

# Moisture Absorption Analysis of Linear-Low-Density-Polyethylene Natural-Rubber Nanocomposite for HV Insulation

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**Abstract**— Insulation for high voltage (HV) application such as cable subjected to several types of degradation. These degradation can lead to premature breakdown and when its happen cost to replace or repair equipment will be higher. Many research was done to improve the insulation properties and currently nanocomposite material get serious attention due to their abilities to enhance electrical performance by addition of nanofiller into the based material. In this paper, water absorption of Linear-Low-Density-Polyethylene (LLDPE) with different amount of nanofiller composition is studied. This study is necessary to be conducted since polymer based material is the most common insulation material used in HV cable. The HV cable normally will be continuously exposed in uncontrolled environment. Because of this, the cable will exposed to watery condition and it is crucially needed for the insulation to remain dry to the cable performance. Three types of nanofillers at different weight percentage (%wt) added into LLDPE, was used in this study are: Silicon dioxide (SiO<sub>2</sub>), Titanium dioxide (TiO<sub>2</sub>) and Monmorillonite (MMT). Percentage absorption of water was measured according to BS 6470 until the samples reaches saturation level. Experimental result demonstrate that SiO<sub>2</sub> absorb less water than other filler while, the MMT has hydrophilic properties which it absorb more water compare to another sample. By used appropriate composition and type of nanofiller, a good insulator that are resistant to environmental influence can be produced

**.Keywords**— Nanocomposite, Nanofiller, Water absorption, Linear-Low-Density-Polyethylene.

## I. INTRODUCTION

Linear-Low-Density-Polyethylene (LLDPE) is a kind of important plastic that is widely used in areas of agro-films, vessels and pipes due to its good softness and processing abilities[1]. The study of new polymer mixed with nanofiller recently famous due to nanofiller ability to enhance the performance of insulation [1-8]. In order to achieve this insulating property, better understanding of specific insulator is important. An outdoor insulator must have dielectric strength greater 10 kV/mm, low dissipation factor, and high resistance value in order to cancel the conductivity [9]. Polymer

nanocomposites are made by adding nanometer sized fillers are homogeneously dispersed into the matrix of polymers composite. Polymeric insulator that have been used for application may experience water absorption and consequently degrade the performance of insulator.

A lot of researches have been conducted to determine electrical properties of nanocomposite as insulating such as dielectric breakdown strength, space charge and conduction current measurement [3, 4, 10-13]. F. Ciuprina and I. Plesa [4] had done a research DC conductivity and the variation of the real part of the complex conductivity with the frequency for three formulations of nanocomposites obtained from polyethylene filled with nanoparticles of Al<sub>2</sub>O<sub>3</sub>, SiO<sub>2</sub> and TiO<sub>2</sub>. The present of water content in polymer are believed to detrimental the performance of the insulation [14, 15]. Moisture diffusion through polymer will cause the conductivity of the material increased. The properties of polymer will changes when a few nanofiller is mixed with the base polymer and certain nanofiller such as silicone rubbers are commonly used in outdoor insulation applications because of their good aging behavior, which is attributed to the hydrophobicity of the surface, restored in time by a mechanism involving the migration of light molecules from the bulk towards the surface [16]. Silicon rubber also has good pollution performance and high discharge resistance [17]. From the result obtained by [18], it can be concluded that nanofiller water absorption is able to worsen dramatically electrical properties.

This paper presents preliminary works on moisture absorption in LLDPE-NR with different of nanofiller and varies amount of the nanofillers. The main objective of this research is to study the properties of nanofillers towards water absorption and identify the best of nanofiller with right amount of nanofillers that can be used for outdoor insulation application.

## II. SAMPLE AND MATERIAL PREPARATION

LLDPE used in this study is a commercial linear low density polyethylene from Titan Chemical, Malaysia [5]. It has a density of 0.918 g/cm<sup>3</sup>, a melt index of 0.25g/min.

