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APPLICATIONS OF MOTT'S THEORY OF CONDUCTIVITY ON DOPED POLYANILINE

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ABSTRACT

Polyaniline is a polymer which undoped state is an insulator. Doping of polyaniline gives a conductive state and becomes a very good conductor of electric current. Since the mechanisms of conductivity in polyaniline are still not clear, this paper attempts to give a specific contribution in explaining the theories of conductivity of the material. It has been shown that conductivity of polyaniline depends on the concentration of doping and temperature. With the decrease in the amount of the doping, the conductivity of polyaniline reduces and faster converges to zero. The "hopping temperatures" and activation energies were determined experimentally for all the samples. The resistance of the samples were measured within the temperature interval of 10 K to 290K, during cooling and heating. The temperature interval of 150 K to 290 K. showed the dependence of resistance as: $\ln R = CT^{-1/2}$, which corresponds to the quasi-one-dimensional (Q1d) Mott's theory of conductivity without the Coulomb electron-electron interaction .

Keywords: polyaniline, resistance, electrical conductivity, activation energies, Mott's theory.

1. INTRODUCTION

Depending on conductivity at room temperature, polymers are at low temperatures conductors, isolators or in a critical regime [1]. First attempts to describe the nature and mechanism of transport in conductive polymers used the assumption that polymers are similar to amorphous semiconductors. Although the search for adequate theory of polymer conductivity lasts for a couple of decades already, it is still not clear which shape basic polymers have.[2]. The purpose of this paper is, on the basis of experimental results, to show the kind of mechanism which conducts electrical current in the samples that we obtained under different conditions.

2. EXPERIMENTAL RESULTS

In this work, controlled doping of samples was done with hydrogen chloride acid of different pH values. If pH value is higher, doping of sample is smaller. After that, two voltage and two electrical contacts were put on the samples. Resistance of sample was measured according to "method of 4 points" which eliminates the resistance of leading-in wires and contacts. Method used for measuring this dependence works in such a way that the resistance is measured by direct curent (DC method) [3]. The sample is in the vacuum (P=10^{-4}mbar), and the pressure is obtained by turbomolecular pomp. Then we let direct current through the sample (10nA), first in one direction and then in the opposite direction.By precise measuring of sample dimensions through a microscope with a scale we get data and determine its resistance [4],that is, conductivity of polyaniline sample at given temperature in the temperature interval from 10K to 290 K (Fig.1).After that, we showed dependence of logarithm of resistance of all dopped samples (Fig.2).

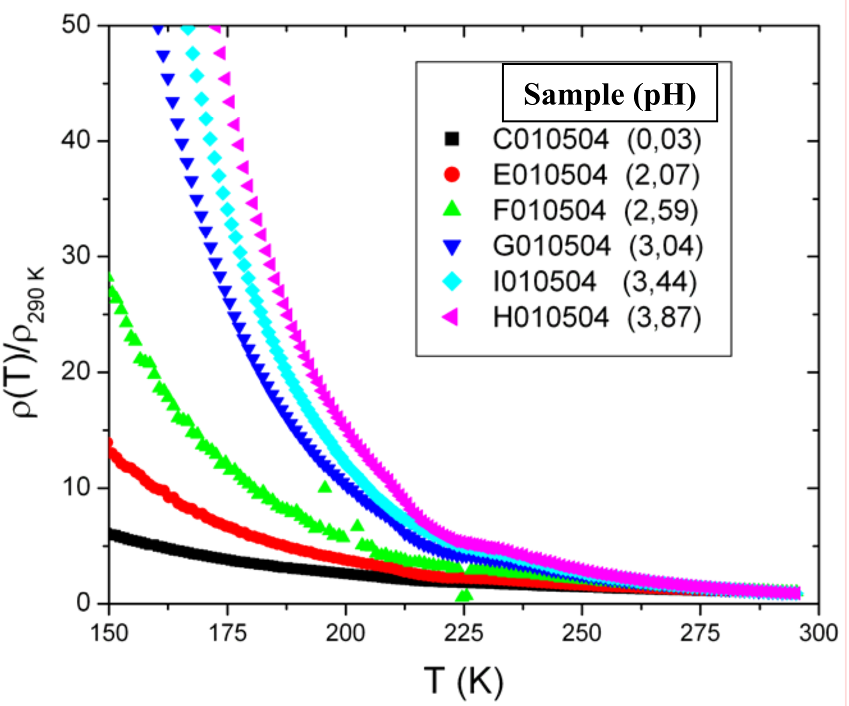

Figure 1. Temperature dependence of standardized resistance (ρ/ρ_{290K}) of all controlled doped samples

