Microwave Absorption, Reflection and EMI Shielding Effectiveness of Polyaniline/ Pva-FlyAsh Composites Free Standing Thin Films

[1*]M. Revanasiddappa, [2]D SiddalingaSwamy and [3]S.C. Raghavendra and Y.T. Ravikiran[4]

[1]*Department of Engineering Chemistry, PESIT Bangalore South Campus, Bangalore*
[3]*Department of Science, JSS International School, Albarsha South, Dubai, U A E*
[3]*Department of Electronics Engineering, Ruwais Colleges, Higher colleges of Technologies, Abu Dhabi, U A E*
[4]*Department of PG studies and Research in Physics, Government Science College, Chitradurga,*

***Abstract*- Composites of conducting polymer – metal oxide nano particles are of great interest in modern physical and chemical researchers due to their unique physical and chemical properties, which are distinct from those of the bulk metal and molecules. In this paper we report the conducting polyaniline/ fly ash nano particles blended in polyvinyl Alcohol (PVA) was synthesized by insitu polymerization technique by varied weight % (10, 20, 30, 40 and 50) amount of fly ash cenosphere was added. The Analysis on the electromagnetic wave absorption, reflection and EMI Shielding Effectiveness (EMI SE) of the composites in the X-band (8-12 GHz) is presented. The composites have shown absorption dominated shielding effectiveness (SE) in the X-band. The influence of fly ash nano particle in PANI over the EMI shielding Effectiveness has been studied. The study shows that all the composites have shown excellent microwave absorption behavior confirmed by the EMI Shielding Effectiveness values of the order of –3 to -12dB. Possible applications of new materials and structures for reducing harmful electromagnetic radiation effects and unwanted radiation of electronic devices were discussed**.

Key words: Polyaniline; Polyvinyl alcohol; composites; Fly ash; EMI shielding;

I. INTRODUCTION

The ever developing wireless communication industry demands the requirement of materials capable of providing a large surface area and smart surface at which the microwave transmittance, reflectance and absorbance can be controlled. This issue is addressed under Electro Magnetic Compatibility (EMC). One of the important parameter in recognizing EMI shielding materials is the Electro Magnetic Interference Shielding effectiveness (EMI SE) values in the frequency range of interest [1]. Most polymer resins are electrically insulating. Increasing the electrical conductivity of these resins allows them to be used in other applications. An electrically conductive resin can be used for static dissipative, semi conductive (e.g., fuel gauges, etc.), and electromagnetic interference / radio frequency interference (EMI/RFI) shielding applications (e.g., computer and cellular phone housings, etc.). The advantages of conductive resins as compared to metals (typically used) includes improved corrosion resistance, lighter weight, and the ability to adapt the shielding effectiveness properties to suit the application needs. Electrical resistivity (1/electrical conductivity) values for various materials are typically 10^{14} to 10^{17} for polymers, 10^{-2} for carbon black, 10^{-4} for highly graphitized pitch based carbon fiber, 10^{-5} for high purity synthetic graphite, and 10^{-6} for metals such as aluminum and copper (all values in ohm-cm). One approach to improving the electrical conductivity of a polymer is through the addition of a conductive filler material, such as carbon and metal [2, 3]. Conductive resins with an electrical resistivity (ER) ranging from 10^{10} to 10^{3}ohm-cm can be used for static dissipative applications. Conductive resins with ER ranging from 10^{2} to 10^{1}ohm/cm can be used for semi conductive applications. Those with ER 100 ohm/cm or less can be used for EMI/RFI shielding applications [4].

EMI is electrical energy that is emitted by computer circuits, radio transmitters, fluorescent lamps, electric motors, overhead power lines, lightning, etc. EMI/RFI can interfere with the operation of other electronic equipment near it, such as causing the unwanted operation of garage door openers, corrupting data in computer systems, and causing pacemakers to malfunction. Federal Communications Commission regulations control the amount of energy that can be emitted by an electronic product. The need for EMI/RFI materials is growing due to more stringent regulation on electronic noise, as well as the increased need for smaller, more densely packed electronic components. A shielding material is typically used to encase an electronic product to prevent the enclosed product from emitting electromagnetic or RF energy. The shielding material either absorbs or reflects the energy within the material [5-7]. The present paper highlights the EMI Shielding Effectiveness and electromagnetic wave attenuation behavior of Polyaniline / PVA / Fly ash conducting free standing composite films.

