Investigation of Mixture of Epoxy Resin/Palm Kernel Shell as Insulation

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ABSTRACT

Palm kernel shells have a high mechanical strength and good insulation strength. From these results it can be concluded that breakdown voltage of epoxy resin/palm kernel shells is higher than pure resin or resin/alumina. The highest breakdown voltage that occurred in the resin/palm kernel shells (8 wt%) is 76 kV. While the highest breakdown voltage that occurred in the epoxy resin/alumina (17 wt%) is 57.15 kV. Breakdown voltages of both samples are higher than the pure epoxy resin of 36 kV. The maximum electric field density (Emax) in the pure resin is 0.24 MV/cm that is lower than the resin/palm kernel shell (8 wt%) of 0.51 MV/cm and the resin/alumina (17 wt%) of 0.38 MV/cm. Discharge current has a lot of pulses and high amplitude when all solid insulation approached the breakdown event. However, the current pulses in the pure resin are higher than in both resin/palm kernel shell and resin/alumina. The epoxy resin mixture with palm kernel shells can be used as a new solid insulator.

KEY WORDS: *Epoxy Resin, Palm Kernel Shell, Breakdown Voltage, Discharge Current, Electric Fi.*

NOMENCLATURE

MV	Mega Volt
cm	centimetre
r_0	Needle tips radius in micro meter.
V	potential (Volt)
d	distance between electrodes in cm
kV	kiloVolt

1.0 INTRODUCTION

For over two decades, the design of composite materials in the order of milli-scale, micro and nanometers from inorganic particles has given attention in the design of high voltage insulation materials. This composite material has improved performance in high temperature and high electric field stresses [1-3,15,16]. Fillers in composite materials commonly used inorganic materials such as aluminum nitride (AlN), boron nitride (BN), silica (SiO_2), alumina (Al_2O_3) and titania (TiO_2), silicon carbide (SiC) and zinc oxide (ZnO), etc. are usually tested in insulation strength, mechanical strength and durability at high temperatures [1,16]. In the electrical power engineering, the first material was the insulating materials made of organic materials such as natural cellulose fiber, silk, cotton, wool, mica, and the natural resin material which was derived from wood, plants and vegetable oils [18].

During the first world war, mica flakes were combined with asphalt that was supported on both sides with cellulose paper called Kraft paper [18]. Dielectric strength and mica surface resistance are high while dielectric losses are low. Mica is characterized by higher resistance than the best organic insulator on creepage discharge and the PDs event. Mica is widely used in high-voltage electric engineering technology [19]. Park synthesized the composite of epoxy resin/mica in order to estimate the breakdown voltage of the insulation material, it would be used as a high voltage insulation on electrical machines. Park did a test the breakdown voltage of the mica epoxy resin composites by using high voltage sphere electrodes. From the test results obtained when mica content of 20 wt% was obtained the optimum breakdown voltage that was higher than the breakdown voltage of pure epoxy resin [4].

Epoxy resin is a polymer material that can be used as a high voltage insulator and it has a high volume resistivity, lighter, high insulation strength and good mechanical strength. Epoxy resins have the disadvantage that it may react when exposed to ultraviolet light and it accelerates insulator aging. In the study epoxy resin as a high voltage insulator, there are a few points to consider in. First, the free volume is associated with a reduction in the permittivity of the material. When the epoxy resin is mixed with titanium particles in the nanometer size, it would increase the permittivity of the material, conversely, it decreases the free volume when mixed with micrometer-sized particles. Second, the permittivity is associated with the increasing in the value of permittivity when the epoxy resin is mixed with inorganic materials. Third, the loss factor (tangent delta) shows the epoxy resin mixed with silica has a low loss factor when compared with the loss factor of pure epoxy resin. This indicates that it is necessary to do some research to find the right mixture of epoxy resin with inorganic and organic compounds [5].

The first research was reported in the international conference that focused on the epoxy resin and nanocomposites, and it provided good results for insulation strength when the epoxy resin was mixed with the metal oxide, aluminum oxide, silicon oxide, clay, barium titanate and copper titanate. [6-9]. In its development, to increase the mechanical strength of epoxy resin, it was made by mixing it with carbon nanotube [10,13] and this was done to get a high insulation strength by using surface fluorinated technique[11].

