Grenze International Journal of Engineering and Technology, June Issue

Polymer Conducting Nanocomposite Film to Improve Electromagnetic Compatibility of Electronic Devices

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***Abstract*—This article presents the analysis of polymer conducting nanocomposites (PCNC) to improve the electromagnetic compatibility of various electronic equipment. PCNC has been fabricated using the reduced graphine oxide (rGo) as a filler, and poly (vinylidene fluoride-co-trifluoroethylene) [P(VDF-TrFE)] polymer as insulating polymer matrix. Simplest and efficient method of solution casting was used for fabrication purpose. The obtained nanocomposite films were characterized for surface structure using Scanning Electron Microscopy (SEM) technique. The dielectric parameters were obtained in the frequency region of 10KHz to 1MHz accordingly the shielding effectiveness was calculated using the dielectric parameters. The developed sheets are cost effective, flexible and showing excellent EMI shielding properties around 30dB for shielding of various electronic equipment to enhance their electromagnetic compatibility.**

***Index Terms*— Nanocomposite, Electromagnetic Interference, Solution casting, Shielding effectiveness, flexibility.**

I. INTRODUCTION

Nowadays various electronic devices are used in close vicinity to each other. The electromagnetic interference (EMI) which occurs due to interference in electrical and magnetic fields of electronic devices could disturb the functioning of any device as well as can interrupt the working of other devices in same confined space, which can be dangerous [1,2,3]. Various studies shown that there has been rise in number of calamity due to EMI. These calamities are mostly found in an environment where so many electronic devices are working at the same time [4] as noted by rathi et al. To tackle with this problem, the manufacturing companies of electronic devices putting their constant efforts. They want to fortify the safety features of electronic devices to the effects of electromagnetic radiations (EM). The solution of this problem is to offer a shielding for EM radiations. By shielding a device, electromagnetic compatibility of the device can be improved. To guard any electronic device, we need to stop the transmission of EM radiation through a shield called EMI shield.
Electrical conductivity is most significant requirement of EMI shield. We know that all metals are very good conductor of electricity. So they are assumed to be perfect source of protection against EMI waves. But they have some limitations also, like heavy weight, rigid and rusting nature. In today scenario, an alternative is used,

Grenze ID: 01.GIJET.9.2.809

which is a polymer based conducting composites. They are considering to be best substitute for EMI shielding over metals [5,6]. Polymer composites are light in weight, flexible, non-corrosive and very cost effective which make them good choice for creating an EMI shield. Conducting polymer composites are fabricated by adding conducting fillers within the insulating polymer matrix. Fillers are added to insulating polymer matrix using techniques like blending, casting, in sites, polymerization etc. These conducting fillers then form conducting channels in polymer matrix to allow the electrons movement. The conducting polymer composite enhance the ability of material to shield EM waves known as EMI Shielding Effectiveness (SE). SE is expressed in dB (SE dB). It is expressed as sum given from reflection, absorption & multiple reflection [7,8]. So, it can be concluded that

$$SE = A + R + CF. \qquad (1)$$

This relation helps in understanding the shielding effect. Here, A is absorption loss, R is reflection loss CF is loss to multiple reflection in the shield.

Nowadays, to resolve the problems of thickness & flexibility we need to fabricate flexible polymer conducting nanocomposite (PCNC) film. For present work poly (vinylidene fluoride-co-trifluoroethylene) [P(VDF-TrFE)] has been used for matrix material & reduced graphene oxide (rGo) has been used as a conducting filler. P(VDF-TrFE) have many features, like its flexibility, easily process able, and of light weight in comparison to other materials [9,10]. It is a ferroelectric copolymer that have a large dipole moment and dielectric constant. rGo is used as a filler due to its property of easy soluble and cost effectiveness, Other main advantages of rGo is that they are efficient in making EMI shield films & they have capability to form thin nano-composites. Different compositions of P(VDF-TrFE)/rGo composite were fabricated with different concentration of rGO as 5wt%, 10wt% and 15wt% so we obtained the films with composition as 95/05 , 90/10 and 85/15 respectively. using solvent casting method. The dielectric properties of the fabricated films were measured as the function of frequency (10KHz to 1MHz) by network analyzer accordingly the SE of the films was calculated. Scanning Electron Microscopy (SEM) was used to get the idea of fabricated film's surface morphology. Mechanical strength of the films was measured to get the idea of flexibility of the films.

II. EXPERIMENTAL

A. Materials

The PCNC films were developed using the polymer P(VDF-TrFE) (99.9 % pure) powder purchased from Piezotec Arkema group. The polymer molecular weight was 200,000 g/mol. rGo was used as the conducting filler having product ID-777684, in powdered form as solutes and for dissolving the solutes and N-N,-Dimethylformamide (DMF) was used as solvent to form a heterogeneous solution. The items were purchased from Sigma Aldrich, India.