Nanoparticle of silicon oxide is made from China with a particle size of about <50nm was used as filler. This nano scale filler has a nearly spherical shape with a specific surface area of about 100 m<sup>2</sup>/g. The filler was dried before use. Natural rubber grade SMR CV 60 supplied by Taiko Plantations Sdn Bhd was used for blending and mixing with LLDPE and nanofiller. Polyethylene nanocomposites were prepared by melt mixing at 165°C using a Brabender type model 835201.041 mixer with chamber size of 50 cm<sup>3</sup>. The mixer has a high shear force and the screw speed was controlled at 35 rpm with the mixing time of 2 minutes. The polymer nanocomposites were finally prepared into square shape of 10 cm x 10 cm with the thickness of 3 mm by hot melt pressing at 1 tone pressure at 170°C for 10 minutes. Four types of polyethylene nanocomposite square shaped with a dimension of 10 cm x 10 cm were prepared with concentrations of nanofiller of 0, 1, 3, 5 and 7 % wt, respectively. Table I shows the compound formulation and designation of LLDPE.

$$M = \frac{\Delta m}{m_0} \times 100\% = \frac{m - m_0}{m_0} \times 100\%$$

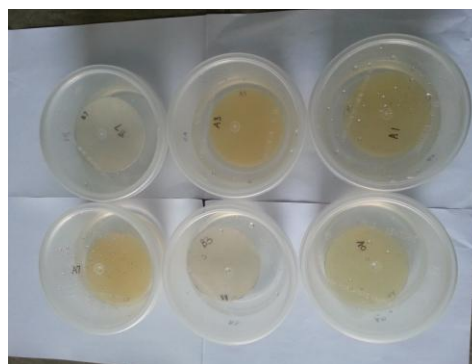


Fig. 1: Sample immersed in distilled water

TABLE I. COMPOUND FORMULATIONS AND DESIGNATION

Test Sample	Constituents Composition % wt			Designation
	LLDPE	Natural Rubber (SMR CV 60)	Nanofiller	
Unfilled LLDPE	80	20	0	R
LLDPE + Natural Rubber + SiO <sub>2</sub>	80	20	1	A1
	80	20	3	A3
	80	20	5	A5
	80	20	7	A7
LLDPE + Natural Rubber + TiO <sub>2</sub>	80	20	1	B1
	80	20	3	B3
	80	20	5	B5
	80	20	7	B7
LLDPE + Natural Rubber + MMT	80	20	3	C3
	80	20	5	C5
	80	20	7	C7

### III. MOISTURE ABSORPTION TEST

Samples of difference types and % wt added of nanofiller are placed in separate container filled with distilled water as shown in Fig. 1. Distilled water is used to avoid an influence of salts or impurities on the measurement results. Each sample was placed in the same room temperature to make sure the temperature does not influence on the rate absorption of water.

There are several possibilities to determine the water absorption of solid materials. The fastest and most simple method is to determine the specimens' mass increase by weighing. Prior to the water storage the mass  $m_0$  of each specimen is determined. During the 92 days water storage the specimen's mass increase  $\Delta m$  is determined in constant time intervals. The current moisture content  $M$  inside the specimens is calculated by  $m_0$  and the absorbed moisture  $\Delta m$ .

(1)

## IV. RESULT AND DISCUSSION

### A. Morphological Structure

The extent of dispersion of SiO<sub>2</sub>, TiO<sub>2</sub> and MMT in LLDPE was studied by FESEM. Fig. 2 shows result of FESEM image for sample R in normal condition. Fig. 3, Fig. 4 and Fig. 5 shows result of FESEM images for each sample of LLDPE-NR/SiO<sub>2</sub>, LLDPE-NR/TiO<sub>2</sub> and LLDPE-NR/MMT. For the compounds filled with low and moderate content of nanofiller the basic components in the compound are homogeneously dispersed and only small agglomeration of the fillers occurs as shown in Fig. 3 (a), Fig. 3 (b), Fig. 4 (a), Fig. 4 (b) and Fig. 5 (a). This shows that the interaction between fillers and the polymer matrix is strong. Fig. 3 (d), Fig. 4 (d) and Fig. 5 (c) shown that more composition % wt of nanofiller tends to agglomerate each other.

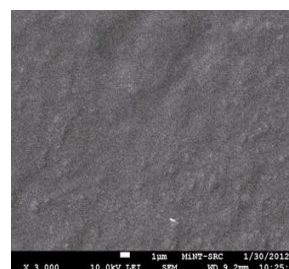
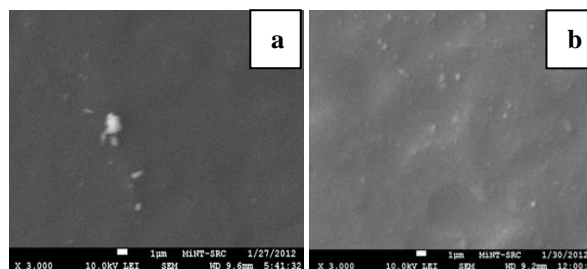


