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Dc electrical transport studies in Polypyrrole composites containing lithium zinc ferrites

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ABSTRACT

DC conductivity was measured as a function of temperature in the 300 K–340 K range. Activation energies were studied from Arrhenius plots for different compositions. Results show that incorporation of additive material significantly reduces the activation energy. The conduction mechanism is studied for different composition. As the polymers are used in the various manufacturing products, this study indicates the possibility of using such polymers in the form of composites as superior insulating material in the fields of electrical or electronic insulation and allied areas.

Keywords **-PPy/Li-Zn ferrite composites; EDAX; XRD; DC conductivity.**

INTRODUCTION

Conducting polymers have attracted a lot of attention in both academic and industrial research because of their prospective applications in the fields of energy storage, optoelectronic devices, electrochromic materials, and organic photovoltaics [1]. Researchers found that conductive polymers display magnetic, optical, and electrical properties resembling those of metals while still retaining the processability and flexibility of regular polymers[2-3]. The process of doping with different chemicals significantly enhances the properties of conducting polymers [4]. With the right doping, these materials' conductivity can be switched from a semiconducting to a metallic regime, which has given rise to a fresh idea for the charge transport process. The majority of the research on these polymers focuses on adapting already existing polymers in acceptable ways to improve their usability [5].

Polypyrrole (Ppy) is one of the most attractive conducting polymers due to its special transport properties, facile synthesis, tunable conductivity and good environmental stability [6]. Nano crystalline ferrites are materials of considerable interest due to their unique dielectric, magnetic and optical properties. Nano crystalline Spinel copper zinc ferrites ($CuZnFe_2O_4$) have been extensively investigated due to their potential applications in non-resonant device, radio frequency circuits, rod antennas, high quality filters and transformer core [7]. Zinc ferrite ($ZnFe_2O_4$) has received a lot of attention due to its exceptional chemical stability, high electromagnetic performance, and mechanical toughness. To make unique and inventive conducting nanocomposites with electric and magnetic responses, $ZnFe_2O_4$ nanoparticles have been mixed with various polymeric materials. In a variety of technical applications, low-cost materials including pure and substituted lithium ferrites are used [8–12]. Lithium ferrite is a material that is utilized in a number of high frequency electronic devices, such as microwave circulators, isolators, phase shifters, and absorbers, because of its high permeability (in the microwave frequency range) and high Curie temperature. Additionally, Li-ferrite is suitable for such applications due to its high electrical resistivity, mechanical toughness, and chemical stability [13,14]. Lithium ferrite, which has the general formula $(A)[B_2]O_4$, and the chemical symbol AB_2O_4, has a spinel structure. The square bracket here stands in for the octahedral site, and the parenthesis for the tetrahedral site[15].In the present work, we report the investigations of electrical transport studies in $Li_{0.5-x/2}Zn_xFe_{2.5-x/2}O_4$ containing Polypyrrole composites.

EXPERIMENTAL

1. *Materials*

The pyrrole monomer, ammonium persulphate (APS), Li_2CO_3, ZnO and Fe_2O_3 chemicals and binding agent polyethylene glycol (PEG) were purchased from Sigma Aldrich of AR grade.

2. *Synthesis of Polypyrrole*

A beaker containing the doubly distilled monomer pyrrole and the oxidizing agent ammonium persulphate (APS) is in situ polymerized on an ice tray with a magnetic stirrer. 0.6 M ammonium persulphate is added to 100ml of water. APS is gradually incorporated into 0.3 M Polypyrrole. The magnetic needle revolved constantly throughout the reaction's six-hour runtime at a temperature of 273 K to 278 K. The resulting precipitate was extracted using a filtration suction method, washed with deionized water, and dried for six hours in a hot air oven. In a muffle furnace, the byproduct was heated to 373 K, yielding 2.25 g of the black Polypyrrole powder, which was then recognized as 100% [12-15].

3. *Synthesis of Lithium zinc ferrites*

Lithium zinc ferrites with the general formula $Li_{0.5-}x/_2Zn_xFe_{2.5-x/2}O_4$ (x = 0.0, 0.2, 0.4, 0.6, 0.8 and 1.0) have been synthesized as per the procedure mentioned in [16-18].

4. *Synthesis of PPy/ Li-Zn ferrite composites*

The samples were obtained by manually homogenizing equal weights of PPy and Li-Zn ferrite ($Li_{0.5-x/2}Zn_xFe_{2.5-x/2}O_4$) in an acetone containing solution. A hydraulic press rated at 80 MPa was used to create the pellets. The produced pellets ranged in thickness by 2 mm and had a 10 mm diameter [18.19]. Additionally, the composites were labelled using a variety of compositions (x = 0.0, 0.2, 0.4, 0.6, 0.8, and 1.0), and the resulting composites were given the labels PLZF0, PLZF2, PLZF4, PLZF6, PLZF8, and PLZF10, respectively.

DC CONDUCTIVITY

In addition to providing an understandable conductivity comparison of all samples, plotting DC conductivity for composite PPy/ Li-Zn ferrite in an Arrhenius plot can also provide insight into how conductivity changes as a function of temperature (figure 4). Figure (5) illustratesthe conductivity of all samples for an identicalweight fraction of PPy/Li-Zn ferrite as a function of temperature from 300 K to 340 K. The most noticeable fluctuation in this regard occurs for the least conductive PPy/ Li-Zn ferrite, where thermally activated conduction mechanism occurs. For PPy/ Li-Zn ferrite, a comparable but less significant break is observed, where two distinct linear zones with constant activation energy can be detected (Fig. 5). Whereas at lower temperatures, conduction may result from electron hopping between Fe^{2+} and Fe^{3+} in the B-sites, while at higher temperatures, it may result from polaron hopping and be characteristic of ferrites [20,21,22]. It has been found that as temperature rises, dc conductivity generally increases. This proves that the samples have semiconducting properties and is in good agreement with the literature because spinel ferrites are known to exhibit semiconducting behavior [23].

