DC Conductivity of γ -Irradiated CuO Doped PANI Nanocomposites

Shranabasamma Amabalagi[1,a)], Mahalesh Devendrappa[2,b)], Balaji Biradar[3], Bharati[4] Manjunath A[5] and Basavaraja Sannakki[6,b)]

[1,2,4,6]*Department of Physics, Gulbarga University, Kalaburagi- 585106, Karnataka.*
[3]*Department of Physics, BVB College, Bidar, 585403, Karnataka.*
[5]*HOD Department of Physics, Govt PU college Shahapur, Yadgir, Karnataka.*

[a)]Corresponding author: shakti6585@gmail.com
[b)]sannakki@rediffmail.com

Abstract. In the present study, CuO doped PANI nanocomposites were irradiated by Gamma (γ) radiation at dose of 8.5kGy. The dc conductivity of PANI and PANI/CuO nanocomposites were studied before and after γ-irradiation. The DC conductivity of the nanocomposites increased and it was ascribed to the creation of vacancies. The Arrhenius plots revealed the decrease in the activation energy from 0.34 eV to 0.31eV for the pure PANI while for the doped ones it has decreased to 0.12 eV and it is ascribed to the creation of vacancies. The conductivity values with increase in weight percentage of CuO in Polyaniline were found to be increased. It is attributed due to extended chain length of Polyaniline which facilitate the hopping of charge carriers.

Keywords: Gamma Irradiation, Nano composites, Dielectric Constant.

INTRODUCTION

The irradiation effects of gamma rays on polymeric materials effect on their structural, optical, electrical and chemical variations that leads to the change in physical properties of Polymeric materials. The effects of gamma irradiation on polymers have been studied earlier by Charles by (1960) and Chapiro (1962). The degradation of the polymer nanocomposites or molecular weight, the generation of free radicals or decrease in the mechanical strength are some of these effects. In order to modify the physical properties of polymers and its nanocomposites for certain applications through ion/gamma (γ) ray irradiation is an expanding field in materials research. When energetic ions/rays traversing in the material media, they lose energy by elastic or inelastic collisions and then impart their energy to the target atoms The irradiation leads to substantial changes because it induces the molecular structure in polymeric materials [1]. The effect of γ-radiation, play a role in the behavior of electrical properties of polymers. 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 [2]. In the present study CuO doped PANI nanocomposites were synthesized and irradiated by gamma rays. The gamma irradiation process was carried out in the air in a conventional γ- chamber and the nanocomposites were exposed to a dose of 8.5kGy. The DC conductivity of both unirradiated and irradiated for PANI and PANI/CuO nanocomposites is studied and also calculated the activation energies for both.

MATERIAL AND METHODS

Synthesis 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 and left 24 hours polymerize completely. The precipitate was filtered, then washed with deionised water and acetone and then dried in hot air oven for 12 hours to get the Polyaniline copper oxide nanocomposite.

The procedure is repeated to synthesize the PANI/CuO nanocomposites at 20, 30, 40 and 50 different weight percentages of Copper oxide. The 250 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 irradiated by gamma radiation in a Gamma chamber using a source of 60Co. The PANI/CuO nanocomposites were exposed to gamma rays at a dose of 8.5KGy at Gamma Agro-Medical Processing Pvt. Ltd, Hyderabad. The unirradiated and irradiated samples were coated with silver paste on both sides of the surface and are used for further studies of dc conductivity.

RESULTS AND DISCUSSION

DC Conductivity: The DC conductivity studies for PANI and PANI/CuO Nanocomposites of 10 wt% to 50 wt% of unirradiated and irradiated of γ –irradiation with dose of 8.5KGy were carried out and is shown in Fig 1.The conductivity varies directly with the temperature, obeying an expression of the following form

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

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 increased for 30 weight % 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 30 wt% is shown in Fig 1(a). 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 [3-7]. After γ -irradiation, the conductivity of the nanocomposites is found to be increased which could be seen in Fig.1(b) the increase in the conductivity is ascribed to creation of vacancies such as oxygen or copper the same could be reflected in the and during irradiation process the charges either get trapped or creation of vacancies. In the trapped phenomena the conductivity of the nanocomposites decreases while when the vacancies increase the conductivity of the materials. After γ -irradiation the conductivity of PANI and PANI/CuO nanocomposites is further increased with weight % of CuO in PANI.

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 [2]

$$\sigma_{dc} = \sigma_o exp\left[\left(\frac{-\Delta E}{kT}\right)\right] \quad (2)$$

The activation energies decreased after irradiation. This was due to the creation of vacancies such as oxygen or copper by the radiation. The activation energy is found to be decreased with increase in the weight percentage of CuO in Polyaniline and after irradiation the values of activation energies are further decreased which could be due to the addition of more carriers to the nanocomposite. The Arrhenius plots revealed the decrease in the activation energy from 0.34 eV to 0.31eV for the pure PANI while for the doped ones it has decreased to 0.12 eV and it is ascribed to the creation of vacancies.

