Frequency and Temperature Dependence of AC Electrical Conductivity of Cadmium Iodide Doped Polyaniline

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Abstract: ***This paper focuses on investigation of the effect of frequency and temperature on ac electrical conductivity of*** **cadmium iodide doped polyaniline** ***synthesized by simple chemical oxidative polymerization method. The ac electrical conductivities as a function of temperature (308-338 K) and frequency (20 Hz- 1 MHz) was measured. The ac conductivity is temperature dependent and it follows the equation $\sigma_{ac} = A\ \omega^{s}$. The value of the frequency exponent "S" was calculated for all the investigated samples .The synthesized material was subjected for structural characterization using FTIR, XRD and SEM.***

Keywords: Ac conductivity, Cadmium Iodide Composites, Doped Polyaniline

1. Introduction

The small concentration of dopant anion results in semiconducting polymer with significant band gap where as the dopant concentration give rise to highly conductive polymers. Conductive polymer composites are attractive materials for use in existing and emerging technologies due to their light weight, low cost, and versatility compared with other standard semiconductors. They can be fabricated by filling an insulation polymer matrix with conducting particles such as metal flakes or metalized fibres, by chemical or electrochemical synthesis method to produce intrinsically conductive polymers [1].

Conductive polyaniline (PANI) has been studied extensively because of its ease of synthesis in aqueous media, its environmental stability and special electrical and other properties. PANI has become a suitable candidate for a variety of technological applications [2-4], such as solar cells, electromagnetic shielding, electrodes for rechargeable batteries, sensors, etc. These composites have the ability to enhance their material properties with desirable mechanical and physical characteristics. The present study focuses on the investigation of the ac conductivity as well as IR spectra of doped polyaniline, X-ray differaction, and Scanning electron microscopy.

2. Materials and Methods

All the materials were obtained from well known companies. Regents Ammoniumpersulfate (APS) was obtained from Merk- Extra pure, Cadmium Iodide was obtained from Research Lab Fine Chem. Industries of AR grade and Aniline Hydrochloride of LobaChemiepvt.Ltd..

Preparation of samples

All materials were used as provided. Aniline hydrochloride was dissolved in distilled water in a volumetric flask to 50mL of solution. Ammonium peroxydisulfate was dissolved in distilled water also to 50ml of solution. Both solutions were kept for 1 h at room temperature (~18–30 °C), then mixed in a beaker, briefly stirred, and left at rest to polymerize. Next day after the reaction was over, polyaniline in the form of flakes or powder was obtained. The precipitated polyaniline was filtered by conventional method. The polymer was washed with distilled water. The polyaniline samples obtained in powder form were dried first at room temperature for few hours and then finally dried in an oven kept at 60^{o}C- 90^{0}C for 1/2-1 hours. The dried polymer powder was then preserved for sample preparation.[5,6]PANI samples with Cadmium iodide were prepared in the aqueous medium with aniline hydrochloride.

3. Measurement

3.1 IR Spectra

IR spectroscopy is important and useful technique for determining functional groups present in a compound. Studies were carried out in order to confirm the presence of Cadmium iodide in the polyaniline/doping concentration of polyaniline with different dopants. The powder samples were mixed inKBr to record the spectra. IR spectra of the samples was taken using a spectrometer (SHIMADZU IRAFFINITY1).The characteristic absorption bands thus obtained are shown in Figure 4. Our results show that, there is a shift in the responses after doping the samples with Cadmium iodide, giving rise to a good comparison between the doped and undoped polymer.

3.2 AC Measurement

The Measurements were carried out in the temperature range 308-358 K and in frequency range 20 Hz to 1MHz using AGILENT 4284A LCR precision meter. The thickness of the pellet was measured by DIGIMATIC micrometer with least count 0.001 mm. The ac conductivity $\sigma_{ac}$was calculated according to following relation.

$$\sigma_{ac} = t / ZA \qquad \text{------ (1)}$$

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Where, t is the pellet thickness, A is the sample area and Z is the impedance of the pellet.

