Frequency Dependence Electrical Conductivity of PANI and PANI/MWCNTs Composites

Suman Lal[1,2], S. K. Tripathi[2], Rajesh Kumar[3] and Samriti Khosla[1*]

1. Materials Science Research Laboratory, Department of Physics, J.C.D.A.V College Dasuya, Punjab-144205, India, email samritis@yahoo.com
2. Centre of Advanced Study in Physics, Panjab University Chandigarh-160014, India
3. Department of Chemistry, J.C.D.A.V College Dasuya, Punjab-144205

Abstract

In this paper, we synthesized pure polyaniline (PANI) and its composites with different concentrations of multiwall carbon nanotubes (MWCNTs) by using *in situ* chemical polymerization of aniline monomer in the presence of carbon nanotubes. The formation of PANI and its composites are characterized by using characterizing tools Fourier transform infrared spectroscopy (FTIR), scanning electron microscope (SEM) and optical absorption (UV-Vis spectroscopy). These analyses investigate the structural and optical properties of the composites and indicating that carbon nanotubes are well dispersed into polymer matrix. The author also studies the effect of frequency on conductivity of synthesized PANI and its composites.

Keywords: Conducting polymer, multiwall carbon nanotubes, polymer matrix and conductivity.

1. Introduction

The conducting polymers have emerged as a new class of materials because of their unique electrical, optical and chemical properties. Among different conducting polymers, conducting polyaniline is the most extensively studied materials due to ease of synthesis, low cost, good environmental stability, unique conduction mechanism and solution process ability. The unique properties of conducting polymers are the great scope of developing the new models to explain their observed properties, particularly various charge transport mechanism [1-3]. PANI (Polyaniline) is also a suitable candidate for a variety of technological applications such as solar cells, electromagnetic shielding, electrodes for rechargeable batteries, sensors, etc [4-7]. Since the discovery by Ijima [8], carbon nanotubes (CNTs) also have received much attention for their possible use in fabricating new classes of advanced material, due to their unique structural, optical, mechanical and electronic properties. In our study, Polyaniline is taken as matrix materials and MWCNTs used as dopant. Polymerization in presence of Carbon nanotuobes leads to a more planar conformation of PANI along with multi wall carbon nanotubes (MWCNTs). The inculcation of MWCNTs into a polymer matrix also improves the electrical as well as dielectric properties of polymers as compare to basic materials.

2. Experimental

2.1 Materials

AR grade Aniline (99%) and Ammonium persulphate (APS) (99%) are purchased from Sigma Aldrich (used as received). Other supplement chemicals are of AR grade and used as received. The MWCNTs used were synthesized at the National Physics Laboratory by a chemical vapour deposition method.

2.2 Synthesis of Polymers

The chemical oxidative polymerization of aniline is carried out as reported in [9]. At the start of the reaction, 0.1 mol/L aniline are dissolved in 1 mol/L HCL solution. Polymerization reaction is started by drop wise addition of aqueous solution of Ammonium persulphate APS and the reaction is carried out for 8 h at 0^0C-5^0C temperature with constant stirring. The reaction mixture is then kept over a whole night at room temperature, after which the formed polymer precipitate is filtered and washed several times with distilled water thoroughly until filtrate become colourless. Finally, the resultant precipitate is dried in oven for 5 hour to achieve a constant weight and then pressed to form powder. Similarly, PANI/MWCNTs composites are also synthesized by following same steps with different concentration of MWCNTs.

3. Result and Discussion

3.1 FTIR Spectra

The peaks obtained from FTIR spectra are same as studied in literature [10]. It is observed that as compared to pure PANI and PANI/MWCNTs composite shows reduced ratio of benzoid to quinoid intensity indicating the stabilized form of PANI/MWCNTs and possible increase of conductivity.