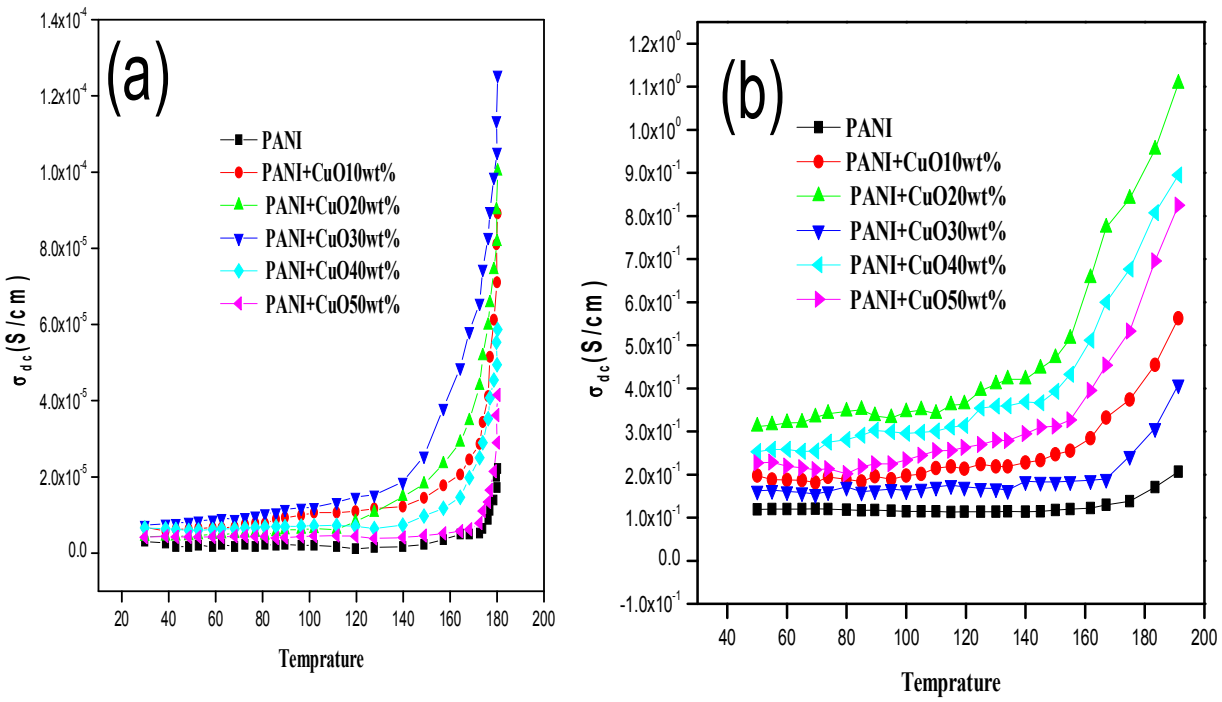

FIGURE 1. Graph of dc conductivity σdc Vs. Temperature (a) Unirradiated (b) Irradiated for PANI and PANI/CuO nanocomposites