4. Results and Discussion

Frequency dependence of ac conductivity

The frequency dependence of ac electrical conductivity $\sigma_{ac}$was measured for all investigated pellets. The plots of log ω against log $\sigma_{ac(}$ $\omega_{)}$ at different temperatures in the frequency range 20 Hz to 1MHz is shown in figure 1. It is observed that ac conductivity(σ_{ac}) increases with increasing frequency. According to [7].the ac conductivity σac of amorphous semiconductors is usually expressed as

$$\sigma_{ac} = \sigma_T - \sigma_{dc} = A\,\omega^s \qquad (2)$$

Where ω is the angular frequency of the applied field (ω= 2πf), σ_T is the total electrical conductivity including the frequency dependent conductivity under ac field, and dc conductivity. A is the constant which depends on temperature, s is the frequency exponent (s is less than or equal to one<=1). σ_{dc} is dc conductivity. From the graph [log (ω) against log σ_{ac}(ω)] value of s is obtained. In most of the cases, the obtained value of s has a tendency to decrease with increasing temperature [8]. Therefore the correlated barrier hopping model (CBH) [9] has been extensively applied to most semiconducting materials. The frequency exponent s is found to decrease with increasing temperature, the theoretical values of s was calculated according to following relation

$$s = 1 - 6kT/\,[W_H + kT\ln(\omega\tau_0)]\text{------} \qquad (3)$$

Where W_H is the effective barrier height and k is the Boltzmann constant, τ_0 is characteristic relaxation time.

Figure 2 shows temperature dependence value of 's' which decreases with increasing temperature.

The theoretical value of 's' is given by the equation (3). The theoretical values of s obtained from equation 3, in which W_H and w τ_0 was taken as fitting parameter that agree with experimental values.

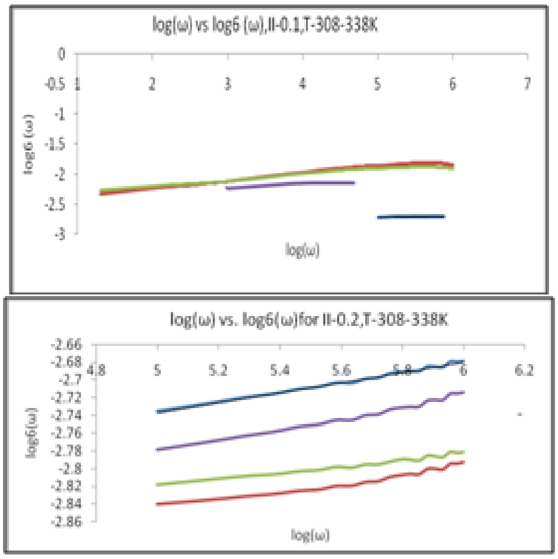


Figure 1: The variation of ac electrical conductivity with frequency (log ω versus log σac) for all doped polyaniline composite pellet in the temperature range 308 to 338 K.

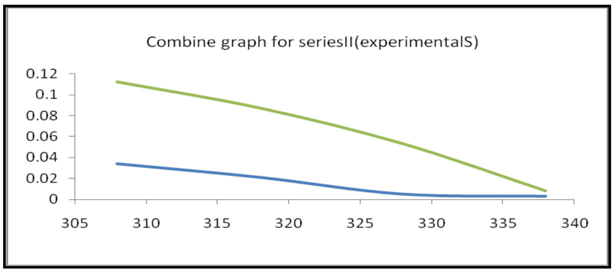


Figure 2: Variation of s with temperature (experimentally)

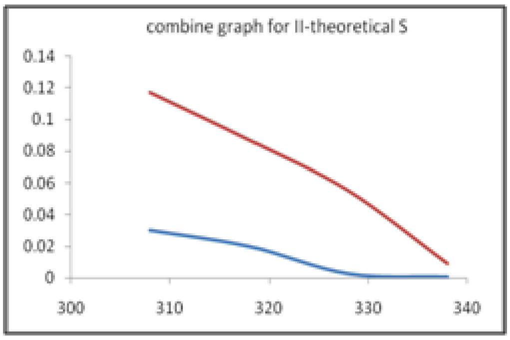


Figure 3: Variation of s with temperature (theoretically)

