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# Electromagnetic properties and performance of exfoliated graphite (EG) – Thermoplastic polyurethane (TPU) nanocomposites at microwaves

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ABSTRACT

Nanocomposite materials based on commercial thermoplastic polyurethane (TPU) loaded with exfoliated graphite (EG) in concentration between 0 and 20 wt.% have been prepared with EG via melt mixing and compression molding. The materials' electromagnetic properties have been measured with wave-guide technique between 8.2 and 12.3 GHz. They had shown a clear proportional dependence of complex permittivity with EG content. Above 16 wt.% permittivity becomes frequency dependent. These results are discussed in view of material microstructure by means of scanning electron microscope (SEM) observations. Samples, with 20 wt.% EG and 4 mm thick, show an average value of −20 dB of shielding effectiveness (SE), which make them suitable as shielding material for commercial application. Simulations of metal backed configuration showed that important narrowband EM absorption (>−15 dB) can be achieved at 1 mm thickness, while multilayer structures are necessary to obtain EM broadband absorption (>−10 dB between 8.5 and 12 GHz) can be achieved in 6 mm thick samples.



## 1. Introduction

Electromagnetic interference (EMI) reduction is a highly interesting topic since it is involved in a variety of industrial applications including enclosures of electronic devices, electronic packaging, military, to cite a few. EMI reduction can be achieved hindering EM waves transmission through a protecting medium, and it is measured by means of SE that is the logarithmic ratio (in dB) of the outcoming to the incoming power of the radiation [1]. SE can be achieved using a perfectly reflecting surface (transmitted power $P_t = 0$) as metals, that are naturally EMI shielding materials, due to their intrinsic electric conductivity, while most plastics are not, due to their insulating nature. SE can be more difficultly gained with an EM absorbing medium in which the energy associated to the incident wave is not transmitted, nor reflected but somehow dissipated. This latter approach is usually reached by means of a lossy medium, which has to show a defined degree of electrical conductivity, which allows energy dissipation [2]. The medium, though, does not has to be too conductive to avoid unwonted reflections. Polymeric composite and nanocomposite materials are perfect candidates as lossy media, since their conductivity can be tuned by adding a variable amount of conductive filler [3]. Moreover, polymers are much lighter and cheaper than metals, therefore their use in mass applications is encouraged. In the case of composite materials, the nature of the conductive filler, its shape, dimensions and dispersion in the host medium are the major features influencing the material final performance [4,5]. Among them, carbon is the most common, either in form of carbon black, graphite, or, more recently, carbonaceous nanofillers (nanotubes, graphene, fullerenes), which showed to be very effective in terms of changing matrix conductivity at very low filler amount [6], hence without introducing any significant alteration to polymer processing [7]. As an example, nanotubes were proven to allow a sufficient level of conductivity to manufacture components with antistatic properties which successfully started to appear in the market [8]. To the best of our knowledge, despite a number of papers dealing with electrical conductivity and percolation of graphene nanocomposites are available in literature [9–12], only few papers deal with the electromagnetic SE performance of such materials. Liang et al. [13] studied the EMI shielding effectiveness in X-band (8.2–212.4 GHz) of solution-processable functionalized graphene (SPFG) in epoxy and showed that an interesting SE of −20 dB (which is the minimum value requested in commercial

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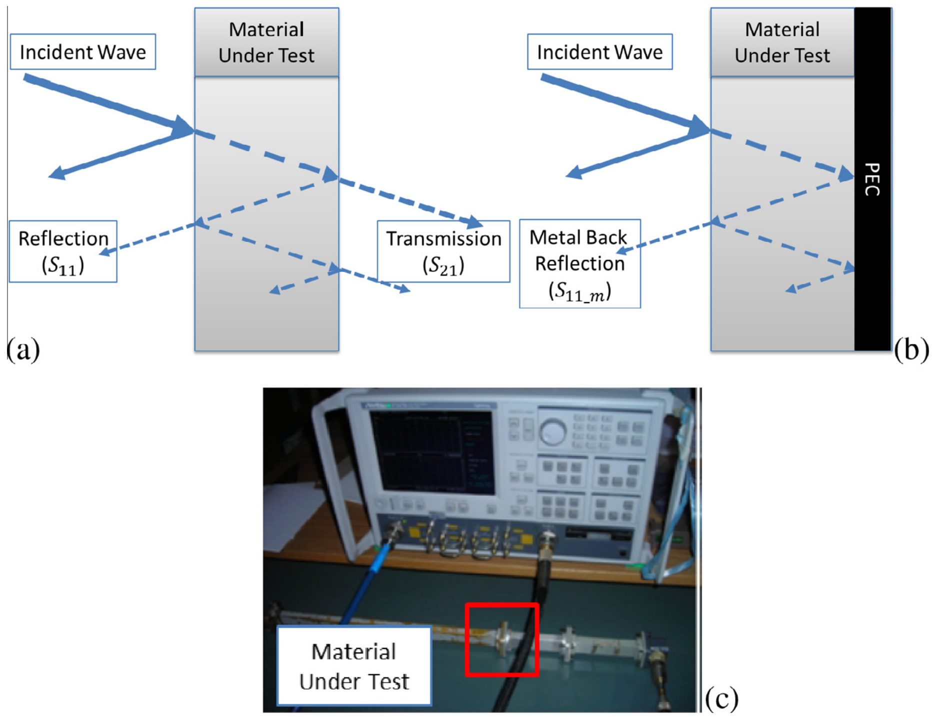


