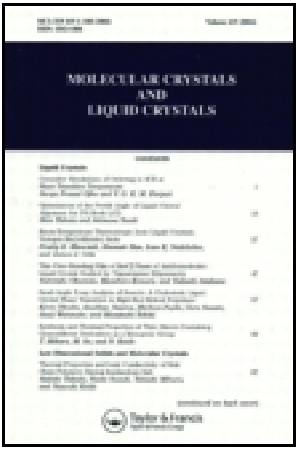

Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl16

Electrical Conductivity of Poly(P-Phenylene)

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Version of record first published: 13 Dec 2006.

Mol. Cryst. Liq. Cryst., 1986, Vol. 137, pp. 131-139
0026-8941/86/1374-0131$15.00/0

ELECTRICAL CONDUCTIVITY OF POLY(P-PHENYLENE)

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Abstract Electrical conductivity measurements have been made on undoped poly(p-phenylene). The current-voltage and current-temperature characteristics showed that the examined material is a semiconducting one with well defined activation energies. The obtained data suggest that conductivity can be approximated by interchain hopping.

INTRODUCTION

It was shown by Ivory et al[1] in 1979 that poly (p-phenylene) (PPP) could be doped to conductivity levels similar to those in polyacetylene by forming highly conducting charge transfer complexes with both n-and p-type dopants. This discovery paved the way for polyaromatic-based conducting polymer systems as a new class of conducting materials-for example poly(p-phenylene sulfide), PPS[2,3], poly(m-phenylene sulfide), PMPS[4], polypyrrole[5], polythiophene[6] - with a nearly degenerate ground state.

In this paper we want to present our results on the d.c. conductivity of undoped (p-phenylene),PPP.

EXPERIMENTAL

Poly(p-phenylene) was obtained from Dr. A. Pron's laboratory. It is known that the shift in the absorption peak is characteristic of increased chain length. By this method we estimated the average chain length of the polymer chain ($\bar{n}$), e.g., the number of the phenyl rings in the polymer molecule.

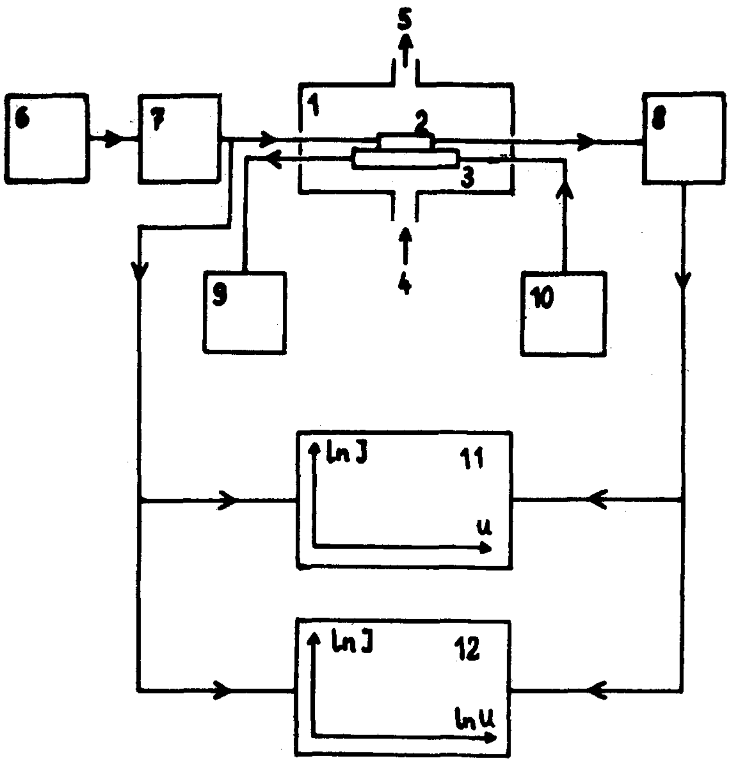

FIGURE 1 Experimental set-up for electrical measurements
1-cryostat, 2-sample, 3-holder, 4-liquid nitrogen, 5-vacuum valve, 6-power supply, 7-linear rising voltage unit, 8-electrometer, 9-temperature - voltage transmitter, 10-temperature regulator, 11-log J - U register, 12-log J - log U - register.

