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Electronic applications of 8-HQ5-SAOF terpolymer resin

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ABSTRACT

Terpolymer resin was synthesized by the condensation of 8-hydroxyquinoline5-sulphonic acid (8-HQ5-SA) and oxamide (O) with formaldehyde (F) in the presence of 2M HCl as catalyst with molar ratios of 1:1:2 reacting monomers. The electrical property of 8-HQ5-SAOF terpolymer resin was measured over a wide range of temperature (313 – 423 K). From the electrical conductivity of this terpolymer resin, activation energy of electrical conduction has been evaluated and was found to be 1.23 x 10^{-4} eV. The electrical conductivity of the terpolymer resin was found to be lies in the range of 3.95 x 10^{-9} to 2.77 x 10^{-5} ohm^{-1} cm^{-1}. The plot of log σ vs. 10^3 / T was found to be linear over a wide range of temperature, which indicates that the Wilson's exponential law $\sigma = \sigma_o$ exp (Ea / k T) is obeyed. On the basis of above studies this terpolymer can be ranked as semiconductor. When a voltage is applied to a thin film of this terpolymer resin then it has emitted light. This remarkable property of this terpolymer resin may be used to make a wide range of semiconducting and electronics electronic devices such as transistors, light emitting diodes, solar cells and even lasers which can be manufactured by much simpler way than conventional inorganic semiconductors.

Keywords: Semiconductor, terpolymer, synthesis, electrical conductivity.

INTRODUCTION

The semiconducting properties of terpolymer resins have gained sufficient ground in recent years. Electrically conducting terpolymer are undoubtedly one of the focal points of current interest in solid-state physics and chemistry. Their discovery has led to the emergency of not only new types of materials capable of replacing metals but also new concepts to explain their high conductivity. In fact, their conductivity and other properties such as thermoconduction, photoconduction, luminescence, etc. are in close connection with their physical and chemical structure. In this connection, studies were made to establish a correlation between the chemical structure and characteristics defining semiconducting properties [1].

Work on organic conducting polymers is carried out extensively due to their wide applications,[2] in areas such as chemically modified electrodes, sensors etc. Pekaln and Kolosonov [3] have studied the electrical conductivity of phenol-formaldehyde resin. An industrially useful semiconducting material has been reported by Dewar,et.al.[4]. The conductivity of 8-hydroxyquinoline–oxamide-formaldehyde terpolymer resins have been reported over a wide range of temperature [5]. Pal et. al. [6-8]have reported electrical conductivity of salicylic acid-biuret / dithioxamide / dithibiuret-trioxane terpolymer resins. Patel and Manavalan[9] reported the electrical properties of p-hydroxybenzoic acid-thioureatrioxane terpolymer. The electrical resistivities of 2-hydrexyaceto-phenoneoxime-thioureatrioxane resin were reported and these polymers are ranked as semiconductors [10]. Since delocalized electrons and conjugation impart semiconducting properties to compounds, the present study deals with electrical properties of some terpolymer resins which may serve as potential semiconductors.

MATERIALS AND METHODS

Synthesis of 8-HQ5-SAOF terpolymer resin

The new terpolymer resin 8-HQ5-SAOF was synthesized (Fig.1) by condensing 8-hydroxyquinoline5-sulphonic acid (8-HQ5-SA) (0.1 mol) and oxamide (O) (0.1 mol) with 37 % formaldehyde (0.2 mol) in a mol ratio of 1:1:2 in the presence of 2M 200 ml HCl as a catalyst at $130^0C \pm 2^0C$ for 5h [11] in an oil bath with occasional shaking to ensure thorough mixing. The separated terpolymer was washed with hot water and methanol to remove unreacted starting materials and acid monomers. The properly washed resin was dried, powdered and then extracted with diethyl ether and then with petroleum ether to remove 8-hydroxyquinoline5-sulphonic acid-formaldehyde copolymer which might be present along with 8-HQ5-SAOF terpolymer.

