Use of $scCO_2$ for the Preparation of Polymer/Carbon Nanotube Foams that are Effective Protective Materials against Electromagnetic Pollution

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INTRODUCTION

With the rapid development of gigahertz electronic systems and telecommunications, electromagnetic pollution has become a serious problem in modern society, which justifies a very active quest for effective electromagnetic interferences (EMI) shielding materials. A large range of applications is concerned from commercial and scientific electronic instruments to antenna systems and military electronic devices [1]. Polymers filled with carbon fillers (e.g., carbon black, carbon fibers and carbon nanotubes) have been widely investigated for EMI shielding purposes because of unique combination of electrical conductivity and polymer flexibility [2,5]. The use of carbon nanotubes (CNTs) presents several advantages over conventional carbon fillers because, as result of their high aspect ratio, the carbon nanotubes can percolate at very low contents (<5 wt.%). Moreover, they can simultaneously enhance the electrical conductivity and reinforce the mechanical performances of the filled polymers.

However, a major drawback of the nanocomposites that contain carbon nanotubes is a high propensity to reflect the electromagnetic radiations rather than to absorb them. Indeed, the reflection of the signals results from a mismatch between the wave impedances for the signal propagating into air and into the absorbing material, respectively. The introduction of air into these nanocomposites by the formation of an open-cell foam will be favorable to the matching of the wave impedances of the expanded material and the ambient atmosphere. For this purpose, $scCO_2$ has been used to foam carbon nanotubes nanocomposites based on different polar polymer matrices. The effect of filling content, pressure and temperature on the main properties of the foam (density, pore size…) has been widely studied which allowed us to isolate several materials with high shielding efficiency combined with a low reflectivity in a broad frequency range (1-40 GHz).

MATERIALS AND METHODS

Materials. Commercially available MWNT thin were supplied by "Nanocyl S.A." Poly(ε-caprolactone) (PCL) was a gift from Solvay Interox.

Preparation and foaming of PCL nanocomposites. The MWNT/PCL nanocomposites were prepared by two techniques. According to the melt-blending technique, the polymer was extruded with the required amount of MWNT at 80°C in a 5-cm^3 DSM microextruder under nitrogen at 200 rpm for 10 min. In the co-precipitation method, PCL was first dissolved in THF (2wt%) followed by the addition of the required amount of MWNT. After 30 min of ultrasonication, the solution was precipitated in heptane.

In a 316 stainless steel high pressure cell (100 ml) from Parr Instruments, a sample (35 x 25 x 8 mm) of PCL nanocomposite was pressurized with CO_2 until 45 bars with an ISCO 260D high pressure syringe pump. The cell was then heated until the desired temperature, and compressed CO_2 was finally added until reaching the desired pressure. This saturation pressure was maintained for 3h before being released within a few seconds. The cell was then opened, and the expanded nanocomposite was recovered.

RESULTS

Transmission electron microscopy showed that the MWNTs were uniformly dispersed as single nanotubes within the matrix in both cases. Because the nanotubes were cut during melt-blending, the percolation threshold was observed at a lower filler content in case of co-precipitation as confirmed by rheological and electrical measurements. Substitution of poly(ethylene-co-octene), polyvinylchloride, polypropylene and polystyrene for PCL resulted in lower shielding efficiencies, which strongly suggests that PCL is a unique matrix for achieving good EMI shielding properties. The foaming of the PCL/MWNTs nanocomposites has been performed by supercritical CO_2 in order to decrease the propensity of the materials to reflect the radiation. The reflection of the signals results indeed from a mismatch between the wave impedances for the signal propagating into air and into the absorbing material, respectively. The relative volume of air in an open-cell foam is very high, which is very favorable to the matching of the wave impedances of the expanded material and the ambient atmosphere. Well defined foams were obtained with pore size around 50 µm and a volume expansion of 5. Shielding efficiency as high as 60 to 80 dB together with a low reflectivity was observed at very low vol% of MWNTs (0.25 vol%). This poster will emphasize both the preparation of advanced nanocomposites foams by the $scCO_2$ technology and their exceptional EMI properties. [6]

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