TRANSPORT PROPERTIES OF CONDUCTING POLYMER POLYANILINE WITH CuO NANOPARTICLES

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Abstract:
In the current study, the DC conductivity of Polyaniline (PANI) and PANI/CuO nanocomposites was examined in relation to CuO nanoparticles doped to PANI. Additional Arrhenius plots showed that both for the pure PANI and its doped Nanocomposites, the activation energy has dropped. Additionally, samples are characterized for XRD analysis in order to ascertain their crystallinity. The weight % of CuO nanoparticles in Polyaniline was revealed to encourage the conductivity values. It is ascribed to Polyaniline long chain, which makes charge carrier hopping easier.

Key Words: DC Conductivity, CuO, Nanocomposites and Arrhenius Plots.

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1. Introduction

The metal oxides such as cupric oxide (CuO) is a transition metal oxide, is one of an important p-type semiconductor with band gap in the range of 1.8 - 2.5 eV [1-2]. It has many potential applications in solar energy conversion, photo thermal, photoconductive, lithium ion batteries, solar cell photo catalytic, degradation of organic pollutants, antimicrobial, chemical and biological sensing etc. Now a day, preparation of nanocomposites plays major role in modification of materials properties.

In present work the nanoparticles of CuO nanoparticles were prepared any additive like ionic liquids, capping agents by low temperature combustion method. The nanocomposites of CuO with Pani at different concentration were synthesized and characterized using X-ray diffraction (XRD) . The properties such as DC conductivity and Arrhenius plots of PANI/CuO nanocomposites have been studied as function of temperature in the range of 30 ^{O}C to 180^{O}C. Polyaniline (PANI), one of the well-known conducting polymers, has been extensively studied by researchers during the last two decades, because of its high electrical conductivity, environmental stability and ease of preparation [3]. In the present study CuO doped PANI nanocomposites were synthesized.

Metal oxides, such as cupric oxide (CuO), are important p-type semiconductors with band gaps between 1.8 and 2.5 eV [1-2]. CuO is a transition metal oxide. It has a wide range of potential uses, including the conversion of solar energy, photo thermal and photoconductive devices, lithium ion batteries, photo catalytic solar cells, the breakdown of organic pollutants, and chemical and biological as well as antimicrobial sensors. The creation of nanocomposites today is crucial for changing the characteristics of materials.
As an addition, such as ionic liquids or capping agents, CuO nanoparticles were created in the current work using a low temperature combustion process. X-ray diffraction (XRD) was used to create and characterise the nanocomposites of CuO with Pani at various concentrations. The characteristics of PANI/CuO nanocomposites, such as DC conductivity and Arrhenius plots

PANI/CuO nanocomposites' characteristics, such as DC conductivity and Arrhenius plots, have been investigated as functions of temperature in the range of 30 OC to 180 OC.

Due to its high electrical conductivity, environmental stability, and simplicity of manufacture, Polyaniline (PANI), one of the well-known conducting polymers, has been the subject of intensive research over the last two decades [3]. CuO doped PANI nanocomposites were synthesized for the study.

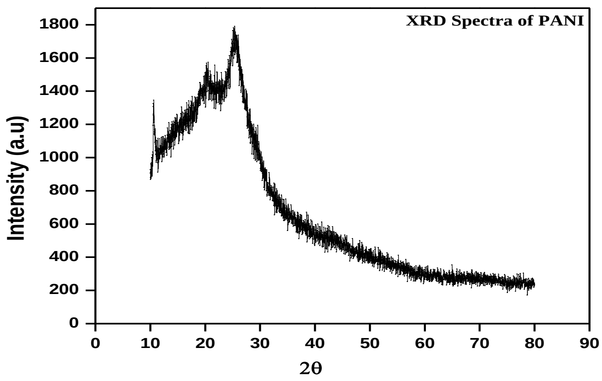
2. Preparation of PANI/CuO nanocomposites

