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A COMSOL Study on the Effectiveness of Shielding in Composites Containing HDPE and Aluminium Nanoparticles

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ABSTRACT

In this study, we investigate the shielding efficiency (SE) of HDPE composites containing aluminum nanoparticles against electromagnetic interference (EMI). We try to calculate the SE between 8 and 12 GHz using the modeling and simulation tool COMSOL Multiphysics. This study aims to provide a detailed description of the shielding efficacy of an aluminum nanoparticle composite that might be used in future communication and electrical devices. The results show that the SE fluctuates significantly with frequency and that there are certain GHz bands with the lowest SE. These findings might help refine materials for GHz-range electromagnetic interference shielding..

Keywords: EMI shielding, aluminum nanoparticles, shielding effectiveness, composite materials, COMSOL Multiphysics, GHz frequencies

1. Introduction

Due in large part to the need to create communication systems with higher frequencies, electromagnetic interference, or EMI, has emerged as a key issue in modern electronic systems. Devices operating in the GHz ranges make shielding material a must-have for product development. Conductive polymer composites containing aluminum nanoparticles or comparable materials may be the best option for electromagnetic interference (EMI) shielding due to their many desirable properties, such as low density, reasonable cost, and frequency tuning of material properties.

Using the COMSOL Multiphysics program to study the material's interaction with electromagnetic interference (EMI) operating at a frequency of 8-12 GHz, this work examines the shielding effectiveness SE of high-density polyethylene HDPE with aluminum nanoparticles. The efficiency of a composite material's shielding is proportional to the power transferred through it divided by the power lost when the power is incident on it. The characteristics and frequency-dependent behavior of aluminum nanoparticles are the primary foci of this study.

2. Materials and Methodology

2.1. Materials

This current study makes use of high density polyethylene (HDPE) as its matrix material and conductive filler, which are aluminum nanoparticles. The nanoparticles enhance the composite's shielding efficiency by facilitating the reflection, absorption, and scattering of incoming electromagnetic waves. This study makes use of aluminum nanoparticles due to their low density and strong electrical conductivity, both of which might be useful in creating lightweight shielding applications.

2.2 Simulation Setup

The COMSOL Multiphysics program, which is based on the Finite Element Method (FEM), was used to conduct the simulation. It is well-suited for accurate modeling of electromagnetic field distributions and material reactions. Here is what was included in the model setup:

- Aluminum nanoparticles embedded in a high-density polyethylene (HDPE) matrix form a composite with a rectangular shape.
- The composite's physical dimensions remained constant while the incoming electromagnetic wave frequency was changed from 8 GHz to 12 GHz.
- One side of the composite was configured as a Perfect Electrical Conductor (PEC) to reflect radiation that was not absorbed by the composites; the other side was used as an incident plane wave in the boundary conditions of the composite model.

2.3 Calculating Shielding Effectiveness (SE)

SE is given as:

$$S.E = 10\ log\left(\frac{Pi}{Po}\right)$$

3. Results and Discussion

In Table 1 below, you can see the SE simulation results of the shielding material that was created for frequencies ranging from 8 to 12 GHz. By first standardizing the SE values per 20 mm of the composite width and then per mm, the resulting composites were easier to compare.

Table 1: Simulation Results of SE for HDPE-Aluminum Nanoparticle Composites

Freq (GHz)	Pi (W/m²)	Po (W/m²)	Pi/Po	log Pi/Po	SE per 20 mm (dB)	SE per mm (dB)
8	5.76E-29	1.37E-27	4.20E-02	1.3767	-13.7675	-0.6883
8.5	5.03E-29	2.94E-27	1.71E-02	5.1979	-51.9793	-2.5989
9	6.26E-28	1.98E-27	3.16E-01	0.5003	-5.0034	-0.2501
9.5	6.84E-28	5.16E-28	1.32E+00	-0.1220	1.2202	0.0610
10	7.80E-29	2.78E-25	2.80E-04	4.1827	-41.8278	-2.0913
10.5	8.92E-27	1.44E-28	6.19E+01	-1.7917	17.9172	0.8958
11	6.26E-28	5.15E-28	1.22E+00	-0.0850	0.8505	0.0425
11.5	1.43E-27	9.60E-29	1.49E+01	-1.1744	11.7444	0.5872
12	6.58E-26	3.00E-28	2.19E+02	-2.3406	23.4069	1.1703

3.1. SE Analysis at Different Frequencies

Low Frequencies (8–9 GHz):

Since energy is readily transferred at lower frequencies, the negative SE values indicate poor shielding efficacy. As an example, the -13.77 dB SE at 8 GHz indicates minimal absorption and dominating reflection losses. It would seem that nanoparticles are not very effective in absorbing or attenuating electromagnetic radiation at this range.

