

ICMCT-2014 [10th – 12th March 2014]
International Conference on Materials and Characterization Techniques

Effect of Mechanical behaviours of Graphene oxide reinforced compatibilized High density Polyethylene

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Abstract: Nanocomposites are new classes of composites for which at least one dimension of the dispersed particles is in the nanometre range. High density polyethylene (HDPE) is widely used as a container for storing food oils and petrochemical products due to its light weight, high specific strength, low cost, high chemical resistance and mechanical flexibility. Hence HDPE based nanocomposites are of great interest. Graphene Oxide is a single atomic-layered material made by oxidizing graphite crystals. The work aims in dispersing graphene oxide in the HDPE matrix in order to improve the properties of the polymer matrix. Since HDPE matrix is a non-polar polymer, the addition of polar graphene oxide may not lead to better compatibility. Hence polar maleic anhydride grafted polyethylene (MA-g-PE) is used as a compatibilizer to disperse graphene oxide in the base HDPE matrix. The changes obtained in the morphology and mechanical properties of the compatibilized nanocomposite were analyzed and compared with uncompatibilized nanocomposites, HDPE/MA-g-PE blend system and pure HDPE.

Keywords: High-Density Polyethylene, Graphene oxide, Maleic Anhydride Grafted Polyethylene, Transmission Electron Microscope.

1.0 Introduction and Experimental:

1.1 Introduction

A material having two or more distinct constituent material may be considered a composite material. Normally a composite material is composed of incorporation of fibers or fillers in to the matrix. The incorporation holds by the matrix and forms the desired shape and structure and the incorporated material enhances the properties of to the base matrix (1). The reinforced materials transfer the load to the matrix. The composites are classified according to the types of material for manufacturing the products, Polymer Matrix Composites (PMC), Ceramic Matrix Composites (CMC), Metal Matrix Composites (MMC). In PMC, polymer is used as base matrix. The reinforcement is called as fibers, it will be either natural or artificial fiber. In CMC the ceramic particles are used as a base matrix, the reinforcements used are alumina, SiC, zirconium or carbon. In MMC, metal is used as base matrix. The reinforcement commonly used is clay, it will be in the form of

particles/particulate, flake and/or fillers used in the aero-space, automotive and thermal applications (2). Commonly used metal matrixes are Aluminium matrix, Copper matrix, Titanium matrix. The objective of the present work is to improve the mechanical properties of HDPE by adding nanofiller, in order to promote the application of HDPE (3). By increasing the mechanical properties of HDPE considerably, the same can be used in automobile and aerospace applications.

1.2 Experimental Procedure:

Initially the graphite is converted into the graphite oxide by adding the polar groups into that, then separated from the stack (4). Modified Hummer's method (5) is performed for this process. If the polar groups are removed from the sheet it is termed as graphene. Initially 13 sample were selected with different composition each sample were given separate code. The tensile strength and modulus (6) for the different combination were studied. The mixing formulation is shown in table.1.

Table.1: Mixing Formulation

S.No	Sample code	HDPE (wt. %)	PE-g-MA (wt. %)	GO (wt. %)
1	H	100	-	-
2	HG1	99.5	-	0.5
3	HG2	99	-	1.0
4	HG3	98.5	-	1.5
5	HG4	98	-	2.0
6	HG5	97.5	-	2.5
7	HG6	97	-	3.0
8	HCG1	98.5	1	0.5
9	HCG2	97	2	1.0
10	HCG3	95.5	3	1.5
11	HCG4	94	4	2.0
12	HCG5	92.5	5	2.5
13	HCG6	91	6	3.0

1.2.1 Melt Mixing & Compression Molding:

The preparation of polymeric nanocomposites was done by adopting melt mixing technique (7). Two roll internal sigma mixer was used for performing melt mixing operation. In melt mixing the granular HDPE is converted to mixed sample at 160 °C and at 50 rpm for pure HDPE and sample code is H. For the sample code HG granular HDPE and graphene oxide is mixed at 160 °C and at 50 rpm for a time period of 10 minutes. For the sample code HCG granular HDPE, graphene oxide and MA-g-PE are mixed at 160 °C and at 50 rpm. Initially the polymer was poured in between the two rolls. GO was slowly poured in between the rolls once after the polymer gets completely melted. Finally the mixed samples had been taken from the chamber. Compression molding is a method of molding in which the molding material, generally preheated, is first placed in an open, heated mold cavity (8). The mold is closed with a top force, pressure is applied to force the material into contact with all mold areas, while heat and pressure are maintained until the molding material has cured. The process employs thermosetting resins in a partially cured stage either in the form of granules. The mixed sample is converted to dumbbell shape in compression molding by giving 160 °C and 50 KN (9). The dumbbell plate for 25 mm sample size is taken and is kept in between aluminium foil percolated by silicon solution and is kept in between the upper and lower plate of compression molding machine. The pressure is given by using hydraulic press ram and then the instrument is switched off to cool (10).

