SPE SOCIETY OF PLASTICS ENGINEERS
Plastics Research Online
10.2417/spepro.006984

# Factors influencing the electromagnetic shielding of polymer/carbon composites

**Claudia Merlini, Alessandro Pegoretti, Patricia Cristine Vargas, Tairan F. da Cunha, Sílvia D.A.S. Ramôa, Guilherme M. O. Barra, and Bluma G. Soares**

*The electromagnetic interference shielding effectiveness of polymer composites filled with nanostructured carbon materials depends on electrical conductivity, morphology, aspect ratio, and filler dispersion.*

The electromagnetic interference (EMI) shielding properties of a material describe its ability to protect against the penetration of electromagnetic waves by, for example, reflecting and/or absorbing electromagnetic radiation. Because of the rapid proliferation of electronic and telecommunication systems, the emission of electromagnetic radiation has increased, especially at high frequencies (e.g., radio waves, such as those that originate from cell phones). These signals can negatively impact the performance of electronic devices, such as computers.[1]

Metals are the most efficient and commonly used materials for EMI shielding. However, in recent decades, interest in developing polymer composites for this purpose—filled with carbonaceous components such as carbon black (CB), multi-walled carbon nanotubes (MWCNT), graphene nanoplatelets (xGnP), and expanded graphite (EG)—has increased significantly. This rise in popularity is due to the viability of producing new lightweight materials with high flexibility and environmental resistance at relatively low cost.[2–6] The main challenge associated with achieving these properties in the fabricated composites is in obtaining high electrical conductivity and electromagnetic interference shielding effectiveness (EMI SE) at low conductive filler content.[7] The EMI SE and electrical conductivity of a nanocomposite depend on a wide variety of parameters, including the composite's structure and properties, the interactions between its constituents (i.e., the polymer matrix and the filler), and the dispersion and distribution of the filler in the matrix.[2,8–10] Moreover, measurements are usually performed at various frequencies and sample thicknesses, thus making it difficult to obtain a direct comparison of performance across sample types.

In our work,[11] we therefore incorporated various nanostructured carbon fillers into a polymer and investigated the effect on the electrical conductivity and EMI SE of the resultant composites. We used thermosetting polyurethane (PU), derived from castor oil, and a range of carbonaceous fillers (CB, MWCNT, xGnP, and EG) to fabricate samples. For each system, we incorporated fillers at the maximum achievable volume fraction (i.e., above which the viscosity of the system prevented the molding of composites).

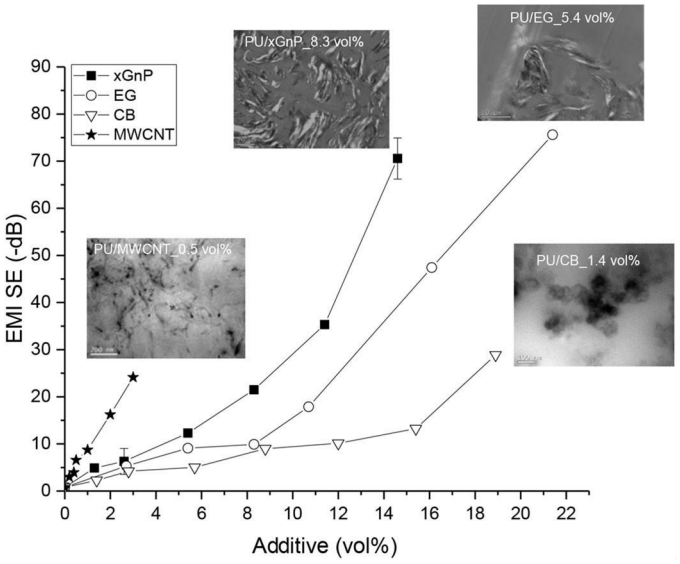


***Figure 1.*** *Measurement results showing the electromagnetic interference shielding effectiveness (EMI SE) of polyurethane (PU)-based composites filled with different nanostructured carbon fillers at a range of filler content. The graph shows the EMI SE in the X-band frequency range. Transmission electron micrographs of the composites at different loadings (vol%) are also shown. PU/xGnP: PU/graphene nanoplatelets. PU/EG: PU/expanded graphite. PU/CB: PU/carbon black. PU/MWCNT: PU/multi-walled carbon nanotubes.*[11]

