Effect of Multi-Walled Carbon Nanotubes (MWCNT) on Mechanical Properties of Acrylonitrile Butadiene Styrene (ABS) Nano-Composite

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Abstract

Acrylonitrile Butadiene Styrene (ABS)/Multi-Walled Carbon Nanotubes (MWCNTs) nanocomposites were prepared using solvent blending technique with chloroform as solvent. ABS has high impact strength and presence of MWCNTs in them can further enhance their mechanical properties without affecting the weight significantly. MWCNTs possess Young's modulus of nearly 1 TPa due to which their presence in polymers even in small quantities can enhance the mechanical properties significantly. The weight of MWCNTs in ABS was varied from 1% to 10% (1, 3, 5, 7, 10 wt%). Thin films of nanocomposite of ABS/MWCNTs at various weight percentages of MWCNTs were analyzed for dispersion of MWCNTs in ABS using Field Emission Scanning Electron Microscope (FESEM). These films were then transformed using a compression moulding machine into disc shaped pallets for mechanical characterization. These compositions when tested for Young’s modulus for compression showed significant enhancement in Young’s modulus in comparison to pure ABS ranging from 150.87% to 330.76% for various compositions of ABS/MWCNT nanocomposite. Thus, by improving the mechanical properties of ABS by incorporation of small quantity of MWCNTs these nanocomposite material can be used to manufacture automotive and aerospace parts.

Keywords: ABS, FESEM, MWCNTs, Nanocomposite, TGA, Young’s Modulus

1. Introduction

Nanocomposites have become a prominent area of current research and development in material science, because even adding a small amount of the nanofiller can significantly improves the strength and stiffness, improves thermal properties, improves electrical properties12. The nanofiller which we have used for our research work is carbon nanotubes (CNTs) to be more specific Multi-Walled Carbon Nanotubes (MWCNTs). Basically CNTs are tubular cylinders of carbon atoms having high flexibility, low mass density, high aspect ratio and very small size. These features of CNTs gives them brilliant mechanical, electrical, thermal, optical and chemical properties. They are the stiffest and strongest man-made material. Due to their such excellent properties they are used as an ideal reinforcement fillers for polymer nanocomposites. The properties of the material in which CNTs are incorporated enhances if there is proper dispersion of CNTs into the polymer matrix17.

Acrylonitrile butadiene styrene (ABS) is thermoplastic polymer with chemical formula \((\text{C}_8\text{H}_8)_x \cdot (\text{C}_4\text{H}_6)_y \cdot (\text{C}_3\text{H}_3\text{N})_z\). Styrene and acrylonitrile are polymerized in the presence of polybutadiene to form a terpolymer known as ABS. Light weight, impact resistance, dimensional stability, good toughness, chemical resi-
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tance to many chemicals and ease with which it can be injection molded and extruded make it useful and important engineering thermoplastics which is widely used in the industry for manufacturing of products such as automotive trim components, automotive bumper bars, golf club heads (because of its good shock absorbance), medical devices for blood access, protective headgear, luggage and protective carrying cases, small kitchen appliances, drain-waste-vent (DWV) pipe systems and toys.

Several methods have been used to fabricate polymer/CNTs composites. In situ interfacial polymerization, Melt mixing, Solution blending are few techniques or methods which are most widely used for the fabrication of polymer/CNTs nanocomposite. From the above given fabrication techniques the technique which we have chosen for our research work would be solution blending technique. This technique is chosen because of its easy approach, cost effective and almost negligible wastage of CNTs and polymer in the formation of the nanocomposite film. The solvent used in preparation of Acrylonitrile Butadiene Styrene (ABS)/Multi-Walled Carbon Nanotubes (MWCNTs) nanocomposites would be chloroform.

2. Experimental Part

2.1 Materials

In our research work we have used majorly three materials Acrylonitrile Butadiene Styrene (ABS), Multi-Walled Carbon Nanotubes (MWCNTs) and chloroform. Acrylonitrile Butadiene Styrene (ABS) was procured from Goyal poly products Limited, Phase-2, Industrial area, Chandigarh, India. Multi-Walled Carbon Nanotubes (MWCNTs) of length 10 micron and diameter varying from 5 to 20 nanometer (nm) were procured from United Nanotech Innovations Private Limited, Bangalore, India. Chloroform which was used as solvent was procured from Ahuja agencies, Chandigarh, India.

