Preparation, Characterization and Study of Mechanical Properties of Graphene/ABS Nano-Composites

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Abstract

Graphene/Acrylonitrile Butadiene Styrene (ABS) based nanocomposite is prepared using solvent mixing method. ABS has outstanding material property and its ease of availability motivated to use it as a polymer material in the present work. Production of Graphene is cheap compared to that of carbon nanotubes and having similar mechanical characteristics. Its incorporation in ABS will improve its mechanical properties significantly. Graphene is added to ABS in variable compositions (1, 2.5, 5, 7.5, 10 wt %) and chloroform is used as solvent.

Keywords: Acrylonitrile Butadiene Styrene (ABS), CNT, Graphene, Mechanical Properties, Nanocomposite, Nanotube, Polymer, PNC, San

1. Introduction

Graphene is a monolayer of sp[2]-hybridized carbon atoms arranged in a two-dimensional lattice, having excellent thermal, mechanical, and electrical properties[1,2]. Due to its various intriguing properties like high electron mobility, exceptional thermal conductivity and superior mechanical properties with improved Young's modulus under room temperature conditions, it has gained significance as filler in nanocomposites[3]. Polymer NanoComposites (PNC) show extensive property enhancements at much lower loadings than polymer composites with conventional micron-scale fillers (such as glass or carbon fibers)[4]. Therefore, incorporation of graphene in polymer matrices acts as an advantage for enhancing its mechanical, physical, electrical and its barrier properties at low loadings. Graphene has attracted attention as a promising candidate to create new PNCs due to its excellent properties and readily availability of its precursor, graphite. Apart from these significant properties, single layer graphene has very high electrical conductivity, up to 6000 S/cm[5] and unlike Carbon

NanoTube (CNT), chirality is not a factor in its electrical conductivity. Also, an extremely high surface area (theoretical limit: 2630 m²/g) and gas impermeability[6] indicate graphene's great potential for improving properties of polymers. The formation of well dispersed nanofiller and strong interfacial interactions is dependent upon the good compatibility between filler and matrix. Different techniques have been adopted to achieve a fine dispersion of graphene and polymer nanocomposites[7-9]. Solution mixing is found to be efficient in dispersing Graphene in ABS with improved mechanical and gas barrier properties[10]. ABS consists of butadiene rubber dispersed in a matrix of poly (Styrene-Co-Acrylonitrile (SAN)). Compared with solution mixing, direct mechanical mixing is less efficient in dispersing graphene but scalable production can be achieved with enhanced mechanical properties of the nanocomposite[10,11]. In the present study, we are dispersing graphene in ABS matrix through solution mixing method and analyzing modifications and amendments in its mechanical properties with the load content of the nanofiller graphene. The extent of the improvement is directly related to the degree of dispersion of the nanofillers in the

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polymer matrix[12]. Therefore, the main aim of the present study is to study the variation in Yound modulus and hence the extent of improvement in the mechanical properties of ABS dispersed graphene nanocomposite with variations in the filler content.

2. Experimental details

2.1 Materials

Graphene procured from Ad-Nano Technologies Private Limited Karnataka, and ABS procured from Goyal poly products Ltd., Industrial area, Chandigarh, India have been used without further purification. Chloroform which was used as solvent was procured from Central Drug House (CDH).

2.2 Fabrication of Graphene/ABS Nanocomposite

In order to synthesize Graphene/ABS nanocompsite solvent blending technique is used. For this purpose, chloroform is used as solvent to mix Graphene and ABS. First 30 g ABS is dissolved in 150 mL chloroform. Thereafter, 2.5% of ABS of Graphene is dispersed in chloroform in a separate flask. Sonication and magnetic mixing is done separately for the two solutions for 2 hours. Finally, these two solutions are mixed, sonicated and stirred magnetically again for 1 hour respectively to ensure proper dispersion of Graphene into Polymer layers. The prepared solution is then poured into Petri plates and the solvent (chloroform) is allowed to evaporate by heating the poured solution in an oven for 3 hours at 70^0 C. After evaporation of chloroform, thin films of Graphene/ABS nanocomposits are formed on Petri plates. These films are then molded into Dog bone shape of specific dimensions machine as shown in Figure 1 with the help of compression moulding. The compositions of Graphene in the ABS were varied from 0 (pure) 2.5, 5 to 7.5% percent. These percentages are changed in order to study the effect of content of graphene loading on ABS and variations in their mechanical properties.
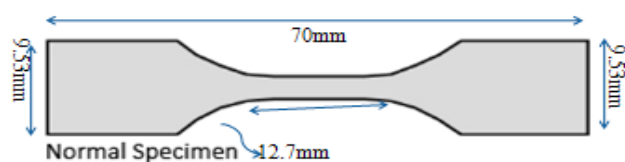

Figure 1. Geometry and dimensions of sample.