**Fig. 1.** Sketch of the measurements in (a) transmission and (b) metal backed condition. In (c) the VNA instrument with the material under test in the wave guide.

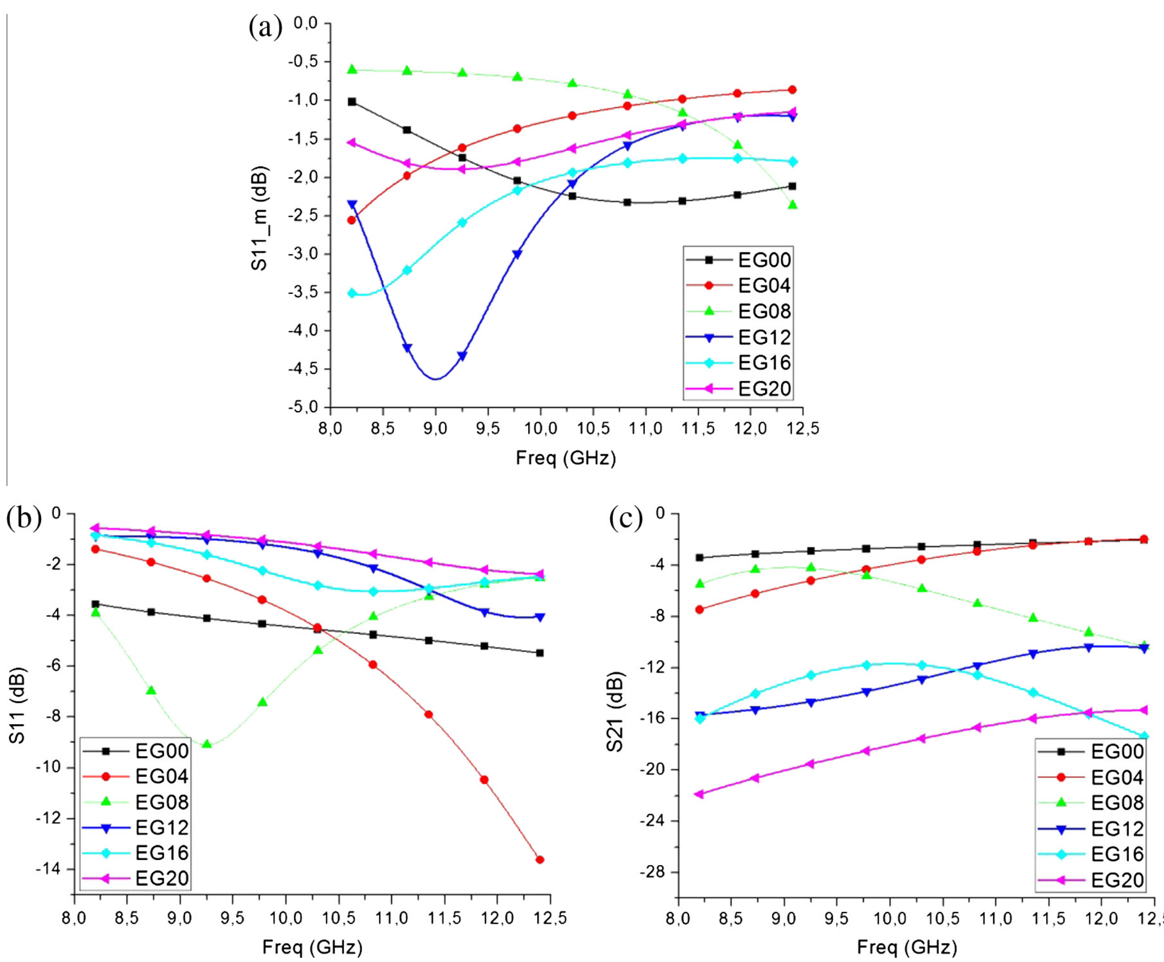


**Fig. 2.** Measured values of (a) metal backed reflection (dB), (b) non-metal backed reflection (dB), and (c) transmission (dB) as a function of frequency for samples with different EG content and 4 mm thickness.