The result for $\bar{n} = 12$ was obtained. PPP powder was compressed at pressure of 10^8 Pa make pellets 10 mm in diameter and 1.5 mm thick. The top and bottom metalic electrodes were deposited by vacuum evaporation of gold.

The experimental set-up for electrical measurements is shown in Fig. 1. The equipment used permitted us to use voltages from 1 mV to 100 V and to measure currents from 10^{-14} to 10^{-4} Amps. Measurements were carried out in a vacuum of the order of 10^{-6} Torr and at temperatures from 173 K to 345 K.

RESULTS AND DISCUSSION

The typical current - voltage characteristics are presented in Fig. 2 and 3.

As we can see from these plots the logarithm of the current against the logarithm of the voltage is almost linear at temperatures above 273 K (Fig. 2) and nonlinear at lower temperatures (Fig. 3).

The temperature depedence of the current of the undoped poly(p-phenylene) could be fitted by an Arrhenius expression as can be seen in (Fig. 4).

We can see from this figure that the examined material is a semiconducting one with a well defined an activation energy of 0.2 eV at temperatures above about 240 K. In the low temperature region (below 240 K) the data are well represented by an activation energy of 0.05 eV, much lower than at the higher temperature region.

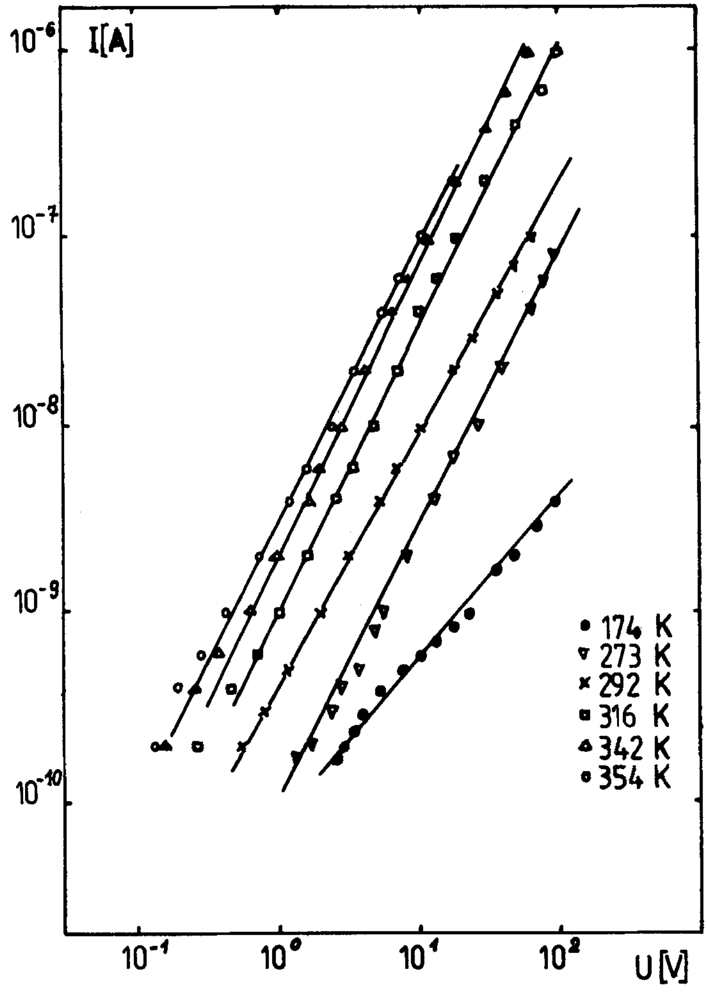

FIGURE 2 Current-voltage characteristics for different temperatures.