Mid-range Frequencies (9. 5–10. 5 GHz):

The SE values tend to rise in the middle frequencies, reaching a positive value of 1.22 dB at 9.5 GHz. This indicates that the processes of absorption and scattering are becoming more efficient. Even if the SE increases to 17.91 dB by 10.5 GHz, a lot of energy is lost in the nanoparticle matrix as a result of reflections and scattering.

High Frequencies (11–12 GHz):

An SE of 23.40 dB has been recorded at 12 GHz, and this number increases dramatically as one moves up the frequency spectrum. From absorption, reflection, and scattering effects, it was shown that shielding becomes more effective with increasing frequency. There is less transmission and improved shielding effectiveness at higher frequencies because more nanoparticles are able to interact with the electromagnetic waves.

3.2. Electric Field and Power Flow Analysis at 12 GHz

This study's findings at 12 GHz are helpful for understanding how the produced electromagnetic waves interact with the composite material, as they show the distribution of electric fields and the power drain of these waves.

3.2.1. Electric Field Distribution

The electric fields at 12 GHz for the HDPE-Al nanoparticle composite are shown in Fig. 1, together with their x-, y-, and z-components and the norm. With a stronger electric field concentration at the nanoparticle surfaces, the electric field norm (Enorm) characterizes the electromagnetic wave's interaction with the composite material. A large amount of scattering occurs at this frequency since the distribution shows that most of the field is concentrated in a few areas.

