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Effect of Humidity on Partial Discharge Characteristics of Epoxy/ Boron Nitride Nanocomposite under High Voltage Stress

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ABSTRACT

Partial discharge (PD) may lead to the degradation of insulating materials and affect the lifetime of high voltage equipment. This paper describes the effect of relative humidity on PD characteristic of epoxy/boron nitride (BN) nanocomposite under high voltage (HV) stress. In this work, CIGRE Method II was utilized as an electrode configuration. BN nanofiller was chosen because of its high insulating properties with high thermal conductivity. The PD characteristics such as PD charge magnitude, PD number or occurrence, and average of PD charge during certain of ageing time under HV stress against relative humidity were examined. The results revealed that PD number of humid samples is higher about 8~14% compared to the normal ones. It is considered due to the decrease of surface resistance of the humid samples. The PD charge magnitudes of humid samples are slightly higher compared to the normal ones. The epoxy/BN nanocomposite has lesser PD number and magnitude compared to the neat epoxy samples.

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1. INTRODUCTION

According to IEC 60270 standard: partial discharge (PD) is defined as a low-level electrical breakdown confined to localized regions of the insulation between two electrodes at different voltages [1]. PD is dangerous phenomena in electrical appliances insulation especially when occur in polymeric cable, as it will slowly shorting lifetime of the insulation and finally cause breakdown of equipment [2]. In time, many researchers tried to form a good insulation composite material that is resistant to thermal, chemical, electrical degradation and good mechanical properties.

The experimental investigation of PD characteristics on different type of polymer-nancomposite materials have been conducted by many researchers since 1980's [3]-[5]. It was found that a combination of nanofiller such as nano-silica (SiO_2), nano-titania (TiO_2), etc and epoxy resin give good composite insulation characteristics [6]-[8].

Boron nitride (BN) is more suitable as nanofiller because it does not contain any oxygen atom and has high electrical resistance compared to the other fillers. There are a few reports on PD characteristics of Epoxy-BN nanocomposite. Thus, the further study on epoxy-boron nanocomposite under high voltage stress is necessary. Effect of boron nitride nanofiller on partial discharge characteristics with different high voltage stress was performed in our previous work [8]. The main objective of this research is to perform an experimental investigation on observing effect of humidity in epoxy-boron nitride (BN) nanofiller against PD characteristics under high voltage AC stress.

2. RESEARCH METHOD

CIGRE Method II electrode configuration is utilized to observe PD performance of epoxy/BN nanocomposites samples. In this method, the material was exposed to partial discharges (PD) formed in a strong, inhomogeneous field in a flat cylindrical void in the non-vented air gap. CIGRE Method II electrode configuration which was used in this research work is shown in Figure 1. The test sample was inserted between the rod electrode and plane electrode of the configuration setup.

PD activities were observed using PD detector of Tettex Instruments (DDX-9101) which is integrated with PD processing software. 5 kV_{rms} of voltage application were applied on the samples and then PD characteristics were observed and analyzed. Experimental works were performed at the laboratory of the Institute of High Voltage & High Current (IVAT), *Universiti Teknologi Malaysia* (UTM), Johor Bahru Campus, Malaysia.

Table 1. Sample Condition

Boron Nitride Amount (wt%)	Hunidity (%)
0, 2, 5	Normal (28), 90

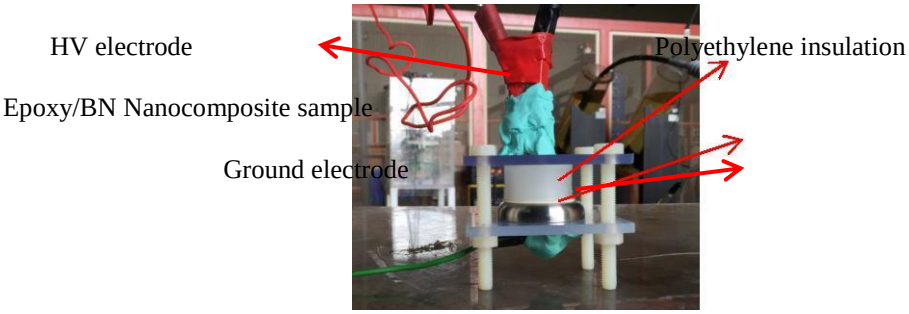


Figure 1. Sample under test in CIGRE Method II electrode configuration

3. RESULTS AND ANALYSIS

Figure 2 shows the total PD number of epoxy/BN nanocomposite samples for normal and humid samples of 0, 2, and 5wt% of BN nanofiller at 1hour ageing test. It can be seen clearly from the figure that humid samples have higher PD number compared to those of normal ones. It was also found that the increasing PD number of humid samples is about 8~14% of normal ones.

