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Measurements of thermal conductivity and thermal diffusivity of polycrystalline indium chalcogenide $In_2Se_{3X}Te_{3(1-X)}$ (x = 0, .2, .4, .6 and .8) at room temperature

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Abstract:
The structure, thermal conductivity and thermal diffusivity of indium chalcogenide $In_2Se_{3X}Te_{3(1-X)}$ (x = 0, .2, .4, .6 and .8) of pellets, prepared under a load of 5 tons were carried out at room temperature using transient plane source (TPS) technique.. Results indicate that the material is of polycrystalline nature and both the values of thermal conductivity and thermal diffusivity decreased with increasing the concentration of selenium at the cost of tellurium. This compositional dependence behaviour of the thermal conductivity and diffusivity has been explained in terms of the iono-covalent type of bond which indium makes with Te as it is incorporated in the In-Se materials.

Key words: TPS technique, thermal conductivity, thermal diffusivity, iono-covalent bond, indium chalcogenide, XRD.

1. Introduction:

Chalcogenide materials are used as photographic materials and have gained much importance recently. Because of its low absorptivity at infrared wavelengths, as well as its visible transmission. It is are interesting material because of their technological application [1] and commercial importance [2]

Great attention has been given to III- VI group Chalcogenide materials, in recent years, mainly due to their wide range of applications as solid state devices both in scientific and technological fields [3]. These materials have come under increased scrutiny because of there wide use in cost reduction of devices for photovoltaic application [4].The research on renewable energies includes the photovoltaic conversion of solar energy and important investigations of novel materials and structures. The group III-IV materials show great structural diversity, a number of different stoichiometries are observed for the binary combination of 13 metal (Ga, In, Ti) and a group 16 chalcogen (S,Se,Te)[5]. In_2Te_3 is a useful material in opto-electronic device. The use of In_2Te_3 for industrial applications needs that the alloy should be synthesized inexpensively and there for, a better understanding for their physical properties are desirable. Investigations on thermal properties yield useful information on several properties of the materials. In the present work, measurement of thermal conductivity and thermal diffusivity of these materials have been carried out at room temperature. The transient plane source (TPS) [6] technique was used for these measurements.

2. Material preparation and experimental techniques

High purity (99.999%) Indium, Tellurium and Selenium in the appropriate atomic percentage were weighed and then sealed into quartz ampoule (length 7 cm and internal diameter 8 mm) in a vacuum of 10^{-5} to 10^{-6} Torr. The sealed ampoule was heated in an electric furnace up to 925 K (+ 5K) and kept around that temperature for 8-9 h. During heating period, the ampoule was continuously rocked after every 2 h to ensure the homogeneity of the sample. The molten sample was rapidly quenched cooled water. The prepared material was processed into the form of pellets (thickness 2 mm and diameter 12 mm) at a load of 5 tons. The structure of as prepared samples were investigated X-ray diffract meter

Bruker, Model-D8Advance with Cu Kα radiation (1.54 Å) and the effective thermal conductivity of the indium chalcogenide $In_2Se_{3X}Te_{3(1-X)}$ (x = 0, .2, .4, .6 and .8) was measured by transient plane source (TPS) technique.