2.0 Results and Discussion:

Figure.1 shows the external surface of the graphite at high magnificent level and selected area of electron diffraction (SAED) image of graphite. It clearly shows the smooth layer of the flake graphite layers before mixture with HDPE. It also shows the location of the carbon atom and it's equally divided and spaced to each other. SAED pattern proves the presence of graphite sheets in stacked form.

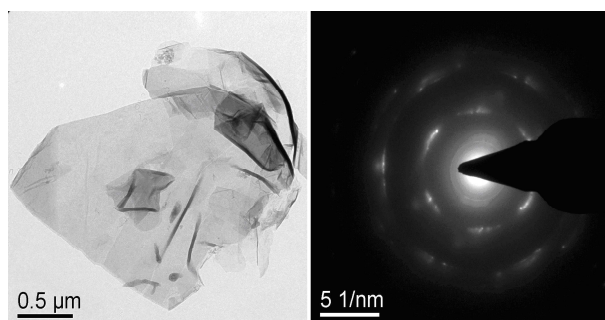
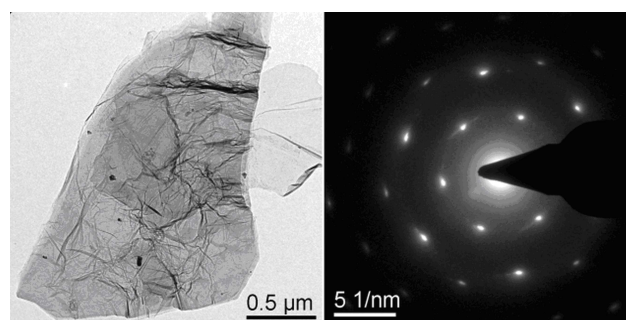
**Figure.1:** TEM & SAED frame of graphite**Figure.2:** TEM & SAED frame of GO

Figure.2 shows the wrinkled surface of the prepared samples of graphene oxide layer which was exfoliated from the flake graphite and indicate the single sheet of graphene oxide SAED image for the each and every single oxygen atom was shared with the 6 carbon atoms in the single layer. SAED pattern proves the presence few layer graphene oxide sheets that has been obtained after chemical synthesis.

Table.2 : Percentage variation in tensile strength and modulus

S.No	Sample code	% Increase in Tensile strength	% Increase in modulus
1	H	-	-
2	HG1	30.9	26.04
3	HG2	41.23	43.21
4	HG3	47.97	63.12
5	HG4	52.12	85.36
6	HG5	36.04	101.20
7	HG6	31.36	121.3
8	HCG1	55.16	191.27
9	HCG2	61.36	233.18
10	HCG3	73.41	278.21
11	HCG4	85.21	318.09
12	HCG5	96.82	352.17
13	HCG6	91.31	371.09

Uncompatibilized nanocomposites shows increase in mechanical properties compared to pure H. This may be due to physical interaction between the GO and HDPE. The improvement in mechanical properties of compatibilized nanocomposites may be due to the better compatibility between GO and HDPE in presence of MA-g-PE. HG5, HG6 and HCG6 shows slender drop in tensile strength compared to low loaded GO nanocomposites. This may be due to the higher loading of GO, which leads to agglomeration of GO sheets in the HDPE matrix. The presence of compatibilizer plays a great role in improving the mechanical properties of HDPE nanocomposite than uncompatibilized HDPE nanocomposite. The improvement in properties may be due to polar-polar interaction between the nanofiller and compatibilizer. The tensile strength and modulus of the compatibilized system is found superior compared to pure HDPE and uncompatibilized systems. In summary, the best result of mechanical properties are high for HCG5 of tensile strength 33.46 MPa and modulus 3.71 GPa. HCG5 has 96.82% enhancement in tensile strength and 352.17% increase in modulus while compared to pure HDPE.

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