MICROTOPOGRAPHY, OPTICAL AND PHOTOELECTROCHEMICAL STUDIES OF SNSENI$_{0.1}$

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ABSTRACT

A device for energy conversion i.e. Photo-electrochemical (PEC) solar cell can be fabricated from nickel doped tin selenide crystals, because of its unique electrical and optical properties. Nickel doped tin selenide crystals has two main properties i.e. Layered structure and band gap value, so this kind of crystals shows great promise for photovoltaic device fabrication. For the study of layered structure, growth mechanism and dislocation densities Surface microtopography is used; band gap value and various optical parameters can be studied by using absorption spectra achieved from UV-Visible spectrometer (200-2500nm). All these characterizations become important for fabrication of photovoltaic device i.e. Photo-electrochemical (PEC) solar cell (liquid-solid junction device). Efficiency and fill factor of this device is further calculated from I-V characteristics taken at 40mW/cm^2 intensities.

I. INTRODUCTION

The main purpose for fabrication of photovoltaic device is that, now a day there is an increased demand for renewable energy conversion devices like solar energy conversion device.[1-3] For this purpose in this paper authors have tried to carry out a brief study of a semiconducting crystals ($SnSeNi_{0.1}$) and its application as photovoltaic device fabrication i.e. study of structural and optical properties of $SnSeNi_{0.1}$ crystals and fabrication of device named Photo-electrochemical (PEC) solar cell. Nickel doped tin selenide crystal is one of the metal chalcogenide, have attracted considerable attention due to their interesting properties and potential applications as energy storage devices as well as photovoltaic device. This paper contains main three parts of device fabrication i.e. a) growth of $SnSeNi_{0.1}$ crystals; b) Study its surface and optical properties and c) Fabrication of energy conversion device by using these properties of crystals. There are different methods for the growth of nickel doped tin selenide crystals, have been described in the literature [1]. Such kind of device fabrication is basically depend on the surface properties of crystals so Surface microtopography becomes very important characterization for study structural properties of crystals like growth mechanism, dislocation density and defects. In photovoltaic devices absorption of solar energy takes place for the conversion of energy, according to allowed band gap of materials or crystals. In this case it is necessary to carried out UV-Visible spectroscopy characterization in the allowed range for obtaining absorption spectra in which absorption of polychromatic light can easily takes place, calculation of band gap value and various optical parameters also becomes possible. After the study of surface and various optical properties of crystals it is possible to fabricate Photo-electro chemical (PEC) solar cell device. Working and efficiency of this fabricated solar cell discussed further.

II. EXPERIMENT AND RESULT

Growth. Semiconductors with narrow band gap have been synthesized by solvothermal route, electrodeposition, vapor technique, sol-gel method and mechanochemical synthesis [1]. Tin selenide is high temperature; insoluble material which melts before its melting point reaches so after a faithful study it becomes clear that, the appropriate and successful growth technique for nickel doped tin selenide crystals is direct vapor transport (DVT) technique. With the help of this technique it is possible to grow large quantity quality crystals with flat and smooth surface for further characterization study.

Surface microstructure. The surface microstructure of the fresh as-grown faces of $SnSeNi_{0.1}$ crystals were examined under 'Epignost' optical microscope (Carl Zeiss Jena GmbH, West Germany). Fig. 1 shows the layered type growth of crystal for orthorhombic crystal. $SnSeNi_{0.1}$ crystals grow in the platelet form along bc-plane having thickness in the direction of crystallographic a-axis, which allows immediate access to observe (400) face by microscope. The reason of clean surface is absence of any dangling bond. Microtopography of the grown crystals shown in Fig. 1 indicates that the growth of $SnSeNi_{0.1}$ crystals promoted by lateral spreading of layers. Moreover their regular shape of growth layers at the edges of smooth flat faces indicates that the growth was rapid [4]. In the case of $SnSeNi_{0.1}$ growth spirals are observed on the crystal surface as shown in Fig. 1 indicating that their growth was driven by a screw dislocation mechanism. In growth from vapour, theory [3] predicts that the growth of a crystal surface with steps will be the result of three processes: (1) transport of molecule from vapour to surface of solid, (2) diffusion of adsorbed molecule to steps, and (3) diffusion of molecules along the edge of a step to a kink. [4-5]

