Asian J. Exp. Sci., Vol. 35, No. 2, 2021; 33-35

Online available on : www.ajesjournal.com, ISSSN : 0971-5444

The Theoretical Study of Electrical Conductivity of Polystyrene Polymer Films under High Pressure

Rajendra Kumar Dixit*, Sandhya Patel
Department of Physics
Dr Harisingh Gour Central University Sagar M.P. India
*rajendradixitsagar@gmail.com, sandhyaparipalak@gmail.com

Received: June 2, 2021; Revised: June 21, 2021; Accepted: June 25, 2021

Abstract: The electrical resistivity and conductivity of polymer materials have been studied experimentally under high pressure by different research groups. In this paper, a formula

Log $\sigma = C + \alpha \log_e (P_c/P) - \beta (P/P_c)$ has proposed for the theoretical study of the pressure effects on the electrical conductivity of thin films of polystyrene films. The constant α is related to intermolecular spacing and β depends on the free path of the electrons. The experimental data have been interpreted with pressure at constant temperature for the polarising field E_P = 5, 8, 10 and 12 KV/cm. Under high pressure, it has been found that electrical conductivity shows exponential growth with the increasing polarising field.

Key Words: - Electro-active polymer, resistivity, High pressure, polystyrene polymer

Introduction

Polymer materials are more popular nowadays due to its wide applicability, environmental friendly, flexibility, low cost etc. Conducting polymers such as polypyrrole, polyvinyl, and polythiophens are well known for their high electrical conductivity (Guanije *et al*., 2021; Shujahadeen *et al.,* 2018) and good environmental stability, on one hand and poor mechanical properties and process ability on the other hand. In recent years numbers of experimental studies have been carried out to the study the variation of electrical properties with temperature and pressure (Yaseen *et al*., 2021; Wang *et al.,* 2019; Yang *et al.,* 2021; Saees *et al.,* 2021). It has found that the structural and electro-optical properties vary with high pressure (Huang et *al.,* 2013; Patel *et.al*, 2008).

In the present paper, the theoretical study has done for electrical conductivity of polystyrene thin films with pressure variation at constant temperature. A formula for the study of the relation between pressure and electrical conductivity of polystyrene thin films has suggested with counting volume effect. The effects of pressure on electrical properties for organic and inorganic materials have been also studied earlier (Kesharwani, 2002; Dixit *et al.,* 2003; Sangwar *et al. and* Adgaonkar 1996).

Theory

The application of the theory to explain the pressure induced electrical properties of polystyrene. After applying an external pressure P on some material, the molecular separation decrease. The electronics shells of the neighbour molecules overlap due to pressure, in this condition a force of repulsion becomes important. At very high pressures, the pathways of the electrons (Patel *et al.,* 2008) come too close to each other due to which mean free time between charge carrier collisions decreases with increase in P.

The results can be easily applicable for studying the variation of electrical conductivity with pressure. The electrical conductivity σ at a pressure is, thus, given by

$$\text{Log}\,\sigma = C + \alpha \log_e (P_c/P) - \beta (P/P_c) \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where C, α and β are constants and P_c is the pressure at which the conductivity is maximum. The constant α is related to intermolecular spacing and β depends on the free path of the electrons.

Results

The experimental measurements on variation of dc electrical conductivity of polystyrene thin films with pressure have been carried out by Sangwar and Adgaonkar (1996). They prepared the desired sample at polarising temperature T_P (=333K) and applied the polarising electric field E_P (= 5,8,10 and 12 KV/cm) between the electrodes. The sample was, the, cooled to room temperature and the field was removed.

In the present paper, we have analysed the experimental results with the help of equation (1). For the polarising field E_P = 5, 8, 10 and 12 KV/cm, we compare our calculated results with the experimental data in fig-1 and table-1.

