Title

POLYMER MATRIX COMPOSITES WITH CARBON NANOTUBES AS ABSORBING AND SHIELDING MATERIALS FOR MICROWAVE AND TERAHERTZ RANGES

Abstract text

Polymer (dielectric) matrix composites filled with carbonaceous particles are known to be effective absorbing and shielding materials in growing variety of applications in electronics and telecommunications, military and civilian microwave techniques. Replacement of carbon nanoparticles by nanotubes with a high aspect ratio results in essential decrease of the percolation threshold concentration of filler. It allows the weight reduction and flexibility improvement of composites. On the other hand, it influences the dielectric loss / conductivity mechanisms contributing to their absorbing and shielding properties.

Here we present analysis of shielding and absorption efficiency of composites of poly(ethylene terephthalate) and multiwalled carbon nanotubes (PET-xMWCNT, x = 0–3 vol.% is the fraction of carbon nanotubes). The analysis is based on the dielectric and ac conductivity spectra studied in a very broad frequency range from 0.1 mHz to 1 THz. It was shown that in addition to the dc conductivity of percolated MWCNT clusters, the ac conductivity of MWCNT in the finite clusters contributes to the conductivity spectra. The ac conductivity increases with frequency and culminates in the THz range for all compositions, achieving ~4 S/cm at 1 THz. The percolation threshold revealed at x ~0.07 vol.% is one of the lowest observed in the melt-processed polymer composites. Both dc and ac conductivity of composites can be effectively controlled by the change of MWCNT concentration. The low percolation threshold and ability to modify the microwave conductivity make PET-MWCNT composites attractive for electromagnetic applications.

Broadband dielectric spectra of PET-xMWCNT composites were used to calculate (neglecting the magnetic field effects in the quasistatic approximation) their shielding efficiency (SE) and microwave absorption (MA) in the microwave and THz ranges. Two model configurations of electromagnetic (EM) field interaction with the composite material in free space were analyzed: a) EM wave transmission through a single layer; b) EM wave reflection from the layer backed by a perfect electric conductor. SE and MA parameters were estimated in dependence on the MWCNT concentration, layer thickness and frequency. The compositions and frequency range optimal for shielding and absorption applications are discussed. SE up to 35 dB can be achieved at 0.3–500 GHz, MA up to 30 dB can be achieved at 2–1000 GHz.

PET-xMWCNT composites are promising microwave and THz shielding and absorbing materials. For MA-based applications, low-x compositions can be used (x < 0.75 vol.%, even below the percolation threshold), while at x > 0.75 vol.% MA does not exceed 10 dB due to the high dc conductivity. For the SE-based applications, high-x compositions are preferable (x > 0.2 vol.%). The very low percolation threshold is an advantage for applications.

Broadband dielectric spectroscopy is an effective tool for the study and development of MW shielding and absorbing composite materials.

Keywords

COMPOSITES, CARBON NANOTUBES, BROADBAND DIELECTRIC SPECTRA, MICROWAVE ABSORPTION, SHIELDING EFFICIENCY, APPLICATION

Authors 5

BOVTUN, VIKTOR (INSTITUTE OF PHYSICS ASCR, PRAGUE)

KEMPA, MARTIN (INSTITUTE OF PHYSICS ASCR, PRAGUE)

NUZHNYY, DMITRY (INSTITUTE OF PHYSICS ASCR, PRAGUE)

SAVINOV, MAXIM (INSTITUTE OF PHYSICS ASCR, PRAGUE)

PETZELT, JAN (INSTITUTE OF PHYSICS ASCR, PRAGUE)