UV-Visible Spectroscopy. The optical absorption data were taken by means of (Perkin Elmer Model: Lambda-19) Spectrophotometer. Morphological study of as grown surfaces of crystal consists of a variety of structures whose study leads to mechanism of growth. The surfaces of this type of grown crystals were mirror like. Crystal flakes were pasted on a thick black paper with a cut exposing the crystal flake to the incident light. The reference used for this work was a replica of the black paper, having the cut in the exactly the same position as the crystal flake. This arrangement was necessary because the crystal size was smaller than that of the sample compartment. In this present case, absorption spectrum taken over the spectral range 200-2500 nm. The absorption coefficient 'α' was determined at every step of 5 nm and had scanning speed 240 nm/min. Fig. 2 shows the UV-Visible absorption spectrum of $SnSeNi_{0.1}$. Fig. 3 shows graph of $(\alpha h\nu)^{1/2}$ vs. photon energy. The point at which the extended line intersects gives the value of direct allowed band gap and it can be calculated using Tauc relation. UV-VIS reflectance spectrum has less effect in scattering than absorption. The sudden decrease of absorption at a particular wavelength, corresponding to the optical band gap means that the particles are almost uniformly distributed in the sample. [6]

The direct band gap energy (Eg) for the $SnSeNi_{0.1}$ is determined by fitting the reflection data to the direct transition equation. For the analysis of the experimental results obtained at constant temperature, this equation is sufficient especially while we are interpreting results from semiconducting materials absorption spectra. Plotting $(\alpha h\nu)^{1/2}$ as a function of photon energy and extrapolating the linear portion of the curve to absorption equal to zero gives the value of the direct band gap to be 0.90 eV. Other than this various optical properties like reflection, transmission, reflective index, extinction coefficient, dielectric constant, dissipation factor etc. It may be mentioned that, in amorphous chalcogenide thin films, the number of defects are higher due to the existence of unsaturated bonds. [5] The reflective index and extinction coefficient linked to the light scattering mechanism and it brings its low dielectric losing. The complex dielectric constant is a fundamental intrinsic property of materials directly linked to its refractive index. The real part of the dielectric constant, ε_r is linked to the electronic polarizability whereas the imaginary part ε_i is related to the absorption phenomenon due to dipole motion.

The Photoelectrochemical (PEC) solar cell. The Photoelectrochemical (PEC) solar cell is one kind of solid-liquid junction diode. The solid junction made up of electrode, made up of $SnSeNi_{0.1}$ crystal, a copper wire for took out contact and a platinum wire as a counter electrode and the liquid junction is made up of freshly prepared transparent electrolyte i.e. 0.1M Na_2SO_4+0.1M KI+0.05M I_2+H_2SO_4. Polychromatic radiations made incident on the solid-liquid interface with the help of sodium light at 40mW/cm^2 illuminated intensity. Fig. 4 shows the schematic circuit diagram of fabricated Photo-electrochemical (PEC) solar cell arrangement. The main principle of the Photovoltaic cell involves the generation of photo voltage due to the absorption incident solar radiation by the semiconducting material and appropriate charge transfer.[8] In general the principle can be considered as combination of 3 steps (Fig 5)

Fig. 6 shows the I-V characteristic of $SnSeNi_{0.1}$ electrode taken by using KEITHLEY LABTRACER 2.0 I-V CURVE TRACING application software at 40 mW/cm^2 incident intensity. Polychromatic light incident at the solid liquid junction of electrode and electrolyte assembly, as soon as light incident on the crystal surface kept in electrolyte assembly, charge transfer of majority charge carrier takes place. This mechanism gives rise to I-V characteristic of $SnSeNi_{0.1}$ electrode. From the graph of I-V characteristic, it becomes possible to find out open circuit voltage (V_{oc}) and short circuit current (I_{sc}) as shown in Fig. 6. By using both these parameters i.e. open circuit voltage (V_{oc}) and short circuit current (I_{sc}); maximum power value (P_{max}), Fill Factor and efficiency (ƞ) can be calculated by using equation 1, 2 and 3 respectively. The parameters calculated from Photoelectrochemical (PEC) cell characterization are displayed in Table 1.