Fig. 2: FESEM images of sample R in normal condition



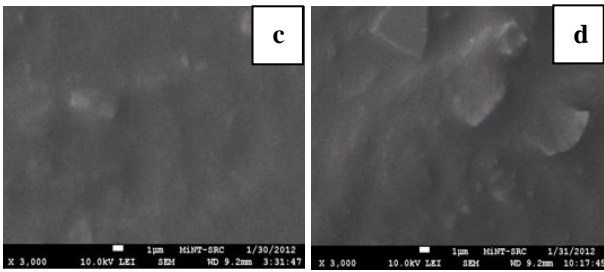


Fig. 3: FESEM images of sample for group A in normal condition. (a) sample A1, (b) sample A3, (c) sample A5, (d) sample A7

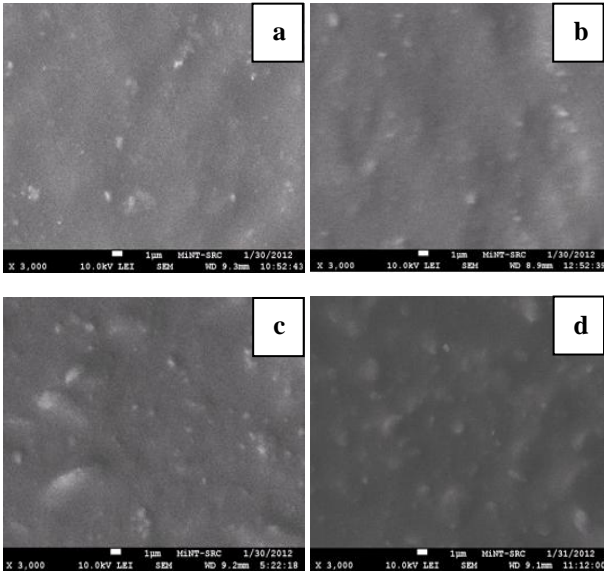


Fig. 4: FESEM images of sample for group B in normal condition. (a) sample B1, (b) sample B3, (c) sample B5, (d) sample B7

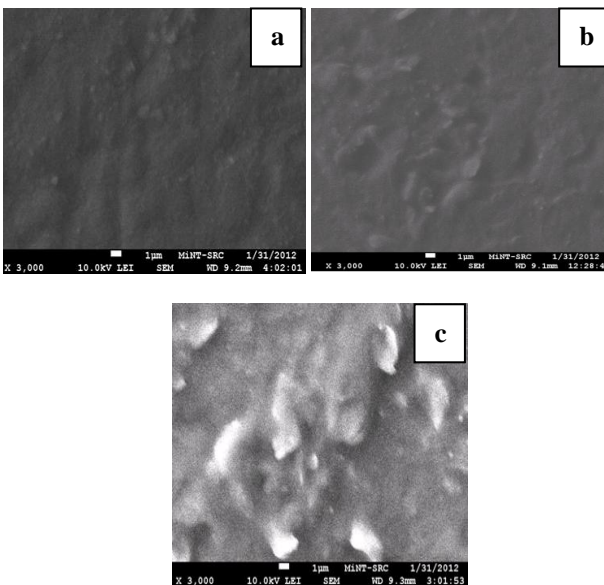


Fig. 5: FESEM images of sample for group C in normal condition. (a) sample C3, (b) sample C5 (c) sample C7

### B. Water Absorption Analysis

The results of water absorption measured for all samples designated A, B and C is shown in Fig. 6, Fig. 7 and Fig. 8. As for SiO<sub>2</sub> as nanofiller, Fig. 6 had shown that Sample A1 with 1% wt additional nanofiller has absorb less water compared with others % wt of nanofiller added for this nanofiller type. It found that, the addition of nanofiller used has change the structure properties of the sample which it tends to absorb water easily. Thus increasing % wt amount of SiO<sub>2</sub> had increased the percentage of water absorption. The duration for this group to reach saturation level are slightly different. The original sample, sample R takes about 55 days to reach the saturation level of water absorption. However, sample that contains SiO<sub>2</sub> nanofiller take a long period to saturation level. It can be shown, as the increase in percent of SiO<sub>2</sub> nanofiller used, the duration of the sample to reach saturation level also increased.