II. EXPERIMENTAL DETAILS: SYNTHESIS OF PANI/FA COMPOSITES

The PANI/FA composites were synthesized according to the literature [8]. Aniline (AR) was purified by distillation before use and ammonium peroxydisulfate $[(NH_4)_2S_2O_8]$, HCl were used as received. A purified fine and fresh (FA) was collected from a local source. The compositions of FA are: silica, alumina, iron oxide lime magnesia and alkalis and different metallic and non-metallic elements [7]. A 0.1 mol of aniline was dissolved in 1000 mL of 2 M HCl to form polyaniline (PANI). Varied wt% amount of FA powder (10, 20, 30, 40 and 50%) was added to the PANI solution with vigorous stirring. A 0.1 mol $(NH_4)_2S_2O_8$ aqueous solution was added slowly with continuous stirring, which acts as the oxidant. The reaction mixture was agitated continuously for another 8 hrs keeping the solution in an ice bath. The precipitate formed was collected by filtration and washed with distilled water and acetone until the filtrate became colorless and free from aniline and SO_4^{2-}. The filtrate was dried at room temperature. The prepared PANI/PVA/FA composites contain 10%, 20%, 30%, 40%, and 50% by weight of FA in PANI.

III. PREPARATION OF FREE-STANDING FILMS

Polyethylene petri dishes were pre cleaned with deionized water and dried at room temperature. Free-standing films (40 – 60µm) were prepared by casting the conducting blend solution (PANI/PVA and PANI-Fly ash/PVA) onto the polyethylene petri dishes using a solution casting method. The films were thoroughly dried on a flat surface at room temperature for a period of 1 − 2 days and kept in silica gel filled desiccators before the measurement. For preparation of PVA films, the fully dissolved 5% PVA aqueous solution was cooled from 80° C to room temperature, and then cast into films using the same procedures as for the blends. The preparation steps for freestanding films are shown in Figure 1.

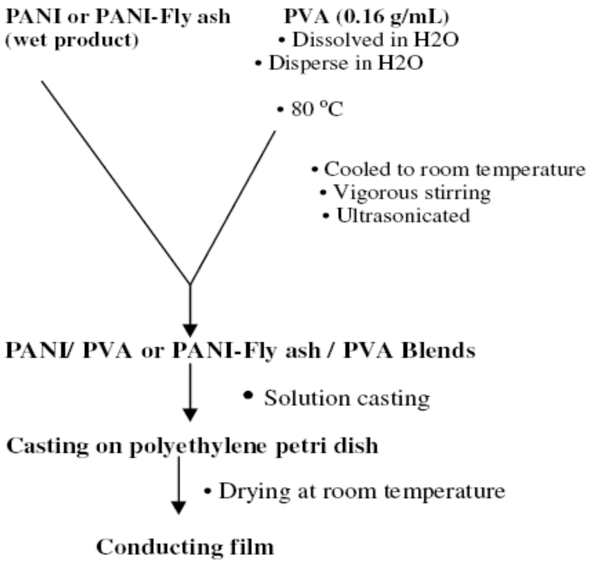

Figure 1. Preparation of PANI/PVA and PANI-Fly ash/PVA blends into conducting films

PANI/PVA/FA free standing conducting film composites thus synthesized were cut into rectangular shape of standard X-band wave guide dimension (WR-62) to clamp exactly between the wave guide adapters of Vector Network Analyzer. EMI shielding analysis was carried out using the complex S parameters in Vector Network Analyzer (HP 8510) by Transmission Line Technique.