2.3 Characterization

Field Emission Scanning Electron Microscopy (FESEM) Hitachi Model no SU8010 Japan is employed for studying the morphology of the prepared nanocomposites. The sample was coated with platinum during analysis using ion sputter instrument model no: MC 1000 from Hitachi, Japan. In order to study the effect of graphene on thermal stability of ABS polymer and to determine its phase transition temperature, Thermal Gravimetric Analysis (TGA) technique was employed using TGA Mettler Doledo united State TGA /DSC /1Star. The prepared samples of the film weighing in the range of 5-10 mg were analyzed using Alumia crucible of 70 microlitre (μl) capacity. The samples were tested at a heating rate of $10^°$C/min under inert atmosphere of Nitrogen gas (N_2 gas) To study the tensile strength of prepared nanocmposites, Universal Testing Machine Electro Force 3200 (TA Instrument USA) is utilized and conducted at room temperature at a strain rate of $0.001s^{-1}$.

3. Results and Discussions

3.1 Surface Properties

In order to view the morphological view of dispersion of graphene in ABS polymer to form ABS-graphene nanocomposite, FE-SEM analysis was done. The results are as shown in Figure 2-3. From Figure 3, we observe that at 5% graphene content, graphene hexagonal sheets are more uniformly dispersed in ABS polymer chains as compared to 2.5% graphene content (Figure 2). This uniformity of 5% graphene content ABS nanocmposite serves as an advantage to enhance its mechanical properties[13,14]. This is because more uniformity indicates
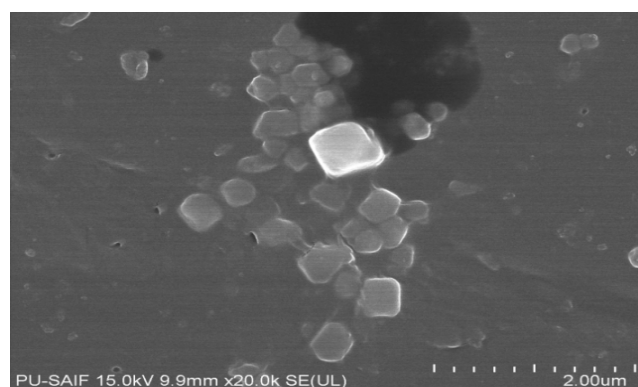

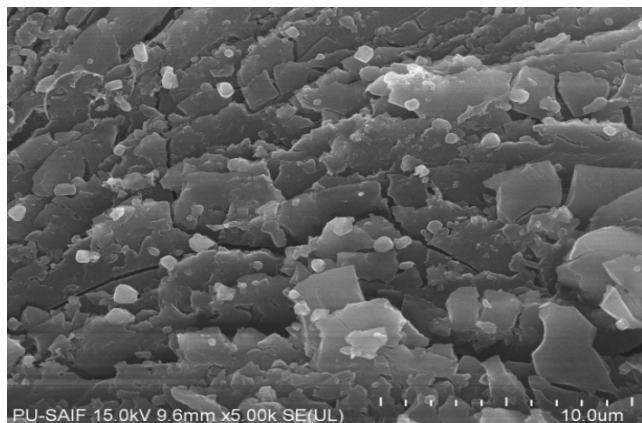**Figure 2.** FESEM 2.5% graphene /ABS nanocomposite.

Figure 3. FESEM 5% graphene /ABS nanocomposite.

Figure 4. TGA analysis of pure ABS and ABS-graphene nanocomposite.

lesser defect states, that do not alter or hampers the stress strain relationship and accordingly, tensile strength will be significantly improved as compared to 2.5% graphene content[15].

Figure 2 shows FESEM image of 2.5% Graphene/ ABS nanocomposite. In this image graphene is seen as dispersed in polymer layer. In Figure 3, as graphene content is increased to 5% it is dispersed uniformly throughout the polymer layers. FESEM show distribution of Graphene in polymer layers. Homogeneous dispersion of Graphene in polymer layer is essential for the enhancement of mechanical properties[16].

