Mechanical, Thermal and Electrical Properties of EPDM/Silicone blend Nanocomposites

Vijayalekshmi.V and Abdul Majeed.S.S.M
(Department of Polymer Technology, B.S. Abdur Rahman University, Vandalur, Chennai – 600 048, India)

ABSTRACT

EPDM/Silicone rubber nanocomposites have been prepared by incorporating various phr of organically modified montmorillonite (OMMT) nanoclay onto EPDM/Silicone rubber blends using two roll mill. Effect of OMMT content on mechanical, electrical and thermal properties of the nanocomposites are investigated. Mechanical properties such as tensile strength and elongation at break were tested. Thermogravimetric analysis was carried out to analyse the thermal stability of the nanocomposites. Dielectric strength, dielectric constant, volume and surface resistivity of the nanocomposites were also measured. The results obtained for various properties indicate that the EPDM/Silicone rubber nanocomposites have improved mechanical, thermal and dielectric properties.

Key Words - Electrical properties, EPDM/Silicone nanocomposites, Polymeric insulators, Rubber nanocomposites, Thermal properties

1.0 Introduction

The development of polymeric nanocomposites is an interesting area in advanced research.The properties of polymers like light weight, high mechanical strength to weight ratio, resistance to vandalism and high voltage resistance make them suitable for outdoor insulators [1, 2]. Silicone rubber is the lead polymer currently used for making high voltage insulators due to its excellent dielectric properties coupled with superior temperature stability, excellent UV resistance and better hydrophobicity. It suffers from poor mechanical strength, tracking resistance and high cost [3,4]. Instead, EPDM possess excellent mechanical strength and tracking resistance and it is a comparatively lower cost material. Blending of polymers has gained considerable importance for achieving property improvement and economic advantages. Inorganic fillers have a major role in improvement of the desired electrical and mechanical properties of polymers [5,6]. Modification of inorganic fillers with organic materials results in improvement of technological properties. [7,8]. The present study was directed to explore the advantages of EPDM/Silicone rubber OMMT nanocomposites for electricl insulation applications.

2.0 Experimental Procedure

2.1 Materials

All the materials used for the development of nanocomposite insulators are commercially available and were used as such without further treatment. Silicone rubber (NE 5160) was supplied by Dongjue Silicone –Nanjing Co Ltd, China. EPDM (KEP 960) was purchased from Kumho Polychem, Korea which contains ethylene norborene as the diene monomer. Fumed silica (Cab-O-Sil) was obtained from Cabot Corporation, Germany. OMMT (Nanofill-5) was supplied by Sud Chemie, Germany. Dicumyl peroxide of 40% active was used as vulcanising agent.

2.2 Preparation of Nanocomposites

Blend of EPDM and Silicone rubber was prepared by mixing equal weight percentages (1:1) of the materials in a two roll mill for about 15 minutes at room temperature. Fumed silica of required quantity was added to the blend and mixing was continued for 10 minutes. For the preparation of EPDM/Silicone rubber nanocomposites with varying content of OMMT, required quantities (0, 1, 3, 5 and 7 phr) were incorporated by mixing the blend in the two roll mill for about 5-10 minutes at room temperature. Then dicumyl peroxide was added and mixed for about 5 minutes. The vulcanization of the rubber compound was carried out in a hydraulically operated press at 150°C for 8 minutes. The vulcanized samples were post-cured at 140°C for 1hr in an air-circulating oven. Test specimens were punched out from the compression-moulded sheets. The nanocomposites prepared with various compositions (Table 1) were tested for their mechanical, electrical, and thermal properties.

Table 1. Composition of EPDM/Silicone rubber-OMMT Nanocomposites

Composition (phr)	Notation				
	ESMT - 0	**ESMT - 1**	**ESMT -3**	**ESMT - 5**	**ESMT -7**
EPDM	50	50	50	50	50
Silicone rubber	50	50	50	50	50
Fumed Silica	25	25	25	25	25
OMMT	0	1	3	5	7
Dicumyl peroxide	6.25	6.25	6.25	6.25	6.25

2.3 Characterization

Tensile strength and percentage elongation at break of the nanocomposites were tested at room temperature as per ASTM D-412. Dielectric strength was tested as per IEC-60243-1 (ASTM D 149) standard at 250 V and 50 Hz. Volume and surface resistivity of the samples were measured as per ASTM D 257 (IEC 60093) standards. Dielectric constant measurements were carried out by using Weis-500 electrochemical work station (impedence analyser) in the frequency range of 10Hz to 10^6Hz at room temperature. Thermo gravimetric analysis was carried out using a Sii TG-DTA 6500 thermal analyzer in a dry nitrogen atmosphere at a heating rate of 20 °C / min.

