International e-Conference on New Horizons And Multidisciplinary Applications In Science And Technology
In Association withInternational Journal of Scientific Research in Science and Technology
Volume 9 | Issue 6 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X (www.ijsrst.com)

Investigation of Gamma Irradiation Effects on Conducting Polymer Based Composite

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ABSTRACT

In the present study, novel electrically conducting material polyaniline (PANI) and its composite with metal oxide (MgO) was synthesized by chemical oxidation method using ammonium persulfate as oxidizing agent. Various samples of PANI/MgO composites were prepared by varying the amount of MgO (5, 10, 15 wt% of aniline monomer). The irradiation effect on the prepared PANI based composite was investigated by means of DC electrical conductivity study. The irradiation process was carried out in air in a conventional gamma ray chamber, which uses 60C0 source, and the composite was exposed to gamma radiation dose of 40kGy under varying experimental conditions. The duration of irradiation of the samples by gamma rays were gradually increased from 0 - 8 mins. The experimental results showed that the DC electrical conductivity of the samples was significantly influenced by gamma irradiation.

Keywords: PANI/MgO, XRD, DC conductivity, gamma irradiation

I. INTRODUCTION

In recent years, Conducting polymers have emerged as a very important class of materials because of their unique electrical, optical, and chemical properties leading to the wide range of technological applications. This class of materials provide tremendous scope for tuning of their electrical conductivity from semiconducting to metallic regime by way of doping[1,2]. These characteristics have led to a large number of potential applications such as rechargeable batteries, semiconductor photo-anode production, in light-emitting, etc. In order to modify the transport, optical and mechanical properties of materials for certain applications, dopants are added into the host materials. Composite materials derived from conducting polymers such as polypyrrole (PPy) and polyaniline (PAni), associated with layered inorganic solids, is a line of investigation of increasing interest, not only for producing improved structural materials, but also for the preparation of new functional materials [3]. Gamma irradiation of polymers causes structural and chemical variations, which leads to variation in physical properties of the material. The effects of gamma irradiation on polymers have been first discussed by Charles and Chapiro. The previous authors used interferometric and other tools to study the effects of gamma irradiation on polymers [4].

In the present study, PANI/MgO composite was synthesized by the chemical oxidation polymerization of aniline in the presence of MgO in aqueous medium containing an oxidant. The effect of radiation on PANI/MgO composite was investigated by means of temperature dependent electrical conductivity in the temperature range of 303 - 373 K, with an intention to know the transport behaviour of the composites

II. METHODS AND MATERIAL

Chemicals used were Aniline hydrochloride, Ammonium persulphate and double distilled water for synthesis of PANI. While Magnesium Nitrate Hexahydrate [Mg $(NO_3)_2(H_2O)6$] and Sodium Hydroxide (NaOH) powder for synthesis of MgO powder. All chemicals used were of AR grade of high purity (LOBA Chemicals) in this work. The distilled water and Ethanol (AR grade 99.9% purity) was used as a solvent and washing reagent in the chemical reaction respectively.

A. Preparation of polyaniline (PANI)

Aniline hydrochloride (purum, 2.59 g, 20 mmol) was dissolved in distilled water in a volumetric flask to 50 ml of solution. Ammonium peroxydisulfate (purum, 5.71 g, 25 mmol) was dissolved in water to make 50 ml solution. Thus using above solutions 0.2 M aniline hydrochloride is oxidised with 0.25 M ammonium peroxydisulfate in aqueous medium. Both solution were kept for 1 hr at room temperature, then mixed in a beaker, briefly stirred, and left to rest in order to polymerize. Next day the PANI precipitate was collected on a filter, washed with 100 ml portions of 0.2 M HCl and similarly with acetone and then dried in air

B. Preparation of MgO powder

Initially the Magnesium Nitrate Hexahydrade (purum, 5.21 g, 0.2 M) was dissolved in 200 ml of distilled water. Then (0.8 g, 0.25 M) of NaOH was dissolved in 200ml distilled water. The prepared NaOH solution was added in the solution of [Mg $(NO_3)_2(H_2O)6$] drop-wise, the obtained solution was briefly stirred for 2 hr, and left to rest. The precipitate obtained was filtered and washed several times by using distilled water and Ethanol so as to get the final products. The final product was kept in vacuum oven at 80 °C for 4 hr for drying. This dried powder was then crushed using mortal pestle and calcinated at 400 ^{0} C for 3 hr. The obtained powder has particle size in nano range.

PANI and PANI/MgO samples both were synthesized by chemical oxidation method. Same procedure as that of PANI, was used to synthesize the composite samples with an additional step of adding the MgO into the prepared aniline hydrochloride solution by varying the amount of MgO (5, 10, 15 wt% of aniline monomer). Obtained samples were named as PM1, PM2 and PM3 respectively.

C. Irradiation of PANI/MgO composite

The obtained powders were converted into pellets of 20 mm in diameter and approximately 2 mm thickness by using hydraulic press. The PANI/MgO composite was exposed to gamma radiation from a $^{60}C_0$ source at room temperature in the presence of air.