B. Fabrication of Nanocomposite Film

The simple and effective technique of solution casting was used to develop P(VDF-TrFE)/rGo PCNC. Fig. 1 describe the process of solution casting method. Firstly the P(VDF-TrFE) is dissolved with DMF in a glass tumbler. The combination of P(VDF-TrFE) and DMF was heated at a temperature of around 80^{O}C for approx 2 h with a stirring speed at 400 rpm so that we get a homogenous solution. After this rGo with different ratio is added in that solution, the obtained solution was again heated at 50^{O}C for around 5 h. Acquired uniform solution is transferred into a glass petri dish and allowed to heat slowly so that solvent can be removed from the petri dish. Once the films are completely dried, the films can be unwrapped from the petri dish. The same process of fabrication was repeated for the different concentration of rGO as 5wt%, 10wt% and 15wt% so we obtained the films with composition P(VDF-TrFE)/rGo as 95/05 , 90/10 and 85/15 respectively.

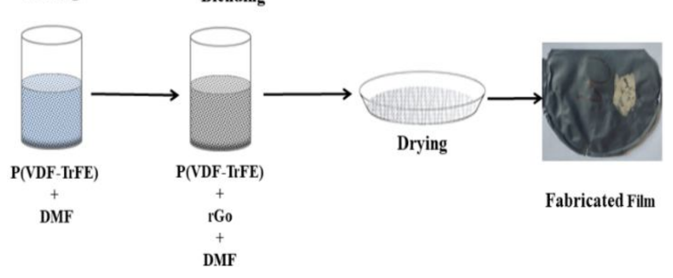

Figure 1. Fabrication process of Composite Film

III. RESULTS AND DISCUSSION

A. Surface morphology of composite films

With the help of SEM images we get the idea of surface morphology of the fabricated CPNC. Fig. 2 shows the SEM images of fabricated films. Fig. 2(a) shows the morphology of pure P(VDF-TrFE) we can see the spotted grain structure like surface of the film as reported earlier [11,12]. Fig. 2(b) and 2(c) shows the SEM image of 90/10 and 85/15 respectively. We can see the effect of rG0 on the surface, clearly the conducting channels can be seen on the surface of P(VDF-TrFE) as concentration of rGo increases the conducting channel increases.

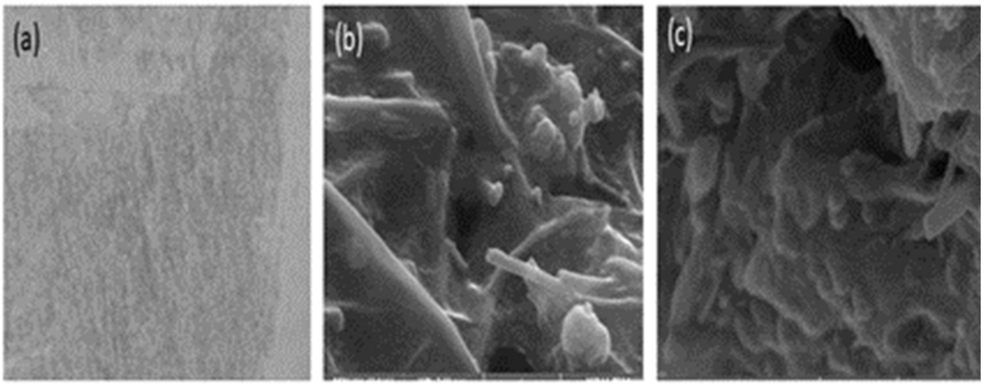

Figure 2. SEM images of (a) pure P(VDF-TrFE); (b-c) SEM images of composition 90/10, 85/15 of P(VDF-TrFE)/rGo respectively

B. Dielectric analysis

SE of fabricated CPNC samples was calculated with help of dielectric parameters in the frequency range of 10 KHz to 1 MHz. Conductivity (σ) and Dielectric constant (ϵ′) of the fabricated CPNCs are shown in Fig. 3(a) and (b) with respect to the frequency. SE of the films mainly depends on conductivity, it is clear from the graph that conductivity of film with 85/15 P(VDF-TrFE)/rGo ratio is maximum and the film with composition 95/05 P(VDF-TrFE)/rGo has smallest value of conductivity. The main cause for this is the formation of various conducting channels between the interfacial area of polymer matrix, which increases the dipole moment. Dielectric constant of the films also calculated and it is maximum for film with 15% of rGo.