The Polyaniline– Copper oxide [PANI/CuO] nanocomposites were synthesized by in-situ polymerization technique. 3 moles of aniline were mixed in 3 moles of hydrochloric acid (HCl) in equal ratio. The solution of aniline hydrochloride was placed on a magnetic stirrer for half an hour. The copper oxide nanoparticles of 10 weight% were added to the solution during polymerization in order to get the homogeneously suspended particles of copper oxide in the solution. After that, 6 moles of ammonium per sulphate as oxidizing agent was slowly added drop-wise with continuous stirring at 25 ^{0}C for 5 hours to polymerize completely. The precipitate was filtered, then washed with deionised water and acetone and then dried in hot air oven for two days to get the Polyaniline with copper oxide nanocomposite. The procedure is repeated to synthesize the PANI/CuO nanocomposites at 30 and 50 different weight percentages of Copper oxide. The 200 mg mixture of PANI/CuO nanocomposites was used for preparation of a pellet. The pellet was prepared by applying 2-3 tons of pressure at room temperature using a pellet making machine [Model-UTM]. The thicknesses of the pellets were measured by using Screw gauge. The samples of PANI/CuO nanocomposites were coated with silver paste on both sides of the surface and are used for further studies of dc conductivity.

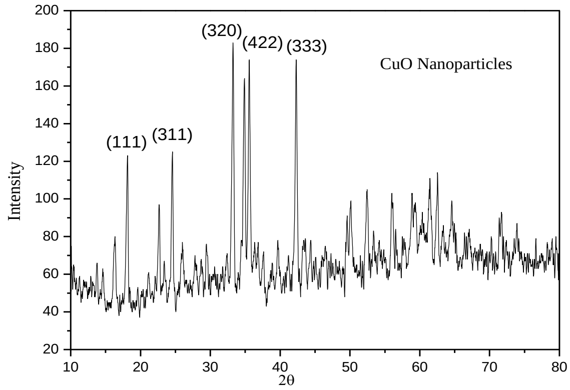
3. Results and discussions

3.1. Characterization of samples XRD

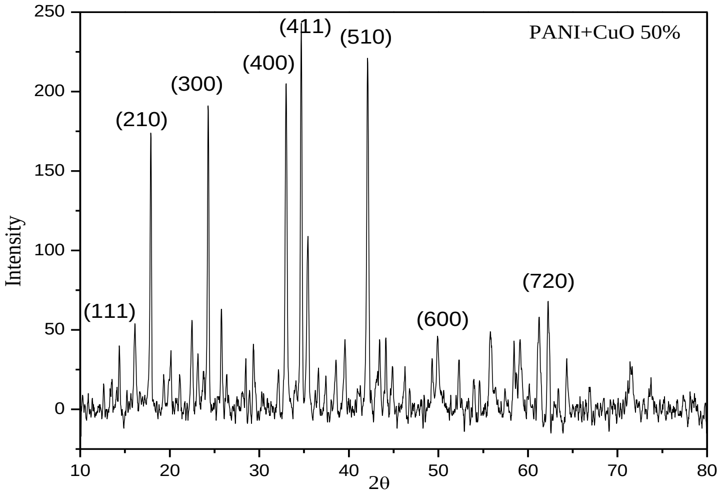
The prepared nanocomposites of CuO with PANI at different concentrations were used for characterization using powder X-ray method (Model: Regaku) of CuK_{α} radiation having a wavelength of 1.54A$^{\circ}$. The XRD pattern with diffraction intensity versus 2θ was recorded over a range of 10 to 90 degrees. The XRD spectra of PANI is shown in Fig.1 (a) for the nanoparticles of CuO (b) and PANI with CuO nanoparticles at 50%wt concentration are given in Fig.1 (c). The sharp peaks observed from these figures indicate that the samples are crystalline in nature. The positions of the peaks observed at angles of 2θ are 18, 24, 33, 36, 38, 42 and 63 degrees are nearly same for the CuO nanoparticles and its nanocomposites with PANI at different concentrations. The positions of peaks for the CuO nanoparticles observed at these angles were same and comparable to the literature [3-4] and hence its structure is monoclinic phase of CuO [5].



