Polyaniline Based Materials for Efficient EMI Shielding

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Abstract

Development of conducting polymers with wonderful electrical and optical properties witnessed significant progress in the last decade. Polyaniline (Pani) has received much attention because of its unique reversible proton doping, high electrical conductivity ease of preparation and low cost. The demand of high quality materials for electromagnetic compatibility is alarmingly increasing. Conventional microwave absorbing materials such as carbon and graphite in the powder form were blended with polyaniline as base at different proportions and microwave properties such as Absorption, Transmission and Shielding Efficiency were evaluated from S parameter measurements. The new material exhibits very good electromagnetic interference shielding efficiency compared to previously developed Pani based composite and is a potential candidate for EMI shielding applications.

1. Introduction

Conducting polymers have a variety of applications in the Industrial, Scientific and Medical (ISM) fields. Applications like anticorrosion, static coating electromagnetic shielding etc comes under first generation. Second generation of electric polymers have applications such as transistors, LEDs, solar cells batteries etc. Controlled conductivity, high temperature resistance, low cost and ease of bulk preparation make these materials attractive in the engineering and scientific world. Polypyrrole (Ppy) and polyaniline (Pani) are especially promising for commercial applications because of their good environmental stability, facile synthesis, and higher conductivity than many other conducting polymers [1-2]. Polyaniline has received much attention because of its unique reversible proton doping, high electrical conductivity, ease of preparation and low cost. The demand of high quality materials for electromagnetic compatibility is alarmingly increasing. We have developed a variety of polyaniline based materials and a detailed microwave study was carried out. Since this paper is intended to establish the effect of conducting polymers in electromagnetic interference shielding, stress is made in the measurement of dielectric parameters and S parameters at microwave frequency. Conventional microwave absorbing materials such as carbon and graphite in the powder form were blended with polyaniline at different proportions and microwave properties such as Absorption, Transmission and Shielding Efficiency were evaluated from S parameter measurements. These properties were compared with results of polyaniline PVC compound already developed for EMI shielding. The new materials developed exhibit greater electromagnetic interference shielding efficiency compared to Pani- PVC composition [3].

2. Experimental Set up and Theory

Chemical oxidative polymerisation of aniline is carried out using ammonium per sulphate as initiator in the presence of 1 M HCl at room temperature. Reaction is carried out for 4 hours. Detailed preparation technique is described else where [3]. Blending materials carbon black and graphite and other chemicals with high A R grade were procured from E.Merk (P) Ltd Mumbai. Polyaniline and carbon powder are blended at 5:1, 5:2, 5:3, and 5:4 ratio. Machine blending was used for perfect mixing. Since microwave measurement was made in the S band frequency of ISM band with wave guide dimensions (a x b) 34mm x 72mm, a perspex holder with the above dimensions was constructed to fill the composite for measurement [1].

The sample holder is kept between two coaxial to wave guide adapters and tightened and then connected to Agilent 8714 ET network analyzer. The network analyzer is the calibrated for measurement and calibration can be stored for measurement for a later time. Scattering parameters (S_{21}) and (S_{11}) of the sample are measured.

Samples of varying thickness are studied using containers of thickness 2.5 mm, 5.0mm, 7.5mm and 10.0 mm at the S-band of microwave frequencies. From the measured data, absorption coefficient A and shielding efficiency SE of the material samples are evaluated.

From the basic theory of wave propagation through matter the amount of electromagnetic energy reflected and transmitted when incident on the sample material is related by the Reflection coefficient R and Transmission coefficient T. These are related to the S parameters as R= $|S_{11}|^2$ and T = $|S_{21}|^2$ .The absorption coefficient A can be obtained from the simple relation A+R+T = 1 indicating that the absorbed power is A = 1-(R+T). If the absolute absorbing capability of a material for a given incident power is the main objective it is necessary to minimize the reflection of the incident energy. Microwave oven is an example. That is why metallic containers are avoided for mw cooking. But for cases like e m shielding main goal is to minimize the penetration of electromagnetic energy. Under such condition non conducting shielding material with high reflection coefficient is a good choice. The EMI shielding efficiency SE is defined [4] as the ratio of the power of the incident wave P_I to that of the transmitted wave P_T

$$SE = 10 \log (P_I / P_T) \text{ dB} \quad (1)$$

Dielectric conductivity σ_e is related to the dielectric loss ε''_r by the expression[5]

$$\sigma_e = \omega\varepsilon'' = 2 \pi f \varepsilon_0 \varepsilon_r'' \quad (2)$$

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This argument supports the validity of expression [5] for absorption coefficient A= $\varepsilon_r''f/nc$ suggesting that microwave absorption increases as dielectric loss increases. This can be easily verified by measuring the dielectric loss ε''_r (the imaginary part of complex permittivity) using the conventional cavity perturbation technique [6].

3. Results and Discussions

In this section the microwave reflection, microwave absorption, EMI shielding and skin depth of poly aniline based composite are analyzed.

3.1 Reflection of Pani based composite

The variation of the reflection coefficient of the Pani-Carbon (PC), Pani-Graphite (PG) composites and Pani alone for different thickness at S band frequencies is given in Fig 2.

