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DC Conduction Studies in Folic Acid

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Abstract : The study of dc conduction in biopolymers in solid form is of great importance not only because the charge transfer characteristics are of fundamental interest but also for the information such study can provide on the nature of electrical contacts. The dc conductivity measurements have been carried on a vitamin, Folic acid, in the solid pellet form provided with silver coated electrodes. The results are presented in the form of Current-Voltage characteristics for the temperature range 300 K – 360 K. The analysis of results has been done by plotting temperature dependence of current density, Poole-Frenkel Plots, Schottky Plots, Richardson Plots and Arrehinious plots. The analysis shows that the Schottky- Richardson mechanism is responsible for the observed dc conduction in Folic acid. The presence of Schottky barriers at metal electrode-insulator suggests that using the silver electrodes satisfactory contacts can be achieved for further electrical investigations on the biomaterial.

1. Introduction

The electrical properties of biopolymers have been found to play key roles for biological action of biopolymers in many biological phenomena[1,2] and in last few years much attention has been focused to the study of electrical properties of biopolymers. The study of electrical conduction is of considerable significance from two major points of view : firstly for its own sake, since charge transfer characteristics are of fundamental interest; and secondly for the information such study can provide on the nature of electrical contacts which may have great influence on the measured electrical properties[3,4].

A systematic study of electric properties of various biopolymers is being undertaken in our laboratories[5,6] and in the present paper results of dc conductivity measurements on solid pellets of Folic acid, a vitamin, are being reported.

2. Experimental

The sample used in present investigation was procured from Central Drug House (CDH), India, in powder form. The dc conductivity measurements have been carried out on Folic acid in the compressed pellet form (diameter-1 cm, thickness-0.3 mm) coated

Key-Words. dc conduction, I-V Characteristics, Schottky-Richardson mechanism, Poole-Frenkel mechanism.

with silver electrodes. The Aplab Medium Voltage dc Power Supply (model no. 7332; range-up to 600 V) was used to apply desired dc electric field and the steady state current was measured using Keithley's Electrometer (model no. 610 C). Measurements have been made at thermostatically controlled temperatures in the range 300 K – 370 K. A dc field in the range 1-6 kV/cm was applied and corresponding value of steady state current was recorded at each fixed temperature.

3. Results and Discussion

The Current-Voltage Characteristics are shown in Fig. 1 in the form of log-log plots. As is evident from the figure the current does not follow a power law, $J = KE^m$, where K and m are constants (for ohmic conduction $m = 1$ and for space charge limited currents $m = 2$ is observed). Thus the observed behaviour of Current-Voltage characteristics rules out the possibility of ohmic as well as space charge limited conduction[7, 8].

