

## PDC Analysis of LLDPE-NR Nanocomposite for Effect of Moisture Absorption

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### ABSTRACT

The properties of insulation have been improved by many research and the ability of nanocomposite material that composes the characteristic of improving electrical performance due to the addition of nanofiller into the based material gets serious attention. Polarization and Depolarization Current (PDC) measurement that has the ability to assess the condition of HV insulations with the initial periods after a DC step voltage application was favoured compared to other non-destructive monitoring techniques. This paper presents the works on moisture absorption in LLDPE-NR nanocomposite with different amount and percentage of nanofillers. The study of PDC level of the LLDPE-NR compound, filled with different amount of SiO<sub>2</sub>, TiO<sub>2</sub> and MMT nanofiller using Polarization and Depolarization Current (PDC) measurement technique is the main objective of this research. These results show that sample A1 has the lowest polarization current value and sample B5 has the lowest depolarization current value.

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## 1. INTRODUCTION

Some research has been done to study on moisture absorption of polymer nanocomposite at different level of water content [1-4]. They have discussed on how the water absorption by nanofiller can significantly affect the material electrical properties. Researchers [5], [6] have tested pure epoxy and epoxy composites thermal properties, moisture absorption and dielectric properties using micron-sized and nano-sized filler. The nano composite has a higher moisture absorption compared to microcomposite from the test results obtained. The filler density, shape and the surface treatment influence the result produced. The dielectric constant ratio and degree of interaction between filler and polymer represents the effective dielectric constant of composite. The Interphase dielectric constant can be increased by the addition of silane coupling agent which could form the chemical bonding and improves the interface interaction in the composite that could be obtained from the experimental data and molecular dipole polarization calculations [5].

Researcher [7] has done the analysis of PDC measurement for cables. This is a case of severe thermal aging. High temperature indicates that the cable was in aging and fault condition. It can be seen that

the conductive contaminants especially free water subject to high conduction current. The improvement can be seen when the result of polarization and depolarization current obtained is lower than the result before changes being made. Polarization and depolarization current measurement can be used to monitor the aging effect due to moisture.

Research had been done on LLDPE-NR nanocomposite using PDC for normal condition [8], [9] and effect of electrical tracking[10], [11]. These researches show that different type of nanofiller gives different level of PDC pattern. Effect of electrical tracking shows higher PDC value compared with normal condition.

### 1.1. Sample Preparation

Brabender mixer with chamber size of 50 cm<sup>3</sup> was used to prepare polyethylene nanocomposites by melting and mixing it under 170°C. The screw speed that rotates at 35rpm with the mixing time of 2min was controlled by the mixer which possesses higher shear force. A circle shaped polymer nanocomposites were mold with the diameter of 7.5cm and the thickness of 3mm by hot melting by exerting the pressure of 1 ton under 170°C. This process was carry out for 10min by varying the concentrations of nanofiller with 1, 3, 5 and 7 % wt respectively. Table 1 shows the compound formulations and designation.

Table 1. 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	80	20	1	A1
LLDPE + Natural Rubber + SiO <sub>2</sub>	80	20	3	A3
	80	20	5	A5
	80	20	7	A7
	80	20	1	B1
LLDPE + Natural Rubber + TiO <sub>2</sub>	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

## 2. RESEARCH METHOD

### 2.1. PDC Measurement Technique

A dc voltage step was applied on the dielectric materials to measure the polarization current whereas by removing the dc voltage source incorporating with a switch which turn on to short circuit at the under tested objects [12-14] depolarization current was obtained. 1000V of dc voltage was applied continuously for about 10,000 seconds for polarization and depolarization time. The PDC measurement is shown in Figure 1. PDC testing was done at IVAT, UTM.