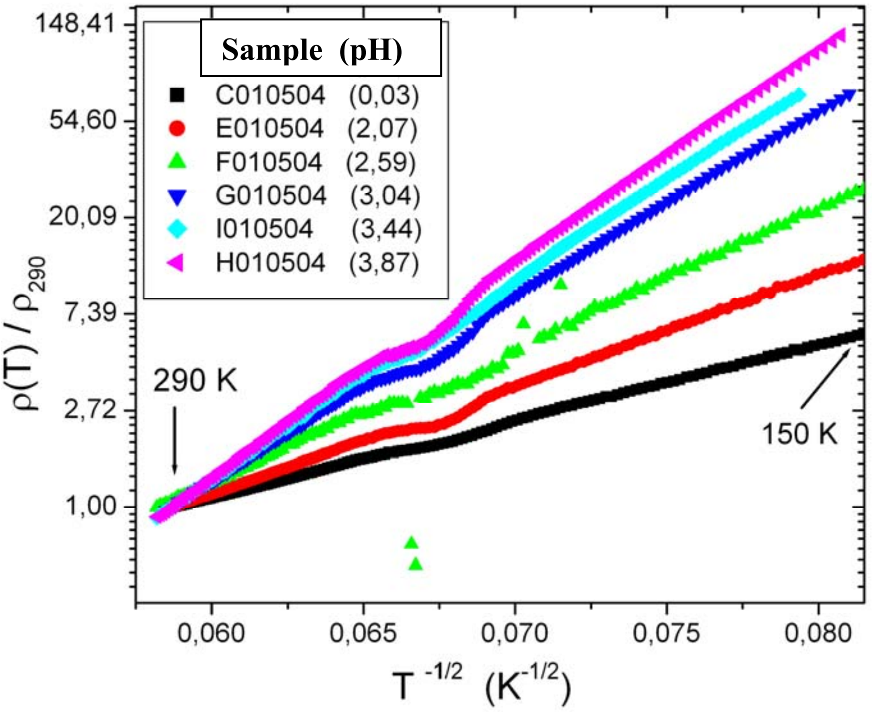

Figure 2. Temperature dependence of standardized resistance of $T^{-1/2}$

All samples in this temperature area show linear behaviour which is in accordance with term (1) for Mott's mechanism of electrical conductivity [5]:

$$\sigma_{DC} = \sigma_0 \exp\left[-\left(\frac{T_0}{T}\right)^{1/(d+1)}\right] \quad (1)$$

In case of quasi one-dimensional system (Q1d) conductivity is, on the basis of term (1), in the following shape: $\sigma_T = \sigma_0 \exp\left[-\left(\frac{T_0}{T}\right)^{1/2}\right]$ (2) which is in accordance with our experimental results (Fig.2).

Parameter T_0 is determined by the highest potential barrier that occurs in the chain and it is called "the temperature of hopping". The parameter depends on the density at Fermi's level $N(E_F)$ and localised length ς: $T_0 \propto \frac{1}{\varsigma^d N(E_F)}$. For Q1d systems it is: $k_B T_0 = \frac{1}{\varsigma\ N(E_F)}$

Value of parameter T_0 is experimentally measured in the following way:

$$\frac{\rho(T)}{\rho_{290}} \propto e^{\left(\frac{T_0}{T}\right)^{\frac{1}{2}}}$$

and if we show this as a logarithm:

$$\ln\frac{\rho(T)}{\rho_{290}} = \left(\frac{T_0}{T}\right)^{\frac{1}{2}} \Rightarrow T_0^{\frac{1}{2}} = \frac{\ln\frac{\rho(T)}{\rho_{290}}}{\frac{1}{T^{\frac{1}{2}}}} \qquad T_0^{\frac{1}{2}} = tg\beta \qquad \Rightarrow$$

$$\boxed{T_0 = tg^2\beta} \quad (3)$$

If we multiply the counted parameter T_0 with Boltzman's constant, we get the activation energy (Table 1.).