Our results[11] show that various levels of EMI SE can be achieved by using carbonaceous fillers at different filler loadings: see Figure 1. For

*Continued on next page*

composites loaded with the same filler material, an increase in the filler content improved the EMI SE, but the level of this effect was strongly dependent on the filler type. We achieved a maximum EMI SE of −76, −70, −29, and −24dB by using 21.4, 14.6, 18.9, and 3.0vol% of EG, xGnP, CB, and MWCNT, respectively.

Among our samples, we found that the PU/EG and PU/xGnP composites exhibited the highest EMI SE values, corresponding to 99.999% of radiation attenuation (at filler content of 16.1 and 14.6vol%, respectively). For the highest CB loading, the EMI SE was significantly lower. We attribute the good EMI SE performance of PU/xGnP and PU/EG to the platelike morphology of the fillers, which leads to composites with elevated aspect ratios and the formation of denser networks. These factors give rise to a more efficient interaction with incident electromagnetic radiation. Transmission electron microscopy micrographs showed that the xGnP particles were well dispersed in the matrix, whereas EG forms agglomerates within the matrix, indicating the presence of stacked EG layers. These agglomerates probably arise due to the low shear rate (i.e., which is too low to exfoliate the filler) of the manual manufacturing process. Finally, we found that the PU/CB composites exhibited the lowest EMI SI performance. This is likely a result of the lower aspect ratio, reduced electrical conductivity, and the tendency of CB particles to form agglomerates (resulting in regions that are transparent to magnetic waves).

In terms of the EMI SE level, we found that the PU/MWCNT composites displayed the highest values (−24.2dB) at lower filler content (3vol%). We attribute this result to the higher aspect ratio of MWCNT, which facilitates the formation of a conductive network and thereby enhances the interaction of the composite with electromagnetic radiation. Composites with xGnP, EG, and CB at similar conductive filler content showed an EMI SE of about −6, −5, and −4dB, respectively, confirming that the best efficiency is achieved with MWCNT. If we consider the behavior of the composites at a given electrical conductivity level, however, the EMI SE of our composites varies significantly. For example, to achieve an electrical conductivity level of around $10^{-1}$ S $cm^{-1}$, the amount of filler required by each system was 11.4, 16.1, 18.9, and 3vol% (for xGNP, EG, CB, and MWCNT, respectively). At this level of electrical conductivity, the EMI SE level of PU/xGnP, PU/EG, PU/CB, and PU/MWCNT was –35, –47, –29, and –24dB, respectively. This behavior indicates that EMI SE is also dependent on the morphology, aspect ratio, and dispersion of fillers.

In summary, we fabricated a number of composite samples based on thermosetting PU (derived from castor oil) with a number of fillers (i.e., xGnP, EG, CB, and MWCNT) to investigate the potential of polymeric composites for EMI shielding applications. We found that the EMI SE of the composites varied significantly depending on the filler used. Specifically, the EMI SE of the composites depended on the electrical conductivity, morphology, aspect ratio, and the dispersion and distribution of the fillers. Based on our results, we conclude that the most effective filler for enhancing the EMI SE of PU is MWCNT. This carbon filler type achieved the highest EMI level at a lower filler content. For example, by using an MWCNT filler at 3vol% in the PU matrix, the resultant composite achieved an EMI SE level higher than is required for commercial applications (about −20dB[12, 13]). In the next stage of our work, we will investigate the effect of sample thickness on EMI SE. We also hope to improve filler dispersion to achieve higher EMI SE values with lower filler content.

