Effect of Graphene Nano Filler on Mechanical Properties of Acrylonitrile Butadiene Styrene (ABS)/ Graphene Nanocomposites

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Abstract

Graphene is a monolayer of sp²-hybridized carbon atoms arranged in a two-dimensional lattice, having excellent thermal, mechanical, and electrical properties. Due to its various intriguing properties, it has gained significance as filler in nanocomposites. Graphene/Acrylonitrile Butadiene Styrene (ABS) based nanocomposite is prepared by using solvent mixing method. ABS has outstanding material property and its ease of availability motivated to use it as a polymer material. The enhancement in the values of Young Modulus of ABS nanocomposite after graphene incorporation is studied using compressive testing technique at different graphene filler contents. The structural and morphological properties of the prepared Graphene/ABS nanocomposites studied using X-Ray diffraction and Field-emission scanning electron microscopy highlighted the effect of dispersion and uniformity of graphene incorporated ABS nanocomposite on their mechanical properties.

Keywords: Graphene Acrylonitrile Butadiene Styrene (ABS) Nanocomposites, Mechanical Properties

1. Introduction

Carbon based nanofillers such as, carbon nanotubes (CNTs) and graphene derivatives have been reported to enhance thermal, mechanical, electrical and gas barrier properties of polymers due to their high strength on account of their sp² bonded carbon atoms [1, 2]. Their large aspect ratio and better dispersion in polymer matrices acts as an advantage to enhance these properties [2, 3]. In polymer composites, effective percolation threshold of CNTs varies from 2 to 5 wt%, however for graphene and its derivatives the percolation threshold lies in the range 0.5 to 2 wt%. Recently, graphene has attracted the attention of researchers and industrialists because it can produce a drastic amendment in the properties at very low filler content [4, 5]. Graphene is considered two-dimensional carbon nanofiller with a one-atom-thick planar sheet of sp² bonded carbon atoms that are densely packed in a honeycomb crystal lattice. It is regarded as the “thinnest material in the universe” with tremendous application potential [6, 7]. Thermal, mechanical and electrical properties of graphene reinforced polymer nanocomposites depends on various topographical features, morphology, weight fraction, dispersion state, and surface functionalization of graphene [8, 9]. When a polymer is reinforced with graphene, the carbonaceous sheets shackle the crack and restrict its advancement. This deflection and obstruction of the crack by the graphene at the interface is the primary mechanism for raising the fracture toughness of nanocomposites [10]. A significant enhancement in thermal and mechanical properties of various polymer nanocomposites like Polyvinylalcohol (PVA), polyethylene terephthalate (PET), Poly-methyl methacrylate (PMMA), epoxy nanocomposites after incorporation of graphene derivatives has been reported.
In the present work, we are incorporating graphene into Acrylonitrile–Butadiene–Styrene (ABS) polymer using solution blending method to form Graphene-ABS nanocomposite. The advantage of solution blending method over other synthesis methods such as melt mixing and in-situ polymerization are achievement of better dispersion of graphene nanofiller in polymer matrix and more amendment in the properties at lower filler contents [15, 16].

2. Experimental details

2.1 Materials used
Graphene procured from Ad-Nano Technologies Private Limited Karnataka, and Acrylonitrile Butadiene Styrene (ABS) was 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 Preparation of Graphene/ABS nanocomposite

In order to synthesize Graphene/ABS nanocomposite solution blending technique is used. For this purpose, Chloroform is used as solvent for mixing Graphene and ABS. Firstly, 30 g ABS is dissolved in 150 mL Chloroform and and 2.5% of ABS of Graphene is dispersed in chloroform in a separate flask. Sonication and magnetic mixing of the obtained solutions is done separately for around 1 hour. Thereafter, 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 pour to Petri plates and the solvent (chloroform) is allowed to evaporate by heating the poured solution in an oven for 3 hours at a temperature of 70° C (Fig. 1).

![Schematic representation of synthesis method of nanocomposite using solution blending method.](image-url)
After evaporation of chloroform thin films of Graphene/ABS nanocomposites are obtained on Petri plates. These nanocomposites films are molded into disc shape pellets of specific dimensions as shown in Fig. 2 to study the compression properties.

![Fig. 2. Disc shaped pellets for studying compression properties.](image)

The composition of Graphene in the ABS was varied from 0 (pure) 2.5, 5 and 7.5% percent, respectively. These percentages are varied in order to study the effect of content of graphene loading on ABS and variations in their mechanical properties.

### 2.3 Instrumentation

X-Ray Diffraction (XRD) pattern of prepared nanocomposites was recorded on a “X’PERT PRO TW 3050 Diffractometer”, using Cu-Kα beam of wavelength 1.54 Å as an incident X-Ray source with 45kV voltage and 40mA current in the scattering angle (2θ) scan range from 5˚ to 70˚. Field Emission Scanning Electron Microscopy (FESEM) Hitachi Model no SU8010 Japan is employed for studying the morphology of the prepared nanocomposites. To study the compressive strength of prepared nanocomposites, Universal Testing Machine Electro Force 3200 (TA Instrument USA) is utilized.