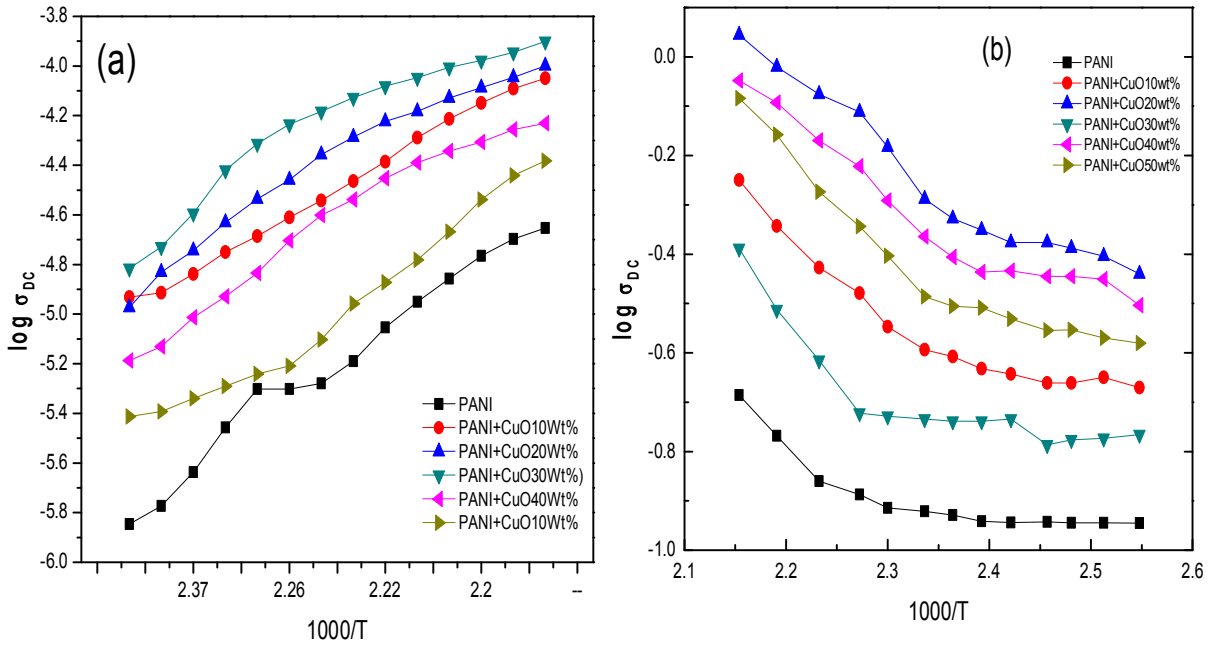

FIGURE 2.Graph of log σdc vs 1000/T (a) unirradiated & (b) irradiated for PANI and PANI/CuO nanocomposites.

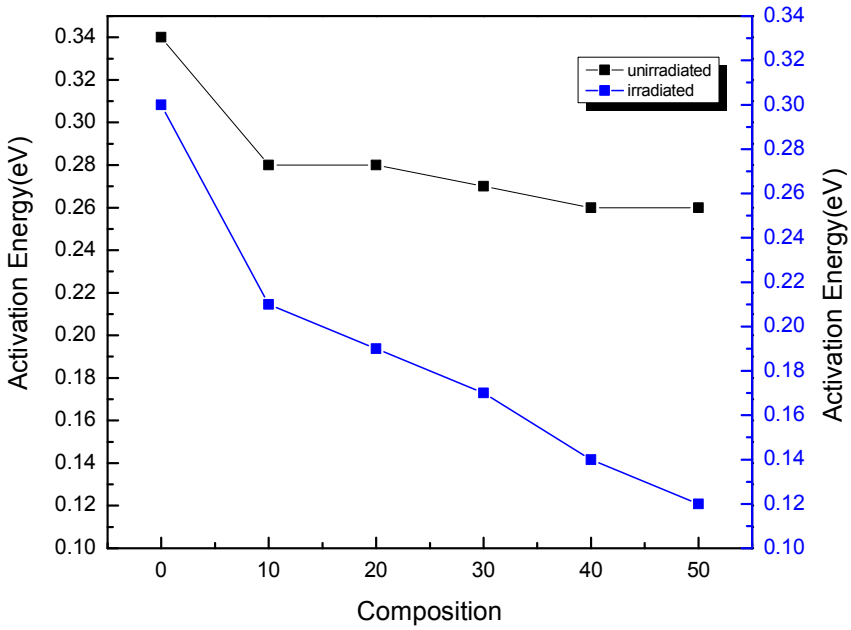

FIGURE 3. Graph of Activation Energy vs Composition of PANI/CuO nanocomposites.

Conclusions

The electrical conductivity in these Nanocomposites shows a strong dependence on content of copper oxide nanoparticles in the Nanocomposites. After the gamma irradiation, it is observed that dc conductivity increased as weight % of CuO increases in PANI and the activation energy decreased after irradiation.

.

ACKNOWLEDGMENTS

The Authors are grateful to the Dept. of Physics, for providing the UGC-BSR fellowship. And also thanks for providing the gamma irradiation facility at the centre Gamma Agro-Medical Processing Pvt. Ltd, Hyderabad.

REFERENCES

1. Orhan Karabulut, Tahir Tilki, Mustafa Yavuz, Abdullah Kaplan, Duygu Takanoglu, Mehmet Cabuk, Seda Dogan. *SDU J. of Sci*. 7112-122 (2012).
2. Zahran, A.H. Ibrahim, E.M., Ezz-Eldin, F.M. and El-Assy, N.B*, Int .J. of Appl. Radiation and Isotopes* **32**, 713-717(1981).
3. S.Raghu, SubramanyaKilarkaje, GaneshSanjeev, G.K.Nagaraja,H. Devendrappa, *Radiation Physics and Chemistry*, **98**, 124-131, (2014).
4. H. Devendrappa. *Radiation Physics and Chemistry* **98**, 124–131 (2014).
5. M. E. Gouda and T. Y. Elrasasi, , *IOSR*-7, issue-**6**, 22-30 (2015).
6. S. A. Nouh & A. S. Abdel-Naby *Radiation Effects & Defects in Solids* **158**,553 – 560 (2003).
7. S.N Mustafaeva, M. M Asadov and A. A. Ismailov, , *Physics of the solid state*, **51**, 2269-2273(2009).
8. S. Fares, *Natural Science*, **3**, 1034-1039 (2011).