Organically modified MMT- Reinforced Epoxy Nanocomposites

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Abstract- *An attempt has been made in the present investigation to develop epoxy/MMT nanocomposites with varying amounts of nanofiller. These nanocomposites have been prepared by the compression molding at different loadings (0,1,2,3,4,5) wt % of MMT. The degradation behavior and thermal stability have been determined with the aid of thermo-gravimetric analyzer (TGA). TGA results reveal that there is appreciable enhancement in thermal stability at 5 Wt. % loading of MMT. Mechanical properties results demonstrate that the maximum tensile strength and modulus has been achieved at 1 wt. % loading of MMT. There is no effect of nanofiller loading on the flexural modulus. Maximum flexural strength has been achieved in the developed nanocomposites at 3 wt % content of MMT in epoxy matrix.*

Keywords- Epoxy, MMT, Thermal properties, Tensile, Flexural.

I. INTRODUCTION

Epoxy resin has gained a vital share among recent reputed technical research publications and patents owing to its multiple applications in paints, adhesive and composites [1-3]. However, flammability of this class of polymer is a measure problem in various hi-tech application oriented utilities. Truly speaking epoxy resin is widely used as matrix materials for structural complexes as an encapsulating material for electronic devices [4-6]. Recently various fillers have been used to improve the antioxidation/flame retardant properties of epoxy resin [7-9]. In general, fillers have been regarded as a good candidate as flame-retardant additives because of their high aspect ratio. Montmorillonite (MMT) is more oftenly used as filler in polymer composites. MMT is a crystalline 2:1 layered clay mineral in which a central alumina octahedral sheet is sandwiched between two silica tetrahedral sheets. MMT can act as a barrier to oxygen and flammable material [10, 11].

In the present scenario MMT is the most widely used filler because it improves both the flame-retardant and mechanical properties of epoxy resin [12-14]. As an extra advantage, MMT do not produce toxic smoke during combustion. Thus MMT filler can be used to produce environment friendly products with extremely high thermal and mechanical properties [15-16].

The present investigation is aimed for the development of nanocomposites based on epoxy reinforced with various loadings of MMT. The developed nanocomposites have been investigated by TGA for their thermal stability and mechanical properties have been determined by UTM.

II. EXPERIMENTAL

Materials

Diglycidylether of bisphenol A (DGEBA) (LY-556) [Ciba Geigy India Ltd] has been used as the epoxy monomer. Triethylenetetramine (TETA) (HY-951) is used as the curing agent.

Nanocomposites preparation

Epoxy resin was heated at $80^{o}C$ for 5 minutes. Organically modified MMT incorporated in the epoxy matrix at various loadings viz (0, 1, 2, 3, 4, 5) wt. % and then manually stirred for one hour. The composite sheets of all compositions were prepared at room temperature under a load of about 80 kg for 24 hours in hydraulic compression molding machine, and at that stage hardener was mixed in a ratio of 10:1 by weight. Obtained sheets were post cured at $60^{o}C$ for another 24 hours after removing out from the mould. Then, the specimens of suitable dimensions were cut from the sheet using a cutter for mechanical testing and various characterizations. Composites compositions are given in Table-1.

Table 1: Composite Formulations

Sample Codes	Epoxy resin (gm)	Organically modified MMT (wt. %)
M0	100	0
M1	100	1
M2	100	2
M3	100	3
M4	100	4
M5	100	5

III. TESTING & CHARACTERIZATION

Mechanical Properties

Mechanical properties of the composites viz tensile strength and tensile modulus and flexural strength and flexural modulus have been determined by a Universal Testing Machine (INSTRON 3382) using 10 KN load cell at a speed of 5 mm/min as per ASTM D 638 and D 790 test methods respectively.

Thermal Properties

Thermo gravimetric analysis of the composites has been performed by a Perkin-Elmer Pyres TGA, in the temperature range of 50-750°C under a constant heating rate of 10°C/min in nitrogen atmosphere to study the thermal stability.

IV. RESULTS AND DISCUSSION

Mechanical Properties

Mechanical properties results are depicted in Table 2. for pure epoxy and developed nanocomposites. It is obvious from table that the nanocomposites having low filler of MMT shows highest mechanical properties that can be attributed to that there may be physisorption of the polymer chains on the silicate surface that stiffened the nanocomposites. Thus, the applied load to the polymer is transferred to the clay. Obviously for such high aspect ratio nanofiller (MMT), the surface area exposed to the polymer is large and therefore, the tensile strength increases remarkably at very low filler content.