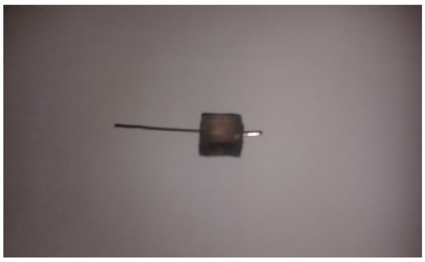
Measurement techniques on epoxy resin mixed with organic and inorganic particles include transmission electron microscopy (TEM), dielectric spectroscopy, the conduction current and the measurement of space charge. From these measurements will be obtained characteristics of electrical insulation materials (epoxy resins and mixtures). TEM is used to determine the composition of the particle size in the micro and nanometer microscopically. Dielectric spectroscopy is used to measure the permittivity of the epoxy resin. The conduction current and the space charge are used to determine the conductivity and electric field that occurs in the insulator material of epoxy resin [12]. The author has studied a mixture of epoxy resin with palm kernel shells and this is a new thing in the research on epoxy resin as a high voltage insulator.

2.0 RESEARCH METHODE

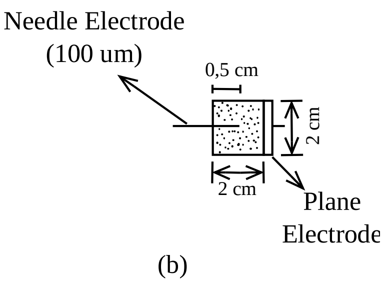
2.1 Sample Treatment

In the preparation of samples, palm kernel shells were crushed and then they were filtered by a mesh filter with a diameter of 1000 micrometer. Particles with a maximum diameter of 1000 micrometer were mixed into the resin with a dose of 0.5 mg to 1.5 mg. After the resin and the particles of palm kernel shells were stirred (sample), the samples were formed by using a silicon rubber mold. Samples were molded in silicon rubber mold with dimensions width of 2 cm, a length of 2 cm and height of 2 cm. In this process found a complicated thing where palm kernel shell particles easily precipitated and they were not spread evenly. The process used to make palm kernel shell particles could be evenly distributed between the two electrodes, a few resin was poured into the mold as much as half of the volume of the mold then it was allowed to be thickened a few minutes. The next step, a mixture of resin/palm kernel shells was poured into the mold simultaneously with dripping liquid hardener (catalyst) and the stirring process still takes a few minutes. A needle with radius 100 um was drilled into the sample with a distance of 0.5 cm to the electrode plate that was also plugged opposite the needle in accordance with Figure 1b. Samples were allowed to dry naturally for 24 hours. In this test the samples were prepared 10 samples with particle composition from 0.5 to 1.5 in mg.

The resin/alumina preparation process followed the following stages. First, a mixture of resin/ alumina powder was mixed well with the alumina masses 0.1 gr, 1.1 gr, 1.2 gr, 1.3 gr, 1.4gr, 1.5gr, 1.6 gr, 1.7gr, 1.8gr, 1.9gr and 2 gr, respectively. Samples were molded in silicon rubber mold with dimensions width of 2 cm, the length of 2 cm and height of 2 cm. To avoid precipitation of alumina, the sample was stirred continuously and then it was added a little catalyst that it became thick liquid and a few alumina powder (masses 0.1gr, 1.1 gr, 1.2 gr, 1.3 gr, 1.4 gr, 1.5 gr, 1.6 gr, 1.7 gr, 1.8 gr, 1.9 gr and 2 gr, respectively) was spread evenly across the sample chamber. This process needed the time for a few minutes. Prior to sample thickens, a plate electrode was implanted on the other side of the sample. A needle electrode with radius 100 um was placed on the opposing side of a plate electrode. The distance between the electrodes was 0.5 cm. After the complete sample (needle electrode, electrode plate and a mixture of resin and alumina) thickens, the sample was allowed to dry itself at room temperature and pressure of 1 atm for 24 hours. The scheme of arrangement of electrodes in the sample can be seen in Figure 1b. The alumina powder used in this experiment was TA1591295 050 Aluminum Oxide Merck with a particle size > 0.2 mm as much as 2%, the size of < 0.0083 mm by 28% and the size > 0.083 mm as much as 72 %.



