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Evaluation of Thermoplastic Vulcanizates in Radomes

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ABSTRACT: The present paper evaluates a thermoplastic vulcanizate (TPV) of polypropylene (PP) and nitrile rubber (NBR), with and without carbon nanotube (CNT), with a potential application in structures that protect radar antennas, radomes. Morphological analysis, izod impact test, electromagnetic properties measurement and S-parameters were performed in order to verify its operational functioning. The presence of CNT affected the morphology of TPV, reducing the size of NBR particles. This enhanced impact strength results, besides the already known reinforcing effect of CNT on polymeric matrices. Electromagnetic parameters showed that both filled and unfilled TPV are low-loss materials. However, better impact result makes the filled TPV the most indicated material for radome application.

KEYWORDS: Thermoplastic vulcanizate; Radome; Impact; S-parameters.

INTRODUCTION

Antennas and radars are indispensable components in the fields of telecommunication, aerospace and military (Zhang *et al*. 2017). These gadgets are subjected to the most varied meteorological and mechanical conditions; therefore, a crucial apparatus is responsible for the structural protection of antennas called radomes (radar + dome). Radomes are physical barriers responsible for protecting antennas from rain, humidity, wind, fluids or aircraft fuel and solvents (Waqas *et al*. 2019). For such application, the constitutive material of a radome must be light, provide good structural rigidity and impact strength, as well as be transparent at the antenna's operation frequency and present low signal reflection on its surface, and this attribute is crucial for its proper performance (Choi *et al*. 2011). As a result, aircraft radomes are usually made of polymeric blends and/or composites, which provide excellent mechanical, thermal and electrical properties and corrosion resistance (Rodriguez *et al*. 2015).

Thermoplastic vulcanizates (TPVs) are polymeric blends in which elastomer particles are crosslinked and finely dispersed in a continuous thermoplastic matrix. These materials combine the elasticity of crosslinked rubber with the processing and recycling abilities of thermoplastics (Drobny 2014). Recently, due to pleas for environmental protection and conscious usage of resources, especially fossil, TPVs have received special attention (Ma *et al*. 2016), especially by substituting pure crosslinked rubber, which cannot be recycled.

The objective of this study is to evaluate the possible application as a radome material of a TPV made of polypropylene (PP) and nitrile rubber (NBR), filled and unfilled with carbon nanotube (CNT).

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MATERIALS AND METHODS

Nitrile rubber (33% acrylonitrile; Mooney viscosity [ML 1+4 at 100 °C] = 50) was gently provided by Nitriflex Ind. e Com. S.A. Polypropylene CP 442XP (MFI = 6 g/10 min at 230 °C) was supplied by Braskem S.A. Dicumyl peroxide (DCP) Retilox DPP 99%, was provided by Retilox Soluções Tecnológicas. Rubber processing aid bis(2-ethylhexyl) phthalate (DOP) was donated by Petroflex Ind. e Com., and multiwalled carbon nanotube NC7000 was purchased from Nanocyl S.A.

Two samples, a TPV and a conductive composite based on the TPV and CNT, named CPC, were prepared in an internal mixer HAAKE Rheomix 600. A masterbatch (MB) of NBR and DOP (10 phr, i.e. parts per hundred resin) was premixed at 50 °C, 90 rpm rotor speed for 10 min. Both samples were prepared at 190 °C and 90 rpm. First, MB was added. After 3 min, PP was added, according to the 50:50 NBR/PP proportion; after 3 more min, DCP was mixed (0.5 phr). Three min later, in case of CPC, CNT (0.2 phr) was added and mixed for 4 min. The total mixing time was 9 min for TPV and 13 min for CPC.

Morphological analysis was conducted in a Scanning Electron Microscope TESCAN VEGA3, at 20 kV. The injection-molded specimen were cryogenically fractured and emerged in osmium tetroxide (OsO_4) for 90 min, for the preferentially staining of NBR phase. A backscattered-electron (BSE) detector was used. Impact test specimen were obtained in a HAAKE MiniJet injection molding system, at 190 °C with pressure of 400 bar. Notched Izod impact test was conducted according to ASTM D256-10 in a Resil Impactor 5,5 J, from Ceast. Electromagnetic properties of real and imaginary permittivity (ε' and ε"), dielectric loss tangent (tg δ_ε) and scattering parameters (S_{11} e S_{21}) were obtained at the X-band (8.2 to 12.4 GHz) in a vector network analyzer (VNA) PNA-L, from Agilent Technologies, coupled in a waveguide. Sample dimensions were 23 × 10 × 2 mm.

