Abstract

Carbon nanotubes (CNTs) impart great multifunctionality due to their excellent intrinsic properties such as high specific strength and stiffness, excellent electrical and thermal conductivities, along with the large aspect ratio resulting in the high surface area, which lends them to be used in different polymer systems as reinforcement nanofillers in a wide variety of applications such as aerospace, automobile, electrical and electronic appliances, space and satellite communication, military and defense sectors, biomedical, sensing and actuation applications, to name a few. In the present work, three novel nanocomposites are fabricated using single-walled carbon nanotube (SWCNT), multi-walled carbon nanotube (MWCNT), and functionalized multi-walled carbon nanotube (F-MWCNT) as reinforcements in ethylene methyl acrylate (EMA) copolymer as matrix material by a simple, cost-effective, and facile solution mixing strategy. The morphological characterization of the nanocomposites is done using a field emission scanning electron microscope (FESEM) and transmission electron microscope (TEM) to study the CNTs' distribution, dispersion, and interaction with the polymer matrix. The cryofractured transverse sections of the nanocomposites have qualitatively revealed that the distribution and dispersion are the best for the SWCNT reinforcements, followed by F-MWCNTs and MWCNTs as justified by their excellent network connection as manifested from the lowest percolation threshold values achieved quantitatively as 1.96wt% for SWCNT/EMA nanocomposite as compared to 5wt%, and 7wt% for FMWCNT/EMA and MWCNT/EMA nanocomposites, respectively, obtained from the DC and AC electrical conductivity tests. The mechanical properties in terms of strength, stiffness, and elongation at break have displayed the superior reinforcement effect by the SWCNTs due to their highest aspect ratios and excellent intrinsic properties compared to the other two nanotubes. The excellent electrical properties are directly correlated with the material's EMI shielding effectiveness (EMI SE) properties. The commercial need for 20 dB of SE is achieved when tested in the X-band (8.2-12.4 GHz) frequency region at just 2, 3, and 5 wt% of SWCNT, FMWCNT, and MWCNT reinforced EMA polymer nanocomposites, respectively. However, the highest SEs are recorded as 45, 30, and 25 dB for SWCNT/EMA, FMWCNT/EMA, and MWCNT/EMA nanocomposites, respectively, at the same highest CNT reinforcements as 15wt% at a nanocomposite thickness of just 1mm. The superior EMI SE of the SWCNT/EMA (SER) nanocomposite has led us to investigate its dynamic mechanical property characterization by sweeping both the temperature and frequency, and the results have revealed the SER nanocomposite's potential to be used as an excellent damping material by tailoring their properties as per the needs. The complex variation of storage modulus and damping factor with the combined variations of temperature, frequency, and SWCNT loading are judiciously modeled, and the damping parameters are represented concisely in terms of two universal dispersion functions named reduced dynamic rigidity and reduced dynamic viscosity. Finally, a successful effort is made to align the SWCNTs in EMA polymer by the simple mechanical stretching method as validated by the mechanical property characterization using a mechanics of composites approach. The novel nanocomposites can be used as excellent flexible EMI shielding material, and it is proposed that SER nanocomposites have the potential as excellent multifunctional material to be used in industry and academia, having superior EMI SE along with excellent damping characteristics.

Keywords: Polymer nanocomposite, Solution mixing, Electrical percolation threshold, EMI shielding effectiveness, Dynamic mechanical properties, Reduced parameters, CNT alignment