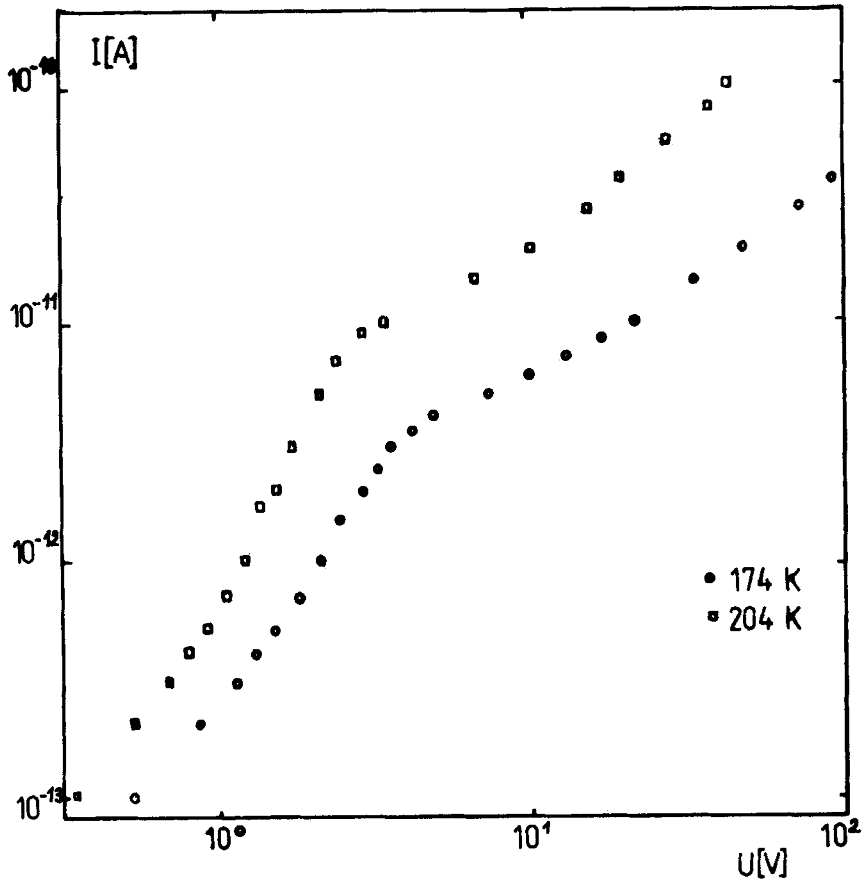

FIGURE 3 Current-voltage characteristics for different temperatures.

It is reasonable to assume that the measured conductivity of undoped and lightly doped polymers is the sum of two components

$$\sigma = \sigma_1 + \sigma_2$$

σ_1 refers to charge motion along a polymer chain and σ_2 refers to charge carrier transport between chains. Due to the short chain length of presently available PPP, the electrical conductivity of undoped and lightly doped polymers will be mainly due to inter-chain hopping. Such a model was proposed by Alexander et al.[7] to explain the electrical conductivity of polyacetylene.

This process can be approximated by variable range hopping by the following equation

$$J = AT^{-\frac{1}{2}} \exp\left(\frac{T_o}{T}\right)^{\frac{1}{4}}$$

The power $\frac{1}{4}$ is characteristic for three-dimensional variable range hopping and fits pretty well the low-temperature conductivity data (Fig. 5) obtained from examined PPP samples although it was originally developed for amorphous semiconductors[8].