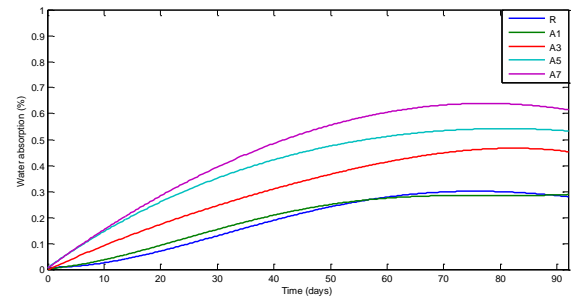


Fig. 6: Percentage of water absorption for SiO<sub>2</sub> nanofiller

Absorption pattern for Sample B group in Fig. 7 have in general same pattern as sample A group. Both sample have higher moisture when % wt of addition nonofiller is increased. For this type of nanofiller, sample B7 was found to absorb more water compared with other samples in this group. This also means that this sample has higher hydrophilic properties which tends to absorb water easily. The graph also shown the duration difference for each sample to reach saturation level of water absorption. Sample B7 has reach saturation level on 70th day and the percentage of water absorption is 0.6% and it continuously until 92 days. As the amount of TiO<sub>2</sub> nanofiller increased, the duration for the sample to be saturated also increase. These trend is same as result shown by group A samples.

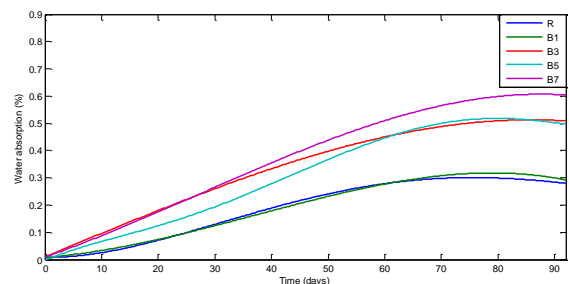


Fig. 7: Percentage of water absorption for TiO<sub>2</sub> nanofiller

Samples for group C, MMT as nanofiller result is shown in Fig. 8. The pattern of this group also agreed with result obtained for group A and B results. Sample C7 show the highest percentage of water absorption than another sample while C1 show the lowest percentages of absorption. For overall sample, it shown the addition of any amount of nanofiller has changed the behavior of original structure. Basically the addition of nanofiller will reduced the water repellency of the materials.

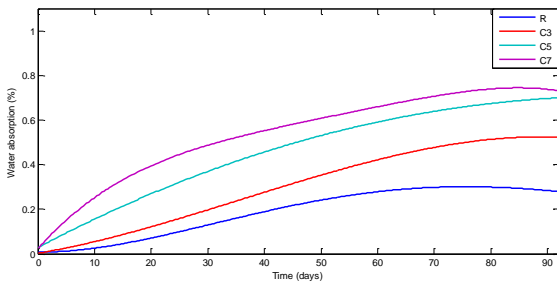


Fig. 8: Percentage of water absorption for MMT nanofiller

### C. Water Absorption Comparison Analysis

This section compared absorption trend of different type of nanofiller at same % wt of amount of nanofiller added. Based on Fig. 9; comparison of absorption at 1% wt of additional nanofiller had shown that addition of 1% wt  $\text{TiO}_2$  had increase the rate of water absorption into LLDPE-NR compared to 1% wt of  $\text{SiO}_2$ . At early stage, the absorption of water for sample A1 is rapidly increase compared to sample B1 that consists of 1% wt  $\text{TiO}_2$  nanofiller. However, as the duration increase for the sample immersed in distilled water, Sample A1 and Sample B1 have achieved different saturation level of water content. The percentage of water absorption at saturation level for sample B1 and sample A1 are 0.32% and 0.27% respectively.  $\text{SiO}_2$  nanofiller show a good water repellency properties than  $\text{TiO}_2$  at 1% wt amount of nanofiller.

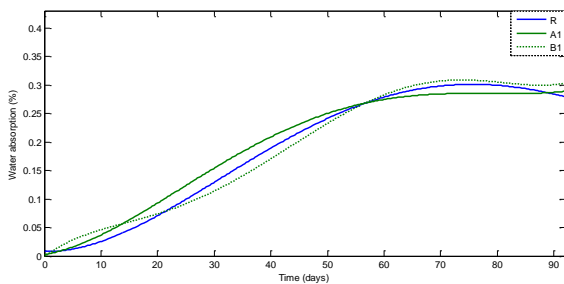


Fig. 9: Percentage of water absorption for  $\text{SiO}_2$  and  $\text{TiO}_2$  at 1% nanofiller

Comparison absorption level of samples with 3% wt of additional nanofiller is shown in Fig. 10. Based on the figure, the addition 3% wt of MMT nanofiller into LLDPE mix with natural rubber has shown the highest percentage followed by  $\text{TiO}_2$  and the lowest is  $\text{SiO}_2$ . MMT samples in this test able to absorb more water up to 0.5%. As the amount of any nanofiller used increased, the structure of the materials are changes and tends to absorb water easily. Based on the plotted graph, sample C3 with 3% wt MMT nanofiller has the lowest water repellency compared with other samples.