2.2 Fabrication of ABS/MWCNTs Nanocomposite

For the fabrication of ABS/MWCNTs nanocomposite by solvent blending technique the following procedure is followed. Dispersion of ABS polymer was done in solvent (chloroform) followed by magnetic stirring for 2-3 hours and sonication for 2-3 hours. Similarly, Dispersion of MWCNTs was done in the same solvent (chloroform) as used for polymer followed by magnetic stirring for 2-3 hours and sonication for 2-3 hours. The above prepared ABS polymer and MWCNTs solutions were then mixed and magnetic stirring was done for 2-3 hours and then sonication was carried out for 2-3 hours. The above prepared nanocomposite solution of ABS/MWCNTs was then poured slowly and uniformly in petridish and kept in undisturbed circumstances for 24 hours so as to allow the solvent to evaporate. The solvent which is still left in the nanocomposite film is removed by heating the nanocomposite films in vacuum oven at around 70° C for 3-4 hours. Thin films obtained after drying were then transformed using a compression moulding machine into disc shaped pallets with 10mm diameter and 5mm thickness. The composition of MWCNTs was varied from 1% to 10% by weight in the ABS. Five percentages 1, 3, 5, 7.5 and 10 were selected on which samples were prepared.

3. Characterization

3.1 Morphological Characterization

The distribution or dispersion of MWCNTs in ABS would be analyzed using Field Emission Scanning Electron Microscope (FE-SEM) model number SU8010 from Hitachi, JAPAN. Before the film sample was analyzed using FESEM machine the sample was coated with platinum using Ion Sputter instrument model number MC1000 from Hitachi, Japan.

3.2 Thermal Characterization

Thermal analysis of the films were done using thermal gravimetric analysis (TGA) technique in which variation of weight percentage of sample with respect to temperature was studied using instrument TGA/DSC 1 star system by Mettler Toledo, United States. Samples of film weighing in the range of 5-10 mg were analyzed using Alumina crucible of capacity 70 micro liter. The sample were tested at a heating rate of 10 °C/min under inert atmosphere (N₂ gas).

3.3 Mechanical Characterization

Disc shaped pallets with 10mm diameter and 5mm thickness of ABS/MWCNTs were tested for variation in mechani-
4. Results and Discussion

4.1 Morphology
Field Emission Scanning Electron Microscope (FE-SEM) of these samples was performed and the images indicated excellent dispersion of MWCNTs in ABS. Following are images of FESEM of ABS/MWCNT at various percentages.

From the images we could see the dispersion level of MWCNTs in ABS. In the image of Figure 1 (A) less number MWCNTs are visible and the region encircled in red show the presence of MWCNTs. The distribution of MWCNT in ABS is not so dense because less amount of MWCNTs were added for 1% composition. In the image of Figure 1 (B) as the amount of MWCNTs has increased to 5% the distribution of MWCNT in ABS tends to

- Figure 1. (A) FESEM image of ABS/MWCNT at 1% composition, (B) FESEM image of ABS/MWCNT at 5% composition, (C) FESEM image of ABS/MWCNT at 10% composition.
increase shown by region encircled in red and at certain places bundles of MWCNTs could be observed shown by region encircled in orange. In the image of Figure 1 (C) amount of MWCNTs has increased to 10% the distribution of MWCNT in ABS becomes very concentrated and agglomeration of these MWCNTs could be observed shown by region encircled in orange.

Figure 2. TGA curve for pure ABS and ABS/MWCNT nanocomposite.

4.2 Thermal Properties
The thermal properties of pure ABS and ABS containing 5% MWCNTs by weight was analyzed using TGA and graph was plotted for variation of weight percentage of sample with respect to change in temperature.

From the Figure 2 we can see that for pure ABS there is a minor degradation initially, which begins at temperature of approximately 125°C and then a major degradation beginning at approximately 360°C. For the 5% sample the minor degradation occurs at a little higher temperature of around 135°C and the major degradation of 5% sample the begins at temperature higher than pure ABS at approximately 370°C.

