Preparation And Characterization of Nanocomposites Based on Silicone Rubber Reinforced With Organically Modified Montmorillonite (MMT)

Sudhir Kumar[1], K.N.Pandey[2], Abrar Ahamad[3], Pratibha Singh[4], R.M. Mishra[5]
Central Institute of Plastics Engineering and Technology, Lucknow-226008, India

Abstract- *The present investigation deals with the preparation and characterization of nanocomposites based on silicone rubber reinforced with various loadings of organically modified montmorillonite (MMT). The thermal stability of developed nanocomposites has been evaluated by thermo-gravimetric analyzer (TGA) and their morphological properties have been visualized through scanning electron microscopy (SEM). The tensile properties and hardness of the developed nanocomposites have been determine with the help of Universal Testing Machine (UTM) and hardness tester (Shore A) respectively. It has been found that there is appreciable increase in thermal stability and mechanical properties with the incorporation of MMT in silicone rubber matrix and these properties have been found to be maximum at 3 phr loading of montmorillonite (MMT) in silicone rubber matrix.*

Keywords- Silicone rubber, TGA, SEM, Tensile Strength, MMT.

I. INTRODUCTION

In the present scenario, there has been considerable focus on the development of polymer composites with different nanoparticles which has attracted vital attention/ interest of the scientist worldwide [1-4]. The essential nanoclay raw material is montmorillonite layered smectite clay mineral with a platey structure. Individual platelet thicknesses are just one nanometer, but surface dimensions are generally 300 to more than 600 nanometers, resulting in an unusually high aspect ratio [5-8]. Unmodified nanoclay disperses in polymers with great difficulty because polymers are generally organophilic. Montmorillonite can be made organophilic or organomodified through clay surface modification, MMT is compatible with conventional organic polymers. Compatibilized nanoclay disperses readily in polymers [9-12]. Silicone rubber has excellent strength and temperature resistance -60^{0}C to +360^{0}C .It helps to provide crushing thermal resistance and mechanical properties ,load bearing and protective shock absorption quality to automotive interiors [13-15].

In the present investigation an attempt has been made develope nanocomposites based on silicone rubber incorporated with modified montmorillonite on the performance of developed nanocomposites developed nanocomposites have been characterization for their thermal and morphological properties by thermo-gravimetric analysis (TGA) and scanning electron microscopy (SEM) respectively.

II. EXPERIMENTAL

2.1 Materials

Silicone rubber VMQ (Silastic NPC- 40) has been the specific gravity on gm/cm3 was supplied by DOW Craning (USA). The Oregano modified montmorillonite (OMMT) clay. Nanomer® 1.31 PS, has been supplied by sigma ALDRICH (USA). Other material like satiric acid, Dicumyl peroxide has been obtained from E-Merck (Germany).

2.2 Nanocomposite Preparation

Silicone rubber has been masticated separately and then mixed together along with other ingredients (Table1). Mixing was carried out in a conventional laboratory two roll mill by melt mixing process (150x330mm) at 40-50^{0}C. After homogenization of the rubber for about (7min), the other ingredients have been added. The processing time after each component addition was about 2min.The compounded rubber was allowed to stand overnight before vulcanization. The compounded blends have been molded to obtained sheet (3-5mm) thickness using an electrically heated hydraulic press at 150^0 C for 20 min at a pressure of 2400 psi.

Table 1: Sample codes and compounding formulation of silicone rubber nanocomposites.

Sample Code	Silicone Rubber (%)	DCP (phr)	Stearic Acid (phr)	MMT (phr)
A	100	2	2	0
B	100	2	2	1
C	100	2	2	3
D	100	2	2	5
E	100	2	2	7

III. TESTING & CHARACTERIZATION

3.1 Mechanical properties

Mechanical properties such as tensile strength and elongation at break of developed nanocomposites have been determined with the help of INSTRON Universal testing machine model 3382 at room temperature with a gauge length of 35 mm and crosshead speed 100 mm/min.Tensile test are evaluated according to standard ASTM D 412 using dumb-bell shaped samples. Hardness of developed nanocomposites has been determine by hardness tester Durometer of Shore A

3.2 Thermo gravimetric analysis (TGA)

The thermal stability and degradation behavior of developed nanocomposites have been studied with the help of Perkin-Elmer Pyres TGA. The TGA measurement were conducted with a constant heating rate of 10^{o}C/min under nitrogen atmosphere from 50 to 650^{o}C.