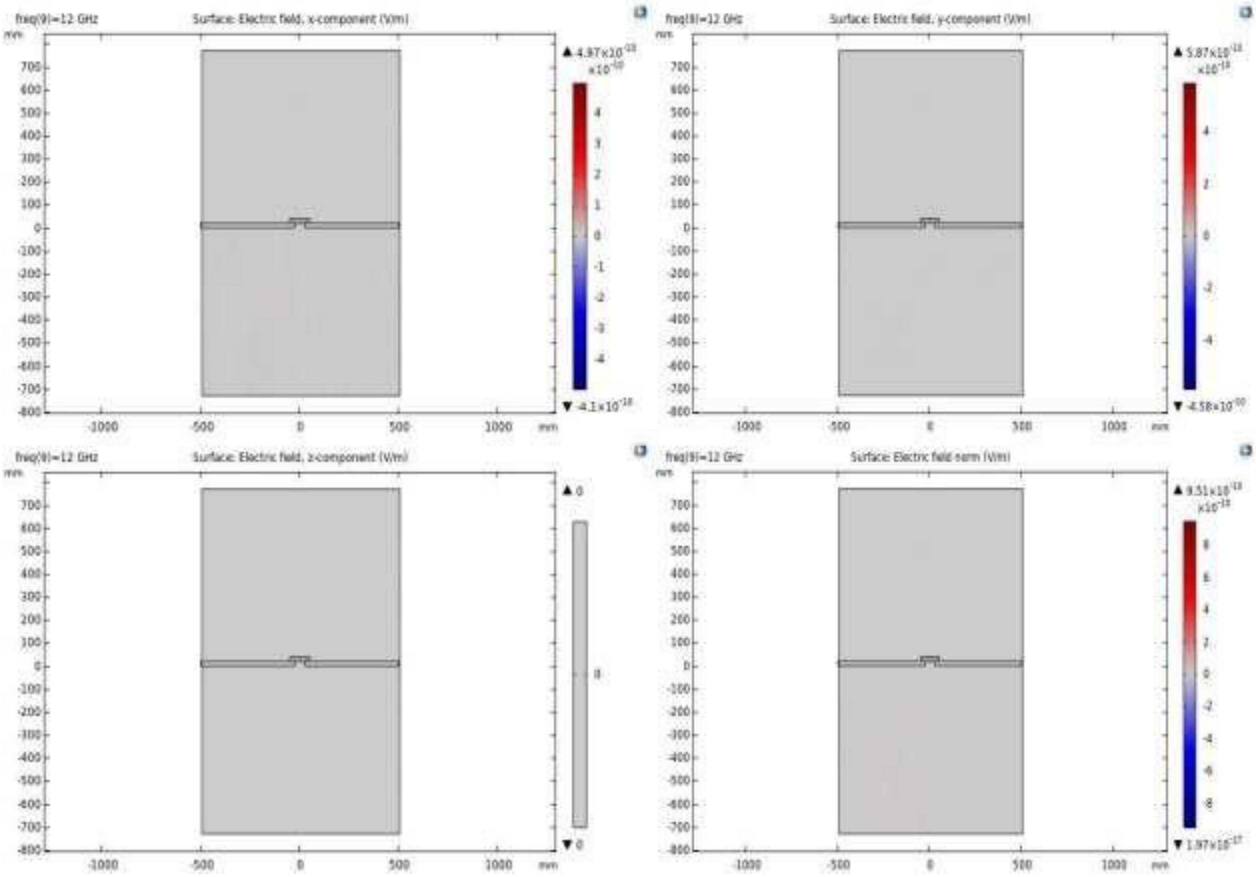


Figure-2: Electric Field at 12 GHz with HDPE + Al Nanoparticles

3.2.2. Power Outflow Analysis

These are the components of the time-averaged power flow and the overall power outflow at 12 GHz, as illustrated in Figure 2. Confirming strong EMI shielding ability at this frequency, the power outflow shows a very low signal of leakage from the composite, which is almost nil in most locations. The increased power flow in some locations is caused by surface resonances of the aluminum nanoparticles.

Composites containing aluminum nanoparticles are well-suited for use as high-frequency electromagnetic interference (EMI) shields, as shown by the accompanying graphs.

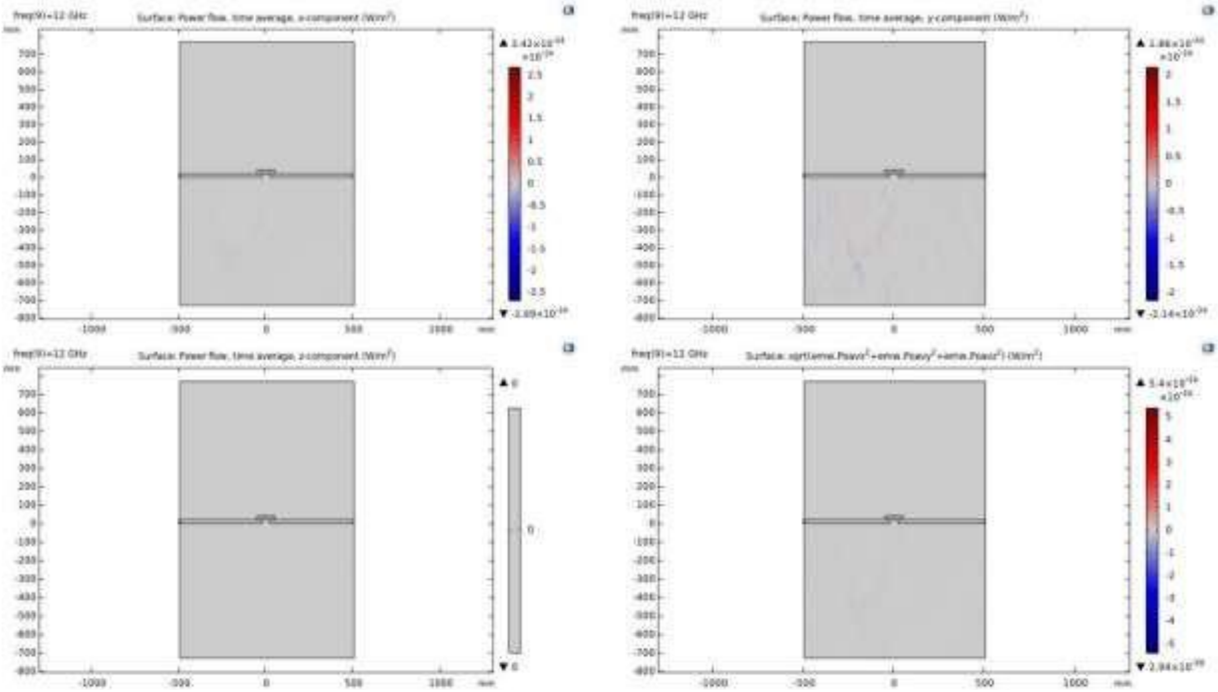
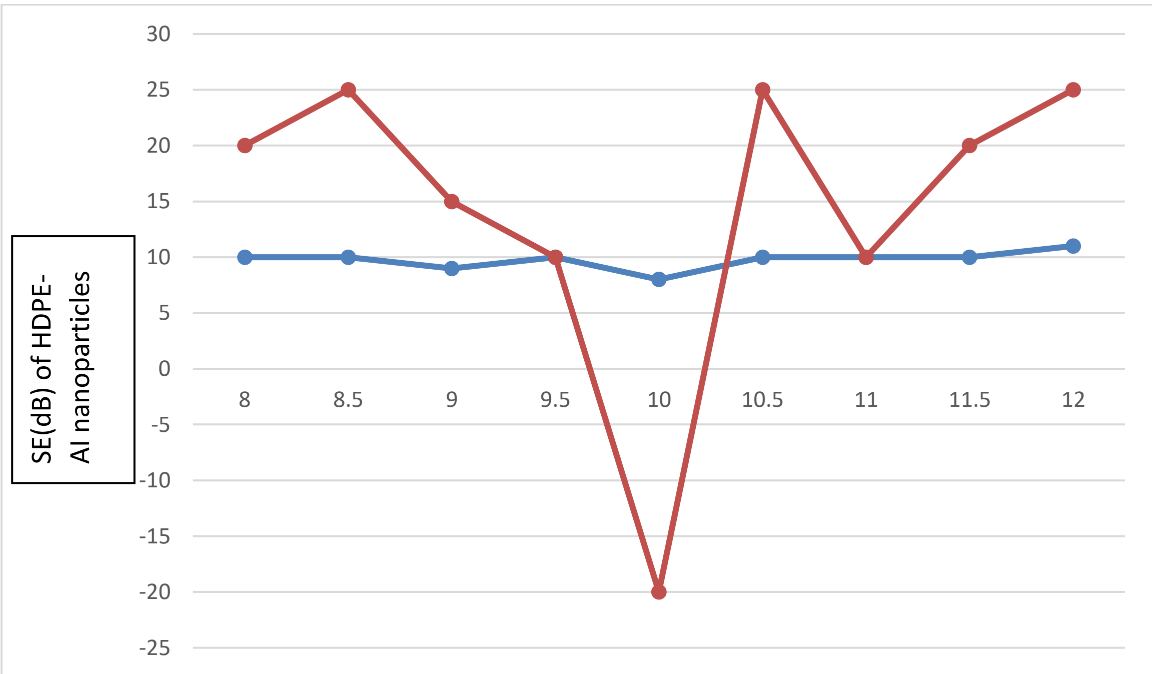