RESULTS AND DISCUSSION

The morphology of TPV and CPC samples is presented in Fig. 1. Classic morphology of TPVs can be observed for both samples: rubber particles (lighter particles) dispersed in the thermoplastic matrix. As expected, CNT caused a reduction in the size of NBR domain, because the presence of a conductive filler tends to reduce interfacial tension between polymers in a blend (Dey *et al.* 2015).

(a)

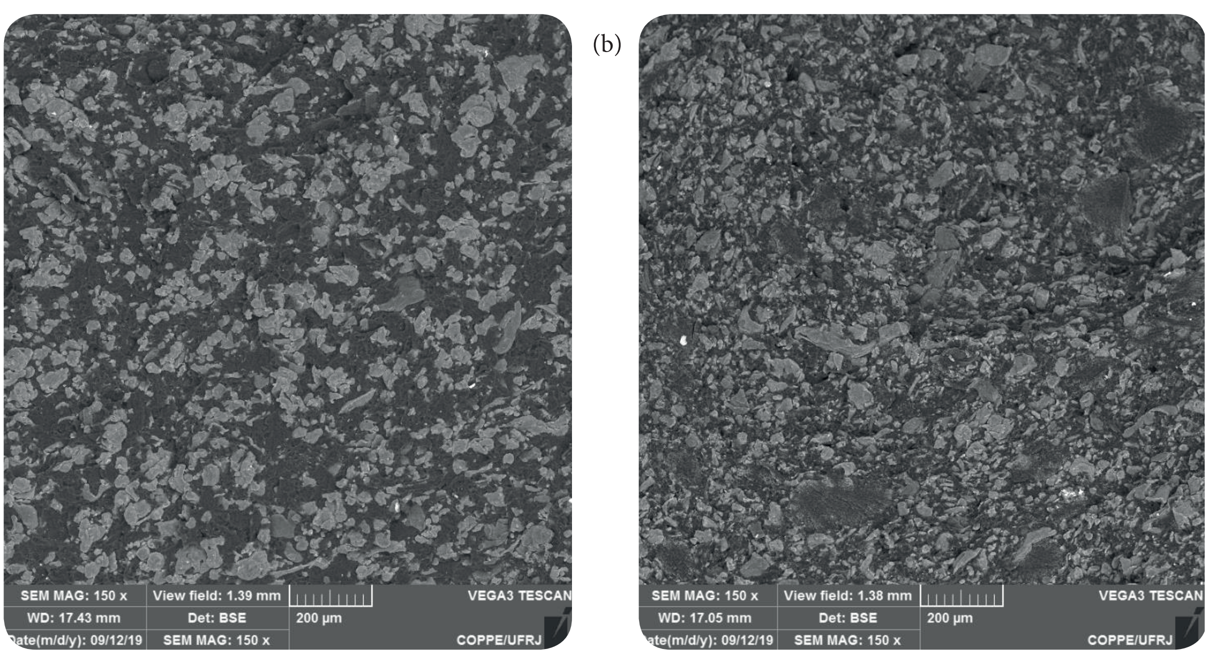

Figure 1. SEM images of (a) TPV; (b) CPC (Nominal zoom: 150x).

In the impact test, the 2.37 J hammer was not able to break the test specimen completely. Considering the hammer impact energy and the total length the fracture should go through (10.16 mm), estimated resilience of the samples were calculated: for TPV: 28.8 J/m, and for CPC: 42.2 J/m. Besides the reinforcing effect that CNT has on polymers, the enhanced impact strength of CPC can also be attributed to its finer morphology. The reduction of interfacial tension between NBR and PP, promoted by CNT, also contributes to better energy transference between the phases.

The results for the electromagnetic properties are presented in Fig. 2. Both TPV (Fig. 2a) and CPC (Fig. 2b) presented low values for ε' (2.4 and 2.7), ε" (0.05 and 0.15) and tg δ_ε (0.02 and 0.05). The slight increase observed in CPC is due to the presence of conductive filler. This indicates that both samples are low-loss materials, and this is one of the pre-requisites for being a radome (Kim *et al*. 2008). Low-loss materials provide good impedance matching between the air and its surface, mitigating reflection on the interface and minimizing signal loss (Wahab 2009).