(a)



(b)



(c)

Fig.1: XRD spectra of (a)PANI (b) CuO nanoparticle and (c) PANI-CuO nanocomposites.

The crystallite size is calculated using the Debye Scherrer equation given by

$$D = \frac{0.9\,\lambda}{\beta\cos\theta} \qquad (1)$$

Where D is the crystallite size, β is FWHM of strong intensive peak, λ is the wavelength of the X-ray and θ is the Bragg angle. The average crystallite size of the synthesized CuO nanoparticles is 50 nm.

3.2. DC Conductivity

The DC conductivity studies for Pure PANI and PANI/CuO Nanocomposites of 10 wt% to 50 wt% were carried out and are shown in Fig 2. The conductivity varies directly with the temperature, obeying an expression of the following form (2).

$$\sigma(T) = \sigma_o exp\left[-\left(\frac{T_o}{T}\right)^{1/4}\right] \qquad (2)$$

Where, σ is the conductivity, T is the temperature and σ_0 is the conductivity at characteristic temperature T_0. The Mott Theory of conductivity for temperature dependence can also result from the effect of finite conjugation length on the frequency of nearest neighbour inter chain hopping. The nearest neighbour hopping process with a distribution of activation energies can give same type of exponential temperature dependence for conductivity. It is observed that the conductivity values increase up to 50 wt % of CuO in Polyaniline; this is attributed due to extended chain length of Polyaniline which facilitate the hopping of charge carriers when the content of CuO is up to 50 wt%. Further the increase in conductivity is observed which may be attributed due to the distribution of CuO nanoparticles which are partially hopping of charge carriers. It is also suggested here that the thermal curling effects of the chain alignment of the Polyaniline leads to the increase in conjugation length and that brings about the increase of conductivity. Also, there will be molecular rearrangement on heating which makes the molecules favourable for electron delocalization [5-7].