4.3 Mechanical Properties
The mechanical property, Young's modulus for compression was analyzed using universal testing machine on which disc shaped pallet samples of 10mm diameter and 5mm thickness for various compositions of ABS/MWCNT nanocomposite were tested to obtain stress strain curve. Stress strain curves obtained from the data were plotted and the Young's modulus for compression was calculated from the curves at various percentages of MWCNTs in ABS. The value of Young's modulus for compression and the percentage enhancement in Young's modulus for compression in comparison to pure ABS is tabulated at 0,1,3,5,7.5,10 percentage by weight of MWCNTs in ABS is given below in Table 1. A graph showing variation of Young's modulus at various percentages of MWCNTs in ABS is given below in Figure 3.

Figure 3. Graph showing percentage improvement of Young's modulus in comparison to pure ABS at various percentages of MWCNTs in ABS.

Table 1. Showing Young's modulus and percentage enhancement of Young's modulus in comparison to pure ABS at various percentages of MWCNTs in ABS

<table>
<thead>
<tr>
<th>Percentages of MWCNTs in ABS by weight (%)</th>
<th>Young's modulus (Y) (MPa)</th>
<th>Percentage improvement of Young's modulus in comparison to pure ABS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>56.14</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>211.16</td>
<td>276.13</td>
</tr>
<tr>
<td>3</td>
<td>241.86</td>
<td>330.76</td>
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<tr>
<td>5</td>
<td>221.66</td>
<td>294.83</td>
</tr>
<tr>
<td>7.5</td>
<td>203.98</td>
<td>263.34</td>
</tr>
<tr>
<td>10</td>
<td>140.84</td>
<td>150.87</td>
</tr>
</tbody>
</table>

From the Table 1 and graph in Figure 3 we can see that with the incorporation of MWCNTs in the ABS there is enhancement in the mechanical property i.e. Young's modulus for compression improves significantly. We can see that at all the percentages varying from 1% to 10% there is enhancement in Young's modulus. The data and trend of graph indicates that the enhancement in Young's modulus is much more significant at lower percentages in comparison to higher percentages. The trend of Young's modulus and percentage improvement of Young's modulus in comparison to pure ABS is increasing initially with maximum value of 241.86 MPa and 330.76 % respectively at 3% composition, then the Young's modulus starts decreasing but the value of Young's modulus and percent-
age enhancement of Young's modulus in comparison to pure ABS still remains higher for other percentages of nanocomposite in comparison to pure ABS, with 10% sample showing Young's modulus of 140.84 MPa percentage enhancement of Young's modulus in comparison to pure ABS of 150.87%.

5. Conclusion

ABS/MWCNTs nanocomposite was fabricated using solvent blending technique and the films obtained from fabrication were moulded into disc shaped pallet samples using compression moulding machine for mechanical testing. The FESEM images in Figure 1 of the nanocomposite films indicate excellent and uniform dispersion of MWCNTs in ABS at lower percentages of 1%, at 5% dispersion is good but there are places where accumulation of MWCNTs is visible and at 10% the MWCNTs get entangled with each other and dispersion is not uniform. From the TGA graph in Figure 2 we could say that for the 5% sample of MWCNTs in ABS the thermal stability increases as degradation begins at higher temperature in comparison to pure sample of ABS. Results of Young's modulus for compression shown in the Table 1 and graph 3, tested using Universal Testing Machine(UTM) indicate significant enhancement in Young's modulus at various compositions of MWCNTs in ABS. We can conclude that the enhancement in Young's modulus of ABS/MWCNT nanocomposite is due to the following reasons high aspect ratio(length/diameter) and high surface/volume ratio of MWCNTs which enhances the load transfer, stress concentration zones are reduced in the nanocomposite due to good dispersion of MWCNTs in ABS particularly in lower percentages of MWCNTs in ABS and strong adhesion between MWCNTs and ABS and ensures proper transfer of stress from polymer matrix to the nanofiller, thus improving the Young's modulus of nanocomposite. Finally we can say that incorporation of MWCNTs in ABS enhances its thermal and mechanical properties mainly at lower percentages\textsuperscript{16-21,23}.

6. Acknowledgements

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7. References

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