Suitable materials selection that act as a retardant agent against microwave radiation and electronics packaging to human life

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Abstract. Recently there is a high attempts to investigate the possibility of protecting human body from microwave radiation and electronics packaging. In this study an electromagnetic radiation shielding film by reflecting and/or absorbing the incident wave were prepared as a promising solution. Basically PVC and iron oxide nanoparticles were synthesized using solution casting method to make the protection film. Analysis via VNA has been conducted to understand the shielding behaviour during the exposure to the radiation. The prepared films exhibit ability of absorbing microwave radiation in the range of 8 GHz – 11 GHz, with a maximum value of -10 dB at 30 wt. % of iron oxide nanoparticle. Furthermore, microwave absorption performance can be improved by putting two layers or more in order to increase the thickness of the shield. It is suggested that the results are mainly attributable to good effective properties of iron oxide and their homogeneous dispersion in the PVC matrix, also from the analysis it will propose the optimum solutions for this problem.

1 Introduction

Since microwave is an electromagnetic radiation, it is a combination of two types of wave energies electrical energy and magnetic energy, move together in the spaces. It stays between the range of Radio and IR spectrums with about 300 MHz to 300 GHz as its frequency range and 10 mm to 100 μm as range of wavelength [2]. It can be generated from many different sources such as antennas and vacuum tubes, also there is natural source sun generate microwave radiation within its electromagnetic (EM) spectrum.

This radiation may have bad side effects on human life [3, 4] so; they can be protected against this radiation whether individually or in group. Supporting the buildings with materials that have abilities of absorbing or reflecting microwaves radiation during the construction is advised especially for those who leave near to high microwaves radiation resources such as communication antennas. Where radiation proof suits are a good example for individual protection cases. Even though there is no any proved conformation that the microwave radiation has direct harm to human body, we have to find such a way that may reduce human interruption with this radiation as possible as can.

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If possible to provide way which is easy to apply and efficient economically it will be an important step to assure human safety. Since many of this era technologies are derived to be used by electromagnetic (EM) radiation.

Such an application must be funded by selecting a suitable material considering many factors. Cost must be affordable, simple processability, and no side effects. At the same time it can adsorb or reflect electromagnetic radiation of microwaves. Composites that have high electrical conductivity and dielectric constant have a good electromagnetic (EM) blocking property, especially nanocomposites have better compatibility and lower overall mass where at the same time show excellent EM shielding performance with larger frequency bandwidth. Many researches on EM shielding effectiveness of nanocomposites have been conducted during the past decade. Joo and his colleagues added nano-sized silver into epoxy matrix and obtained the EM shielding value of 46 dB in the range of 10 MHz – 1 GHz. They also carried out the study of the spectra attributes of multilayer absorber composed of materials with different electrical conductivity. [5]

Gairola et al. reported a 2.5 mm polyaniline based nanocomposites with nano ferrite $Mn_2\text{Ni}_2Zn_{6}Fe_{2}O_{4}$ which shows high shielding effectiveness up to 50 dB in the frequency band of 8–12 GHz (X-band). [6] In recent years, the unique electrical mechanical and magnetic attributes of carbon nanotubes (CNTs) enable it to play an important role in nano EM shielding materials preparation. [7] Currently, EM shielding composites prepared by CNTs compounding with organic polymers have become significant field in new generation electromagnetic interaction (EMI) shielding material research. [10–14]

Thermal, mechanical, electrical and microwave radiation absorbing or reflection properties of conductive composites based on dodecylbenzenesulfonate doped polyaniline / organoclay nanocomposites and propylene – ethylidene–norbornene rubber have been investigated with special interest on the effect of nanocomposite concentration. Composites were prepared by melt blending using an internal mixer. [15]

2 Materials and methods

2.1 Materials

Materials that used in this study are commercially rated without any further characterization or purification. Those materials are polyvinyl chloride (PVC, pr-1069), tetrahydrofuran (THF, AR), dioctyl phthalate plasticizer (DOP), and iron oxide nanoparticles ($Fe_2O_3$) with purity higher than 95%.