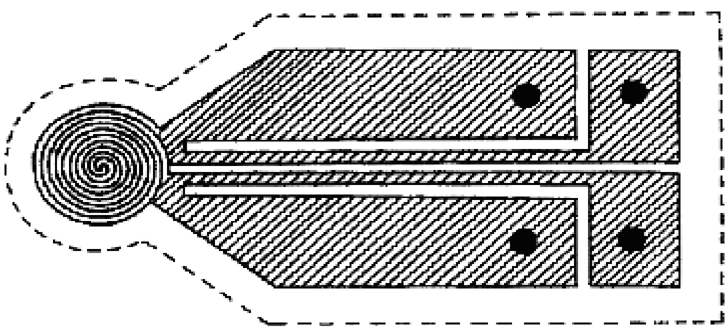

Fig. 1 Schematic diagram of TPS sensor

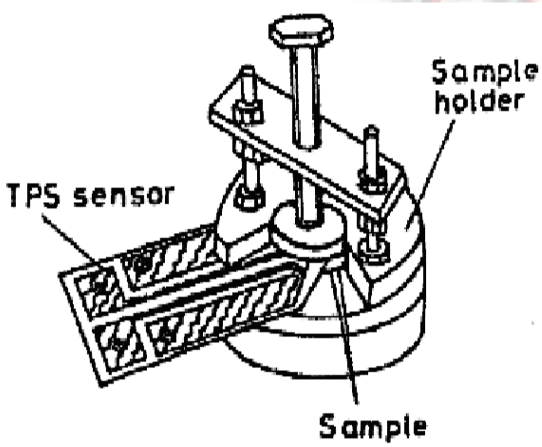

Fig. 2 Sample older diagram with TPS sensor

The TPS sensor shown in Fig. 1 is sandwiched between the two pellets of sample material in the sample holder shown in Fig. 2. Schematic diagram of electrical circuit used for measurement of effective thermal conductivity is shown in Fig.3. Several runs of the experiment are performed and recorded at room temperature to ensure the reproducibility of these results. Also, to attain thermal equilibrium, the samples were maintained at a room temperature for at least 2 h before the experimental data were recorded. The change in the voltage was recorded with a digital voltmeter, which was online to the personal computer. The power output to the sample was adjusted according to the nature of the sample material, in most of cases range is 6 × 10−6 to 16 × 10−6 W/m2.

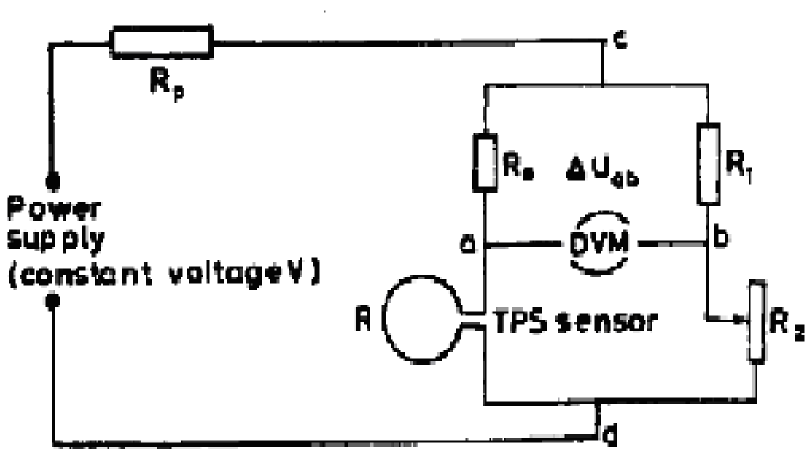

Fig. 3 Schematic diagram of the electrical circuit used for measurement of effective thermal conductivity.

The TPS element is made of a 10 µm thick nickel foil (having a resistance of about 3.26 Ω and TCR around 4.6× 10−3 K−1) with an insulating layer made of 50 µm thick Kapton, on each side of the metal pattern. Evaluation of these measurements was performed in a way that was outlined by Gustafsson [7]. In experiments with insulating layers of such thickness, it is necessary to ignore the voltage recorded during the first few seconds because of the influence of the insulating layers. However, owing to the size of the heated area of the TPS element, the characteristic time of the experiment is so long that it is possible to ignore a few second of recorded potential difference values and still obtain very good result.

An important aspect of the design of any TPS element is that the pattern should be such that as large a part of the "hot" area as possible should be covered by the electrically conducting pattern, as long as there is insulation between the different parts of the pattern. This is particularly important, when insulating layers are covering the conduction pattern and the surface(s) of the sample. It should be noted that the temperature difference across the insulating layer can after a short initial transient, be considered constant.

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3. Results and discussion:

XRD pattern of In_2Te_3 at X=0 show in fig (4) it observed that material is polycrystalline in nature. The formation of indium telluride at x = 0 confirm with the help of ASTM (JCPDC 16-445, 445a) cards. Measurement of effective thermal conductivity and thermal diffusivity of pellets of $In_2Se_{3x}Te_{3(1-X)}$ (X = 0, .2, .4, .6, .8) Indium chalcogenide and sample prepared by quenching method, compacted under a load of 5 tons, have been carried out at room temperature using TPS technique. The results have been plotted in figures (5) and (6) respectively. It can be observed from the figures 6.1 and, 6.2 that the effective thermal conductivity and thermal diffusivity of the indium chalcogenide decreased with the increase of composition of selenium in the In-Se-Te materials. The decreased in the effective thermal conductivity and thermal diffusivity could be explained by considering the structural change due to the introduction of more Selenium atoms. Indium makes the iono- covalent bonds with selenium and is probably dissolved in the Se chain. The decrease in thermal conductivity (λ) and thermal diffusivity (χ) may be described in terms of changing of iono-covalent bonds in to covalent bonds. Indium is metallic in nature while Te which in its stable state, exhibit semiconductor properties and have a trigonal structures.