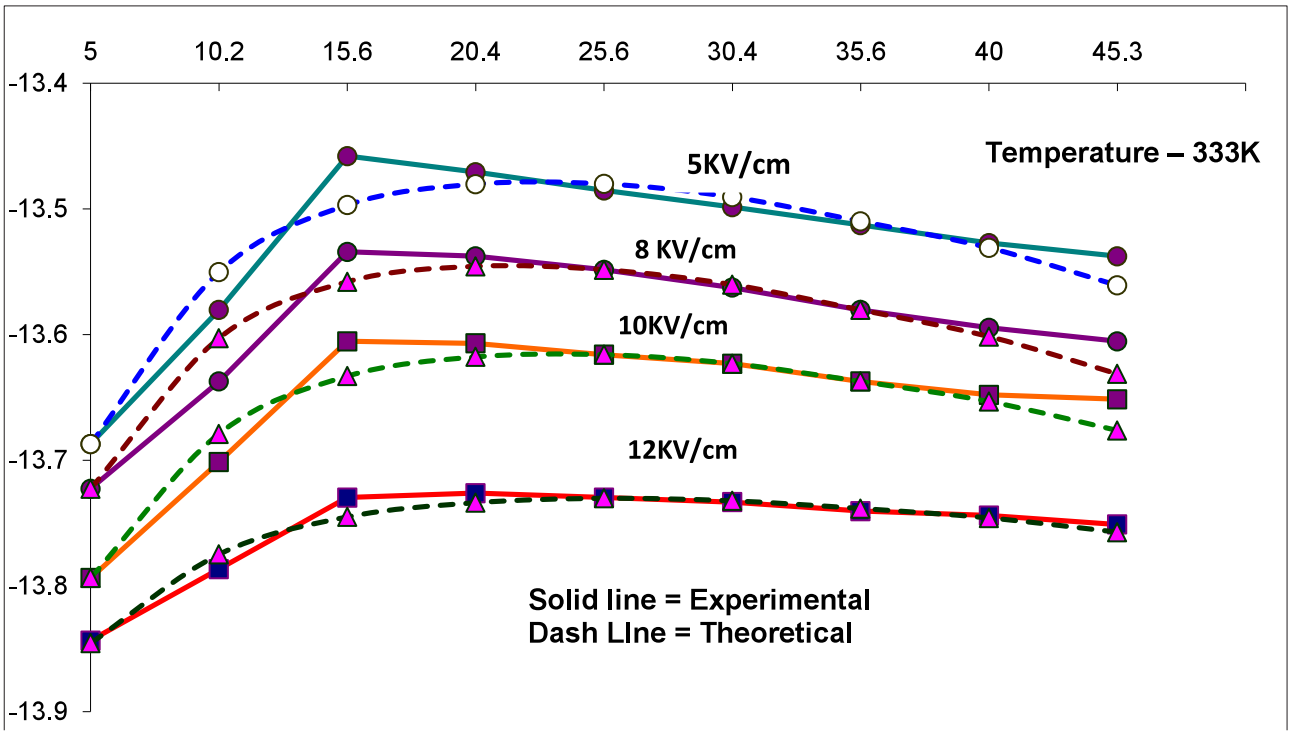

Fig (1):- Conductivity log σ (ohm-cm^{-1}) VS Pressure P (in KPa)

Table 1: The values of α and β for different polarising field

E_P	α	β	α/β
5KV/cm	-0.24	0.17	-1.41
8KV/cm	-0.37	0.27	-1.37
10KV/cm	-0.40	0.30	-1.33
12KV/cm	-0.42	0.30	-1.40

The calculated values of the constants used in the analysis are summarised in table-1. We find that our results are in close agreement with the experiments. The values of conductivity have found maximum for theoretically and experimentally at the critical pressure P_c =15.6 KPa for the polarising field E_P = 5, 8, 10 and 12 KV/cm (Fig.-1). The experimental and theoretical results have good agreement in the high pressure range 20 KPa to 45 KPa. In the low pressure range 5 KPa to critical pressure P_c =15.6 KPa, the theoretical values are showing a little disagreement with the experimental values.