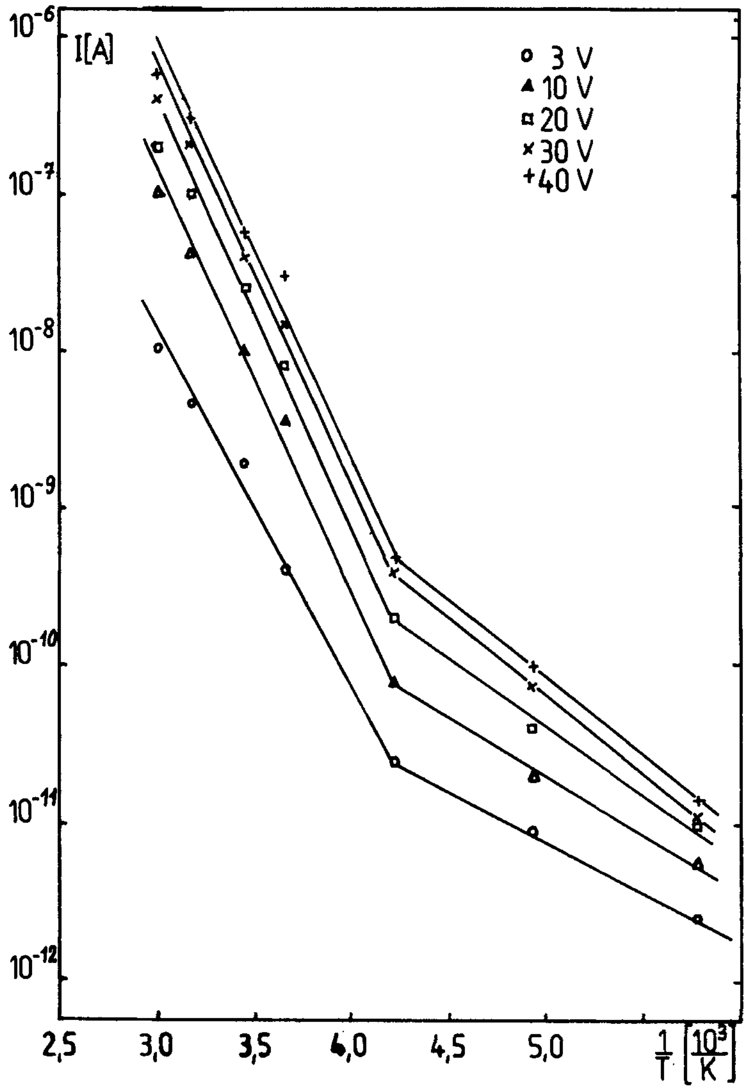

FIGURE 4 The log. J vs T^{-1} depedences for different voltages.

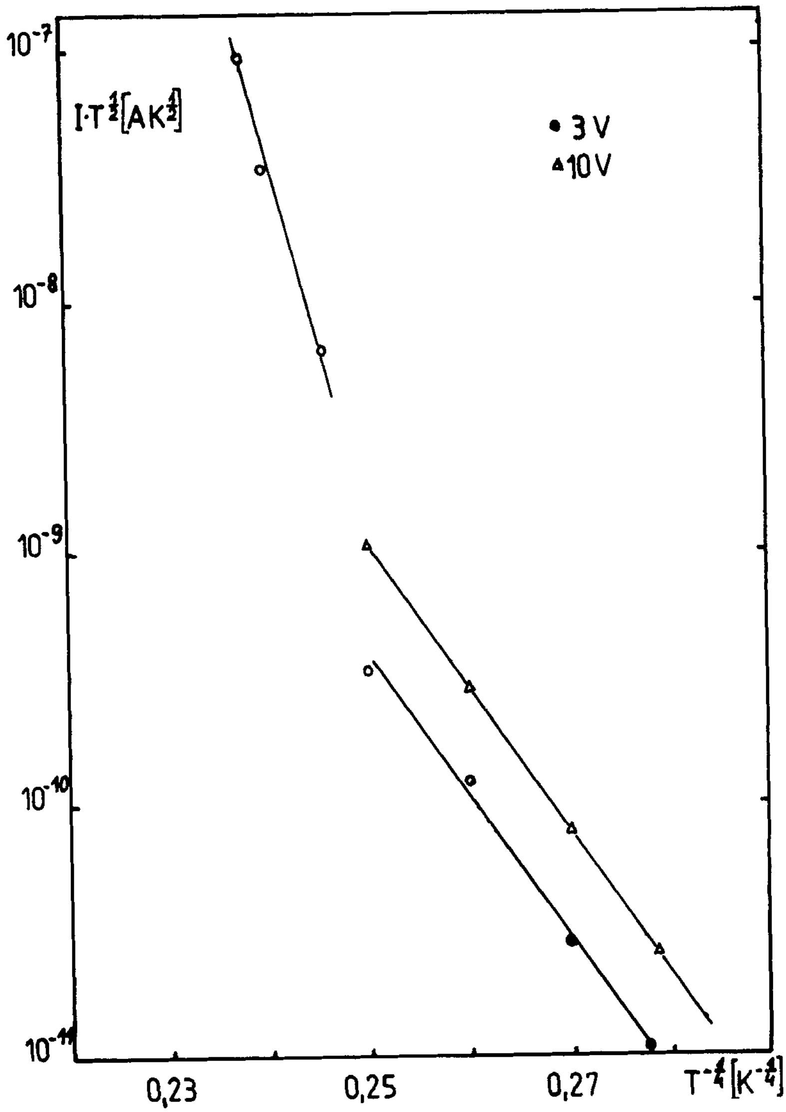

FIGURE 5 $IT^{-\frac{1}{2}}$ VS $T^{-\frac{1}{4}}$ depedences for poly (p-phenylene)

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