From the measurement of S-parameters, the absorption coefficient and the shielding efficiency of the material were calculated. The sample sheet was clamped tightly between two coaxial waveguide adapters. Using the vector network analyzer, the S-parameters, S11 and S21, were measured. Reflection coefficient, R, and transmission coefficient, T are given as $R = |S11|^2$ and $T = |S21|^2$ .The absorption coefficient, A, can be obtained from the simple relation A + R + T = 1. The EMI shielding efficiency, SE, is defined as the ratio of the power of the incident wave P_I to that of the transmitted wave P_T [9]:

$$SE = 10 \log_{10} (P_I/P_T) \qquad (1)$$

IV. RESULTS AND DISCUSSIONS

Figure 1, shows the Electromagnetic Interference Shielding Effectiveness (EMI SE in dB) versus frequency for different weight percentage (wt%) of Polyaniline-Polyvinyl alcohol-fly ash composites. There is a stabilized increase in observed EMI SE with increased weight percentage of fly ash. Except for few range of frequencies, EMI-SE of composites is independent of frequency within an average shielding effectiveness of -3.5 to -12.5 dB. It is also reported that EMI-SE of a composite depends not only on conductivity, but also on permittivity of the composite. Thus the composition of the sample, nature of the dispersed phase, its particle size and shape etc are important factors and can affect the EM radiation absorption and EMI-SE [10].

Here the higher shielding efficiency observed for the composites may be attributed to the action between the magnetic and electric dipoles present in the composites and the enhancement of this dipole effect in the presence of fly ash cenosphere particles in polyaniline / polyvinyl alcohol molecular chains. Also, higher interfacial area provided by the fly ash cenosphereparticles in PANI molecular chains can also contribute such effective electromagnetic wave attenuation. Altogether the composites show very effective shielding in the entire X-band.

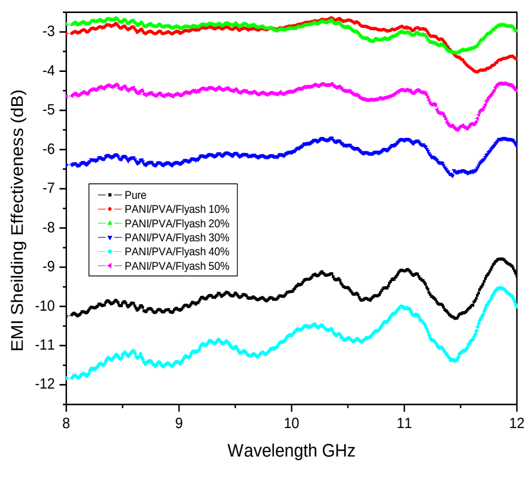

Figure 1.Variation of EMI Shielding Effectiveness with Concentration (wt %) of Fly ash

V. ABSORPTION COEFFICIENT

Variation of absorption coefficient of the Polyaniline / Polyvinyl alcohol / Fly ash free standing conducting film composites with different weight percentage amount of fly ash atX-band frequencies is given in Fig. 2. Fig. 2 shows that the absorption coefficient increases with the fly ash content in the sample but the trend remains the same. The behavior of electromagnetic absorption will critically depend on the dielectric and magnetic properties of the materials that are represented by the complex permittivity and complex permeability [11].

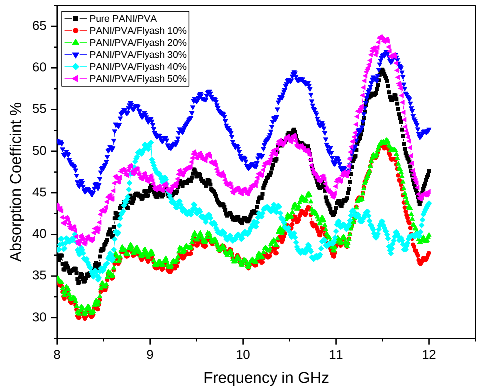

Figure 2. Variation of absorption coefficient with Concentration (wt %) of Fly ash at X-band frequencies

VI. REFLECTION COEFFICIENT

The variation in the reflection coefficient of the Polyaniline / Polyvinyl alcohol / Fly ash free standing conducting film composite for different concentration of cenosphere particles at X-band frequencies is given in Fig. 3. The variations in reflection coefficient with X-band frequencies showsimilar behavior. Reflection seems to be very frequency specific. As the concentration of cenosphere particles increases, the reflection also increases but the trend is maintained up to 30% amount of cenosphere fly ash particles. The matching condition can be explained by the cancellation of the incident and reflected waves at the surface of the absorber [12]. Similar peaks and dips have been reported by Phang et al. for polymers [13].