3.2 Morphological Analysis

Figure 1. Shows SEM images of PANI and PANI/MWCNT composites. The SEM images of PANI/MWCNT

composites (figure 1b and 1c) shows presence of MWCNTs coated with pure PANI. The sorption of the aniline monomer on MWCNTs is possible because of its high surface area [11]. The sorbed monomer then polymerizes to form PANI-coated MWCNTs. This morphology facilitates electron transfer throughout the composite which results in high electrical conductivity.

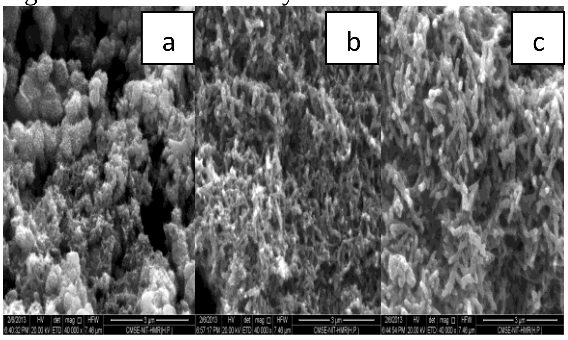


Figure 1. SEM images (a) PANI (b) PANI-0.1% MWCNT and (c) PANI+0.3% MWCNT

3.3 Optical Studies

The characteristics absorption play vital role in the utilization of the materials in the optoelectronic applications. The band gap of PANI and PANI/MWCNTs composites are obtained from Tauc's relation by calculating λ_{max} from UV spectra [12]. The calculated values of the optical band gap for PANI and PANI/MWCNTs composites decrease appreciably but one PANI/MWCNTs composites shows anomalous behavior due to distribution of MWCNTs on pure PANI as shown in Figure 1. This type of behavior is also observed in frequency dependence conductivity measurements.

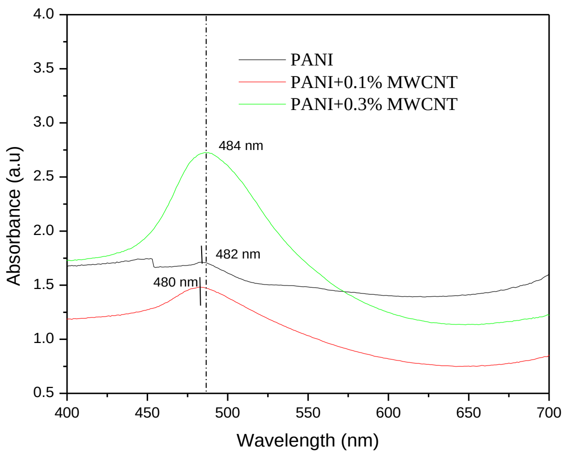
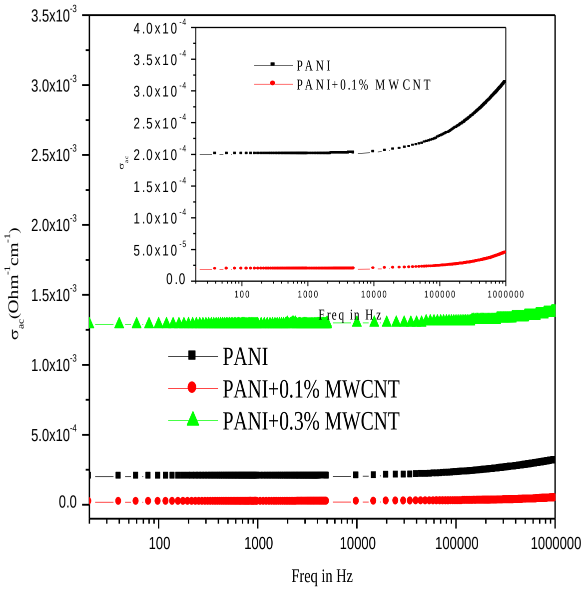