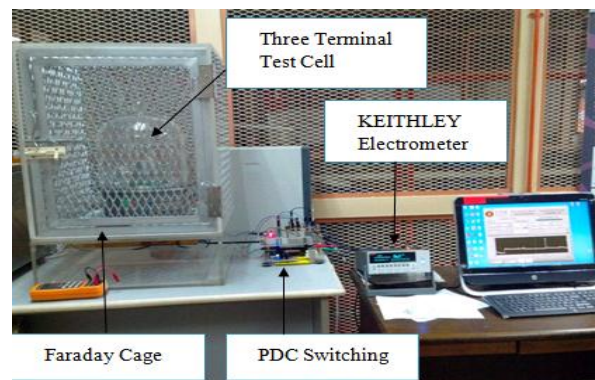


Figure 1. PDC testing

## 2.2. Moisture Absorption Test

Samples of difference types and % wt added of nanofiller are placed in separate container filled with distilled water as shown in Figure 2. Distilled water is used to avoid an influence of salts or impurities on the measurement results. To ensure the temperature does not influence the rate of absorption of water, each sample was placed in a room under the same temperature.

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 95 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  $\Delta m$ .

$$M = \frac{\Delta m}{m_0} \times 100\% = \frac{m - m_0}{m_0} \times 100\% \quad (1)$$

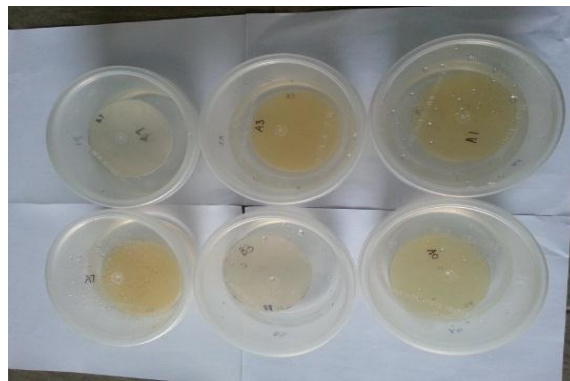


Figure 2. Sample immersed in distilled water

## 3. RESULTS AND ANALYSIS

### 3.1. Moisture Absorption

Table 2 shows the moisture absorption percentage of saturation for all samples. From the table, it shows that sample group A and C gives more moisture absorption effect for nanofiller more than 5% compared with sample group B. From the results obtained, it shows that LLDPE-NR/MMT sample give the highest moisture absorption effect compared with sample LLDPE-NR/SiO<sub>2</sub> and sample LLDPE-NR/TiO<sub>2</sub>. LLDPE-NR/MMT at 7% of MMT shows the highest absorption rate of water compare to other samples. It was found that concentration of MMT nanofiller has increased the percentage of water absorption into LLDPE-NR nanocomposite. These results approved that MMT is reactive semiconductor filler and it is not good for dielectric application.

Table 2. Moisture absorption percentage of saturation

Sample	R	A1	A3	A5	A7	B1	B3	B5	B7	C3	C5	C7
Moisture absorption percentage (%)	0.29	0.29	0.46	0.54	0.63	0.30	0.5	0.50	0.59	0.51	0.68	0.73

MMT and SiO<sub>2</sub> nanofiller is hydrophilic hydroxyl characteristic groups. They tend to absorbed more water compared with TiO<sub>2</sub> nanofiller. LLDPE-NR/MMT and LLDPE-NR/SiO<sub>2</sub> sample at 7% wt nanofiller showed dramatic increase in moisture uptake. This can be due to hydrophilic nature of the nano-sized MMT and silica surface tend to attract moisture.

The enlarge size of the hydrated ion may inhibit its migration through the limited free space in the solid dielectric. The hydrated ions may penetrate the composite dielectric by migration through the available free space as in a homogeneous specimen. However, in a composite specimen, the possibility exists that the water may migrate via the interfaces between the component parts.

### 3.2. Polarization Current

Figure 3 shows polarization current trends for samples after 95 days immersed in water for sample R and samples group A. It is shown that sample A1 has lowest polarization current in group A. Sample A1 shows the lowest moisture absorption rate compare to the others compounds as there is only 0.29% moisture absorption before getting saturated.