(a)



(b)

Figure 1: Resin sample and filler a) sample photograph, b) sample dimension

2.2 AC Breakdown Test and Discharge Current Measurement

Figure 2 shows the schematic diagram of breakdown test on the resin/filler. The high-voltage transformer HV 9000 Terço made in Sweden was used in the experiment. A sample was placed in a transparent container that contained lubricating oil. The usefulness of lubricating oil is to increase the strength of the surface insulation and it can avoid surface discharge at the time of testing. AC high voltage with the frequency of 50 Hz was

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connected to the needle electrode. Breakdown voltage test on the samples was done by adjusting the applied voltage rises gradually and uniformly. The increasing of voltage was every 1 minute until the sample brook down. The same tests were also performed to other samples. To obtain accurate data, this test was done 2 phases with the same composition. From the results, the comparison of the breakdown voltage between pure resin and a mixture of resin/palm kernel shell and also a mixture resin/alumina powder was estimated.

The discharge current measurement was recorded by a current probe (Hantek CC 650 to 400Hz bandwidth, 1mV / 10mA, 650A). A current probe was connected to a digital oscilloscope (Hantek DSO5202BMV 200MHz). The current measurement was to observe the current characteristics at the approach of breakdown voltage. This research was carried out at a pressure of 1 atm and room temperature.

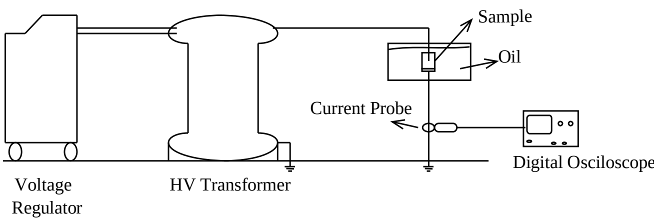

Figure 2: Schematic diagram of resin/filler breakdown test

3.0 RESULTS AND ANALYSIS

3.1 Electric Field Density

The insulation strength (breakdown voltage) test on epoxy resin can use a combination of electrode plates or needle-plate electrodes. Plate electrodes generate a uniform electric field and it is lower than a non-uniform electric field in needle-plate electrodes. Consequently, the breakdown voltage test in plate electrodes requires a higher voltage than the needle-plate electrodes. Then, this high voltage can trigger flashover on the surface of the insulating resin. Therefore, the breakdown voltage test on the resin was implemented by using needle-plate electrodes. Needle-plate electrodes produce a non-uniform electric field that can be calculated by the following equation 1 [14].

$$E_{max} \approx \frac{2V}{\ln\left(\frac{4d}{r_0}\right)} \frac{1}{r_0} \quad (1)$$

Where Emax is maximum electric field density in kV/cm, V is applied voltage is connected to needle-plate electrodes in kV, d is a distance of needle-plate electrodes (cm) and r0 is needle tips radius in micrometer. Electric fields profile can be simulated with the aid of software Quickfield student version 6.1 [20]. Figure 3 presents electric fields density around the needle electrode. This value is higher than other places. A high electric fields density is due to the non-uniform electric fields that are more tightly around the needle. If there is a high electric fields around the needle, it can trigger breakdown voltage in the solid insulating material (epoxy resin) at a certain voltage level. The breakdown voltage of resin in the non-uniform fields is lower than in the uniform fields.

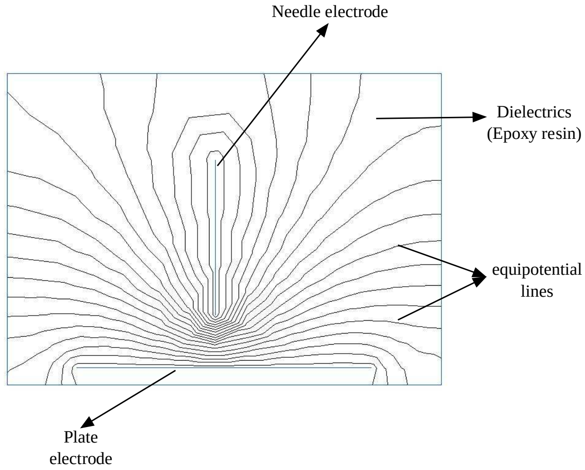

Figure 3: Profile of electric fields density between needle-plat electrodes.

By applying the value of breakdown voltage into equation 1, we can estimate the maximum electric fields density (Emax) that occurred in all samples. Emax in figure 4 can be used to calculate the estimation of Emax in the pure resin test and a mixture of resin/palm kernel shell (0.5 gr to 1.4gr in mass). These values are about 0.24 MV/cm to 0.51 MV/cm that trigger the breakdown voltage for each sample refer to figure 4. Emax in the pure resin is 0.24 MV/cm that is lower than a mixture of resin/palm kernel shell. The high Emax occurred in the mixture of resin/palm kernel shell of 8 wt% is 0.51 MV/cm.