3.3 Morphological study

The surface morphology of the tensile fractured surface was carried out through SEM (JEOL JSM 6490LV) with an accelerating voltage of 10 kV. Prior to SEM analysis fracture surfaces of nanocomposites were gold coated with the help of gold sputtering unit just to avoid the charging effect and to enhance the emission of secondary electron.

IV. RESULTS AND DISCUSSION

4.1 Mechanical Properties

Mechanical properties of the developed nanocomposite are given in Table 2 and figure (1-3). It is evident from Table 2 and figure (1-3) that there is a significant improvement of tensile strength, elongation at break, and hardness silicone rubber with this incorporation OMMT. But the enhancement is more prominent in case of nanocomposites having 3phr content of OMMT.

Table 2: Mechanical properties (Tensile, elongation at break and hardness) of silicone rubber nanocomposites.

Sample Codes	Tensile strength (MPa)	Elongation at break (%)	Hardness (Shore A)
A	3.53	1503.33	23.8
B	4.73	1526.93	34.4
C	6.52	1540.00	37.7
D	5.80	1233.33	32.5
E	4.74	1367.13	33.5

Incorporation of OMMT increases the tensile strength of the nanocomposites to a greater extent when compared to virgin silicone rubber. It is well known that the nanocomposites have enhanced mechanical properties as compared to virgin silicone rubber. This might be due to stress transfer from polymer matrix to nanofiller interfacial interaction between the silicone rubber and OMMT, and dispersion of the nanofiller in the polymer matrix may cause affecting stress transfer between the rubber and nanofiller. Generally, the hardness of the nanocomposites have an universe relationship with elongation at break. But in our case the unexpected phenomena of increase in elongation have been observed. This might be due to the surfactant role of the compatibilizer OMMT. Simultaneously increased in the tensile strength and elongation at break can be explained by improved interfacial adhesion between the OMMT and rubber matrix. Modified OMMT has provided better dispersion when compared with unmodified OMMT reduces the MMT-filler, slippage at the interface. The increase in hardness with the increase of nano filler content in rubber matrix may be attributed to the cross-link density. Maximum mechanical properties have been achieved at 3phr loading of OMMT in silicone rubber.

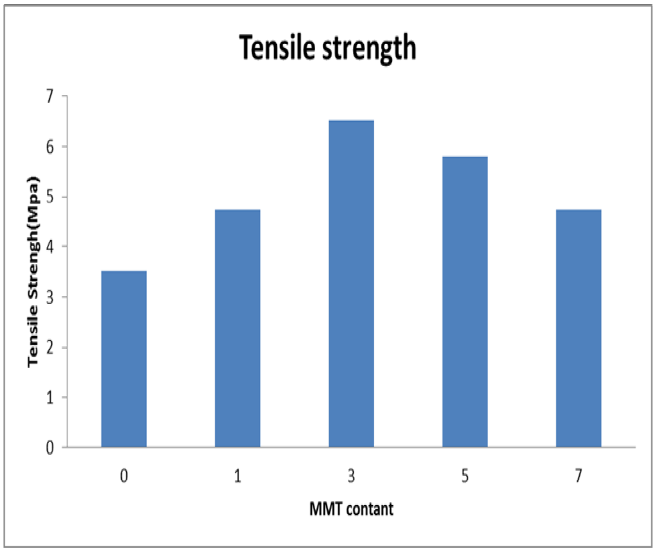

Figure 1: Tensile strength of silicone rubber nanocomposites.