3.2 Thermal Properties

In order to study the effect of graphene content on thermal stability of ABS nanocmposite, TGA is conducted for pure ABS and ABS with 5% graphene content. The results are as shown in Figure 4 (plot of weight loss of pure ABS and ABS-graphene nanocomposite wih respect to temperature). Figure 4, we observe that at around 110˚C, thermal stability of pure ABS is enhanced after graphene 5% incorporation (150˚C). This is concluded on the basis of the fact that pure ABS undergo first phase transition at around 124˚C, whereas Graphene/ABS nanocomposite remained thermally stable upto 138˚C showing 11.3% improvement as compared to pure sample of ABS and thereafter it undergo phase transition. The enhancement in thermal stability again serves as an advantage for modifying mechanical properties. This is because more thermal stability promotes lesser probability of strain due to lesser thermal vibrational motions and hence better tensile strength and Yound modulus[16,17].
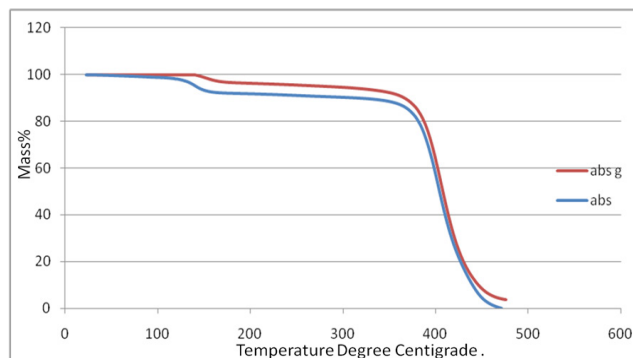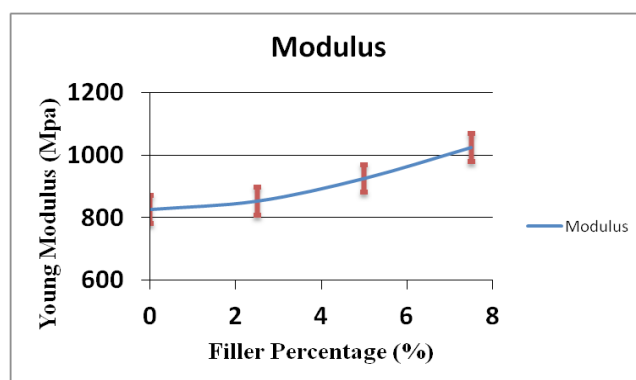

Figure 5. Variation of young modulus with graphene percentage in ABS.

3.3 Mechanical Properties

In the present study, mechanical properties of tensile specimens of Graphene/ABS nanocomposites are studied. The tensile sample dimensions are shown in Figure 1. The strengths of different samples are studied under the strain rate of 0.001 S^{-1}. From the strength and strain graphs, Young modulus are studied and analyzed at different load content. The results are as shown in Figure 5. From Figure 5, we observe that with increase in percentages of graphene content (from 2.5% to 7.5%) in ABS polymer nanocomposite, the Young modulus percentage increases to 3.27, 11.63 and 24.24, respectively. These values have been calculated using the percentage of ratio of change in initial value to final value and the graphically observed values are shown in Figure 5 and listed in Table 1. The values indicate that with increase in graphene content, mechanical properties of ABS nanocompsite is significantly enhanced. This is because increase in young modulus indicates increase in the

Table 1. Values of young modulus.

Graphene content (%)	Young's Modulus (MPa)	Percentage Improvement in Young's Modulus
0	825	-
2.5%	852	3.27
5%	925	11.63
7.5%	1025	24.24

strength of the material[17,18]. This is because the inter layer cross links of graphene sheets under loads, which could lead to ordering of the hierarchical structures, have great significance for enhancing the mechanical properties of these nanocomposites[19,20.]

4. Conclusion

Graphene/ABS nanocomposite prepared using solution mixing method showed enhancement in the Young modulus and mechanical properties with increase in the filler content of Graphene from 2.5% to 7%. This indicates that Graphene nanosheets act as a supporting medium to modify the mechanical properties of ABS nanocomposite. TGA analysis of pure ABS and ABS with 5% Graphene content shows increase in the phase transition temperature which indicates that thermal stability of ABS is enhanced with graphene incorporation. FE-SEM analysis reveals that with increase in the graphene filler content in ABS a uniformly dispersed nanocomposite material is obtained. Uniformity in morphology of nanocomposite proves to be a nanocomposite with better mechanical properties as compared to a non uniform polymer.

5. Acknowledgement

6. References

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