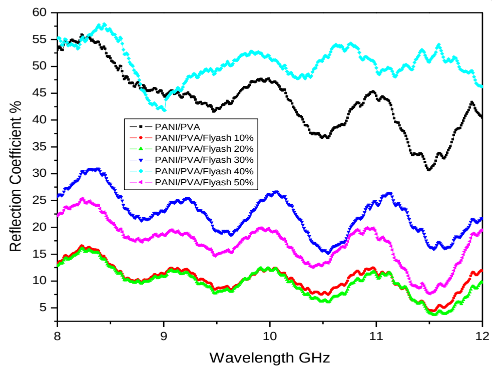

Figure 3. Variation of reflection coefficient with Concentration (wt %) of Fly ash at X-band frequencies

VII. CONCLUSIONS

The conducting polymer composites have been synthesized by in situ polymerization technique by the incorporation of cenospheres in PVA dispersed polymer matrix. The electromagnetic shielding effectiveness of the synthesized free standing conducting PANI/PVA/FA composite films was measured using the Vector Network Analyzer. The results of the measurements show that the concentration (wt %) of cenosphere (fly ash particles) have major role in enhancing the EMI-SE of the composite films. Our study leads us to conclude that PANI/PVA/FA polyblend matrix possesses better EMI-SE properties.

ACKNOWLEDGEMENT

The authors acknowledge Visvesvaraya Technological University, Belgaum for providing financial assistance in the form of a research project (Project No.:VTU/Aca-RGS/2008-2009/7190 dated 03 Oct. 2008).

REFERENCES

[1] Salvatore Celozzi, Rodolfo Araneo, GiampieroLovat, Electromagnetic Shielding, Wiley-Interscience, 2008.
[2] J.-B. Donnet, R.C. Bansal, and M.-J. Wang, *Carbon Black*, 2nd ed., Marcel Dekker, New York (1993).
[3] J.-C. Huang, *Adv. Polym. Technol.*, **21**, 299 (2002).3.
[4] D.M. Bigg, *Polym. Compos.*,**8**, 1 (1987).4.
[5] D.R.J. White, A Handbook Series on Electromagnetic Interference and Compatibility, Vol. 5, Don White Consultants, Germantown, MD (1971).
[6] "Measuring the Electromagnetic Shielding Effectiveness of Planar Materials," ASTM Standard D 4935-89 Reapproved 1994, American Society for Testing and Materials, Philadelphia, PA (1996).
[7] W.C. Bushko, V.K. Stokes, and J. Wilson, Proceedings of the Society of Plastics Engineers Annual Technical Conference, New York, 1499 (1999).
[8] S. C. Raghavendra, S. Khasim, M. Revanasiddappa, M. Prasad, and A. B. Kulkarni, Bull. Mater. Sci. 26, 733 (2003).
[9] Mathew KT, Praveen Kumar AV, Honey J. Polyaniline and polypyrrole with PVC content for effective EMI shielding. In: IEEE international symposium on electromagnetic compatibility; 2006. p. 443–5.
[10] P.K.Pramanik,T.N.Saha, D.Khastgir, J. Elastomers Plast. 23(1991) 345.
[11] Truong VT, Riddell SZ, Muscat RF. J Mater Sci 1998; 4971–4976:33.
[12] Yusoff AN, Abdullah MH, Ahmad SH, Jusof SF, Mansor A A,Hamid SAA. J ApplPhys 2002;876–882:92.
[13] Phang SW et al. Thin Solid Films 2005; 477:125–30.