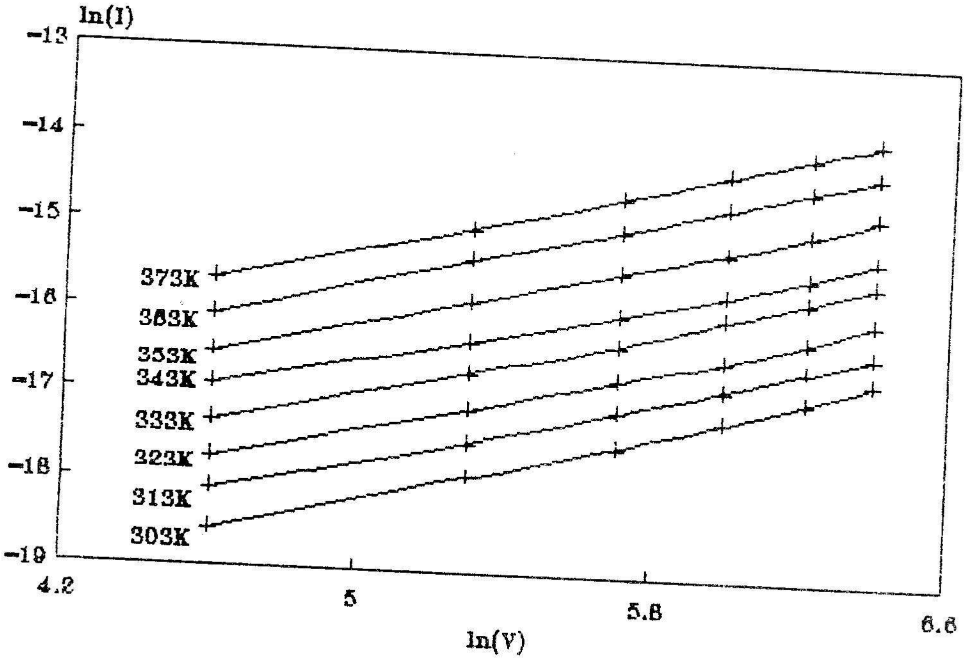

Fig. 1 : Current-Voltage Characteristics

The temperature dependence of current density as presented in the form of ln(J) vs temperature plots, Fig. 2, shows that ln(J) increases linearly with temperature. The strong temperature dependence suggests that thermally activated process may be operative in the present case[8, 9]. Further, the straight lines with a single slope are observed for all the fields indicating the absence of any thermodynamic transition in the temperature range studied[9].

The other likely processes which may be operative in the present case are the field enhanced emission of charge carriers from localised coloumbic trape i.e. Poole-Frenkel mechanism, or the thermionic emission of charge carriers over the metal-insulator interface barrier, i.e. Schottky-Richardson mechanism[8-12].

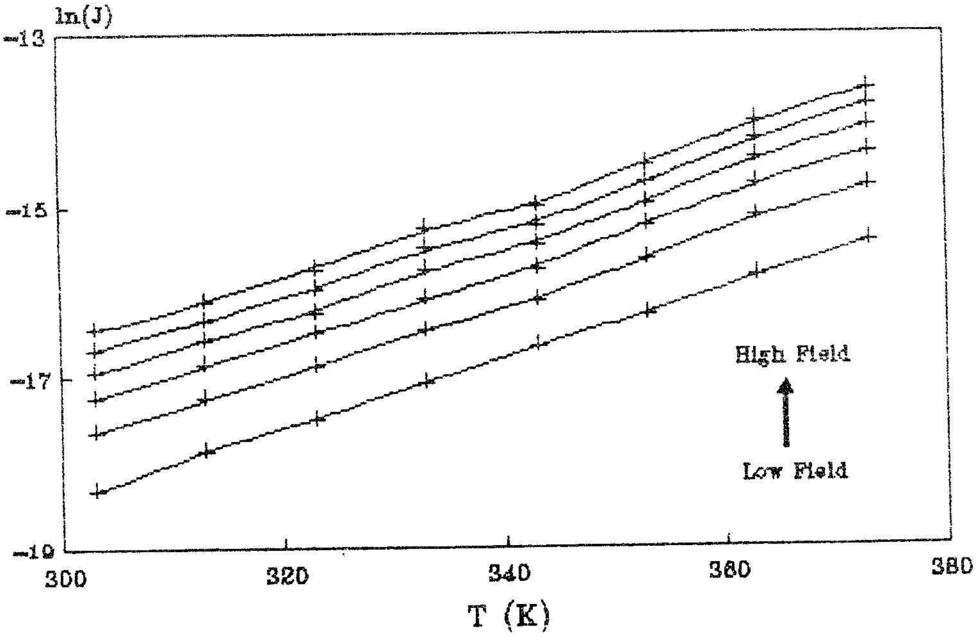

Fig. 2 : Current density vs Temp. Plots

In case of the measurements on compressed pellets which may contain traps, the thermal excitation of trapped electrons into the conduction band of insulator via field assisted lowering of trap depth, the Poole-Frenkel effect[11], may profoundly affect the conduction process. The Poole-Frenkel mechanism predicts a field dependence for the conductivity expressed as $\sigma = \sigma_0 \exp(\beta_{PF} E^{1/2}/2kT)$ and the Poole-Frenkel mechanism is characteristed by the linearity of $\ln(\sigma)$ *vs* $E^{1/2}$ plots i.e. Poole-Frenkel plots.

In the case of Folic acid the contribution of this mechanism is not appreciable as is evident from the Poole-Frenkel plots (Fig. 3); $\ln(\sigma)$ does not show a linear increase with $E^{1/2}$, as predicted by the expression for conductivity.

