ELECTRICAL PROPERTIES OF RARE EARTH CHALCOGENIDES UNDER THE EFFECT OF PRESSURE

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ABSTRACT
The numerical analysis of electrical properties involved in transport mechanism such as carrier concentration, carrier mobility, carrier effective mass, electrical resistivity and electrical conductivity for some rare earth chalcogenides is discussed. The formulae are derived and used to obtain numerical values of these electrical parameters, which are useful to describe the electrical behavior (insulating, semiconducting and metallic) of rare earth chalcogenides.

Key words: Conductivity, resistivity, trivalent,carrier effective mass and mobility

INTRODUCTION
Rare earth chalcogenides crystallized in the NaCl-type structure (Landelli, 1961) and is semiconducting if the rare earth ion is in the divalent state and metallic when it is trivalent (Reid 1964). The high-pressure resistivity studies (Jayaraman 1970) on rare earth chalcogenides revealed that these undergo a pressure induced electronic phase transition. For some rare earth chalcogenides this transition is found to be continuous while discontinuous for others. This phenomenon was interpreted as due to the promotion of a *4f* electron of the rare earth ion into the *5d* conduction band states as the energy separation between the localized *4f* electronic states and the latter decreased with pressure. This electronic transition involves a change of the valency state of the rare earth ion from divalent to a higher valency state tending towards trivalency in a full *4f*- shell for the Ytterbium ions, half full for Europium ions and nearly half-full for the Samarium ions (Verma, 1976). The highly localized *f* electrons do not contribute to the electrical conductivity (McClure, 1963).

METHODS
Experimental results showed that the rare earth chalcogenides have no conduction electrons in ground state. The most likely process, which gives carriers for conductors, is thermal activation of electrons from the *4f* shell to the conduction band. Such type of mechanism give n-type conductivity (McClure1963). In case of acoustic scattering the electrical conductivity (σ) may be calculated by using the formula (Ariponnammal 1994).

$$\sigma = ne\mu = \frac{1}{\rho} \text{----------[1]}$$

where n is the carrier concentration, e is the electronic charge, μ is the mobility and ρ is the electrical resistivity. The values of n and μ for SmX and YbX (where X =S, Se and Te) at different pressures are given in Table 1. Using these values of n and μ we have calculated electrical resistivity (ρ) and electrical conductivity (σ) for SmX and YbX at different pressures. These calculated values of ρ and σ for SmX and YbX at different pressures are

reported in Table 1. It is found that electrical resistivity decreases with increasing pressure and hence the conductivity increases with increasing pressure which shows valency transition from divalent semiconducting state to higher valency state tending towards trivalent metallic state.

RESULTS AND DISCUSSION

The electrical resistivity and conductivity of rare earth chalcogenides were calculated from the simple theoretical model. Figures 1-6 illustrate the relationships the electrical resistivity and conductivity with pressure. Fig. 2, 3 and 6; which corresponds to the compounds SmSe, SmTe and YbTe shows that the theoretical and experimental values of conductivity are exactly the same. In Fig. 1, 4 and 5 corresponding to SmS, YbS and YbSe, the theoretical and experimental values of conductivity are nearly close to each other. The results also give the evidence of pressure dependence of semiconducting to metal transition of these compounds. The transition is probably due to the decrease in band gap at high pressure resulting the promotion of electron from the *4f* level into the conduction band. These results indicate that the simple theoretical model presented in the paper can be used as a tool for determining the conductivities of rare earth chalcogenide compounds.

CONCLUSION

We have presented an analysis of electrical properties and electronic phase transition of rare earth chalcogenides under the effect of pressure. We have calculated and reported electrical resistivity and conductivity for SmX and YbX. It is found that electrical resistivity decreases with increase in pressure and a corresponding increase in conductivity with pressure. This shows a valency transition from divalent semiconducting state to higher valency state tending towards trivalent metallic state.

REFERENCES

1. Ariponnammal, S., Natarajan, Parmana, S., 1994. Transport phenomena of Sm Se_{i-x} As_x Journal of Physics, 42(5), 421.

