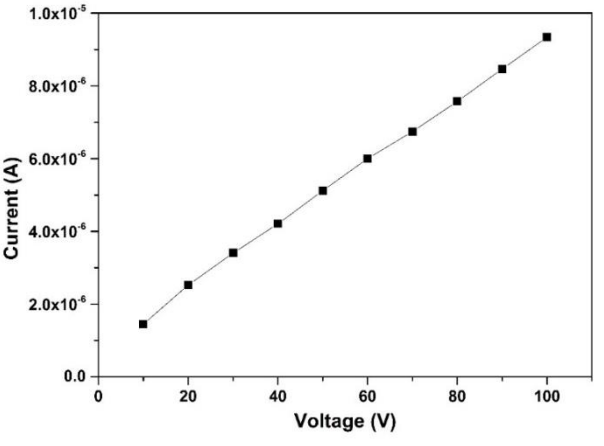

Fig. 4 (a). I-V characteristics of $Ni_xSn_{1-x}O_2$thin films with x= 0

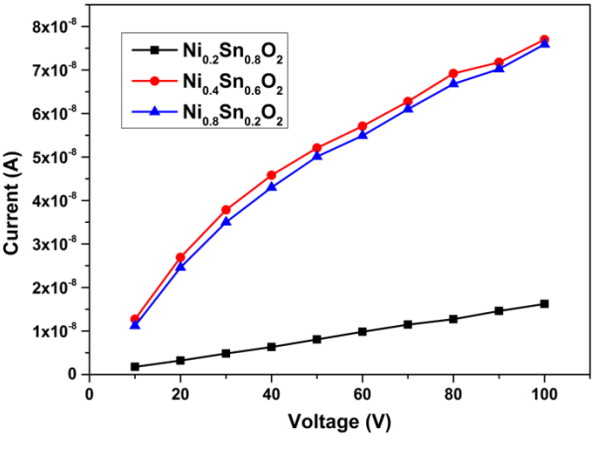

Fig. 4 (b). I-V characteristics of $Ni_xSn_{1-x}O_2$thin films.

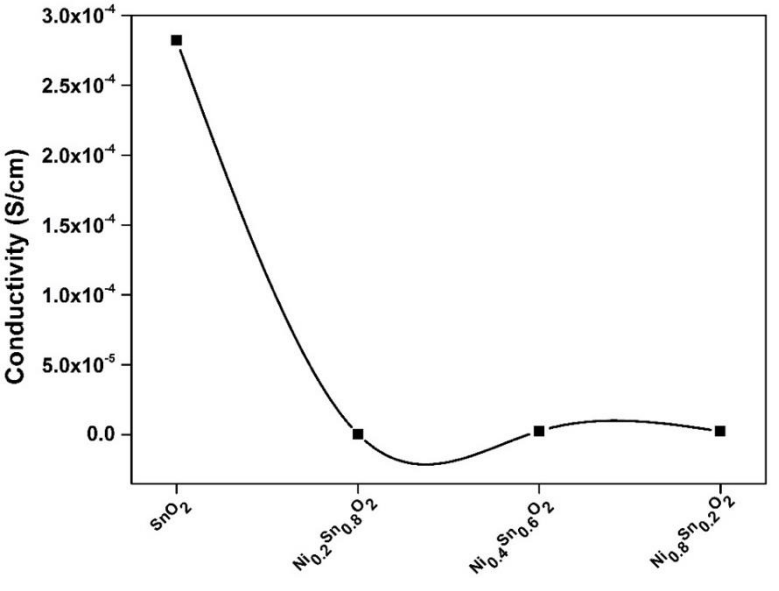

Fig. 5. Electrical conductivity of $Ni_xSn_{1-x}O_2$ thin films.

4. Conclusion

The $Ni_xSn1-_xO_2$ thin films are prepared by Nebulizer spray pyrolysis technique with different Ni and Sn volume concertation (x=0, 0.2, 0.4 and 0.8). The XRD Pattern of $Ni_xSn1-_xO_2$ shows the polycrystalline nature with orthorhombic structure and is oriented through (021) direction. The grain size of the prepared films is increased up to x=0.2 and then decreased slightly, for x= 0.8 the grain increases. The decreases of grain size may be due to the same composition of Ni and Sn concentration in the prepared films. Then x=0.2 shows the interconnected fibre with some grain with average size of 365 nm due to presents of Ni concentration in the prepared films. The conductivity of $Ni_xSn1-_xO_2$(x=0) at room temperature is 2.8×10^{-4}s/cm and the other compositions (x=0.2, 0.4, 0.8) show the decrease of conductivity to 2.4×10^{-5}s/cm. The maximum transmittance (~75%) shows in IR region and ~70%of transmittance in the visible region at x=0.4. The band gap value of $Ni_xSn1-_xO_2$ films is 2.96, 2.98 and 3.0 eV for x=0.8 0.2 and 0.4 respectively. It can be used for diode and solar cell applications due to the higher transmittance and decreases of band gap energy.

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