Table 2: Mechanical Properties Results

Sample Codes	Tensile Strength (Mpa)	Tensile Modulus (Mpa)	Elongation at break (%)	Flexural Strength (Mpa)	Flexural Modulus (Mpa)
M0	35.85	1145.6	3.3	68.87	2170.8
M1	40.63	995.2	4.17	64.65	3952.1
M2	32.65	1026.4	3.37	50.92	3787.0
M3	20.85	975.2	1.87	54.36	3242.7
M4	35.38	951.3	3.67	57.88	3991.9
M5	26.76	1053.0	2.63	52.23	3404.7

Flexural modulus and strength results for the epoxy and developed nanocomposites are given in Table 2. It can be observed that the addition of MMT increases the modulus of developed nanocpomsites. This is thought to be assisted by the rule of mixture theorem, postulated that the addition of micro and nano-particle offer greater stiffness than the epoxy matrix [17, 18]. From the Table 2, it is observe able that the flexural modulus values almost remain constant for all nanocomposites, with the main exception of the nanocpomsites having 3 wt. % of nanoclay. This reduction may be attributed to smaller aggregates and disordered nature of the clay. It is very well documented in the open literature that when platelets are ordered, their are anisotropic behavior can render higher stiffness when aligned in the direction of strain. Therefore, a disordered morphology may have the opposite effect. Truly speaking, it appears that the modulus effect differs when the particle size changes. It is also demonstrated [19] that there is a critical particle size that alters the nanocomposites modulus, which in our studies takes place for the nanocomposites having the 3 wt. % of MMT. It is also obvious from Table 2 that the inclusion of MMT platelets increases the flexural strength properties of the developed nanocomposites by upto 20%. Flexural strength can be influenced by the void content, clay dispersion, interfacial interaction between clay and epoxy and structure of materials.

Thermal Properties

The TGA thermo-gram of pure epoxy and nanocomposites with various loadings of MMT and depicted in Figure 1 and Table 3.

Table 3: Thermal stability results.

Sample Code	Onset Temperature (^{0}C)	Final Temperature (^{0}C)	Residue (wt %) at 700^{0}C
M0	250.16	663.96	8.132
M1	220.36	662.29	28.124
M2	231.78	666.89	29.161
M3	215.43	670.15	29.488
M4	208.79	661.03	30.207
M5	285.34	697.00	27.479
ZB	196.62	686.95	25.643

It can be seen the initial decomposition of pure epoxy takes place at 250^{0}C while for nanocomposites, the decomposition occurs at 220, 231, 215, 208 and 285^{0}C for various loadings of MMT respectively. However, the stability upto 250^{0}C for pure epoxy can be explained from the crosslinking between the free hydroxyl group, which may be present in the fatty acids or generated during the amine crosslinking reaction as well as good chemical interactions via hydrogen bonding and polar-polar interactions. Appreciable enhancement in the thermal stability of nanocomposites has been observed. The increment of onset degradation temperature upto 35 ^{0}C has been achieved by the formation of nanocomposites. The increase in initial decomposition temperature for nanocomposites may be because of the protection of polymer chains that are present between the nanoclay layers. The networks of polymer chains present between the nanoclay layers are confined due to restricted segmental motion, which results in higher thermal stability than the pure system. Inorganic compounds like oxides of silicon, aluminum and magnesium that are formed in the nanocomposites are responsible for enhancement in thermal stability of the developed nanocomposites. The formation of char after thermal decomposition may also enhance the thermal stability of the developed nanocomposites [20].
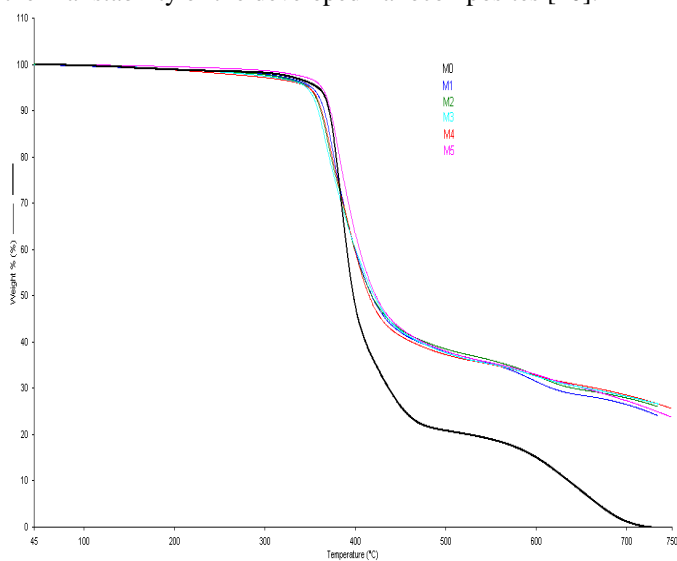

Figure 1. TGA thermo gram of epoxy nanocomposites with different loading of MMT.

V. CONCLUSIONS

Nanocomposites of epoxy reinforced with organically modified MMT have been prepared with the help of compression molding. It has been found that incorporation of MMT in epoxy matrix increases the thermal stability and mechanical properties viz tensile strength, tensile modulus, flexural strength, flexural modulus etc. The studies also demonstrate that maximum tensile strength has been achieved at 1 wt. % loading of nanofiller. The maximum thermal stability has been observed at 3 wt. % loading of MMT in developed nanocomposites.

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