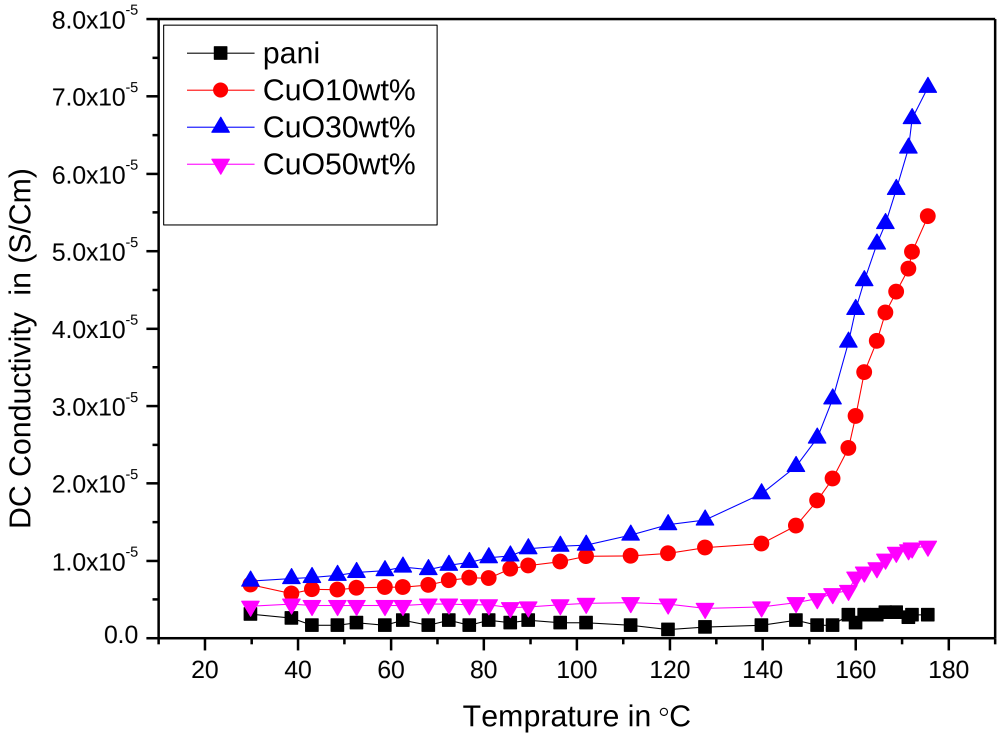


Fig.2. Graph of DC Conductivity σ dc Vs. Temperature of PANI and PANI/CuO nanocomposites

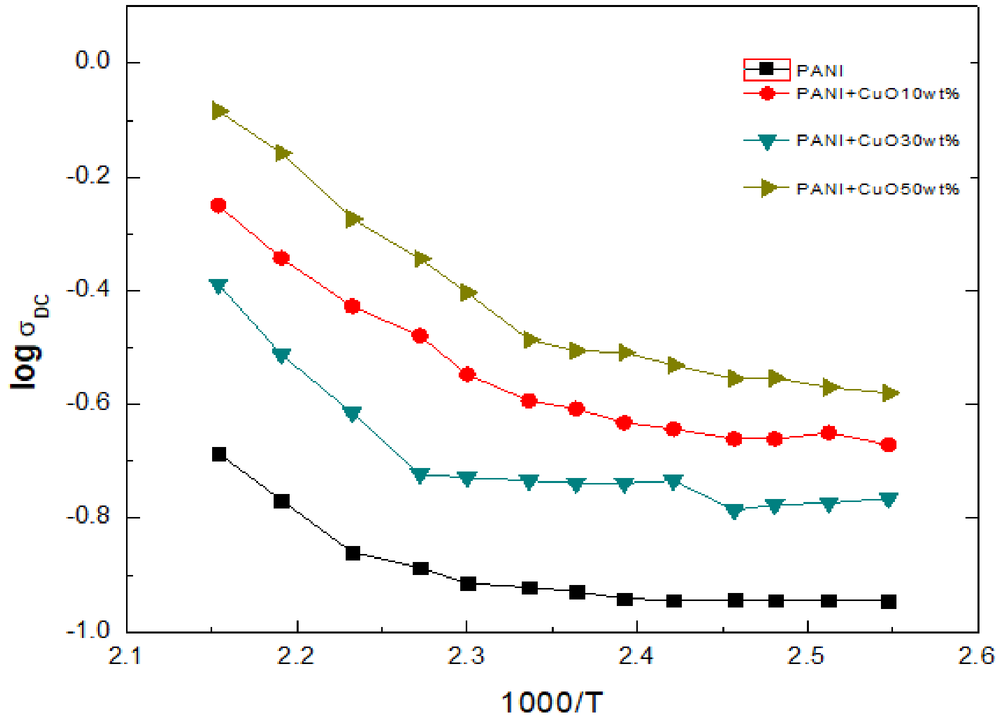


Fig.3. Graph of log σ dc Vs. 1000/T of PANI and PANI/CuO nanocomposites

Arrhenius plot of DC conductivity shows straight line behaviour. The DC conductivity of pure PANI increased exponentially with doping, exhibiting semiconductor characteristics. The conductivity as a function of temperature can be represented by the relation [8].

$$\sigma_{dc} = \sigma_o exp\left[\left(\frac{-\Delta E}{kT}\right)\right] \quad (3)$$

The activation energy is found to be decreased with increase in the weight percentage of CuO in Polyaniline and the values of activation energies are further decreased which could be due to the addition of more carriers to the nanocomposite.

3.3. Conclusions

The electrical conductivity in these Nanocomposites shows a strong dependence on content of copper oxide nanoparticles in the Nanocomposites. It is observed that dc conductivity increased for all compositions while the activation energy decreased which could be due to the addition of more carriers to the nanocomposite.

3.4. Acknowledgement

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