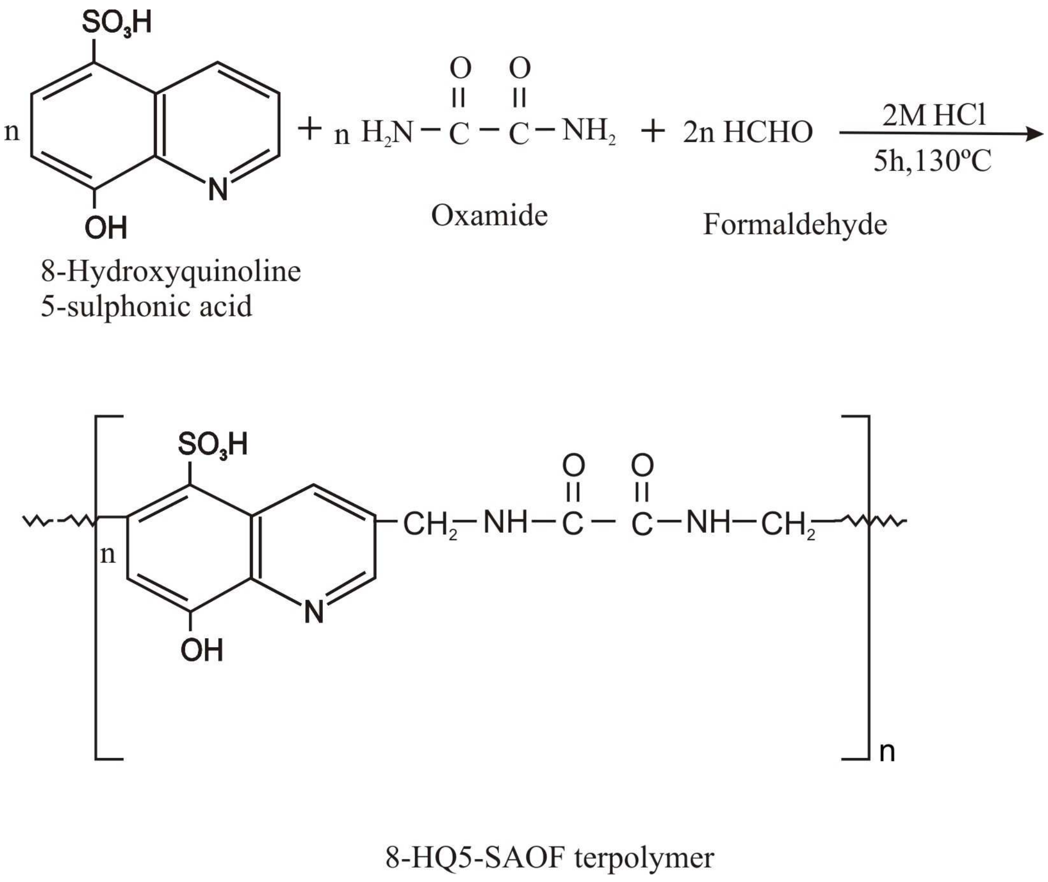

Fig.1 Reaction and expected structure of 8-HQ5-SAOF terpolymer resin

Conductivity Measurement

Experimental Techniques

The DC electrical conductivity measurements in solid state was carried out in a suitable sample holder designed for the purpose, in the temperature range of 313K to 463K at constant voltage of 50 volts across the pellet prepared from terpolymer resin. The measurements were made by Auto Compact LCR-Q tester model 4910.

(1) Preparation of Pellet

The terpolymer sample was dried properly and thoroughly ground to a fine powder in agate mortar and pestle. The pellet was prepared of the well powdered terpolymer resin isotectically in a steel die at under a pressure of 10 metric tons cm^{-2} with the help of hydraulic press.

(2) Measurement of DC electrical resistivity

a. Sample holder :

The pellet of terpolymer resin sample was mounted between the two brass electrodes.

b. Furnace for heating the sample :

For measurement of resistivity at different temperatures, a suitable digital muffle furnace embedded with high grade glass wool after single line brick lining and Alumel-Chromel thermocouple up to 1200ºC having heating control regulator, was used. The current supplied to the furnace was recorded by means of AC ammeter. The pellet fitted in the sample holder is kept in the furnace. The connecting wires of two electrodes of the sample holder were taken out for the connection.

c. Data recording :

The connecting wires from the sample holder kept in the furnace, were connected to the terminals of LCR-Q tester model 4910. In this way corresponding resistances of the pellet at various temperature was measured directly. The temperature of the digital furnace slowly increases and resistance is noted on LCR meter, nearly from temperature range 30ºC to 190ºC .

RESULTS AND DISCUSSION

The thermal activation energy and the values of electrical conductivity at different temperatures are given in Table 1. The resistance values of the pellets of the terpolymers ranging from 313 K to 423 K were converted into conductivity values (σ) by taking into account the thickness of the pellet and its diameter and evaluating thickness area parameters of the pellet of a particular terpolymer. Generally the diameter of the pellet remained constant (1.3 cm) since the same die was used and the thickness varied from 0.241 to 0.261 cm according to the amount of sample present. The temperature dependence of the electrical conductivity of the terpolymers is shown in Fig. 2. In the electrical conduction domain, the temperature dependence of the electrical conductivity obeys the well known equation [12].

$$\sigma = \sigma_o \exp^{(\Delta\_E/kT)}$$

Where, k = Boltzmann constant, σ_o = electrical conductivity at temperature $T \rightarrow \infty$

σ = electrical conductivity at temperature T

ΔE = electrical conductivity energy of electrical conduction.