2. Davide, A., CRC, D., 1972. Amorphous Semiconductors (South Africa, Batter Worth), 2

3. Didchenko, R., Gortsema, F. P., 1963. J. Phys. Chem. Sol. 24, 863

4. Jayaraman, A., Narayanamurti, V., Bucher, E., Maines, R.G., 1970. Pressure induced metal-semiconductor transition and 4f electron delocalization in Sm Te. Phys. Rev. Letters, 25, 368.

5. Jayaraman, A., Bucher, E., Mcwhan, D. B., 1970. Pressure induced electronic collapse and structured changes in rare earth monochalcogenides. In Proceedings of the eighth Rare Earth Research Conference (U.S. G.P.O. Washington D.C)

6. Jayaraman, A., Narayanamurti, V., Bucher, E., Maines, R.G., 1970. Continuous and discontinuous semiconductor metal transition in samarium monochalgogenides under pressure. Phys, Rev. Letter, 25, 1430.

7. Landelli, A., 1961. Reactions of dichlorobis (cyclopentadienyl) titanium (IV) with multidentate Schiff bases. In Rare Earth Research, Edited by E. V. Klever (Mc Millan, New York), 135.

8. Lovett, D.R., 1977. Semimetals and Narrow Band Gap Semiconductors (Great Britain, Pior Ltd.) 72.

9. McClure, J.W., 1963. Experimental multivalent ionic radii. J. Phys. Chem. Soilds, 24, 871.

10. Neuensehwander, J., Wachter, P., 1990. A high pressure low temperature study on rare earth compounds: Semi conductor to metal transition. Physica, B-160, 231.

11. Reid, F.J., Matson, L.K., Miller, J. F., Himes, R.C., 1964. high pressure band structures and structured stability of EuS. J. Phys. Chem. Solids, 25, 969 .