Figure 4 shows polarization current trends effect of moisture absorption for sample group B. It is shown that sample B5 has lowest polarization current in group B. Sample B5 absorb water only 0.5% for it to be saturated. Even though sample B5 has higher effect of water absorption, it still has lowest polarization current compared with sample B1 which has lowest absorption rate. It shows that hydrophobic characteristic of TiO<sub>2</sub> nanofiller will not affect the dielectric properties of LLDPE-NR/TiO<sub>2</sub> due to moisture absorption.

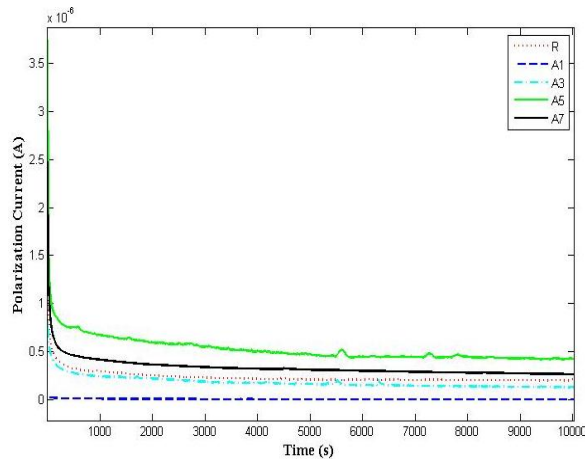


Figure 3. Polarization current pattern for sample R, A1, A3, A5 and A7 after water absorption

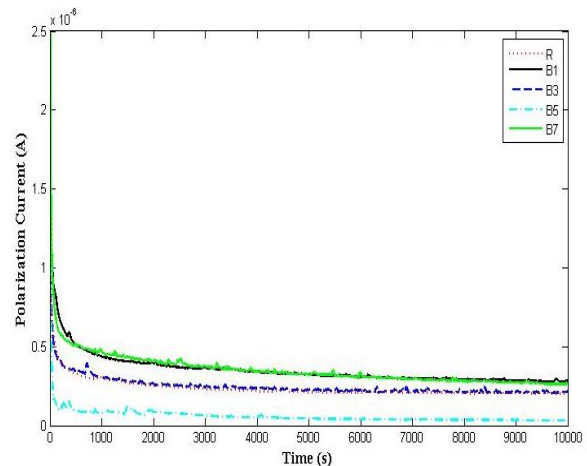


Figure 4. Polarization current pattern for sample B1, B3, B5 and B7 after water absorption

Figure 5 shows polarization current trends effect of moisture absorption for sample group C. It is shown that sample C3 has lowest polarization current in group C. Sample C3 shows the lowest moisture absorption rate compare to the others compounds as there is only 0.51% moisture absorption before getting saturated.

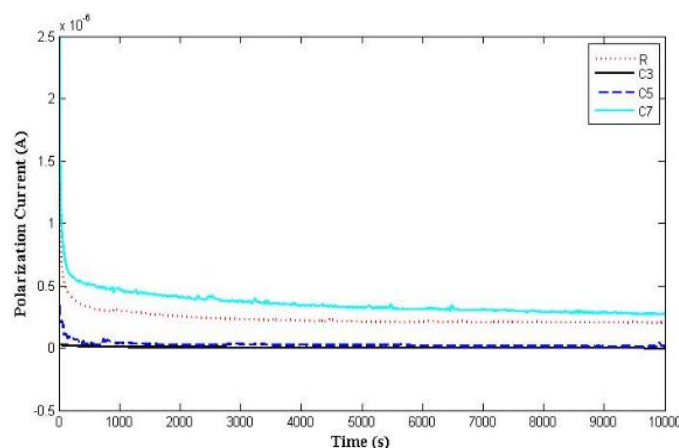


Figure 5. Polarization current pattern for sample C3, C5 and C7 after water absorption

### 3.3. Depolarization Current

Figure 6 shows depolarization current trends for samples after 95 days immersed in water for sample R and samples group A. It is shown that sample A1 has lowest depolarization current in group A.

Figure 7 shows depolarization current trends effect of moisture absorption for sample group B. It is shown that sample B5 has lowest depolarization current in group B.