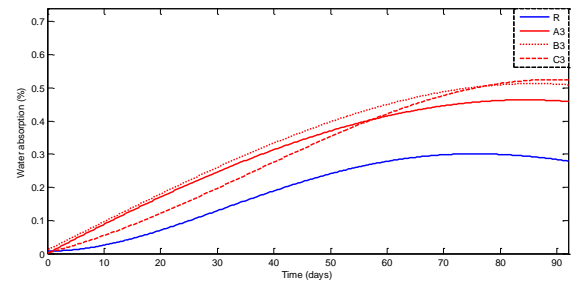


Fig. 10: Percentage of water absorption for  $\text{SiO}_2$ ,  $\text{TiO}_2$  and MMT at 3% nanofiller

When each samples was added with more than 3% wt of nanofiller, the value of absorption increased dramatically and behave differently. Fig. 11 and Fig. 12 shows the water absorption for 5% wt and 7% wt additional of nanofiller respectively. Based on the plotted graph, sample A5 with 5% wt  $\text{SiO}_2$  nanofiller filler and Sample B7 with 7% wt  $\text{TiO}_2$  nanofiller were the best sample since them able to absorb less water compared with other samples. The samples contains of 5% wt and 7% wt of MMT nanofiller obviously shows the highest absorption of water which are not suitable to use this type of nanofiller in high voltage application. These result approved MMT has a properties as hydrophilic nanofiller and it is not good for dielectric application compared with  $\text{SiO}_2$  and  $\text{TiO}_2$ .

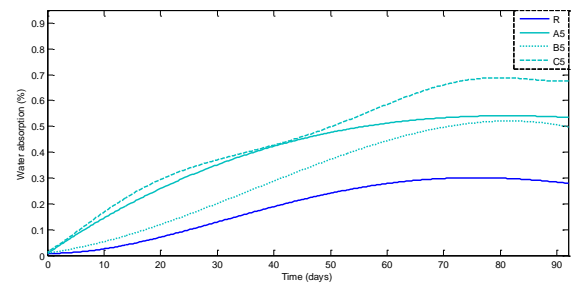


Fig. 11: Percentage of water absorption for  $\text{SiO}_2$ ,  $\text{TiO}_2$  and MMT at 5% nanofiller

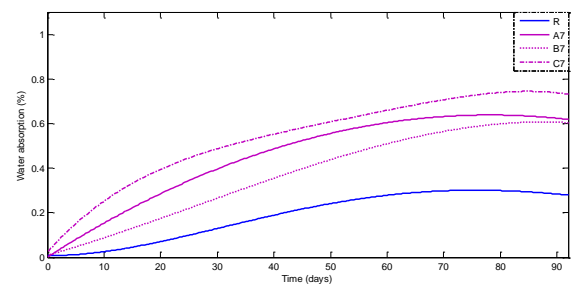


Fig. 12: Percentage of water absorption for  $\text{SiO}_2$ ,  $\text{TiO}_2$  and MMT at 7% nanofiller

## V. CONCLUSIONS

The water absorption for each sample contained different types of nanofiller have been studied in this paper. In conclusion, the experimental result shows that different type of nanofiller has different percentage of water absorption. In particularly, as the amount of nanofillers increase, the

percentage of water absorption also increased. The differences in percentage of water absorption give different characteristic for insulation and can be associated directly due to different filler morphological characteristic such as nanoparticle ratio. Based on the experiment result, it is found that sample LLDPE-NR with SiO<sub>2</sub> as a nanofiller was the best samples in water absorption because SiO<sub>2</sub> has a good water repellency and has hydrophobic behavior compared to TiO<sub>2</sub> and MMT nanofiller. This investigation is important in order to select the best nanocomposite material in relation with its morphology and water absorption properties. This will support the design of manufacturing process for insulation in high voltage application.

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