In the case of Schottky-Richardson mechanism[11, 12] thermal activation of electrons over metal insulator interface barrier takes place with the added effect that the applied electric field reduces the height of the barrier. The current voltage relationship for this Schottky-Richardson mechanism is expressed as

$$J = A\,T^2 \exp\left\{\left(-\phi_S + \beta_{SR} E^{1/2}\right)/K\,T\right\}$$

where A is a constant, T is absolute temperature, ϕ_S is the metal-insulator potential barrier,

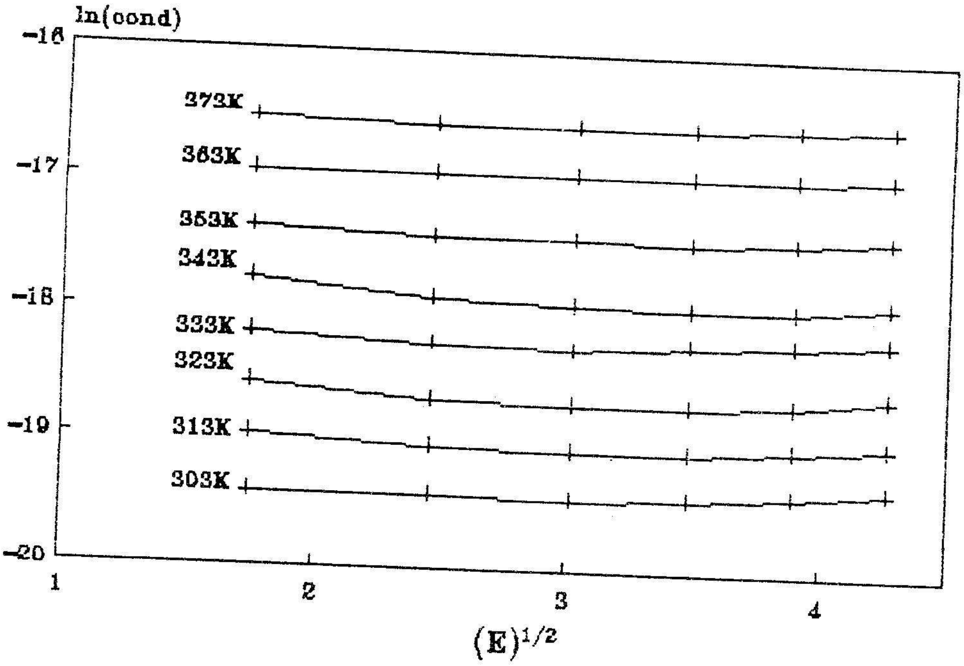

Fig. 3 : Poole-Frenkel Plots

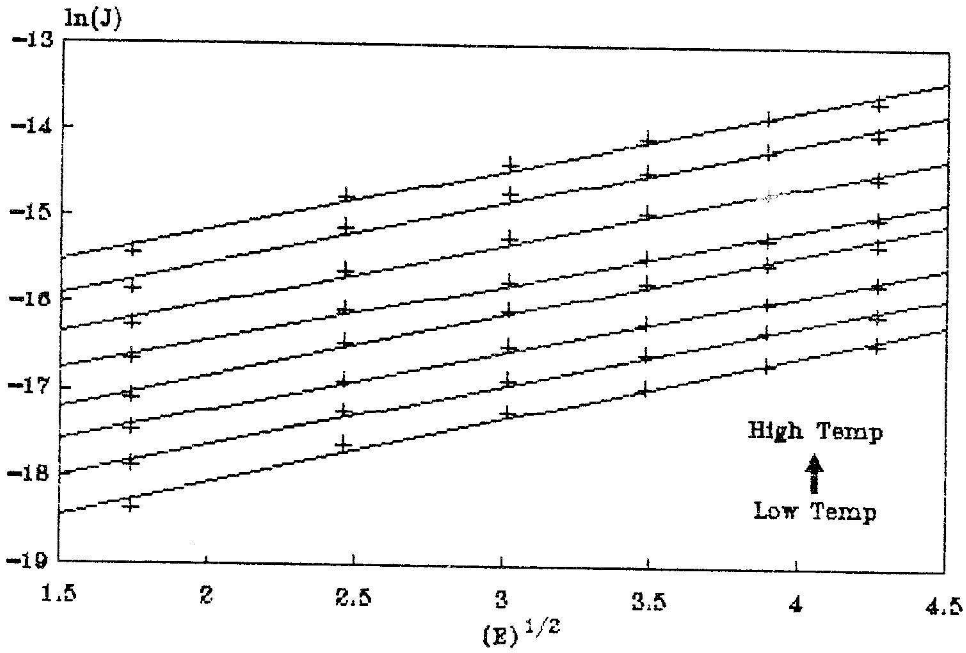

Fig. 4 : Schottky Plots

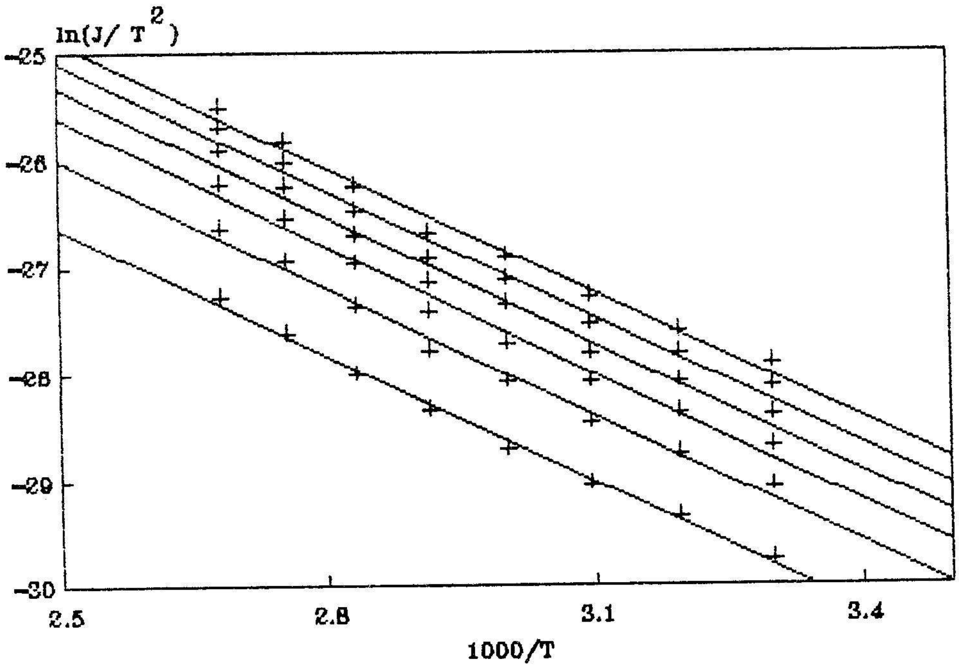

Fig. 5 : Richardson Plots

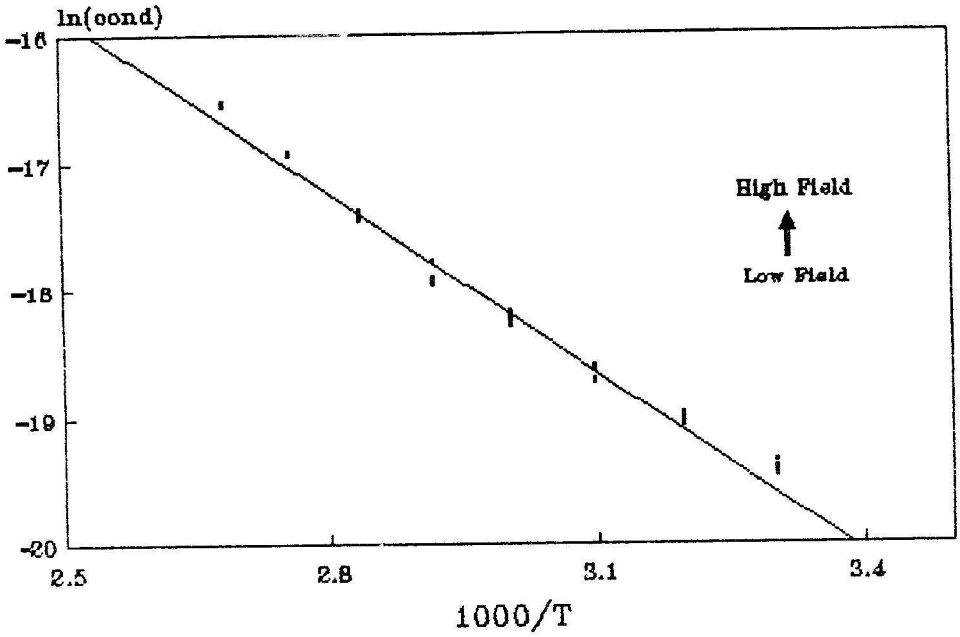

Fig. 6 : Arrehenius Plots

k is Boltzmann constant, E is applied electric field, and β_{SR} is the Schottky field lowering constant which is given by

