Foams of Polyurethane/MWNT Nanocomposites for Efficient EMI Reduction

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Introduction

Due to the steady growth of communication technology and the adverse effects of electromagnetic radiations on the human body and electronic devices, it is critical to reduce the electromagnetic interference (EMI) and its impact on medical apparatus and electronic engineering. In that context, polymer/multi-walled carbon nanotubes (MWNT) nanocomposites are proposed for their high EMI shielding performance.[1-11] The strategy is to render the polymer conductive by adding MWNTs and to promote wave absorption by foaming the polymer-based composite. These MWNT/PU polymeric foams thus show a promising EMI shielding efficiency due to their high capacity to absorb electromagnetic radiation at low MWNT content.

1. Absorption of electromagnetic waves

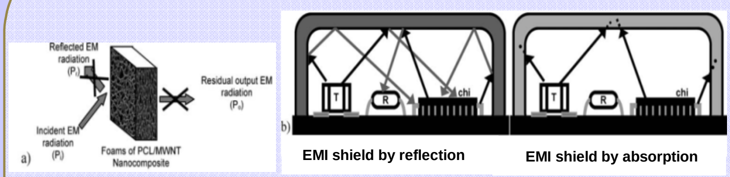

Fig 1: a) Behavior of nanocomposite foams under EMI radiation, b) difference between an EMI shield by reflection and by absorption.

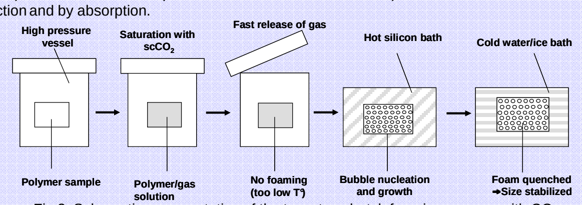

Fig 2: Schematic representation of the two-steps batch foaming process with CO_2.

The MWNT/polymer foam can effectively protect an electronic device from waves interference thanks to its capacity to absorb the waves instead of reflecting them.

2. Nanocomposite preparation

1 and 2 wt% MWNT (NC7000, Nanocyl™, Belgium)/PU(Desmopan 2590A, Bayer, Germany) composites were prepared by melt blending in a twin-screw internal mixer (180°C, 60 rpm, 5 min) and then molded into 2mm thick sheets under a hot press (180°c) for 5min.

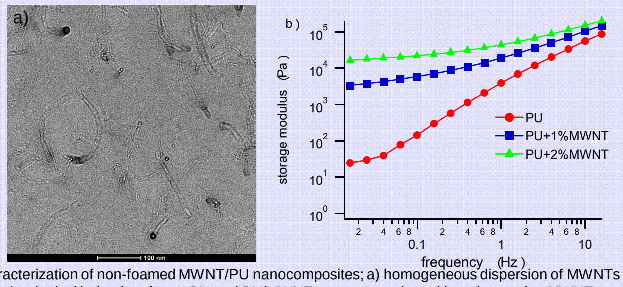

Fig 3: Characterization of non-foamed MWNT/PU nanocomposites; a) homogeneous dispersion of MWNTs observed by TEM, b) rheological behavior of pure PU and PU/MWNT nanocomposites with an increasing MWNT content.

✓ MWNTs are very well-dispersed within PU matrix.
✓ The percolation threshold is reached with a low carbon nanotubes loading (1wt%), as proved by rheological analysis.
In fact, the nanocomposites show solid-like behavior at low frequency range.

3. Nanocomposite foams preparation

The nanocomposite is saturated in $scCO_2$ for 24h at 40°C and 60-300bar. The vessel is then quickly depressurized and the sample is transferred in a hot press (120°C) for 2min in order to allow cell growth. The foam is finally quenched in an ice/water bath.