This relation has been modified as Electrical Properties of 8-HQ5-SAOF terpolymer

$$\log \sigma = \log \sigma_o + \frac{-\Delta E}{2.303kT}$$

According to this relation, a plot of log σ Vs. 1000/T would be linear with a negative slope. The result of the D.C. conductivities are presented here in the form of plots of log σ Vs. 1000/T for each set of data, as the range of conductivities was found to be 3.95 x 10^{-9} to 2.77 x 10^{-5} ohm^{-1} cm^{-1}.

It will be seen from the plot (Fig. 1) of terpolymer that there is a consistent increase in electrical conductivity as the temperature rises roughly from 313 K to 423 K. these trend is a characteristic of semiconducting [13.14]. The activation energy was determined from the curves log σ Vs. (10^3/T). The temperature dependence of the electrical conductivity in pellet of the terpolymer is of the same type. The plot of log σ Vs. 10^3/T are found to be linear (Fig. 1) over wide range of temperature which indicates the semiconducting nature of terpolymer [15, 16].

From the analysis of our results it can be assumed that the difference in electrical be assumed that the difference in electrical properties of terpolymer studied are mainly by their chemical structure, over the whole temperature range the values of the electrical conductivity vary between 3.95 x 10^{-9} to 2.77 x 10^{-5} ohm^{-1} cm^{-1}. The conductivities are in the order of 10^{-5} to 10^{-9} ohm^{-1} cm^{-1} due to comparatively small intra intermolecular charge transfer of terpolymer [17].

Plastics semiconductors are easier, safer and less expensive to manufactures than conventional semiconductors. Because of the lower cost of manufacturing 8-HQ5-SAOF semiconducting terpolymer may be used as transistors, integrated circuits (IC) for low cost as well as chemical sensors in electronic devices.

Table 1 Electrical Conductivity Data of 8-HQ5-SAOF Terpolymer Resin

Terpolymers	Electrical Conductivity		ΔT	ΔE
	313 K	423 K	(K)	(ev)
8-HQ5-SAOF	3.95 x 10^{-9}	2.77 x 10^{-5}	313 – 423	1.23 x 10^{-4}

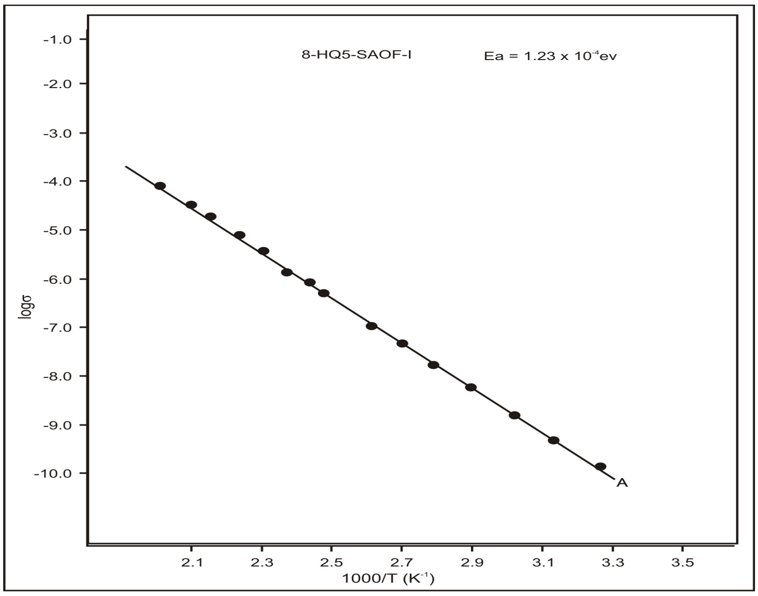

Figure 1: Electrical conductivity plot of 8-HQ5-SAOF terpolymer resin (Temperature dependence of log σ)

CONCLUSION

1. The electrical conductivity of 8-HQ5-SAOF terpolymer at room temperature lies in the range of 3.95 x 10^{-9} to 2.77 x 10^{-5} ohm^{-1} cm^{-1}.
2. The plots of log σ vs 1/T is found to be linear in the temperature range under study, which indicate that the Wilson's exponential law $\sigma = \sigma_o \exp^{(-\Delta E/KT)}$ is obeyed.
3. Electrical conductivity of each of these terpolymer resins increases with increase in temperature. Hence, these terpolymers may be ranked as semiconductor.

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