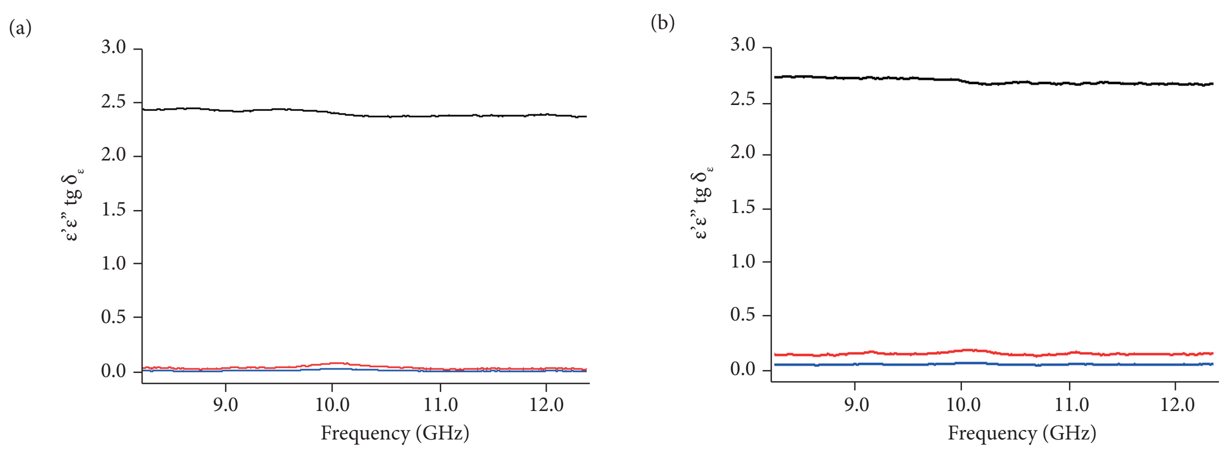

Figure 2. Dielectric properties of: (a) TPV; (b) CPC.

Scattering parameters, or S-parameters, presented in Fig. 3, reveal that both materials have low reflection property. Parameter S_{21} corresponds to the transmitted signal and S_{11} to the reflected signal. Low values of permittivity and dielectric loss tangent and high values of S_{11} (-9 and -8 dB, for TPV and CPC respectively) denote low reflection for both samples. In addition, high values of S_{21} (-0.8 and -1 dB, for TPV and CPC respectively) reveal that 90 and 80% of the incident signal are transmitted in most part of the analyzed frequency range, which is another pre-requisite for radomes (Kim *et al.* 2008). Such characteristic is related to the transparency at the operation range.

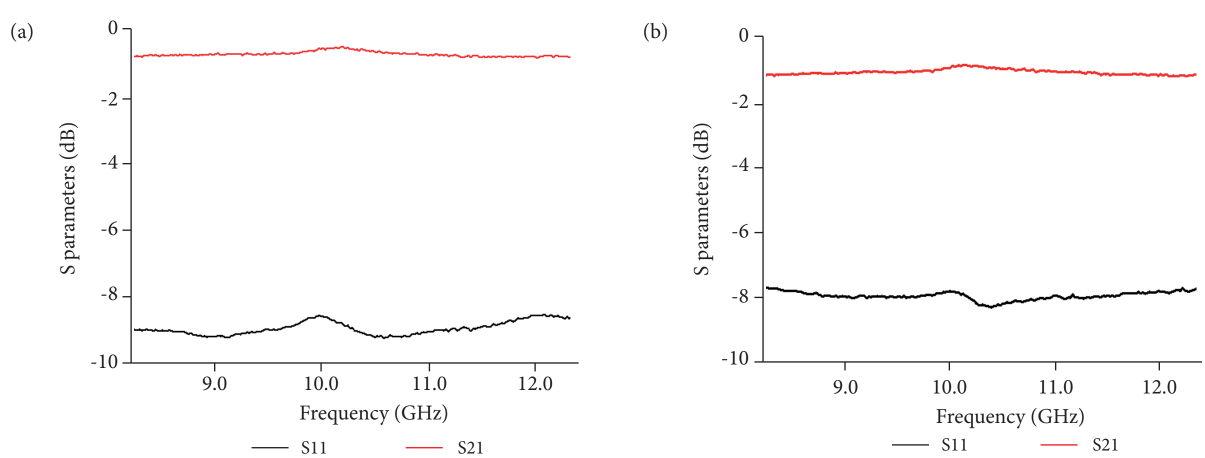

Figure 3. Scattering parameters of: (a) TPV; (b) CPC.

CONCLUSION

Both samples of TPV, filled and unfilled with CNT, present low dielectric properties and scattering parameters, which fit in the requisites of impedance matching and radar operation frequency transparency. Because CPC presented higher impact strength, due to the presence of CNT, it is the most suitable for radome application.

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AUTHORS' CONTRIBUTION

Conceptualization, Gabino A and Indrusiak T; Methodology, Gabino A and Indrusiak T; Research, Gabino A and Indrusiak T; Writing - First version, Gabino A and Indrusiak T; Writing - Review & Editing, Gabino A; Acquisition of Funding, Soares B; Resources, Soares B; Supervision, Soares B.

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