III. EQUATIONS

$$\alpha h\nu = A\,(h\nu - Eg)^{1/2} \qquad (1)$$

Where α is the optical absorption coefficient, hν is the photon energy, Eg is the direct band gap and A is photon energy.

$$V_{oc} = \left(\frac{nkT}{e}\right) \ln I_L \qquad (2)$$

Where, V_{oc}= open circuit voltage, n = ideality factor, kT/e = 0.0259 volt at 300K, I_L = Intensity of illumination.

$$I_{sc} = I_0\left[exp\left(\frac{eV_{oc}}{kT} - 1\right)\right] \qquad (3)$$

Where, I_{sc} = short circuit current, Voc = Open Circuit Voltage, I_o = Reverse saturation Current, k = Boltzmann Constant, T = Room Temperature.

$$FF = \frac{P_{max}}{I_{sc} \times V_{oc}} \qquad (4)$$

Where, FF= Fill Factor, P_{max} = maximum power point, I_{sc} = short circuit current, V_{oc}= open circuit voltage.

$$\eta = \frac{I_{SC} \times V_{OC} \times FF}{I_L \times A} \qquad (5)$$

Where, η=efficiency, I_{sc} = short circuit current, V_{oc}= open circuit voltage, FF= Fill Factor, I_L = Intensity of illumination, A= area of solar cell