### 3. Results and Discussions

#### 3.1 XRD Results

Fig. 3 shows the XRD spectra of graphene nanofiller and Graphene/ABS nanocomposite at different graphene filler contents ranging from 2.5 to 7.5 wt %. From the observed results, we observe that, the characteristic peak of graphene observed at 26˚ is shifted to 27˚ after incorporation into ABS polymer. The broad peak in the range of 13˚ to 24˚ corresponds to amorphous nature of polymer. This peak appears to be suppressed with increase in graphene content, which indicates that with increase in graphene content, the dispersion of graphene in ABS polymer is enhanced [16]. Better dispersion is on account of successful intercalation of graphene nanofiller in ABS polymer chains. This dispersion enables better mechanical properties of ABS nanocomposites [16, 17].

![Fig. 3. XRD spectra of graphene and Graphene/ABS nanocomposites.](image)
3.2. FE-SEM Results

Figs. 4 (a, b) gives the FE-SEM images of Graphene/ABS nanocomposites at 2.5, 5 and 7.5 wt% graphene contents, respectively. From images, we observe that at 2.5 wt %, graphene nanofillers are more uniformly arranged as compared to 5 and 7.5 wt % graphene contents, respectively. Graphene sheets appear to be intercalated successfully into ABS polymer chains at 5 and 7.5 wt % contents, which leads to more homogeneity of the nanocomposite, which is consistent with our XRD results [15, 16].

![Fig. 4 (a, b, c) FE-SEM images of Graphene-ABS nanocomposites at 2.5, 5% and 7.5 wt% graphene content.](image)

3.3 Mechanical Properties

In this present study, mechanical properties of compressive specimens of Graphene/ABS nanocomposites are studied. The compressive sample dimensions are 10 mm in diameter and 5mm in width as shown in Fig. 2. The compressive strengths of different samples are studied under the strain rate of 2.5 S⁻¹. From the strength and strain graphs, Young modulus for compression is studied at different load content. The results are as shown in Fig. 5. From this we observe that with increase in percentages of graphene content (from 2.5%, 5% to 7.5%) in ABS polymer nanocomposite, the Young modulus percentage increases to 37.83, 26.21 and 18.43 % respectively. The values indicate that with increase in graphene content, mechanical properties of ABS nanocomposite is significantly enhanced as there is significant increase in young modulus of compression.

![Fig. 5. Young Modulus variations at different loading content of graphene.](image)
The graph is plotted as per the data and it indicates that the enhancement in Young’s modulus is more significant at lower percentages in comparison to higher percentages. The Young’s modulus value of pure ABS is 124.79 MPa. Its value is enhanced to 172, 157.5 and 147.8 (MPa) at 2.5%, 5% and 7.5 respectively as shown in table 1. The Young’s modulus and its percentage improvement in comparison to pure ABS is increased to 37.83% at 2.5% graphene content. After increasing graphene loading to beyond 2.5% there is increase in Young’s modulus but to lesser extent. As shown in table 2 Nanocomposites shows enhancements of 26.21% and 18.43% improvement with 5% and 7.5% Graphene loading respectively which is less as compared to 2.5%. This is due to proper dispersion of graphene nanofiller in ABS matrix at lower wt% loading. Graphene nanofiller are well and uniformly dispersed in polymer matrix at low filler content which leads to higher improvement in Young’s Modulus of compression. This is because uniform dispersion results in enhanced tensile strength and agglomerated graphene leads to drop in tensile strength values [18]

### Table 1: Young’s Modulus values in percentage.

<table>
<thead>
<tr>
<th>Percentages of Graphene in ABS/Graphene Nanocomposites (%WT)</th>
<th>Young’s modulus (Y) (MPa)</th>
<th>Percentage Improvement in Young’s modulus as comparison to pure ABS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>124.79</td>
<td>—</td>
</tr>
<tr>
<td>2.5%</td>
<td>172</td>
<td>37.83%</td>
</tr>
<tr>
<td>5%</td>
<td>157.5</td>
<td>26.21%</td>
</tr>
<tr>
<td>7.5%</td>
<td>147.8</td>
<td>18.43%</td>
</tr>
</tbody>
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Table 2. Enhancement in Young Modulus with Graphene content.
4. Conclusions
Graphene-ABS nanocomposite prepared using solution blending method enables better dispersion of graphene in ABS polymer. XRD and FE-SEM images revealed the structural and morphological view of the prepared nanocomposites at different graphene load contents and indicated their successful dispersion. Values of Young’s Modulus for compression for ABS and ABS nanocomposites at respective percentages were found to increase with graphene incorporation and exhibited maximum increase at 2.5 wt% Graphene loading. This may be due to successful intercalation of the Graphene sheets at this low filler content. Young’s Modulus at higher Graphene loading may be comparatively increased in future with better dispersion of graphene nanofiller in polymer matrix.

5. Acknowledgements
In this study of Graphene /ABS Nanocomposite we are very thankful to IIT Ropar and SAIF department, Panjab University, Chandigarh for providing the necessary facilities. We are also thankful to TEQIP II for regular financial support for the experiment and laboratory.

References