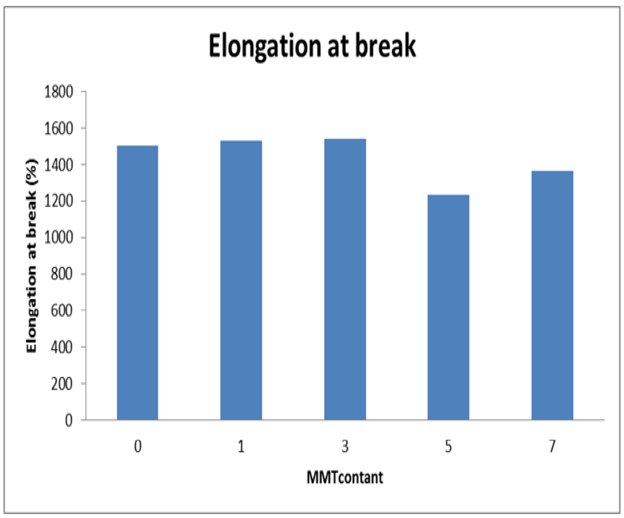

Figure 2: Elongation at break of silicone rubber nanocomposites

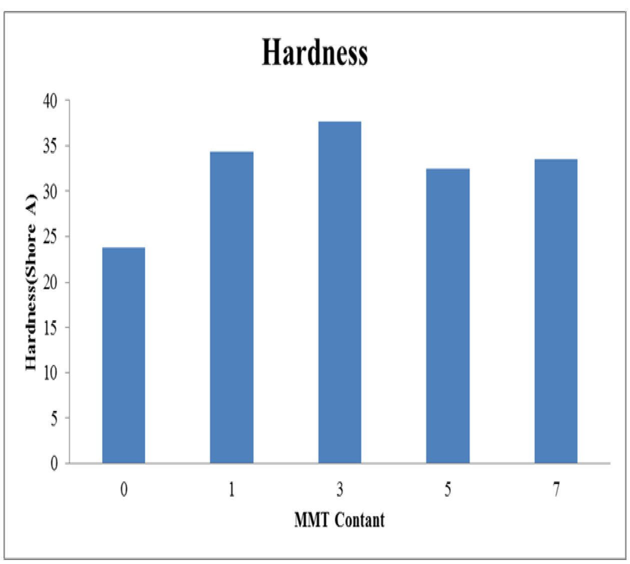

Figure 3: Hardness of silicone rubber nanocomposites

4.2 Thermogravimertric Analysis

TGA thermograms of developed nanocomposites are shown in Figure 4. This is evident from thermo-grams that maximum thermal stability has been achieved at 3 phr loading of OMMT in silicone rubber matrix. With the incorporation of OMMT in silicone rubber matrix, a vast number of restricted sites for the polymer matrix are created which constraint the chain mobility and reduces thermal vibrations of carbon-carbon bond [16]. Higher amount of energy will be needed for the degradation of matrix which in turn increases the thermal stability of nanocomposite due to better dispersion of OMMT. The vast number of restricted sites will be more in nanocomposites having 3phr loading of OMMT in polymer matrices. TGA results also demonstrate that there is minimum weight loss reason at 3 phr loading of OMMT in polymer matrix. Probably due to this reason, the thermal stability of silicone rubber reinforced with 3phr OMMT is higher than the virgin silicone rubber.

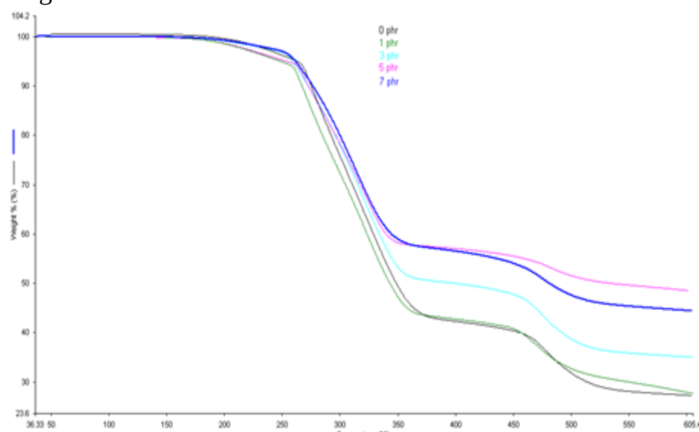

Figure 4: TGA thermograph for various loadings of modified OMMT in silicone rubber matrix.

4.3 Morphological study

The tensile fractured surface of the nanocomposites and the pure silicone rubber are visualized by SEM and the micrographs are depicted in the Figure 5(a-e). SEM micrographs Fig. 5(d) reveal that it has smallest domain size. This reduction in domain size may be attributed to compatibilizing efficacy of the modified MMT when its concentration is 3 phr in silicone rubber. These results are similar to other earlier studies [17]. It is evident from SEM micrographs that the nanocomposites containing 3 phr amount of OMMT has a better dispersion as compared to other nanocomposites.

