ABSTRACT

The main objective of the present thesis is to develop effective light weight, mechanically strong and conductive EMI shielding systems using polycarbonate/ethylene methyl acrylate [95/5 w/w] as matrix and multiwalled carbon nanotubes (MWCNTs) or/ graphene or/ graphene/MWCNT hybrids as fillers. These nanocomposites were characterized thoroughly for morphological (SEM & TEM), structural (XRD & Raman), mechanical (tensile & impact), thermal (TGA & DSC) and electrical properties. Evaluation of electromagnetic interference (EMI) shielding was carried out in the frequency range of 8.2-12.4 GHz (X-band).

The thesis has been divided in seven chapters. Chapter 1 provides the necessary background relevant to the contents of the thesis, literature review, motivation behind this work, as well as the objectives of this work. It summarizes the literature based on the morphological, thermal, mechanical and electrical properties of CNTs and graphene based polycarbonate nanocomposites. An overview of the work and structure of thesis is summarized in this chapter. Chapter 2 describes the detailed methods used for the synthesis of graphene oxide (GO), graphene (using dry ice) and graphene/multiwalled carbon nanotube (GCNT) hybrid fillers. This chapter also describes the different characterization techniques and their principles. In Chapter 3, the effect of ethylene methyl acrylate copolymer [EMA] content on the morphological, mechanical and thermal properties of polycarbonate/EMA blends which prepared by melt blending is discussed. The notched izod impact strength of PC/EMA blends showed a positive blending effect and incorporation of EMA rubber (1-30 wt.%) in PC matrix enhances the Izod impact strength by 184–452% with decrease in tensile strength and tensile modulus. Tensile data was also analyzed by using theoretical models. The theoretical analysis of tensile properties shows that there is an extent of interaction between PC and EMA up to 5 wt.% EMA content, whereas the interfacial adhesion deceased as EMA v content was >5 wt.%. Scanning electron microscopy studies indicate a two-phase structure with fine globular rubber domains in the PC because of debonding of PC and EMA. This novel PC/EMA blends having significantly higher impact strength compared to PC can be used as an excellent impact absorber in various industries. The electrically conductive nanocomposites of toughened polycarbonate (PC/EMA 95/5 w/w) fabricated by using melt blending method with varying loading of MWCNTs ranging from 0.25-10 phr are discussed in Chapter 4. The nanocomposites were characterized for morphology [SEM and TEM], mechanical properties (tensile and impact using the universal testing machine), thermal property [using TGA and DSC], electrical conductivity [two probe method] and electromagnetic interference shielding effectiveness [using VNA]. The impact strength of toughened PC [prepared by blending PC with 5 wt.% of ethylene methyl acrylate copolymer having 318 J/m i.e. 381% improvement in impact strength as compared to neat PC (~68 J/m)] increased to 378 J/m (19%) after 1 phr addition of MWCNTs. The tensile strength and modulus of PC/EMA blends increased about 39 and 60% respectively, upon incorporation of 10 phr of MWCNTs. The electrical percolation threshold occurred at low loading i.e. between 0.5 and 1 phr.
loading of MWCNTs in PC/EMA (95/5) blend. Additionally, highest electrical conductivity of \(1.56 \times 10^{-3} \, \text{S cm}^{-1}\) and highest EMI SE i.e. \(-26 \, \text{dB}\) in X-band (8–12 GHz) which is mainly used for VSAT systems and satellite communication applications, were achieved for nanocomposites having 10 phr of MWCNTs. The effect of graphene oxide (GO) or graphene on the morphological, thermal, mechanical and electrical properties of polycarbonate/ethylene methyl acrylate nanocomposites is discussed in Chapter 5. The polymer shows uniform adherence with the filler nanosheets and this adhesion is indicative of strong interactions between filler and matrix. Enhancement in the thermal stability of PC/EMA (95/5 w/w) blend was observed with the addition of nanofillers. Addition of GO/graphene vi leads to improvement of tensile modulus indicating the increase in stiffness of the composite. However, the tensile strength and percent elongation of composites decreased with increasing GO/graphene content which is attributed to the filler agglomeration effect and poor stress transfer characteristics. The developed PCEGO and PCEG nanocomposites exhibited an EMI shielding value of \(-27\) and \(-29 \, \text{dB}\) in the X-band for 15 phr loading of GO and graphene respectively indicating that the composites can meet the commercial application demands. Chapter 6 deals with the effect of graphene/MWCNT hybrid [GCNT] nanostructure on the mechanical, thermal, electrical and EMI shielding properties of polycarbonate/ethylene methyl acrylate nanocomposites. The PC/EMA-GCNT nanocomposites having 10 phr loading of GCNT hybrid filler with varying ratio of graphene : MWCNT (1:3, 1:1 and 3:1) were prepared using melt blending method. The synergism in the GCNT hybrid nanostructure originates from the bridging of MWCNTs between the graphene layers which lead to the improved mechanical properties, electrical conductivity and EMI shielding properties of PCEGNT composites. The maximum electrical conductivity has been achieved up to \(9.13 \times 10^{-2} \, \text{S/cm}\) for PCEGNT(1:3) (10 phr) composite which is higher than the single filler loaded nanocomposites. This significant improvement in electrical conductivity is thus responsible to achieve up to \(-34 \, \text{dB}\) EMI shielding effectiveness in X-band frequency range (8.2–12.4 GHz). Chapter 7 summarizes the key findings of the study, gives major conclusions and offers the need to demonstrate the practical utility and commercial viability of these nanocomposites as EMI shields. Suggestions for the future work are also included.