## Author Information

**Claudia Merlini**
Department of Engineering
Federal University of Santa Catarina
Blumenau, Brazil

Claudia Merlini obtained her PhD in materials science and engineering. Her work now focuses on electrospinning, and the development of intrinsically conducting polymers and nanocomposites.

**Alessandro Pegoretti**
Department of Industrial Engineering
University of Trento
Trento, Italy

**Patricia Cristine Vargas, Tairan F. da Cunha, Sílvia D.A.S. Ramôa, and Guilherme M. O. Barra**
Department of Mechanical Engineering
Federal University of Santa Catarina
Florianópolis, Brazil

**Bluma G. Soares**
Department of Metallurgical and Materials Engineering
Federal University of Rio de Janeiro
Rio de Janeiro, Brazil

**References**

1. D. D. L. Chung, *Materials for electromagnetic interference shielding*, **J. Mater. Eng. Perf. 30**, pp. 350–354, 2000.
2. J.-M. Thomassin, C. Jérôme, T. Pardoen, C. Bailly, I. Huynen, and C. Detrembleur, *Polymer/carbon based composites as electromagnetic interference (EMI) shielding materials*, **Mater. Sci. Eng.: R: Rep. 74**, pp. 211–232, 2013.
3. D. D. L. Chung, *Electromagnetic interference shielding effectiveness of carbon materials*, **Carbon 39**, pp. 279–285, 2001.
4. M. Rahaman, T. K. Chaki, and D. Khastgir, *Development of high performance EMI shielding material from EVA, NBR, and their blends: effect of carbon black structure*, **J. Mater. Sci. 46**, pp. 3989–3999, 2011.

*Continued on next page*

5. Y. Wang and X. Jing, *Intrinsically conducting polymers for electromagnetic interference shielding*, **Polym. Adv. Technol. 16**, pp. 344–351, 2005.
6. Z. Liu, G. Bai, Y. Huang, Y. Ma, F. Du, F. Li, T. Guo, and Y. Chen, *Reflection and absorption contributions to the electromagnetic interference shielding of single-walled carbon nanotube/polyurethane composites*, **Carbon 45**, pp. 821–827, 2007.
7. J. S. F. Barrett, A. A. Abdala, and F. Srienc, *Poly(hydroxyalkanoate) elastomers and their graphene nanocomposites*, **Macromolecules 47**, pp. 3926–3941, 2014.
8. A. Gupta and V. Choudhary, *Electromagnetic interference shielding behavior of poly(trimethylene terephthalate)/multi-walled carbon nanotube composites*, **Compos. Sci. Technol. 71**, pp. 1563–1568, 2011.
9. M. Magioli, B. G. Soares, A. S. Sirqueira, M. Rahaman, and D. Khastgir, *EMI shielding effectiveness and dielectrical properties of SBS/PAni.DBSA blends: effect of blend preparation*, **J. Appl. Polym. Sci. 125**, pp. 1476–1485, 2012.
10. J. Huo, L. Wang, and H. Yu, *Polymeric nanocomposites for electromagnetic wave absorption*, **J. Mater. Sci. 44**, pp. 3917–3927, 2009.
11. C. Merlini, A. Pegoretti, P. C. Vargas, T. F. Cunha, S. D. A. S. Ramôa, B. G. Soares, and G. M. O. Barra, *Electromagnetic interference shielding effectiveness of composites based on polyurethane derived from castor oil and nanostructured carbon fillers*, **Polym. Compos.**, 2017. doi:10.1002/pc.24501
12. M. H. Al-Saleh, W. H. Saadeh, and U. Sundararaj, *EMI shielding effectiveness of carbon based nanostructured polymeric materials: a comparative study*, **Carbon 60**, pp. 146–156, 2013.
13. Y. Yang, M. C. Gupta, and K. L. Dudley, *Towards cost-efficient EMI shielding materials using carbon nanostructure-based nanocomposites*, **Nanotechnology 18**, p. 345701, 2007.