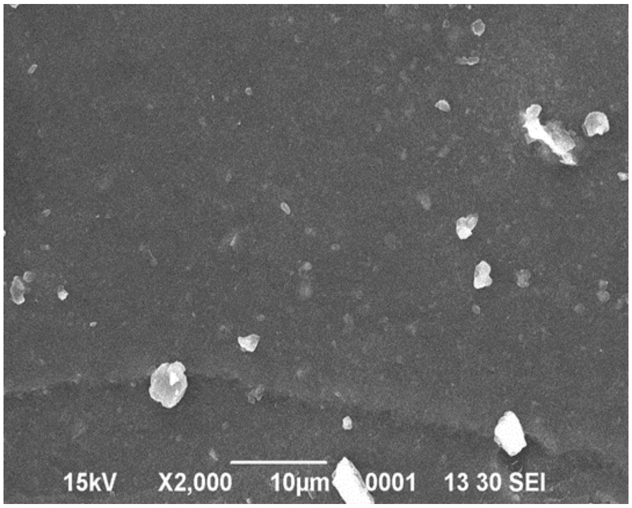

Figure 5 (a). SEM micrographs at 0 phr

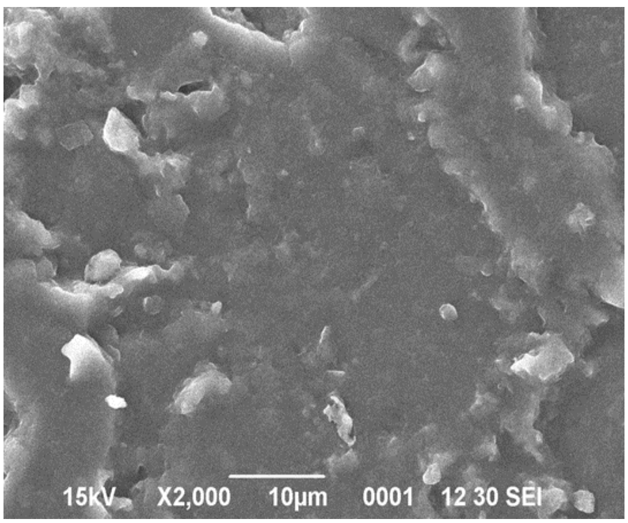

Figure 5 (b). SEM micrographs at 1 phr

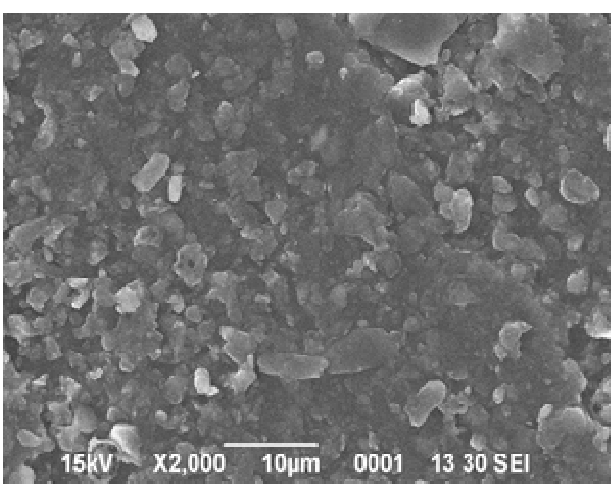

Figure 5 (c). SEM micrographs at 3 phr

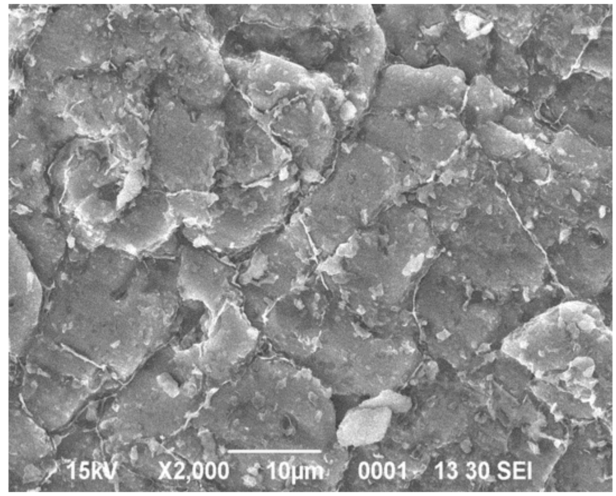

Figure 5 (d). SEM micrographs at 5 phr

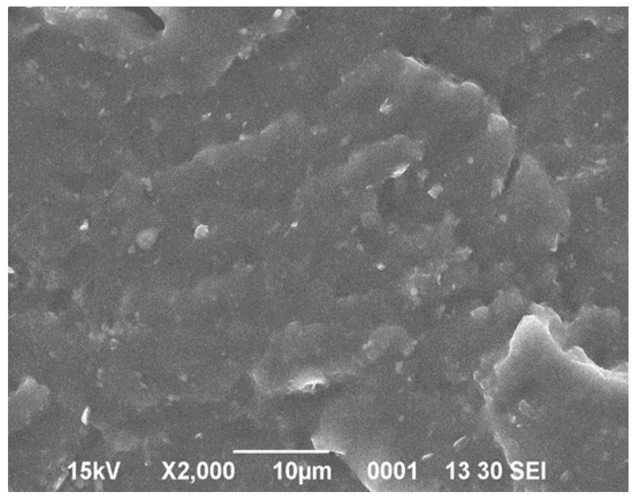

Figure 5 (e). SEM micrographs at 7 phr

V. CONCLUSION

The nanocomposites based on silicone rubber filled with various loadings of modified MMT have been prepared by melt mixing process with the help of two roll mill. It has been found that modified MMT in the polymer matrix shows the prominent effect on the performance of polymer nanocomposites, due to better dispersion of nanoclay. Better dispersion of modified MMT results in the enhancement of thermal, mechanical and morphological properties of nanocomposites when compared with pure silicone rubber.

REFRENCES

[1] Alesandre, M; Dabais P. Polymer layered silicate nanocomposites preparation properties and use of a new class of material .Master Sci Eng.2000, pp-281- 63.

[2] Fornes TD, hunter D L .Paul DR, Nylon 6 nanocomposites from alkyl ammonium. Modified clay.

The role of alkyl tails on exfoliation macromolecule 2004; 37: pp-1793-8.

[3] Sadhu S Bhowmick AK; preparation and properties of nanocompositis based on acrylonitrile butadiene rubber, styrene butadiene rubber and poly butadiene rubber, J. poly sci Part B; Polym phys 2004; 42, pp-1573.

[4] Wanger MP, reinforcing silicone and silicate rubber chem. Technology 1976; 49**,** pp-703-74.

[5] B hattacharyya, KG; Gupta, SS "Adsorption of a few heavy". Advances in colloid and interface science, 2008, 140 pp. 114–31.

[6] Saary, J; Qureshi, R; Palda, V; Dekoven, J; Pratt, M;Skotnicki-Grant, S; Holness, L "A systematic review of contact dermatitis treatment and prevention". Journal of the American Academy of Dermatology 2005, 53 (5), pp. 845.