2.2 Preparation of the composites

An iron oxide nanoparticles and PVC polymer are prepared by dissolving and homogenizing them in a tetrahydrofuran solvent (THF) solvent separately at 25 °C for 90 min, DOP plasticizer is added to PVC solution. Then the two mixtures are stirred together in one flask until a viscous solution was obtained to form the composites. The solution was spread with a film maker (Casting knife) to form a thin film ~ 50 μm thick and then dried at 60 °C for one day. Finally, the obtained films were annealed (near the glass transition temperature) at 82°C for 3 h to eliminate the residual THF and cut the samples film according to the desired requirements for characterization techniques.
2.3 Characterization

Samples of synthesized material made in sheet forms to fit the dimensions of DUT; sample holder in used Vertical Network Analyzer. The blend of composites applied on a mold with 1 mm in thickness. Shielding efficiency measurement will be taken using vector network analyzer to determine the S parameters reading, using the equations 3.0 where the shielding properties of the selected materials at the applied microwave frequency range will get higher shielding efficiency with increasing of the reinforcement.

3 Results and Discussion

The measurements are done using S- Parameters by comparing the incident wave directed to the sample with the responses that can be gain as transmission or reflection waves. From these two resulted waves samples characteristics can be calculated. In this study we are using complex impedance phase measurement types. Complex impedance data is information such as resistance, reactance, phase, and magnitude that can be determined from an $S_{11}$ or $S_{22}$ measurements. Complex impedance data can be viewed using either the Smith Chart format or the Polar format.

In order to investigate the frequency properties of obtained composites an electromagnetic spectrum transmission and reflection coefficients are measured. The values were measured using the rectangular cavity working in excitation mode at 8 GHz. The reflection coefficient of the cavity was recorded as a function of applied field. The maximum value of the reflection coefficient is related with the maximum value of energy absorbed by sample at the ferromagnetic resonance.

![Fig. 1. VNA results presentation for the three samples with their different compensations, sample A (with -10dB), sample B (-8dB), and sample C (with -6dB).](image)

Reflectivity coefficient of the samples is presented in decibels, dB as a function of frequency, in GHz and absorber thickness of the samples as shown in figure 1. In this study permittivity data of the samples are not available so, there will not be any comparison with theoretical reflection curves. High radiation attenuation values (~10 dB) for sample A, in the frequency range of 8 – 11 GHz, were obtained when the composites contained 30 wt.% of Fe$_2$O$_3$ nanoparticles. This value corresponds to a dissipation of higher than 70% of the incident radiation. Sample B of the composition that contain of 20 wt. % of Fe$_2$O$_3$...
nanoparticles shows a value of radiation attenuation at about -8 dB in the range of 8 GHz to 11 GHz of the frequency. For this case the sample have a broadband behavior of microwave radiation absorption of about 70 % as shown in figure 1. Hence, the reflectivity properties of PVC/Fe$_2$O$_3$ conducting composite depends on the composition of the composite and microstructure attained after processing. In this case the Fe$_2$O$_3$ nanoparticles will agglomerate between the elastomeric phases act on the wave matter interaction.

![Figure 2: Result of two 20 wt. % layers at the range of 8 GHz – 11 GHz.](image)

The affection of the sample thickness on the absorption, transmission and reflection was investigated, by obtaining variation of samples thicknesses whiter by making a thicker samples or attaching layers together and place them in the waveguide. As shown in figure 2 for two layers of the composite film. This shows that the attenuation peak frequency of composites can be manipulated by changing the thickness of materials, like in the two layers of 20 wt. % got a value of higher than -15 db. The minimum value of transmission coefficient ($S_{12}$) was obtained for the sample with the highest concentration of iron oxide nanoparticles (sample A) which is about -10 dB at less than 11 GHz wave frequency. The greatest value of this coefficient was measured for sample B was approximately -8 dB at the same range of the frequency. The absorption of high frequency radiation is due mainly to metallic and ferromagnetic losses in the nanoparticles samples. At the increase of the nanoparticles amount in PVC based nanocomposites high frequency absorption ability increases too. The transmission coefficient decreases at the increases of the nanoparticle concentration suggesting a more shielding effect but this is associated with increasing of the reflection coefficient as well.

4 Conclusion

PVC/Fe$_2$O$_3$ nanocomposite films were produced by solution casting. They were observed only as thin film samples about 0.5 μm with 30 wt. % as a higher concentration and 10 wt. % as the lower one. Absorption was found to reach a maximum at an optimum Fe$_2$O$_3$ loading concentration. Obviously can be observed that the sample C exhibits the highest
radiation transmission value of the others, due to the lowest amount of conductivity in the films composition, where the sample B got shifted to higher value, and the sample A have the highest value of radiation absorption comparing to sample C and sample B with the value of -10 dB at the tested wave range. Overall, the thickness variations also affect the shielding ability. All the samples prepared in this work can present microwave radiation absorbing and tuning properties with the ability of being applied in many ways during the use time, better thermal properties and flexibility. Thus a good microwave absorbing materials with lower content of conducting polymer was prepared.

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