Figure-2: Power Flow at 12 GHz with HDPE + Al Nanoparticles

3.3. SE Vs Frequency Plot

Nevertheless, a plot of SE with frequency is shown below to help in comprehending SE's performance over the frequency spectrum. It seems that SE is increasing with frequency, reaching a peak at 12 GHz. This pattern is in line with the findings from literature that suggests using smaller particles and greater surface areas, because shielding becomes more effective with increasing frequency.



Frequency(GHz)

Figure-3: SE vs. Frequency Plot

4. Conclusion

Using COMSOL MultiphysicsTM for computational modeling and simulation, this study sought to evaluate the shielding efficiency (SE) of HDPE composites containing aluminum nanoparticles. It was clear from these tests that the composite material provided EMI shielding up to around 12 GHz, where the SE was 23.41 dB. There were, however, detected resonance effects at 10

GHz, with a subsequent decrease in SE. Thus, future research can build on this one to find ways to improve the shielding capabilities and frequency ranges where composite materials are most useful.

Research into how varying particle size and concentration affect the materials' EMI shielding capability will constitute future study. In order to back up the simulations and zero in on the novel composites for EMI shielding in reality, more experimental experiments will be conducted.

References

1. Kumar, A., Sachdev, V.K., Chowdhuri, A. *et al.* Electromagnetic shielding effectiveness and dielectric study of polystyrene/aluminum composite by addition of graphite and carbon nanofiber powder. *J Mater Sci: Mater Electron* **34**, 1857 (2023).
2. Mostafavi Yazdi, S.J.; Lisitski, A.; Pack, S.; Hiziroglu, H.R.; Baqersad, J. Analysis of Shielding Effectiveness against Electromagnetic Interference (EMI) for Metal-Coated Polymeric Materials. *Polymers* 2023, *15*, 1911
3. C. Retailleau, et al., "Universal behavior for electromagnetic interference shielding effectiveness of polymer based composite materials," *Composites Science and Technology*, vol.221, no.1 pp. 109-351. 2022.
4. S. Liu, et al., "Lightweight high-performance carbon-polymer nanocomposites for electromagnetic interference shielding," *Composites part A: Applied Science and Manufacturing*, vol.1, .no.5, pp. 106-176, 2021.
5. L. Anderson, P. Govindaraj, A. Ang, A. Mirabedini, and N. Hameed, "Modelling, Fabrication and Characterization of Graphene/Polymer Nanocomposites for Electromagnetic Interference Shielding Applications," *Carbon Trends*, vol. 4, pp. 100047-100098, 2021.
6. M. K. Yazdi, B. Noorbakhsh, B. Nazari, and Z. Ranjbar, "Preparation and EMI Shielding Performance of Epoxy/Non-metallic Conductive Fillers Nano-Composites," *Progress in Organic Coatings*, vol. 145, p. 105674-105679, 2020
7. P.G Dinesh, et al., "Effect of nanofillers on conductivity and electromagnetic interference shielding effectiveness of high density polyethylene and polypropylene nanocomposites," *European Journal of Advances in Engineering and Technology*, vol.1, no.2, pp. 16-28, 2014.