[7] Q.T. Nguyen and D.G. Baird, Preparation of polymer–clay nanocomposites and their properties, Advances in Polymer Technology 2000, 25, pp. 270-285.

[8] Q.X. Zhang, Z.Z. Yu, M. Yang, J. Ma and Y.W. Mai., Multiple melting and crystallization of nylon66/montmorillonite nanocomposites, J. Polym. Sci.Polym. Phy. 2003, 41, pp.2861–2870.

[9] Liang, G., Xu, J., Bao, S. and XU, W., Polyethylene/maleic anhydride grafted polyethylene/organic-montmorillonite nanocomposites.Preparation, microstructure, and mechanical properties, Appl. Polym. Sci. 2004, 91, pp. 3974-3980.

[10] Tambe, S.P., Naik, R.S., Singh, S.K., Patri, M. And Kumar, D. Studies on effect of nanoclay on the properties of thermally sprayable EVA and EVAI coatings, Progress in Organic Coatings, 2009, 65, pp. 484–489.

[11] Paul, M.A., Alexander, M., Degee, P., Henrist, C., Rulmont A. and Dubois, P., New Nanocomposites Materials Based on Plasticized Poly (L-lactide) and Organo-modified Montmorillonites, Thermal and Morphological Study, Polymer. 2003, 44, pp.443–450.

[12] Costache, M.C., Jiang, D.D.and Wilkie, C.A. Polymer. 2005, 46, pp. 6947.

[13] Alex salinier, Sylva, Dagereow, Fredericl, Christophe derail Nuria Nav ascures electrical meologicak and mechanicalbased on poly (etheremide) short glass fibres /motivated corbon nanotube composites structure, 2013, 81, pp-39.

[14] Kellerel .A self-Healing poly (dimethel siloxane) advanced functional material 2007, 17, pp 2399-2404.

[15] Ganasg Ch. Nayak, R rajashekhar, chapel Kumar Das .effect of sili coated MWCNTs on the thermal and mechanical properties of PEI/LCP blend composites; Part A41, 2010, pp-1662 – 1667.

[16] Abdalla M, Dean D, Adivenmpe D. Nyairo E, Robinsion P, Polymer 2007, 48, pp-5662.

[17] Betterbruch, L, Anders, S, Engineering thermoplastics polycarbonate, Polyacetals, Polyesters cellulose, Estins, Hancer, Verlad Munich 1996.