Table 1. Readings of parameter T_0 and activation energy

Sample designation	pH-value of the HCl solution	Parameter T_0 (K)	Activation energy (eV)
H010504	3,87	49684	4,29
I010504	3,44	42700	3,69
G010504	3,04	36952	3,19
F010504	2,59	19572	1,69
E010504	2,04	12696	1,09
C010504	0,03	7010	0,60

On the basis of obtained table results regarding activation energy, we can conclude that the values are in accordance with activation energies of semiconductors. Samples which were doped more than others (smaller pH value) have a lower activation energy which means that the width of their forbidden zone is smaller, and their resistance is smaller as well. Given conclusions are in accordance with experimental graphic figures 1 and 2.

From figure 3. we can draw certain conclusions about conductive behaviour of doped samples at low temperatures. If the pH value is higher, conductivity is lower, that is, it moves faster towards zero.

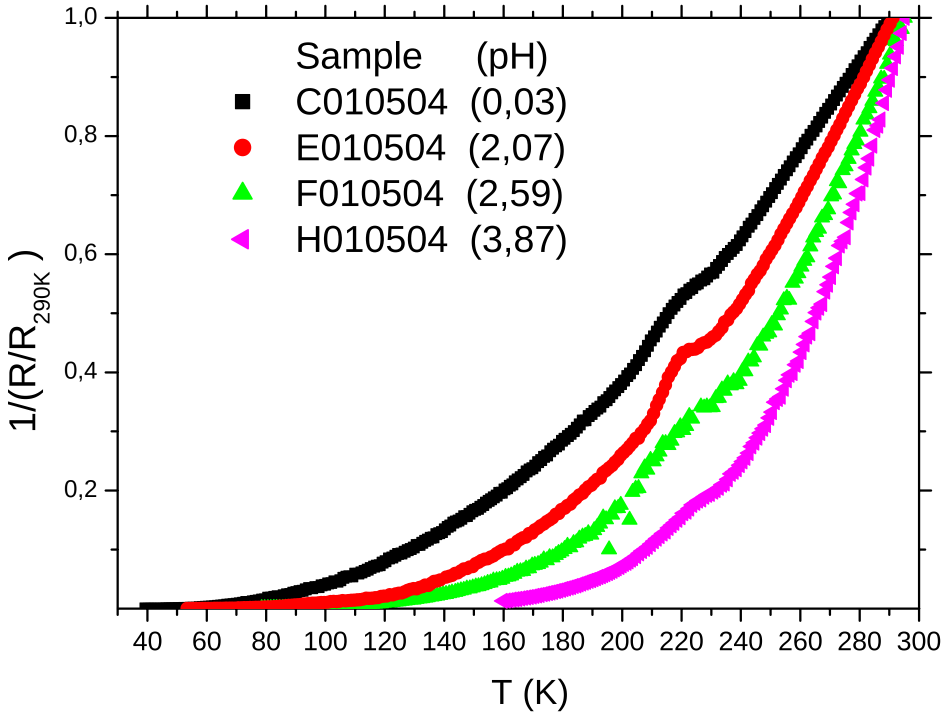

Figure 3. Dependence of standardized conductivity of controlled doped samples on temperature

3. CONCLUSION

Resistance of samples was measured in temperature interval from 10K to 290K. All controlled doped samples show the same temperature dependence of resistance. In temperature interval from 150K to 290K resistance of all samples shows the following dependence $\ln R = C\,T^{-1/2}$, from which we can see that in that temperature area Mott's theory of conductivity for quasi one-dimensional (Q1d) systems without Coulomb electron-electron interaction is valid. "Temperatures of hopping" and activation energies are experimentally measured.Values of activation energies depend on the amount of doping. If doping of sample is higher (lower pH value), activation energies are smaller, and conductivity of sample is better which is confirmed by all experimentally obtained graphics. The sample that was doped the most of all has the best conductivity which goes up to 40K and the sample which was doped the least of all loses its conductivity already at 160K.

4. REFERENCES

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