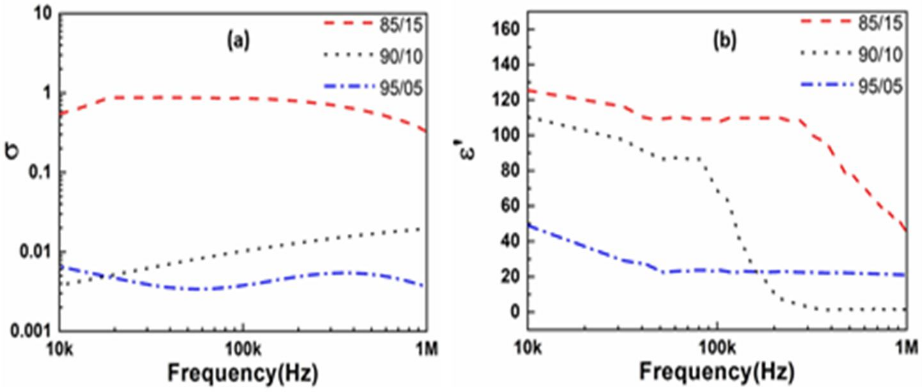

Figure 3. (a) Conductivity; (b) Dielectric constant of fabricated films

C. Mechanical Properties

The mechanical properties analysis gives the idea about the performance of the fabricated films when the films are lay open to stretching or pulling force before it fails [13]. The mechanical properties of films with combination labels 85/15,90/10,95/05 are depicted in the stress – strain diagram shown in Fig. 4. From the graph we can observe that 85/15 is the most brittle among these films and 95/05 is the most ductile material. The toughness of the films will depend on area under the curve in stress – strain diagram which is different for all hence, the toughness for them will also be different. The film with composition of 90/10 is the most satisfactory material according to the graph but still we can see the composition 85/15 have flexibility of 0.7mm and can bear a load of around 1.5 MPa however as the concentration of conducting filler decreases the flexibility and mechanical strength of the films increases.

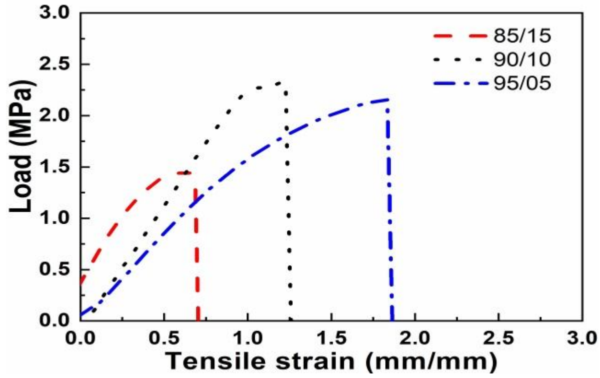

Figure 4. Shielding Effectiveness of obtained films

D. EMI Shielding Analysis

We have already described that SE can be measured with the help of A, R and CF. Total value of SE of P(VDF-TrFE)/rGo is presented in Fig. 5. We can see from the figure that the SE value increased with increase in rGo content and decreased with frequency generally. The CPNC having 15 wt% of rGo filler content showed maximum value of SE. The maximum value of 36 dB at 10KHz was attained for 15 wt% of rGo in P(VDF-TrFE)/rGo conducting polymer composite. The film with 5wt% of rGo the SE is low it is around 10dB for examined frequency region. After the concentration of 15wt% of rGO there is no significant increase in SE, so that should be its percolation threshold level.

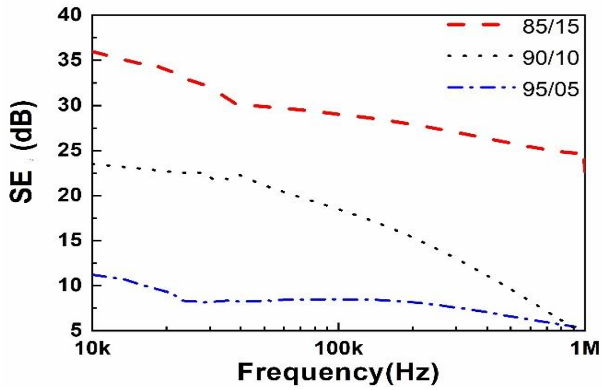

Figure 5. SE of obtained films

IV. Conclusion

In the presented work thin, cost effective and flexible composite sheets have been developed for EMI shielding application. As we increase the content of filler in the composition of film the SE of films get increases as well. With the study of dielectric and SE analysis, we can say that the CPNC with 15wt% of rGo is giving most suitable result as, it's SE is highest and it is in between 36dB to 25dB for examined frequency range of 10khz to 1Mhz. It conductivity is also highest among other fabricated CPNC. Also the mechanical properties of CPNC with 15wt% of rGo is satisfactory. This is also clear from SEM images that the rGo filler distributed evenly through P(VDF-TrFE) polymer matrix. The fabricated P(VDF-TrFE)/rGo composite film has a very good prospect to be used as a flexible EMI shielding film to increase the electromagnetic compatibility of various electronic equipment.

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