3.0 Results and Discussion

3.1 Mechanical Properties

The effect of OMMT content on the mechanical properties of EPDM/Silicone rubber nanocomposites was analysed and the values are presented in Fig 1 and Fig 2.

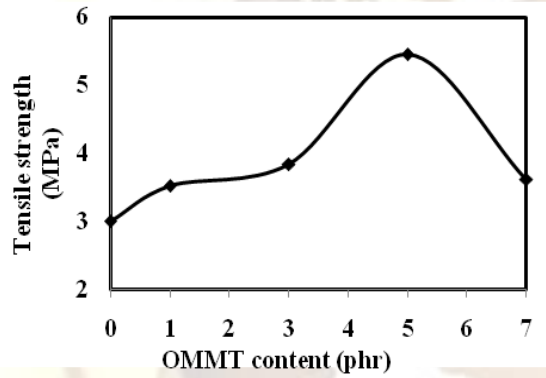

Figure 1. Effect of OMMT content on Tensile strength of EPDM/Silicone rubber nanocomposites.

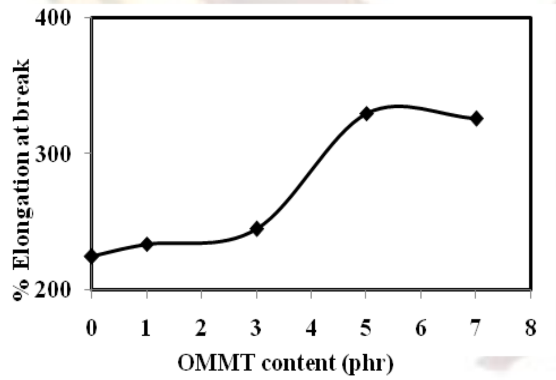

Figure 2. Effect of OMMT content on % elongation at break of EPDM/Silicone rubber nanocomposite

From the Figures 1 and 2, the maximum value of tensile strength and % elongation is observed for the nanocomposite containing OMMT loading of 5 phr. Tensile strength of EPDM/Silicone rubber nanocomposites was found to be increased to 81% by the addition of 5 phr of OMMT. Percentage elongation at break was also increased up to 47% at loading of 5 phr OMMT. The values for tensile strength and % elongation decreased as the level of OMMT content increased beyond 5phr.

3.2 Electrical properties

3.2.1 Dielectric strength

Dielectric strength of EPDM/Silicone blends containing varying OMMT content was examined and the results are shown in Fig 3.

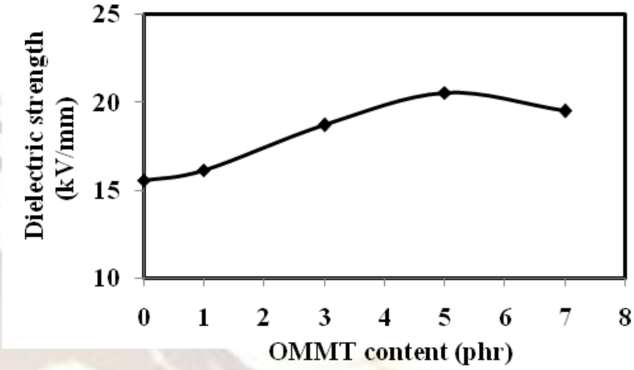

Figure 3. Effect of OMMT content on Dielectric strength of EPDM/Silicone rubber nanocomposites

From the figure, it is observed that dielectric strength of EPDM/Silicone rubber nanocomposites increased up to the filler loading of 5 phr and then decreased with further addition. The addition of 5 phr of OMMT onto the system caused about 32% increase in dielectric strength compared to that of neat blend (ESMT-0). However on further increment of OMMT on to the system causes a decrease in dielectric strength. This may be due to the lower interspacing between filler particles.

3.2.2 Dielectric constant

Dielectric constant (relative permitivity) for EPDM/Silicone rubber nanocomposites with varying content of OMMT are shown in Fig 4 and Fig 5. It can be seen from the fig 4 that the dielectric constant of nanocomposites decreased with increasing frequency.