Effect of MWNT addition on cellular morphology

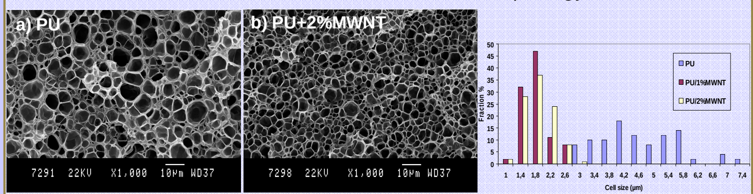

Fig. 4: Porous structure of a) pure PU and b) PU/2%MWNT observed by SEM. C) Cell size distribution of pure PU and nanocomposite foams.

✓ The composites foams have smaller cell size and narrower cell size distribution compared to neat PU foam.
✓The nanofiller acts as a heterogeneous nucleating agent, increasing the cell density.

Effect of foaming conditions and MWNT content on cell size and foam density

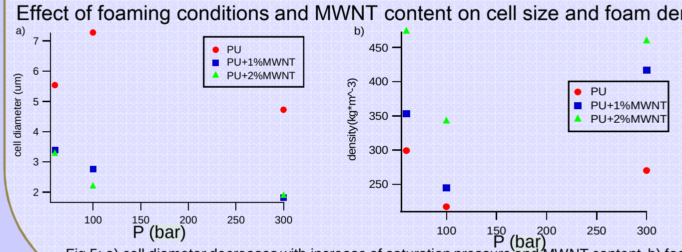

Fig 5: a) cell diameter decreases with increase of saturation pressure and MWNT content, b) foam density decreases and then increases with the pressure and is higher for nanocomposite foams.

4. Electrical properties

High electrical conductivity is directly related to good EMI shielding effectiveness, while low permittivity is required in order to avoid wave reflection and promote wave absorption. Therefore, accurate foaming conditions must be found to reach both high conductivity and low permittivity.

Effect of MWNT addition on electrical properties

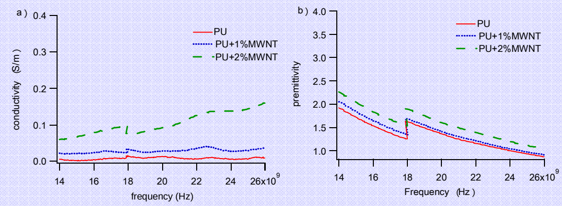

Fig 6: a) Conductivity and b) permittivity of pure and nanocomposite foams (d~0.4 g/cm³) as a function of wave frequency.
While pure PU foam is isolative, MWNT addition renders the foam conductive, but it also increases the foam permittivity. The effect is more pronounced at 2wt% loading.

Effect of foam density on electrical properties PU/2wt%MWNT

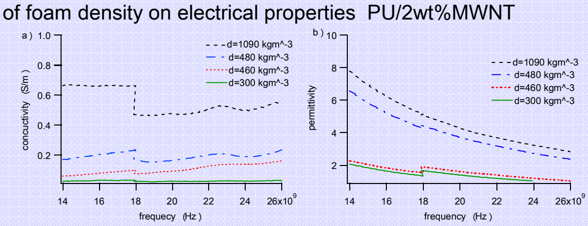

Fig 7: a) Conductivity and b) permittivity of PU/2wt%MWNT foams as a function of foam density. Foams with lower density lead to low permittivity, high absorption, and low conductivity.

Decreasing the foam density leads to lower permittivity but also to lower conductivity (lower EMI shielding effectiveness).
The carbon nanotube content as well as foaming conditions must therefore be optimized in order to find a compromise between high conductivity and low permittivity, which will result in excellent EMI shielding performance.

Conclusions

MWNT/PU composites with an uniform porous structure have been successfully prepared by melt blending and accordingly foamed with $scCO_2$. We have shown that the cellular morphology and foam density can be controlled by varying the foaming parameters. The electrical properties, which are directly related to EMI shielding effectiveness, are improved by adding MWNTs (conductivity) and foaming (permittivity). Although the results obtained here still need optimization in order to be competitive, these MWNT/PU polymeric foams are very promising EMI shielding materials due to their high capacity to absorb electromagnetic radiation at low MWNT content.

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