Figure 2. UV-VIS spectra for PANI and PANI/MWCNTs

3.4 Frequency Dependence a.c Electrical Conductivity of PANI/MWCNTs Composites

The electrical conductivity of PANI and PANI/MWCNTs composite sample at room temperature is measured using GWInstek LCR-8110G LCR meter. The Variation of ac conductivity as a function of frequency for PANI and PANI/MWCNTs composites is shown in Figure 3. It is found that ac conductivity for all sample increased with increasing value of frequency, however it



remains constant up to frequency ~5 KHz (as shown in inset). This frequency independent plateau in low region is followed by a high frequency dispersed region in these composites obeyed the power law indicating the universal behavior of the a.c conductivity in disordered media [13]. Among all composites, 0.3% MWCNTs in PANI matrix has provided better conductivity for the conductive paths reflected in the increase of ac conductivity. This high value of conductivity is also due to interfacial polarization. However, in case of PANI with 0.1% MWCNTs composites conductivity value is low in comparison pure PANI because of increase in disorderliness in the composite and hence reduction in the delocalization length. This type of behavior is due to non-uniform distribution of MWCNTs on polymer matrix which do not make conducting bridge.

4. Conclusion

From present study, it is conclude that PANI/MWCNTs composites are successfully synthesized by chemical oxidation polymerization of monomer aniline. The FTIR spectra confirm the synthesis of PANI/MWCNTs composites. The morphological study of PANI/MWCNT composites shows presence of MWCNTs coated with pure PANI. This morphology facilitates electron transfer throughout the composite which results in high electrical conductivity. From optical study, it is observed that the decrease in the optical band gap in PANI/MWCNTs composites (for higher content of MWCNTs) may be due to reduction in the disorder of the system and increase in the density of defect states. The a.c conductivity of PANI/MWCNTs composite increased with increasing value of frequency (above ~5 KHz) due to interfacial polarization.

All these behavior conclude that MWCNTs into PANI matrix improved the charge transport properties of PANI.

Acknowledgement

We are very grateful to Dr. Rajesh K. Mahajan (Principal JCDAV College, Dasuya) for their unlimited help and support. The authors are indebted to UGC for financial support under major research project scheme.

5. References

1. A. J. Hernandez and P. K. Kamloth, *J. Phys. D: Appl. Phys*., 34, 2001, pp. 1700
2. D. Ashis, A. De, and S. K. De, *J. Phys. Cond. Matter*, 17, 2005, 5895
3. J. Mathai, C. Saravanan, S. Anantharaman, M. R. Venkitachalam, and S. Jayalekshmi, *Phys. D: Appl. Phys.*, 35, 2002, pp. 240-245.
4. T. K. Vishnuvardhan, V. R. Kulkarni, C. Basavaraja, and S. C., Raghavendra, *Bull.Mater. Sci., Indian Academy of Sciences*,. 29, 2006, pp. 77-83.
5. W. Chen, L. Xingwei, W. Zhaoquang, and Z., Wenquing, *Appl. Surf. Sci.*, 218, 2003, pp. 216.
6. S. D. Patil, S. C. Raghavendra, M. Revansiddappa, P. Narsimha, and M. V. N. Prasad, *Bull. Mater. Sci.*, 30, 2007, pp. 89-92.
7. L. Chun, and S. Gaoquan, *Electrochimica Acta.*, 56, 2011, pp.10737-10743.
8. S. Iijima *Nature*, 354, 1991, pp. 56
9. P. K. Upadhyay and A. Ahmad, *Chinese Journal of Polymer Science*, 28(2), 2010, pp. 191−197
10. S. B. Kondwar, M. D. Deshpande and S. P. Agrawal, *International Journal of Composite Materials*, 2(3), 2012, pp. 32-36.
11.P. Saini , V. Chaudhary, B. P. Singh,, R. B. Mathur and S. K. Dhawan, *Mater. Chem. Phys*., 113, 2009, pp. 919.
12. K. Gupta, P. C. Jana and A. K. Meikap, *Synthetic Metals*, 160, 2010, pp. 1566-1573.
13. A. N. Papathanassiou, I. Sakellis, J. Appl. Phys. Lett. ,91, 2007, pp. 122911.