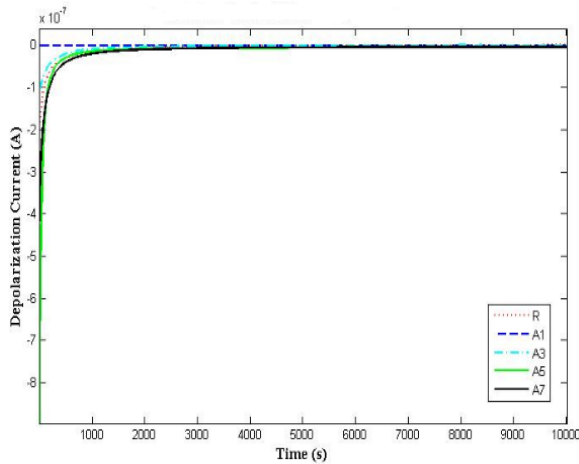


Figure 6. Depolarization current pattern for sample R, A1, A3, A5 and A7 after water absorption

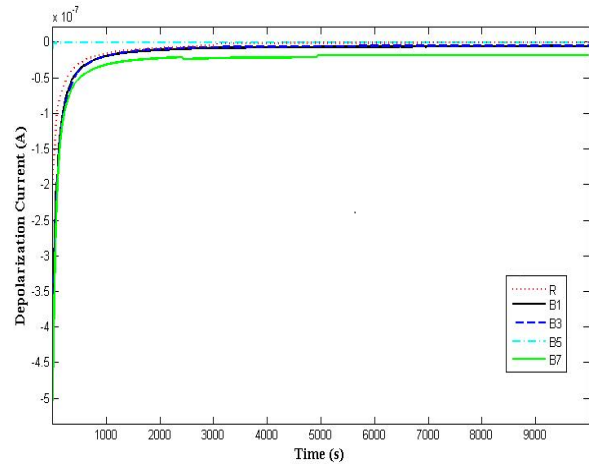


Figure 7. Depolarization current pattern for sample B1, B3, B5 and B7 after water absorption

Figure 8 shows depolarization current trends effect of moisture absorption for sample group C. It is shown that sample C5 and C7 show the lowest depolarization current.

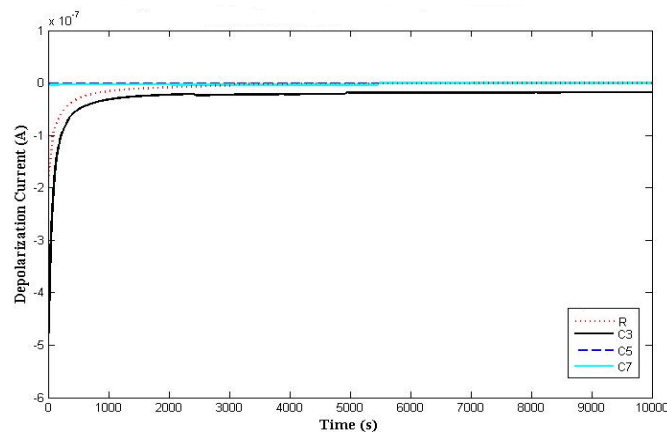


Figure 8. Depolarization current pattern for sample C3, C5 and C7 after water absorption

It clearly shows the depolarization current is small and getting close to zero axes in the time range from 1000 to 10000s. It means that the nanofiller could suppress depolarization current in LLDPE-NR after introduction of nanofiller. The variation of depolarization current is not distinct with the increase of nanofiller concentration for normal and moisture absorption effect.

#### 4. CONCLUSION

Results show that sample A1 has the lowest polarization current and sample B5 has the lowest depolarization current value. These samples contribute to the best sample due to lowest PDC values for effect of moisture absorption. Hydrophobic filler contributes to lower moisture absorption, particularly in the interfacial regions between fillers and polymer matrix and thus effect the composite dielectric response. Besides that, quality dispersion of nanofiller and the presence of absorbed moisture also contribute to dielectric response changes.

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