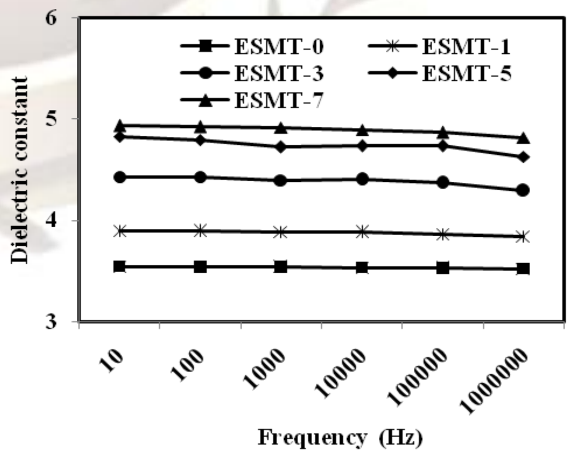

Figure 4. Effect of OMMT content on Dielectric constant of EPDM/Silicone rubber nanocomposites at various frequencies

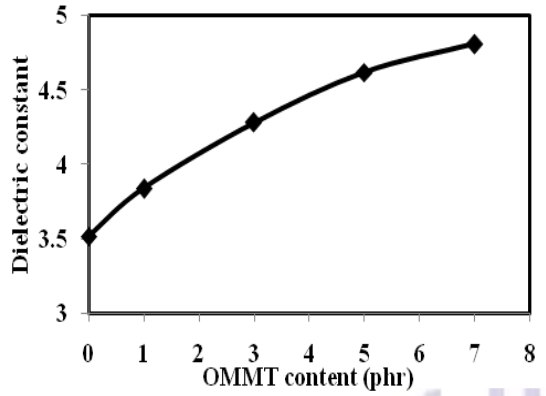

Figure 5. Effect of OMMT content on Dielectric constant of EPDM/Silicone rubber nanocomposites at 1MHz

Fig 5 shows the dielectric constant of nanocomposites with increasing OMMT content at frequency of 1MHz. The values of dielectric constant of nanocomposites increases with increasing content of OMMT.

3.2.3 Surface and Volume resistivity

In Fig 6, the surface resistivity of the nanocomposites is plotted against OMMT content. From the figure, it was noticed that the surface resistivity increased with increasing level of OMMT content due to the better interaction of nanofiller with rubber matrix.

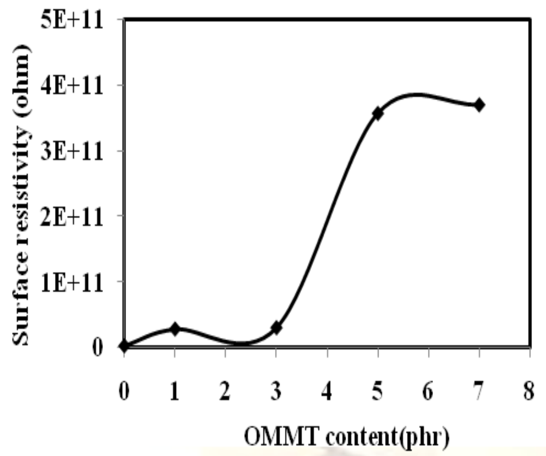

Figure 6. Effect of OMMT content on surface resistivity of EPDM/Silicone rubber nanocomposites

The values of volume resistivity obtained for various nanocomposites are presented in Fig 7. From the the Figure, it is observed that 5 phr of OMMT is the critical level for achieving higher volume resisstivity

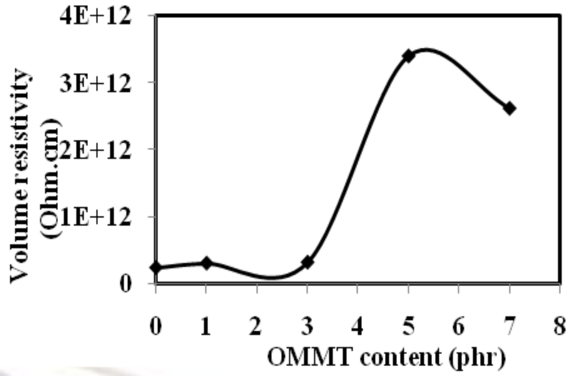

Figure 7. Effect of OMMT content on volume resistivity of EPDM/Silicone rubber nanocomposites

3.3 Thermogravimetric analysis

TGA thermograms obtained for the nanocomposites are presented in Fig 8. TGA thermograms showed that the thermal stability of nanocomposites increases with increasing OMMT loading, which shows the ability of nanofiller in retarding the heat diffusion into the rubber matrix. In Fig 9, the temperature at which 50% decomposition takes place is plotted against the OMMT content. The Figure shows the improvement in thermal stsbility of nanocomposites when OMMT content increased. This improvement attributes the delay in diffusion of volatile decomposition products from the nanocomposite structure.