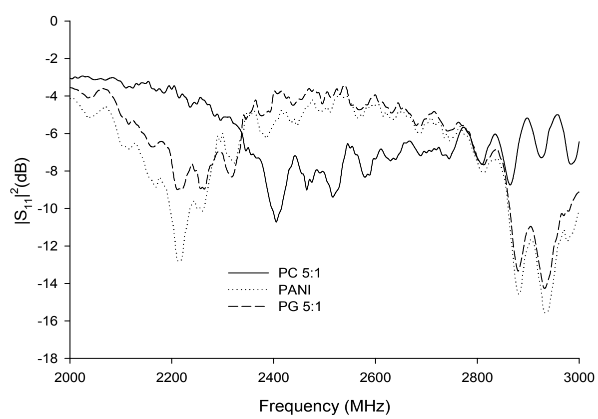

Fig 2. Variation of Reflection coefficient for 5mm thickness

Basic theory states that minimal reflection of the microwave power or matching condition occurs when the sample's thickness, 't' of the absorber approximates to a quarter of the propagating wavelength multiplied by an odd number, that is t $= n\lambda / 4$ (n=1, 3, 5, 7, 9,. . .), where n=1 corresponds to the first dip at low frequency. The propagating wavelength (λ) in the material is given by:

$$\lambda = \lambda_0 / \left(\left| \mu_r^* \right| / \left| \varepsilon_r^* \right| \right)^{1/2} \qquad (3)$$

where, λ_0 is the free space wavelength and $|\mu_r^*|$ and $|\varepsilon_r^*|$ are the moduli of μ_r^* and ε_r^* respectively. The matching condition can be explained by the cancellation of the incident and reflected waves at the surface of the absorber. The minimum reflection loss or the dip is due to the minimal reflection or maximal absorption of the microwave power for the particular thickness of the sample. The position and intensity of dip are sensitive to the thickness [9]. It is observed that in the frequency range 2000M Hz -2350 MHz and 2800 MHz-3000MHz PC composite has high absorption while Pani and P G composite exhibit good reflection between 2350 MHz and 2800 MHz frequency.

3.2 Absorption of Pani based composite

Microwave absorption of different combinations of carbon and graphite with Pani is shown in Table 1 for two thicknesses.

Frequency (MHz)	Thickness (5 mm)			Thickness (7.5 mm)		
	PANI	PC 5:1	PG 5:1	PANI	PC 5:1	PG 5:1
2200	0.905	0.566	0.817	0.888	0.606	0.828
2300	0.731	0.692	0.793	0.675	0.680	0.840
2400	0.701	0.897	0.572	0.618	0.810	0.618
2500	0.636	0.820	0.592	0.658	0.864	0.630
2600	0.610	0.774	0.572	0.640	0.821	0.584
2700	0.675	0.769	0.666	0.696	0.787	0.670
2800	0.764	0.790	0.767	0.813	0.807	0.768
2900	0.821	0.672	0.823	0.779	0.693	0.838
3000	0.792	0.742	0.785	0.729	0.740	0.779

Table1. Absorption coefficient of different composites for 5mm and 7.5 mm thickness

It is clear that the absorption of e m wave varies with frequency. The absorption has the reverse effect of reflection. In other words at the lower and upper frequency ranges the absorption of energy is high for Pani and Pani-graphite composites while at these ranges the Pani-carbon composite has low absorption values. But the 2400MHz - 2800 MHz range shows high value of absorption. These effects will not be changed with thickness of the sample material.

3.3 Transmission coefficient

Variation of transmission coefficient with frequency for three composites is shown in Fig.3. From graph it is clear that Pani-Carbon composite is the best choice for electromagnetic shielding applications. This can be further confirmed by studying the shielding efficiency SE of this composite. In the whole frequency range of our observation Pani-Carbon composite has minimum transmission coefficient. The result is verified for other combinations and thickness of the composite.

3.4 Shielding Efficiency

Variation of EMI shielding efficiency of optimum Pani composite for different thickness at S band frequencies is given in Fig 4. Higher the SE value in decibel (dB), lesser the energy passing through the sample. All measured SE is the combination of the electro magnetic (EM) radiation, i.e. reflection from the material's surface, absorption of the EM energy and multiple internal reflections of the EM radiation. From the graph it is clear that Pani-Carbon composite has the highest EMI shielding efficiency.

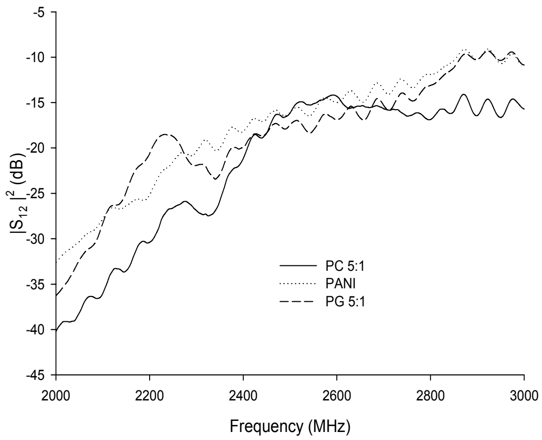

Fig.3 Variation of Transmission coefficient for thickness 7.5 mm

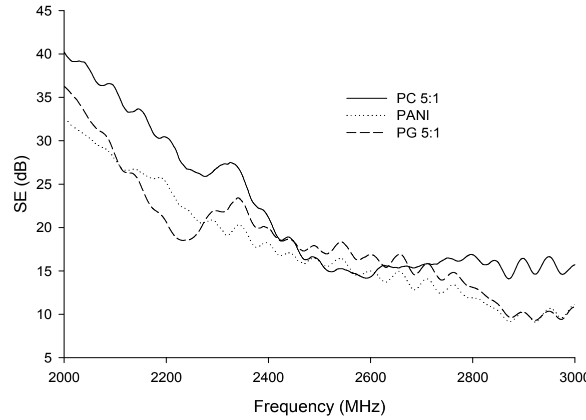

Fig 4. Shielding efficiency for different composites

4. Conclusions

An exhaustive study of different polyaniline based composites clearly reveals that these composites can be efficiently used as EMI shielding materials. These materials find applications in mobile phones for reducing specific absorption rate (SAR). Because of its high EMI shielding efficiency it can be used in electromagnetic compatibility study. It can be used as a material for anechoic chamber.

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