III. RESULTS AND DISCUSSION

A. DC conductivity analysis

V-I method is used to measure the dc conductivity of the samples. The resistance of the samples is measured at different temperatures from 303-373K by Ohms law method. Initially the conductivity of virgin samples is calculated. Thereafter 15% MgO sample is exposed to gamma radiation for 2, 4, 6, 8 and 10 mins. The 15% MgO sample has maximum conductivity as compared to others.

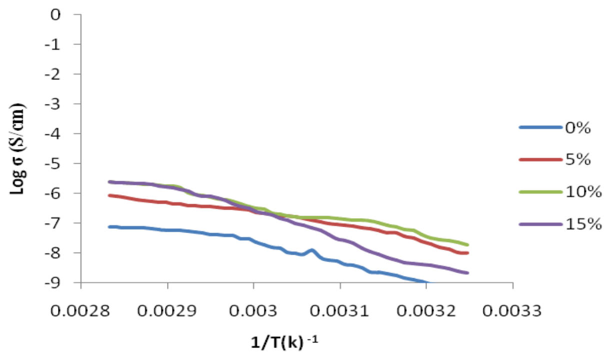
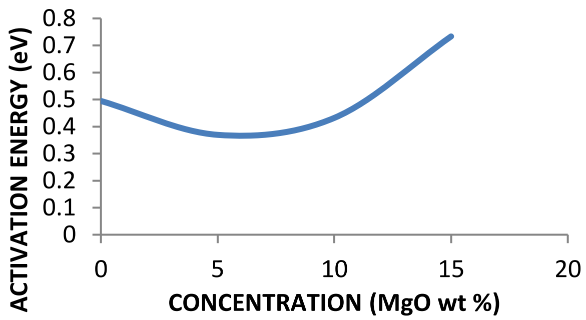


Fig 1: Variation of log σ versus 1/T

From Fig(1) it is observed that conductivity increases with increase in temperature due to increase in mobility of electrons. The curve is linear and its slope gives the value of activation energy. The experimental study revealed that the electrical conductivity of the samples increases with increase in temperature and the graph follows the Arrhenius relation.

$\sigma = \sigma 0 \exp(-W/KT)$

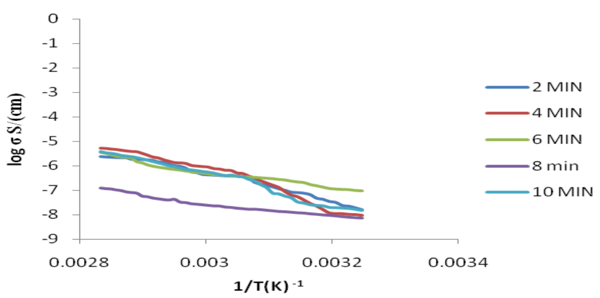
Where σ0 (ohm-cm) -1 is the pre-exponential factor, W(eV) is the activation energy, T(K) is the temperature and K is the Boltzmann constant respectively. From the slope of straight line the activation energy was calculated and plotted as shown in Fig (2).



Fig(2): Variation of activation energy versus concentration

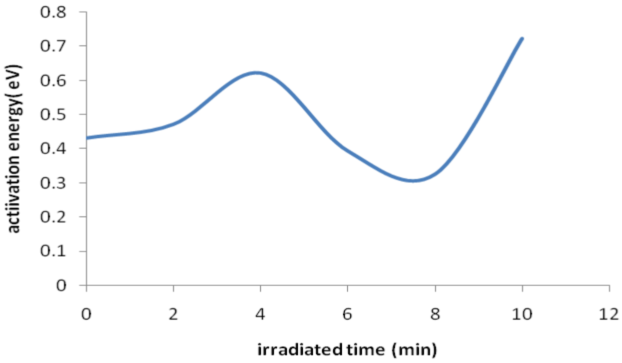
The obtained values of Activation Energy for PANI/MgO samples shows that the activation energy increases with increasing concentration of MgO and is maximum for 15% MgO. In such type of materials hopping of charge carriers through polymeric chains is responsible for the conductivity of sample.

The selected 15% MgO sample was selected and irradiating with gamma source for 4, 6, 8, and 10 min and the obtained results are shown in Fig(3) below,



Fig(3): Variation of log σ versus 1/ T

From Fig(3) it is observe that the sample after irradiation for 6 min. shows the higher conductivity while the sample irradiated for 8 and 10 min. showed lower conductivity. The obtained values of activation energy for PM2 sample using different irradiation time is shown Fig(4) below,



Fig(4):Variation of activation energy versus irradiated time

IV. CONCLUSION

The gamma radiation increases the conductivity of the polymer-composites due to either increase in the charge density of carriers or the mobility of charge carriers. The possibility of increase in the mobility of charge carriers is more. Actually in polyaniline MgO composite the hopping of polarons along the chain and charge transfer mechanism are responsible for conductivity. The gamma radiation dose increases the defect level in the composite which cause to increase the conductivity with higher dose of irradiation the polarons get trapped inside the defects and traps which could require more energy to release from it. Hence the conductivity gets reduced after higher dose.

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