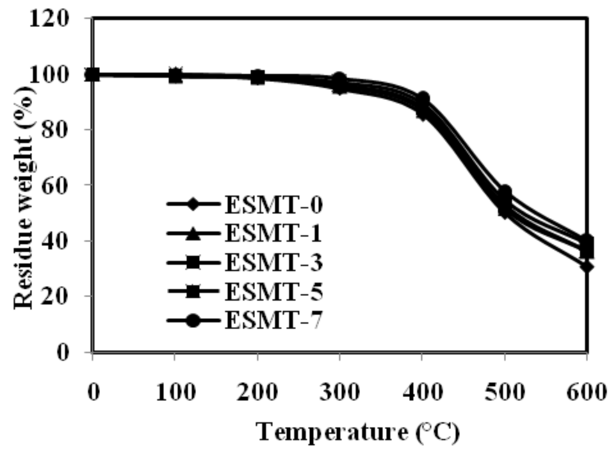

Figure 8. TGA curves for EPDM/Silicone rubber nanocomposites

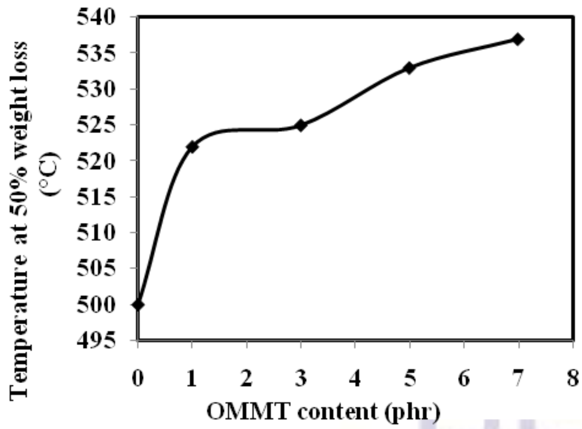

Figure 9. Effect of OMMT on thermal satbility of EPDM/Silicone rubber nanocomposites

4.0 Conclusion

EPDM/Silicone nanocomposites were developed with varying proportions of organically modified montmorillonite nanoclay (OMMT). The effect of OMMT content on mechanical, electrical and thermal properties have been investigated.The results obtained for mechanical properties showed the significant improvement in tensile strength and elongation at break of nanocomposites. The study of electrical properties revealed that the presence of OMMT in EPDM/Silicone nanocomposites offers marked improvement in dielectric strength and volume resistivity. Thermogravimetric analysis confirmed the improvement in thermal stability of nanocomposites with increasing content of OMMT. The experimental results showed that the EPDM/Silicone nanocomposite could be a better candidate for high voltage electrical insulators due its enhanced mechanical, themal and dielectric characteristics.

References

1. Raja Prabu R, Usa S, Udayakumar K, Abdul Majeed S.S.M, Abdullah Khan M, ‘Electrical insulation characteristics of Silicone and EPDM Polymeric blends-Part I’, *IEEE Transactions on Dielectrics and Electrical insulation Vol.14, No.5*, October 2007,1207-1214.
2. Jeffry Mackevich, Minesh Shah, ‘Polymer outdoor insulating materials Part-I: Comparison of Porcelain and Polymer electrical insulation’, *IEEE Electrical insulation magazine, Vol.13, No.3*, May/June 1997, 5-10.
3. Stephane Simmons, Jeffry Mackevich, Minesh Shah, Chang R.J, ‘Polymer outdoor insulating materials Part-III: Silicone Elastomer considerations’, *IEEE Electrical insulation magazine, Vol.13, No.5*, September/October 1997, 25-32.
4. Ehsani M, Borsi H, Gockenbach E, Bakhshandeh G.R, Morshedian J,Abedi N, ‘Study of Electrical, dynamic mechanical and surface properties of silicone – EPDM blends’, *IEEE International conference on solid dielectrics*, Toulouse, France, July2004, 5-9.
5. Jeffry Mackevich, Stephane Simmons, ‘Polymer outdoor insulating materials Part-II: Material considerations’, *IEEE Electrical insulation magazine, Vol.13, No.4*, July/August 1997, 10-16.
6. Cherney E. A, ‘Silicone Rubber Dielectrics Modified by Inorganic Fillers for Outdoor High Voltage Insulation Applications’ , *IEEE Transactions on Dielectrics and Electrical Insulation, Vol. 12, No. 6* ,2005, 1108-1115.
7. Cherney E. A, ‘Silicone Rubber Dielectrics Modified by Inorganic Fillers for Outdoor High Voltage Insulation Applications’ , *IEEE Transactions on Dielectrics and Electrical Insulation, Vol. 12, No. 6* ,2005, 1108-1115.
8. Grazyna Janowska, Agnieszka kucharska Jastrzabek, Przemyslan Rybinski, ’Thermal stability, flammability and fire hazard of butadiene-acrylonitrile rubber nanocomposites, *Journal of thermal analysis calorim*, vol *103*, 2011, 1039-1046.