

Impact of electrical resistance and TEP in layered SnSe crystals under high pressure

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SnSe crystals belong to IV-VI layered binary semiconducting compound category. These layered compounds have generated a great deal of interest due to their interesting electronic properties. These electronic materials are useful because of their applications in holographic-recording systems, optoelectronics and memory switching. Earlier, several investigators have studied and reported the influence of temperature and pressure over the phase transitions in SnS and SnSe semiconductors. They also utilized Mossbauer Spectroscopy and Hydrostatic Pressure techniques to examine the bonding of the Sn atoms in SnS and SnSe. It is therefore thought worthwhile to study the effect of pressure on the thermoelectric power and the electrical resistance of SnSe crystals synthesized by a modified direct vapour transport technique. The electrical resistance has been found to be pressure dependent. The transition in electrical resistance behaviour, observed at 65 Kbar, has been explained on the basis of transition from a predominantly two-dimensional material to a more three-dimensional one. Similar to the resistance behaviour, the thermoelectric power is also found to be pressure dependent. The increase in thermoelectric power with pressure at the transition pressure of 65 Kbar has been explained. The implications are discussed.

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1 Introduction

Tin monoselenide (SnSe) belongs to IV-VI layered binary semiconducting compound category with orthorhombic structure. The structures are intermediate between three and two-dimensional nature. The material finds wide applications in opto-electronics and memory switching [1,2]. There are no reports available on the effect of pressure on the electrical resistance and thermoelectric power in these interesting semiconducting compounds.

2 Experiment

Single crystals of SnSe were grown by a direct vapour transport technique. The crystals could be characterized structurally utilizing X-ray and Electron Diffraction techniques. The compositional analysis could be made by Energy Dispersive Analysis of X-rays (EDAX) [3]. For the room temperature (303K) measurements of electrical resistance and thermoelectric power as a function of pressure upto 75 Kbar, the pressures were generated with a Bridgman type tungsten carbide opposed anvil apparatus with *in situ* pressure calibration.

3 Results and discussion

The hot probe method indicated the grown SnSe single crystals to be p-type in nature. The DC electrical resistance was found to decrease with pressure indicating a reduction in the energy gap of the material. However, two distinct regions of response, one corresponding to the low pressure range of 0-65 Kbar and the other corresponding to a high pressure range of 65-100 Kbar could be observed as shown in figure 1.

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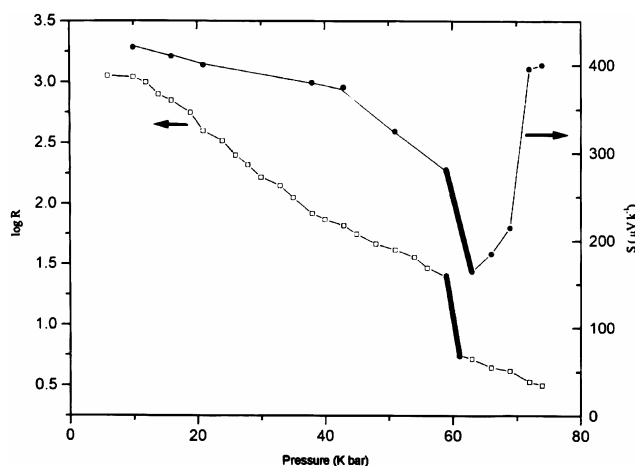


Fig. 1 Variation of electrical resistance and thermoelectric power with pressure in SnSe crystals.

This could not be attributed to any phase transition, as no such transitions could be observed upto 350 Kbar in SnSe [4]. The interlayer spacing in SnSe changes more rapidly than the intralayer spacing below 300 Kbar. Since the interlayer bonds are much weaker than the intralayer bonds, the transition from a predominantly two-dimensional material to a more three-dimensional material can be the only explanation of the observation of two ranges of response in the resistance variation with pressure. The variation of thermoelectric power with pressure also follows the same nature (Fig.1). The initial decrease of thermoelectric power can be related to the decreasing of unit cell parameters and energy gap as in a non-degenerate semiconductor. The thermoelectric power is then found to increase from 65 Kbar onwards.

Upon application of pressure, the increase in resonance scattering usually contributes to the increase in both resistance and thermoelectric power. However, in the present case the resistance is found to decrease even after the transitional pressure. Hence, the increase in thermoelectric power cannot be attributed to the presence of a continuous valence transition in this compound. The transition can be appropriately explained by the appearance of some defects in the crystal structure of SnSe at high pressure. These defects can lead to the appearance of an acceptor level in the band structure. The contribution of acceptor carriers in thermoelectric power becomes more and more significant at higher pressures and leads to an increase in the magnitude of thermoelectric power as observed in the present case. Among the various transport parameters the thermoelectric power is the most sensitive one for various scattering mechanisms. Hence, a substantial increase in Seebeck coefficient with pressure above 65 Kbar, probably arises from a resonant scattering of carriers. However, further investigations needs to be carried out and are in progress.

4 Conclusion

The electrical resistance of SnSe semiconducting single crystals has been found to be pressure dependent. The transition at 65 Kbar could be explained on the basis of a transition from a predominantly two-dimensional material to a more three-dimensional one. The transition in thermoelectric power at 65 Kbar can be explained in terms of defects, which originate in the crystal structure of SnSe in the presence of pressure and carrier scattering.

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