12. Verma, C.M., 1976. Mixed valence compounds. Rev. Modern Phys. 48, 219.

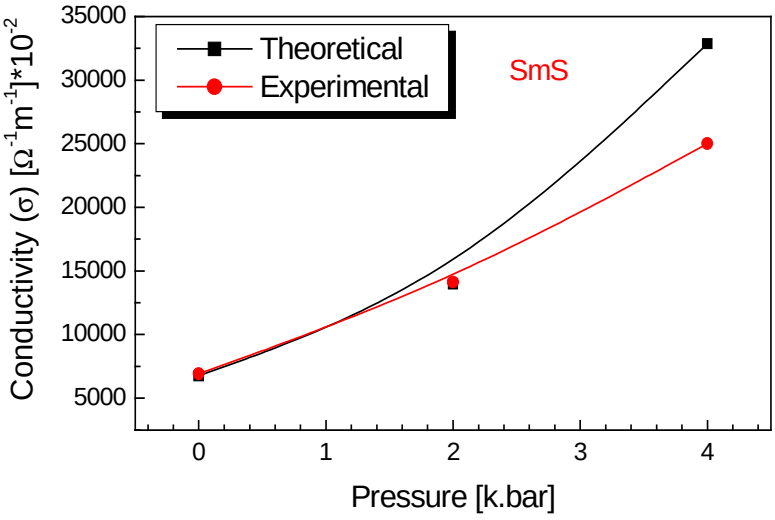

Fig. 1. The pressure dependence of conductivity of SmS

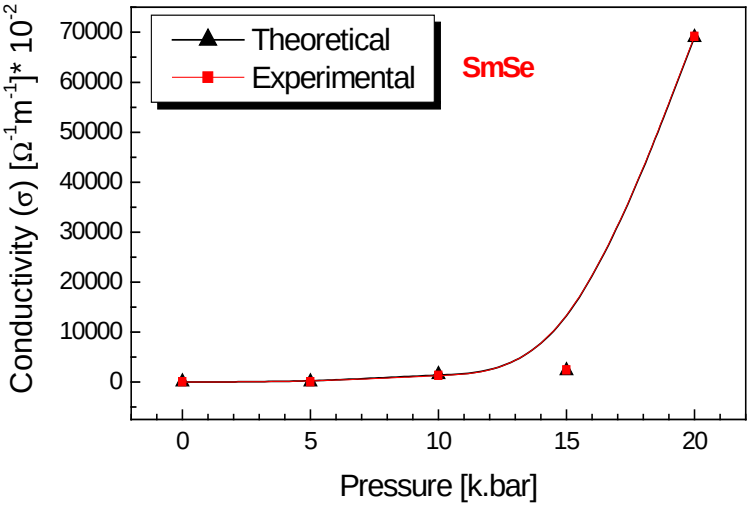

Fig. 2. The pressure dependence of conductivity of SmSe

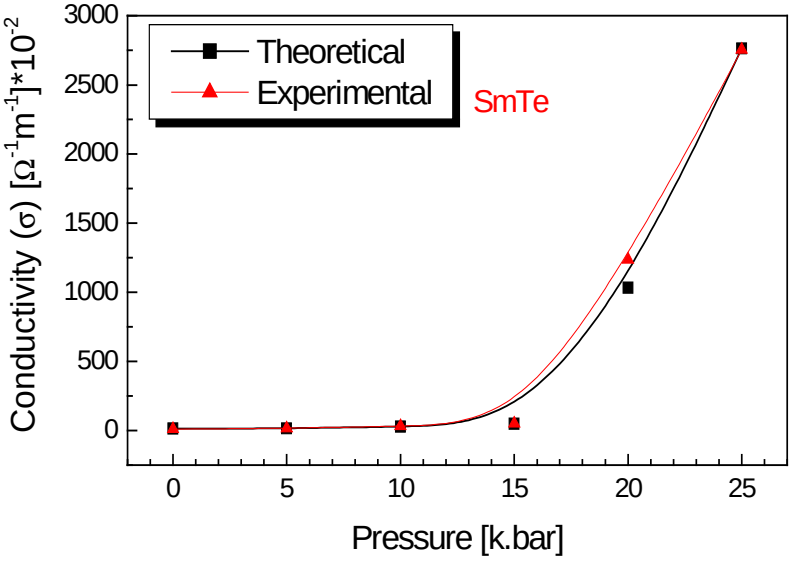

Fig. 3. The pressure dependence of conductivity of SmTe

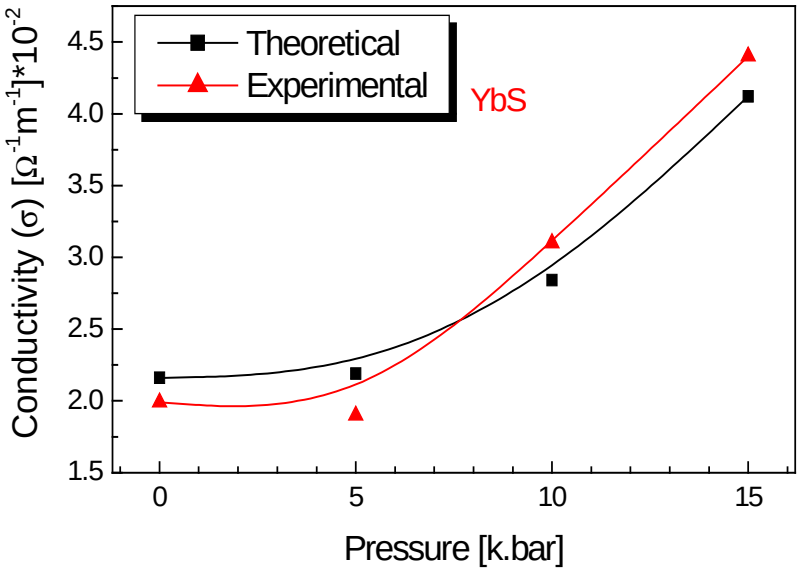

Fig. 4. The pressure dependence of conductivity of YbS

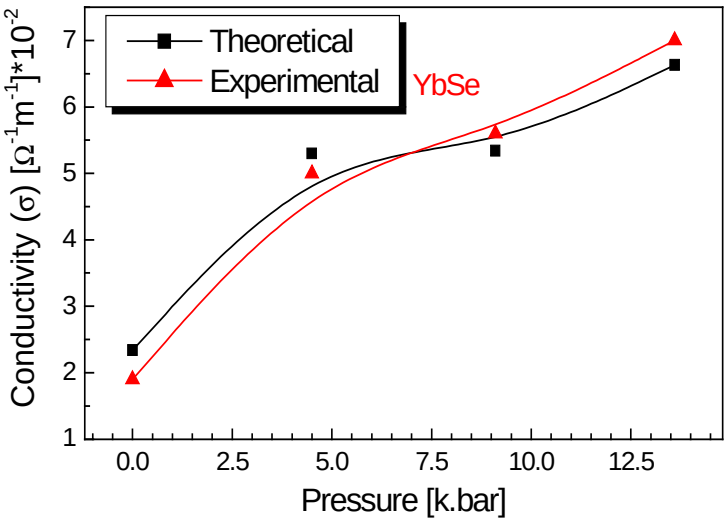

Fig. 5. The pressure dependence of conductivity of YbSe

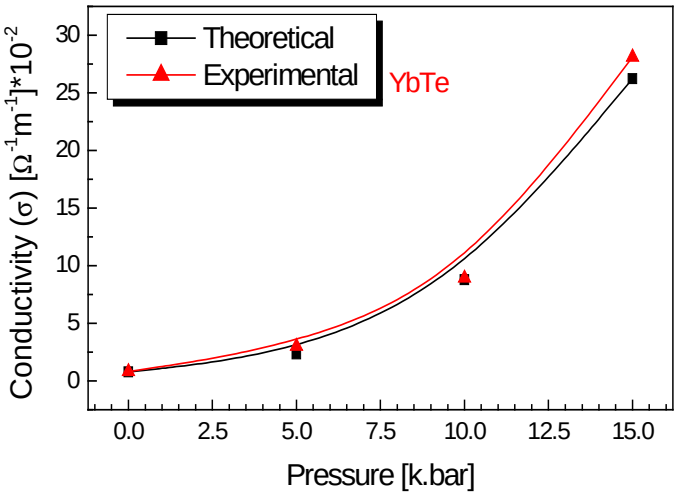

Fig. 6. The pressure dependence of conductivity of YbTe

Table 1. Values of carrier concentration and mobilities for some rare earth chalcogenide compounds ate different pressures.

S.N.	Compound	Pressure (k.bar)	Carrier concentration (n) (m^{-3})	Mobility (μ) ($m^2V^{-1}sec^{-1}$)