The observed behavior of increasing conductivity with increasing temperature clearly indicates that the present PPy/ Li-Zn ferrite composites have semiconductor like behavior, in which the conductivity is explained by Arrhenious relation;[24-25]

$$\sigma T = \sigma_o exp^{(-E_a/k_B\ T)} \qquad (3)$$

Where σ is the conductivity of the composites, $\sigma_o$is the pre-exponential factor and is constant, $E_a$is the activation energy, k_B is the Boltzmann's Constant, T is the absolute temperature of the samples.

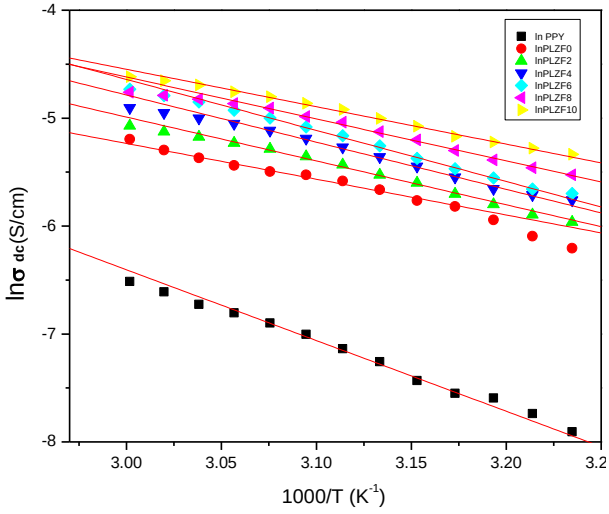

Fig.1 Temperature Dependent DC Conductivity of Ppy/$Li_{0.5-x/2}Zn_xFe_{2.5-x/2}O_4$ Composites

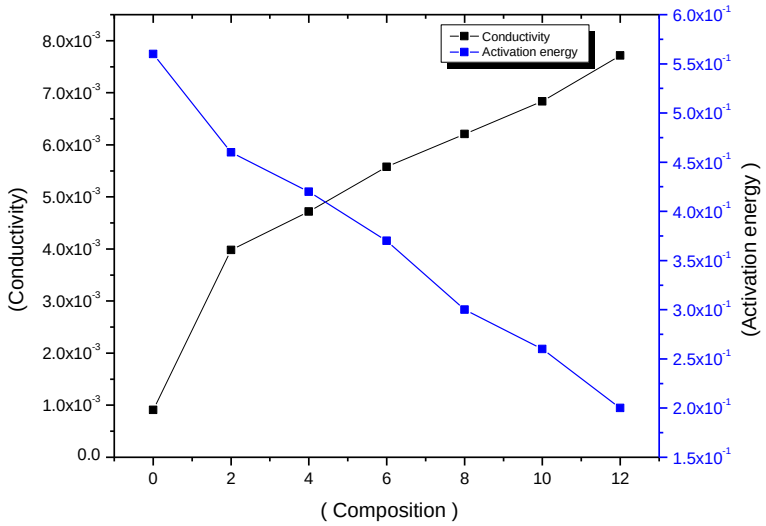

Fig.2 Activation Energy Graph of Ppy/$Li_{0.5-x/2}Zn_xFe_{2.5-x/2}O_4$ at Temperature 323K.

As per equation 3, the least square linear fittings were made to the plots in the high temperature region. The best fits to the $\sigma(T)$ versus $(1/T)$ plots gave the r^2 =0.991 to 0.998 (r= correlation coefficient). The slope of linear fits is determined from the plots and activation energies, E_a, were calculated. The activation energies, E_a, were estimated to be 0.29eV to 0.56eV. for all the composites[21]. From the graphs, it can be observed that the conductivity increases linearly with increase in LZF dopant. The activation energy has been found to decrease with increase in LZF content in the composites. The increase in dc conductivity with increase in LZF dopant has been attributed to the complete and homogenous dispersion of LZF ferrite in the polypyrrole matrix [21].

CONCLUSIONS

The PPy/$LiZnFe_2O_4$ composites were synthesized successfully, Electric properties of PPy/ Li-Zn ferrite composite, comprising ferrite particles covered by Ppy, ultimately depend on electric properties of Ppy particles the weight percentage can increase conductivity of such composite system while deepened Ppy, which in turn depend upon mesoscale charge transport in Ppy,. In its conductive form (pristine ferrites magnetic material), for the PPy/Li-Zn ferritecomposites Ppy connected with the octahedral and hierarchical structure with the ferrite , the conduction mechanism, namely by charge (electron) hopping, at higher temperature it may be due to polaron hopping and it is typical in ferrites. Activation energy of conduction process in PPy/ Li-Zn ferriteincreases with temperature indicating a change in conduction mechanism also confirms that higher conductivity is associated with lower activation energies and vice versa. Consequently, it has been shown that ferrite particles, used in order to alter magnetic properties of such composite materials [20, 27, 29], can rather significantly change their electric properties.

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