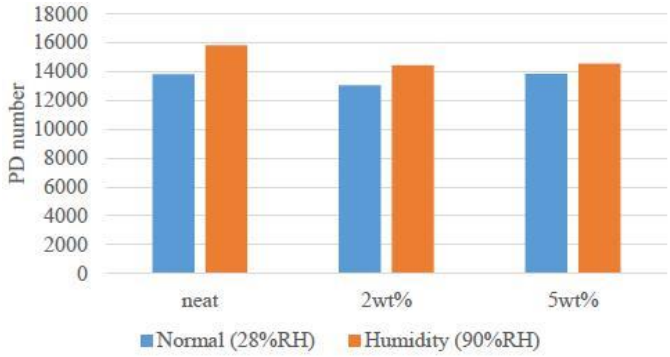


Figure 2. Total PD number of epoxy/BN nanocomposite for normal and humid sample

Figure 3, 4, and 5 depict the average PD charge magnitude graphs of each sample type for 1h of test. It can be seen clearly, the overall PD charge patterns start to change during 1 hour of ageing time. For neat epoxy sample, the PD charge magnitudes fluctuate during the ageing time with humid sample has slightly higher PD magnitude compared to the neat sample as shown in Figure 3. The PD charge fluctuates in the range of 220~900 pC. Similar trend is shown for epoxy with 2wt% of BN nanofiller but with relatively lower PD charge magnitude around 230~520 pC as shown in Figure 4. While for epoxy with 2wt% of BN

nanofiller, a first 300 seconds, PD charge significantly decrease from 500 and 600 pC to 75 and 90 pC for normal and humid sample, respectively. Then PD charges slightly increase and fluctuate for the rest of ageing hour with the range of 70~430 pC as shown in Figure 5. The fluctuation in the PD charge pattern during the test might be caused by decreasing in statistical time lag for discharge and increasing conductivity at the sample surface.

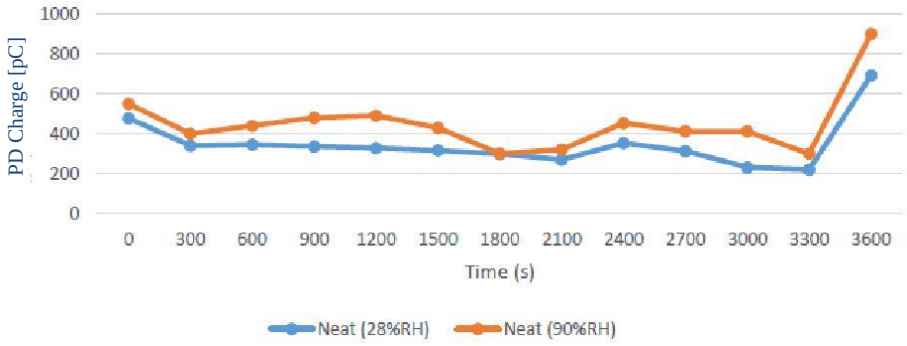


Figure 3. PD charge trend of neat epoxy for normal and humid sample

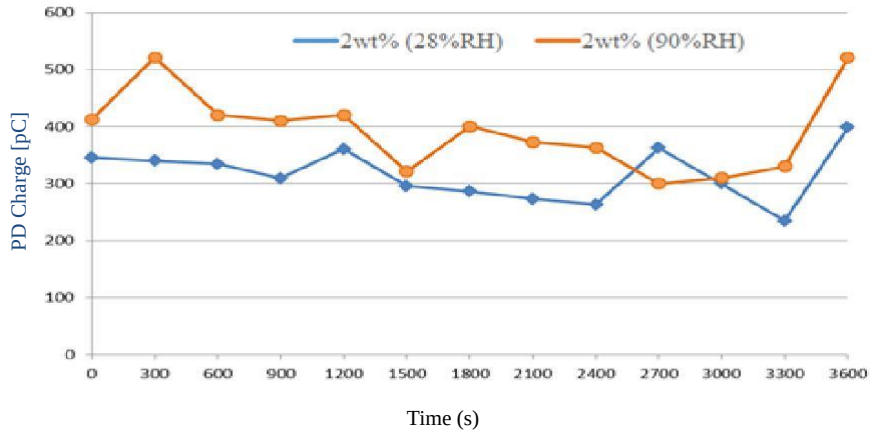


Figure 4. PD charge trend of neat epoxy with 2wt% of BN nanofiller for normal and humid sample