1	SmS	0 2 4	3.276×10^{23} 3.277×10^{23} 3.251×10^{23}	1.293×10^{-3} 2.667×10^{-3} 6.315×10^{-3}
2	SmSe	0 5 10 15 20	1.805×10^{21} 6.598×10^{21} 2.000×10^{22} 7.127×10^{22} 2.100×10^{23}	2.402×10^{-4} 1.187×10^{-4} 4.660×10^{-3} 2.000×10^{-3} 2.053×10^{-2}
3	SmTe	0 5 10 15 20 25	8.097×10^{21} 9.580×10^{21} 1.253×10^{22} 1.552×10^{22} 2.918×10^{23} 4.036×10^{23}	1.018×10^{-4} 9.140×10^{-5} 1.392×10^{-4} 1.966×10^{-4} 2.210×10^{-4} 4.281×10^{-4}
4	YbS	0 5 10 15	2.100×10^{21} 2.361×10^{21} 2.878×10^{21} 2.938×10^{21}	6.436×10^{-5} 5.814×10^{-5} 6.171×10^{-5} 8.785×10^{-5}
5	YbSe	0 4.5 9.1 13.6	2.321×10^{21} 2.749×10^{21} 3.949×10^{21} 4.724×10^{21}	6.320×10^{-5} 1.207×10^{-4} 8.459×10^{-5} 8.774×10^{-5}
6	YbTe	0 5 10 15	8.336×10^{20} 2.284×10^{21} 6.113×10^{21} 1.468×10^{22}	5.775×10^{-5} 6.396×10^{-5} 8.971×10^{-5} 1.117×10^{-4}