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# Influence of post deposition annealing on thermoelectric properties of $In_2Se_3$ thin films

Chanchal Jeengar [a], Monika Tomar [b,f], Kajal Jindal [c], Anjali Sharma [d,f,*], Pradip K. Jha [e]

[a] Department of Physics and Astrophysics, University of Delhi, New Delhi, 110007, India
[b] Department of Physics, Miranda House, University of Delhi, New Delhi, 110007, India
[c] Department of Physics, Kirori mal College, University of Delhi, New Delhi, 110007, India
[d] Department of Physics, ARSD College, University of Delhi, New Delhi, 110021, India
[e] Department of Physics, DDUC College, University of Delhi, New Delhi, 110078, India
[f] Institute of Eminence, University of Delhi, Delhi-110007, India

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ABSTRACT

In the present work, thermoelectric properties of thin films of $In_2Se_3$ are explored, with its low thermal conductivity and high electrical conductivity simultaneously, reported for the bulk ceramics and improved results for the doped systems for both cation and anion sites. Here, $In_2Se_3$ thin films are grown using thermal evaporation technique and the effect of post deposition annealing on the thermoelectric properties of $In_2Se_3$ thin films are studied. XRD, Raman and UV–visible spectroscopy show that the as grown film corresponds to α-$In_2Se_3$ phase which gets transformed to the γ-phase of $In_2Se_3$ upon annealing at 300 °C. The Hall measurements indicate that the films exhibit a high electron mobility and electrical conductivity. 3ω-method is employed for the thermal conductivity measurements of the as grown thin films of $In_2Se_3$ which is found to be 0.75 $Wm^{-1}K^{-1}$. Thermoelectric properties including the power factor and the ZT values are found to reach as high as 12.04 μW $m^{-1}K^{-2}$ and $4.9 \times 10^{-3}$ respectively for the films post annealed at 300 °C. Our findings pave the simple way of energy generation based on the waste heat dissipation with the device size of few nm for the next generation device applications.

## 1. Introduction

A global demand of energy is increasing every day and the sources of energy are still majorly dependent upon the fossil fuels which lead to global warming and are also decaying continuously. This makes it necessary to find out alternate energy sources or harvest the waste energy. Thermoelectric effect is one of the important phenomena in which the temperature difference can be directly converted into electrical energy. It serves an efficient method to harvest energy from the waste heat dissipated from industries, heavy automotive vehicles and the heat coming from the sun [1]. The choice of a good thermoelectric material depends on its conversion efficiency of least spatial temperature gradient. The efficiency of a thermoelectric material is defined as [2]:

$$\eta \cdot = \cdot \frac{\sqrt{1+ZT}}{\sqrt{1+ZT}+\frac{T_c}{T_h}} \times \frac{\Delta T}{T_h} \quad (1)$$

where, $T_c$ and $T_h$ are the temperature at the cold and hot ends, $\Delta T$ is the difference between the two temperatures ($T_c - T_h$). The relation between the figure of merit (ZT), electrical and thermal conductivity is as follows:

$$ZT = \frac{\sigma S^2 T}{\kappa} \quad (2)$$

where, σ and κ are the electrical conductivity and the thermal conductivity, respectively. The Seebeck coefficient (S) is defined as the change in the generated voltage with respect to the change in temperature between the two ends, where one end is kept at a fixed temperature T [1]. There are many materials like oxides (Al:ZnO, $Zn_xO_y$) [3,4], silicides ($SrSi_2$, $CrSi_2$) [5,6], stannides ($Mg_2Sn$) [7], Heusler alloys ($Fe_2VAl$) [8,9], skutterudites ($CoSb_3$) [10] etc. explored as the thermoelectric material, but they exhibit low thermoelectric performance and rapidly lose their useful properties because of oxidation [11]. The metal chalcogenides explored so far for the conventional thermoelectric applications are PbTe, $Bi_2Te_3$, $Sb_2Te_3$, SnTe, GeTe etc., where $Bi_2Te_3$ is being one of

* Corresponding author. Department of Physics, ARSD College, University of Delhi, New Delhi, 110021, India.
*E-mail address:* anjalisharma31@gmail.com (A. Sharma).

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