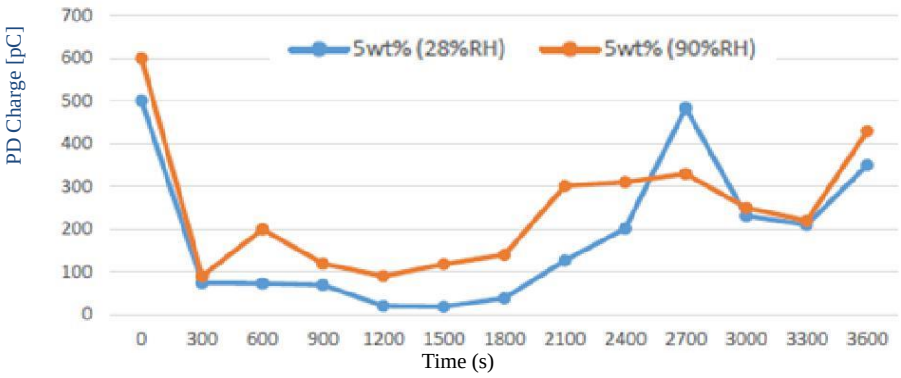


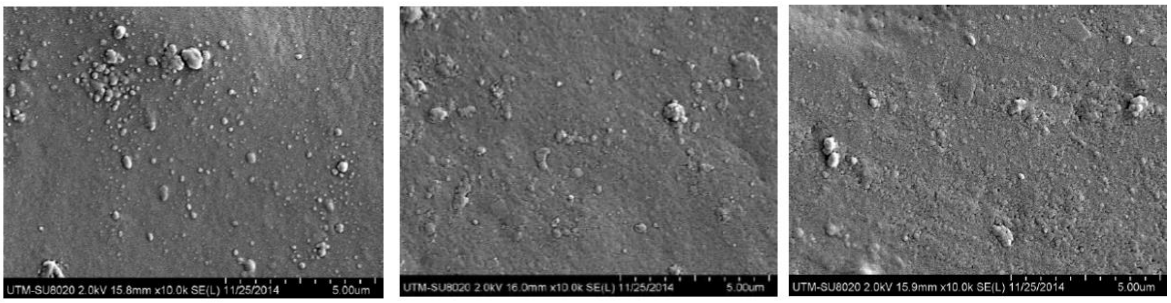
Figure 5. PD charge trend of neat epoxy with 5wt% of BN nanofiller for normal and humid sample

PD activities are influenced by voltage application on the sample. As reported in [9], the void within cavity may experience a PD activity which was caused by the breakdown voltages at a critical value of high

voltage. Some value of voltage in excess of the nominal breakdown voltage (BDV) of the sample may initiate the BDV values occur in the void [9].

The higher of PD number of humid sample is considered due to decrease of surface resistance of the tested samples. As reported by Nawawi et. al., the reduction of surface resistance indicates that the relative humidity plays significance roles in determination of the PD number and PD magnitude [10].

Field-emission scanning electron micrographs (FESEM) of all sample type are shown in Figure 6. As cab be seen from Figure 6 (a), it was found that some agglomeration at the surface of neat epoxy sample. Less agglomeration was observed for epoxy with 2wt% and 5wt% of BN nanofiller as shown in Figure 6 (b) and (c) respectively.



(a) (b) (c)

Figure 6. Field emission scanning micrograph (FESEM) different sample type, (a) neat epoxy, (b) epoxy with 2wt% of BN nanofiller, (c) epoxy with 5wt% of BN nanofiller

4. CONCLUSION

Effect of relative humidity of epoxy/BN nanofiller on PD characteristics has been conducted in this work. It is found that PD number of humid samples is higher about 8~14% compared to the normal ones. It is considered due to the decrease of surface resistance of the humid samples. The PD charge magnitudes of humid samples are slightly higher compared to the normal ones. The epoxy/BN nanocomposite has lesser PD number and PD charge compared to the neat epoxy samples.

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Noor 'Aliaa Awang was born in Kelantan, Malaysia on June 29, 1989. She received her Electrical Engineering (Education) diploma degree from Universiti Tun Hussein Onn Malaysia (UTHM), Johor in 2010 and received B.Eng in Electrical Engineering with Honors from UTHM in 2013. She then completed her M.Eng degree in electrical power engineering from Universiti Teknologi Malaysia (UTM) in 2015. She is currently pursuing Ph.D. degree at Institute of High Voltage and High Current (IVAT) in Faculty of Electrical Engineering, UTM. Her research interests include the partial discharges phenomenon and polymer nanocomposites insulating materials.

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