Discussion

The calculations reveal that the values of magnitude of α (= |α|) and β Increases as the polarising field is increased. The value α/β remains constant (= -1.4) for each value of E_P (Table 1), the value of β is close to 0.3. A similar result was obtained in reference (Kesharwani, 2002) for the studies on variation of electrical properties with pressure on thin films of polyprrole blended with PVC where β was found to be 1/3, the value of β suggested that electrical Conductivity is varies exponential with high pressure.

Acknowledgement

The authors are thankful to Dr. K. M. Kesharwani (retired) and Prof. Ranveer Kumar Head of Department of Physics, Dr. Harisingh Gour Central University Sagar M.P. India for co-operation during the present investigations.

References

Dixit R.K. and Kesharwani K.M. (2003). A study on effects of polarising fields on electrical conductivity of polystyrene thin films" Proceeding of Indian Science Congress Bangalore, Jan. 3-7, 185.

Gong L. Gaungbo Chen *et. al* (2021). Phase transition enabled $MnFe_2O_4$ nanoparticles modulated by high pressure with enhanced electrical transport properties. *Applied Surface Science.*, (In press). 150532.

Guanije He. Yiyanj Liu. Daisy E. Gray. E. and James Othon (2021). Conductive polymer composites cathodes for rechargeable aqueous ZN-ion batteries: A mini review" *Journal of Composites Communication,* (In press), 100882.

Huang D. Xie D. Gao J. Wangchun Lv and Hong S. (2013). Pressure dependence of electrical resistivity in polymer polyaniline. *Advances in Materials Science and Engineering* 5, 124365.

Kesharwani K. M. (2002). Effect of pressure on electrical resistivity of polypyrrole/PVC blended film" Proceedings of Indian Science Congress (Lucknow), Part iv, no.1 .

Patel A. S. and Kesharwani K.M. (2008). A theoretical study of band gap and electrical resistivity of FeS_2 (Pyrite) at high pressur. High Pressure Research 28, 69-73.

Prunet G. Pawuala F. Fleury G. Clouter E. Robinson A. Haziiannou G. And Pakdel A. (2021). Conductive polymers and their hybrids for flexible and wearable thermoelectric application- A mini review" *Materials Today Physics*. (In Press) 100402.

Saees M. Azmal M. Shah Murad *et. al*. (2021). Pressure induced structural electrical, optical and thermal properties of $CsYbBr_3$ a theoretical investigation. *Journal of materials research and Technology*. 10, 687-696.

Sangwar W. and Adgaonkar C.S. (1996). Effects of pressure on dc electrical conductivity of polystyrene thin film thermo-electrets. *Indian Journal of Pure and Applied Physics.* 34, 101-105.

Shujahadeen B. Aziz, Thompson J. Woo, M.F. Z Kadir, Hameed M. Ahmeed (2018). A Conceptual review on polymer electrolytes and ion transport models. *Journal of Science*: *Advanced materials and devices* 3:1-17.

Wang Y. Tao Wu, Liang Xu. Y Zhou, Z He, X Li X Cao, Chaunmin Meng, Wenjun Zhu, Lixin Lia (2019). Pressure induced semiconductor metal transitionin polycrystalline β-$Ag_{0.33}V_2O_5$. *Materials Letters* 236, 271-275.

Yang L.I., Li-ping Ding, Peng Saho, YumHao Tiandong *et al*. (2021). Influence of pressure on phase transition, electronic and thermoelectric properties of SnSe. *Journal of Alloys and Compounds* 853, 157362.

Yaseen M. Amber H. Mahmood R. Iqbal M. Iqbal J. *et al*. (2021). Investigation of optical and thermoelectric properties of $PbTiO_3$ under pressur. *Physica B: Condensed matter.* 615, 412857.