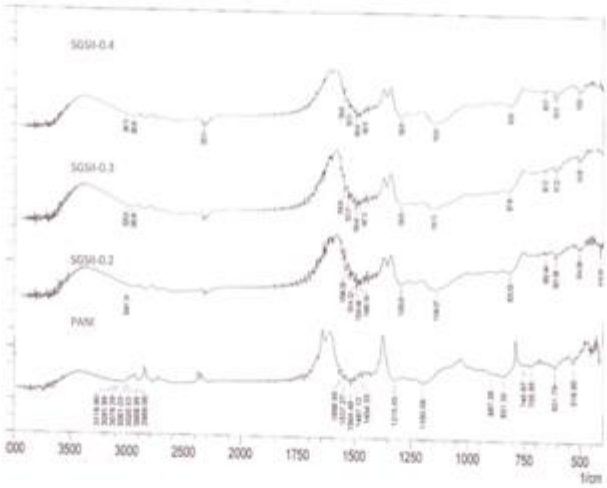


Figure 4: IR Spectra of pure polyaniline and doped polyaniline

XRD

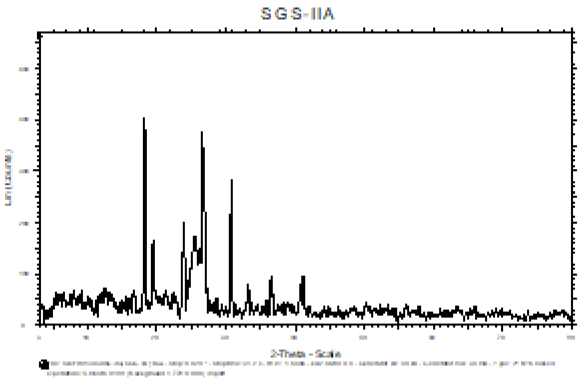


Figure 3.1(a)

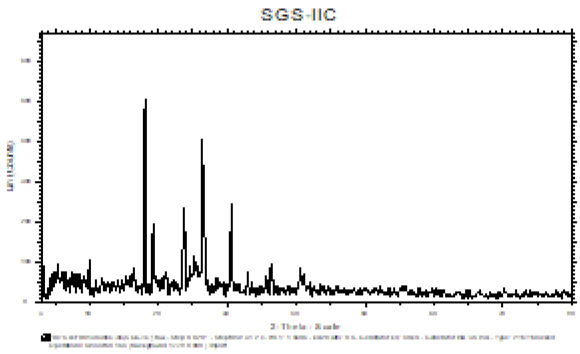
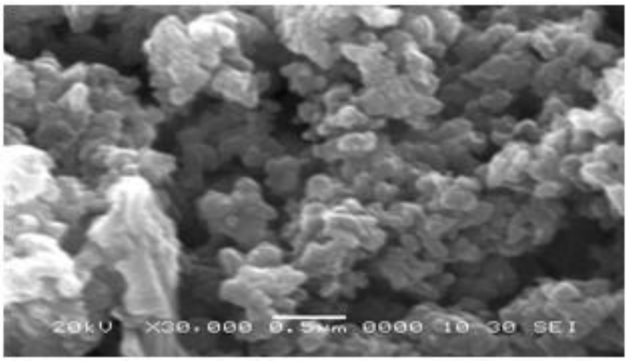
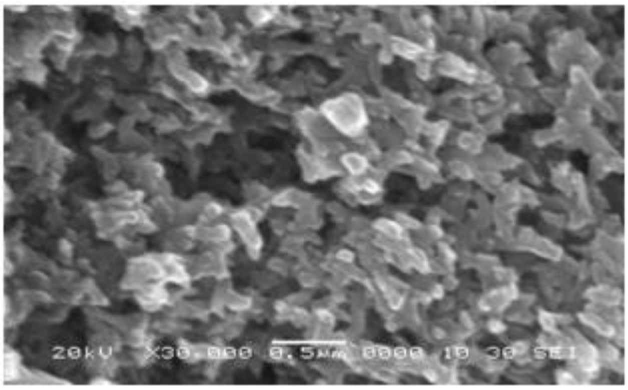


Figure 3.1(b)

Figure 3.1(a) and 3.1(b) shows the XRD pattern of cadmium iodide doped polyaniline. The sharpness in the peak shows semi crystalline nature of the doped polyaniline. The X-RD spectra for doped polyaniline show large variation in the peak. The incorporation of cadmium iodide inpolyaniline, increases crystallinity which indicates the well dispersion of cadmium iodide in polymer matrix. The characteristic peak of polyaniline has been shifted slightly in these composites.

SEM:





From the SEM image it is observed that, grains are well resolved. The morphology of the materials shows agglomerated form of particles and are of irregular nature.

5. Conclusion

The ac electrical conductivity of cadmium iodide doped polyaniline pellets of different wt % have been investigated in the frequency range 20 Hz –
1MHz and temperature range 308-358 K.

From the above studies, it is observed that the σac is frequency and temperature dependent and it follows the equation 2. The ac conductivity follows linearity with frequency. The temperature dependence of frequency exponent 's' was found to decrease with increasing temperature..

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