IV.FIGURES AND TABLES

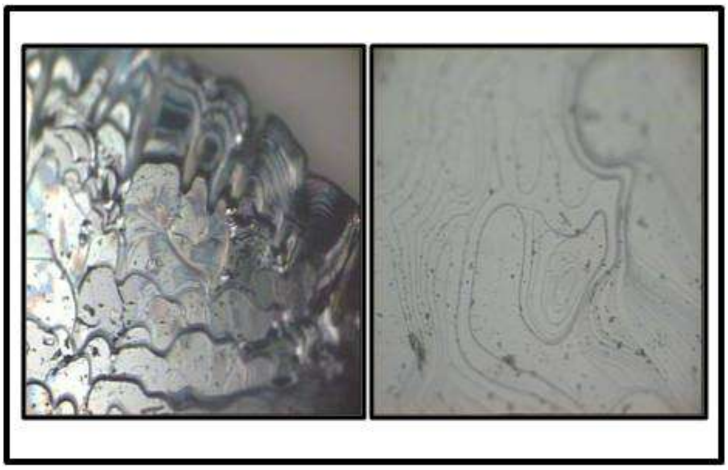

Figure 1 surface microstructure showing layered growth and spirals respectively

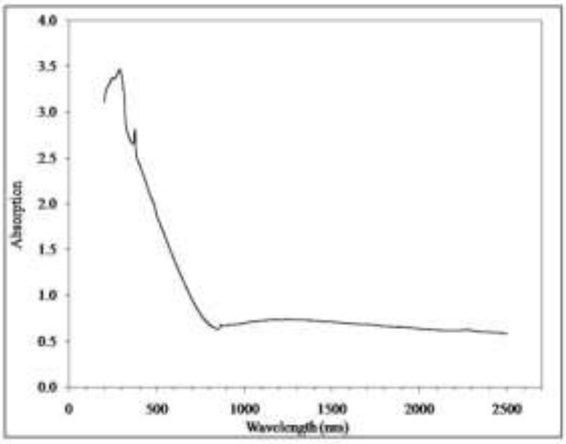

Figure 2 UV-Visible absorption spectrum of $SnSeNi_{0.1}$

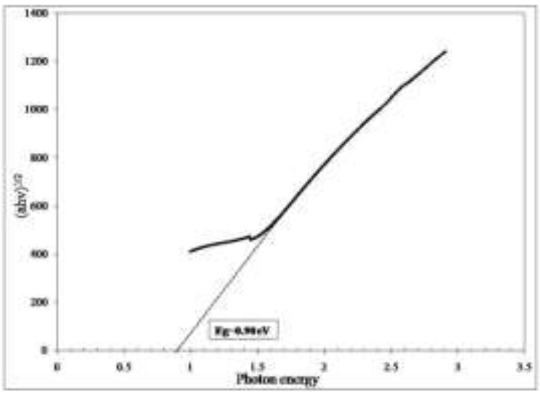

Figure 3 graph of $(\alpha h\nu)^{1/2}$ vs. photon energy for $SnSeNi_{0.1}$

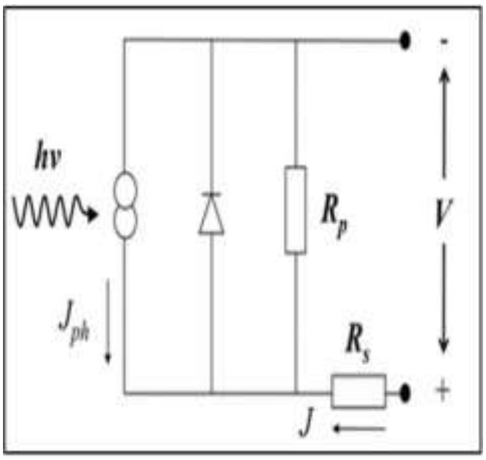

Figure 4 circuit arrangements for Photo Electrochemical (PEC) solar cell

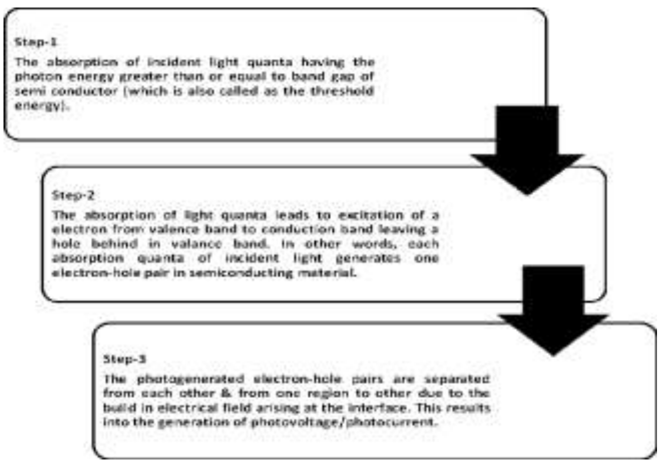

Figure 5 Photo Electrochemical (PEC) Solar Cell Principle

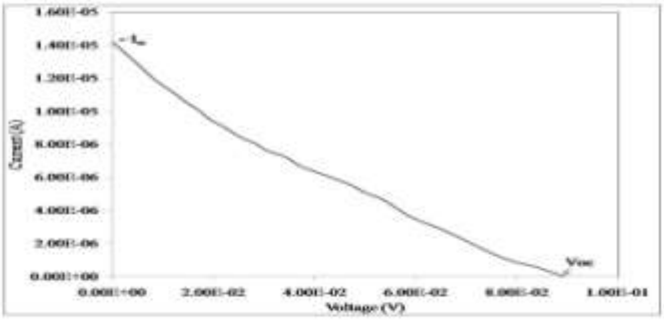

Figure 6 I-V Characteristics for Snseni$_{0.1}$ Electrode at 40mw/Cm^2

Table 1 Parameters Calculated From Photo Electrochemical (PEC) Solar Cell

Electrode	I_{sc}(A)	V_{oc}(V)	P_{max} (watt)	Fill Factor	Efficiency (η%)
SnSeNi$_{0.1}$	1.42E-05	0.08915	2.61633E-07	0.2	0.032

V. CONCLUSION

Good quality nickel doped tin selenide crystals can be successfully grown by Direct vapour transport (DVT) technique and the surface microstructure study confirms the layered growth of the crystal as well as it become essential tool for choosing less defect flat surface crystal. Another than that the band gap value (0.90 eV) of nickel doped tin selenide is falls in the range of semiconducting material, from the band gap value it can be concluded as good Photo-electrochemical (PEC) solar cell device can be fabricated from this crystal. In reference to that the UV-Visible characterization also shows there is maximum absorption in the visible range (solar radiation) of light spectrum. From all these characterizations it can be concluded that a very easy and a compatible device i.e. Photo-electrochemical (PEC) solar cell can be fabricated at low cost. From I-V characteristics and value of efficiency, it clears that this material can become very good solar cell if some modifications added to it.

VI. ACKNOWLEDGEMENTS

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