$$\beta_{SR} = \left(e^3/4\pi\ \varepsilon\ \varepsilon_0\ d\right)^{1/2}$$

where e is electronic charge, ε is dielectric constant, ε_0 is permittivity of free space and d is thickness of the sample. It is clear that ln(J) is a linear function of square root of the field strength; results plotted with the axes marked in this way are referred to as Schottky plots and linear positive slopes on Schottky plots generally characterise Schottky-Richardson mechanism[11].

Schottky plots for the case of Folic acid are shown in Fig. 4. It is evident from the figure that ln(J) is a linear function of square root of the field strength; linear positive slopes on Schottky plots are observed indicating the applicability of Schottky-Richardson mechanism.

Another characteristic feature of the Schottky-Richardson mechanism is linearity of Richardson plots, i.e. the $\ln(J/T^2)\ vs\ (1/KT)$ plots. The observed Richardson plots (Fig. 5), are straight lines in agreement with the Schottky-Richardson mechanism. The effective metal insulator potential barrier has also been computed and is found to be in the neighbourhood of 0.35 eV (Table 1) for all the field strengths.

The activation energy for the conduction process is calculated from Arrehinious plots (Fig. 6) i.e. ln(σ) vs inverse absolute temperature plots and is found to be in the neighbourhood of 0.4 eV (Table 1). The activation energy values are of the same order as the experimentally determined metal- insulator effective potential barrier; this supports the aplicability of the Schottky-Richardson mechanism for conduction in Folic acid. The fairly low value of activation energy rules out the possibility of charge carriers being ionic in nature[11].

Table 1 : Comparison of experimentally calculated potential barrier and corresponding activation energy

Applied Field (kV/cm)	Effective Barrier (eV)	Activation Energy (eV)
3	0.34	0.42
6	0.35	0.42
10	0.35	0.41
13	0.36	0.41
16	0.35	0.41
19	0.35	0.42

The results of the present investigation indicate that silver electrodes provide satisfactory electrical contacts for study of electrical properties of the biopolymer. The formation of Schottky barriers[12] at the metal-insulator interface rules out the possibility of free injection of charge carriers in the low temperature range (80-300 K) where the measurements are generally made with the biopolymers[1] and therefore, inherent electrical characteristics of the biopolymer can be studied.

4. Conclusion

The results of the dc conductivity measurements on Folic acid as analysed in terms of different possible mechanisms suggest that the Schottky-Richardson mechanism is primarily responsible for the observed conduction in the temperature range studied. Further, the presence of Schottky barriers at metal electrode-insulator interface suggests that using the silver electrodes satisfactory non-injecting contacts can be achieved for further electrical investigations on the biomaterial.

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References

1. S. Mascarenhas : *Electrets*, Springer-Verlag, Berlin, 1987, Chapter 6.
2. M. A. Fox and J. K. Whitesell : *Organic Chemistry*, Jones and Bertlett, London, 1994, Chapter 20.
3. S. K. Shrivastava, J. D. Ranade and A. P. Srivastava : Polymer, **22** (1985) 1645.
4. R. Nath and D. R. Bhawalkar : *Czeh J. Phys.*, **B25** (1975) 210.
5. Vinay Mishra and R. Nath : *Indian J. Pure and Appl. Phys.*, **34** (1996) 197.
6. Vinay Mishra and R. Nath : *Indian J. Pure and Appl. Phys.*, **35** (1997).
7. P. S. Nikam and H. S. Aher : *Indian J. Pure and Appl. Phys.*, **34** (1996) 393.
8. J. K. Quamara and B. K. Kaushik : *Indian J. Pure and Appl. Phys.* **34** (1996) 553.
9. J. M. Keller, K. D. Vyas, R. K. Dubey and S. C. Datt : *Polymer International*, **38** (1995) 53
10. P. Khare and A. P. Srivastava : *Indian J. Pure and Appl. Phys.*, **29** (1991) 410.
11. M. A. Lampart and P. Mark : *Current Injection in Solids*, Academic Press, London, 1970.
12. G. M. Sessler, Hans B. and D. Y. Yoon : *J. Appl. Phys.*, **60** (1986) 318.