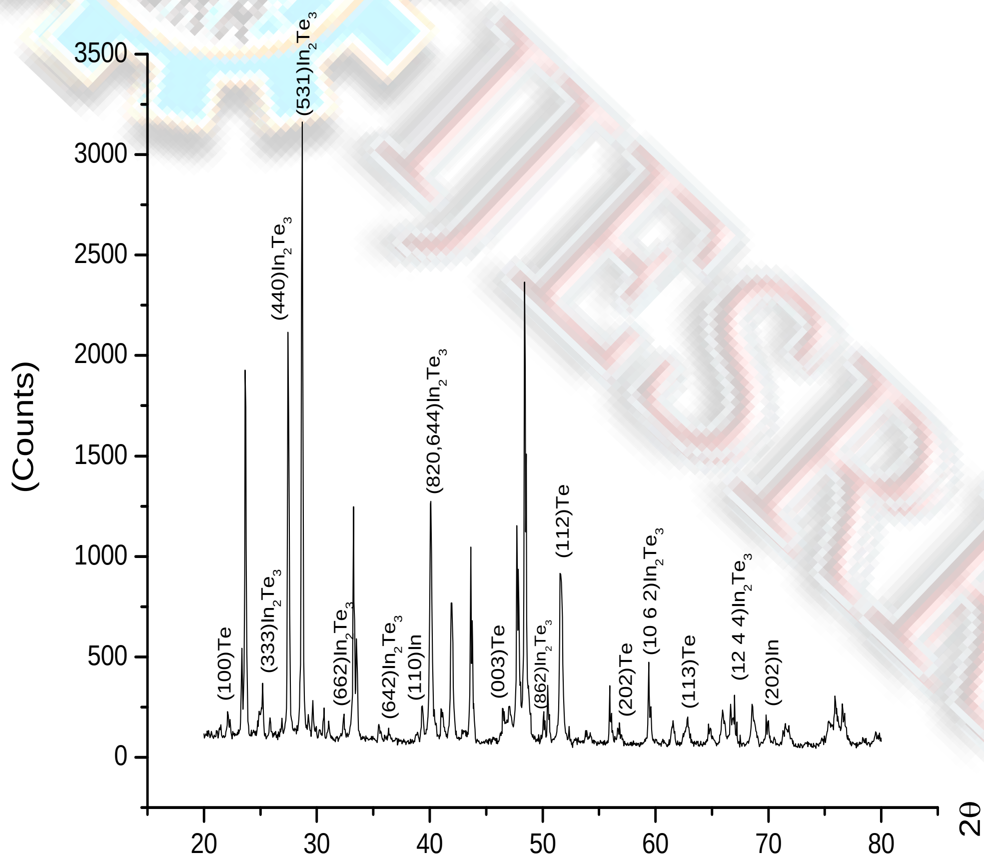
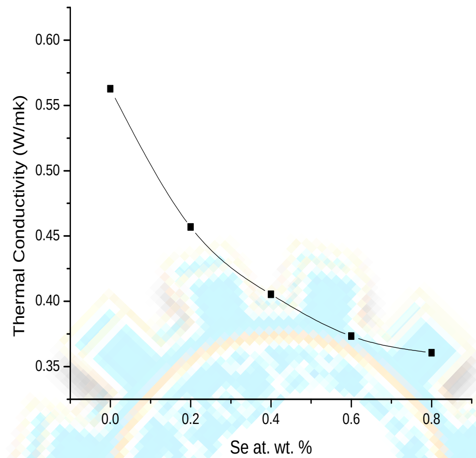


Fig.4 XRD pattern of In_2Te_3 at X = 0



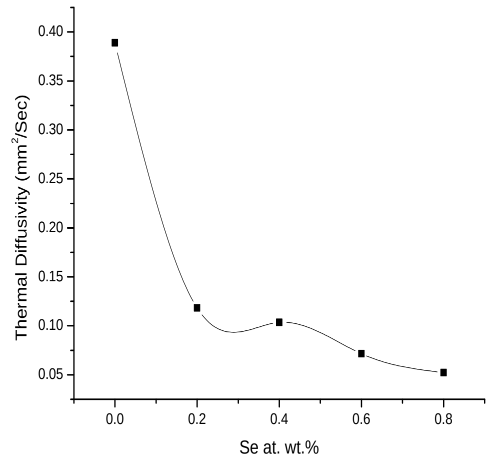


Fig 5 Thermal conductivity $In_2Se_{3x}Te_{3(1-x)}$ **Fig 6** Thermal diffusivity $In_2Se_{3x}Te_{3(1-x)}$

(X= 0, .2, .4, .6, .8)

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In order to make use of the materials in industrials applications, a better understanding of their thermal properties is desirable. Thermal properties like thermal conductivity, thermal diffusivity of these materials are influenced with temperature by the scattering of phonons with crystal defects, impurities and dislocation present in them. The knowledge of thermal properties with temperature of a material in bulk form is not only important but also useful in selecting a material for cryogenic to high temperature application.

4. Conclusion

It is concluded from the above studies that the material is of polycrystalline in nature and thermal conductivity and thermal diffusivity of indium chalcogenide decrease may be described in terms of changing of iono- covalent bonds in to covalent bonds .the thermo physical properties can show large variation at low concentration of selenium.

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