Maximum electric fields density occurred in a mixture of resin/alumina (17 wt%) is 0.38 MV/cm as shown in figure 5. However, it is higher than pure resin in 0.24 MV/cm. Thus the maximum electric fields density that occurred in resin/alumina (17 wt%) is one and a half times higher than the pure resin. Average maximum electric fields density for various compositions resin and alumina are 0.36 MV/cm.

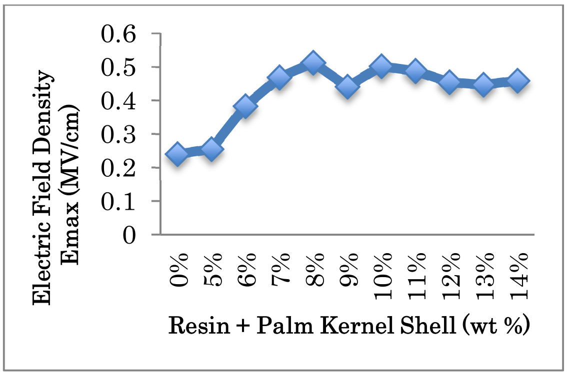

Figure 4: Emax versus resin/palm kernel shell composition

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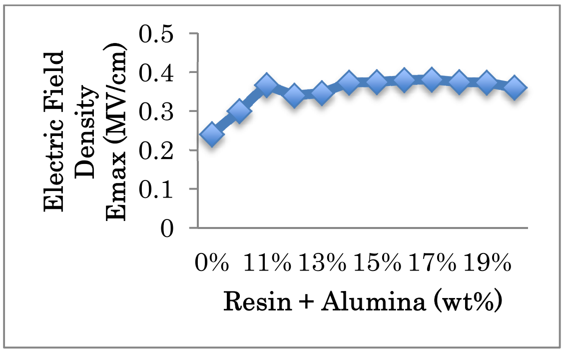

Figure 5: Emax versus resin/alumina composition

3.2 AC Breakdown Test Data

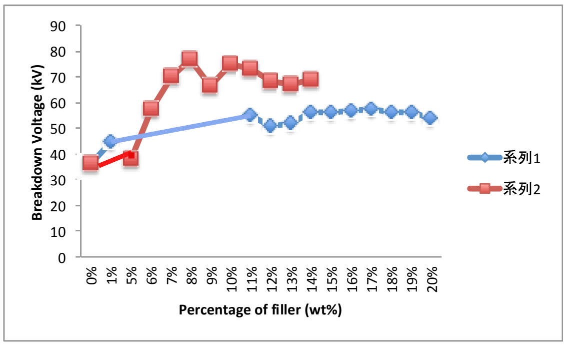

Figure 6: AC breakdown voltage versus percentage of filler: (1) alumina powder (2) palm kernel shell.

Figure 6 presents breakdown voltage value for pure resin (0 on the x-axis), it also shows the value of the lowest breakdown voltage. The breakdown voltage for composition of resin and palm kernel shell from 5 wt% to 8 wt% sharply increased, while for its composition of 9 wt% to 14 wt% seen the value of breakdown voltage slightly dropped. The maximum breakdown voltage value obtained on the composition of resin/palm kernel shell of 8 wt% was 76.72 kV which was higher than the breakdown voltage on pure resin of 36 kV. It can be summarized that by addition of palm kernel shell can increase the value of breakdown voltage on a solid insulator composites (with composition 1.4 mg/14 wt%). The increasing of breakdown voltage can be caused by the increasing of insulation resistance after addition of palm kernel shell.

Figure 6 also presents breakdown voltage value for resin/alumina that was higher than pure resin. The highest breakdown voltage of resin/alumina (17 wt%) was occurred at 57.15 kV, while it was at 36 kV for pure resin. The average breakdown voltage for several composition mixtures of resin/alumina was 54.5 kV. By the addition of alumina powder into the resin, it can increase the breakdown voltage of resin. However, the breakdown voltage of resin/alumina (18 wt% to 20 wt%) slightly decrease. The increasing of breakdown voltage of resin/alumina is caused by insulation resistance of alumina powder is higher than pure resin. The comparison of breakdown voltage between a mixture of resin/alumina (1) and a mixture of resin/palm kernel shell (2) is indicated that breakdown voltage of resin/alumina is lower than resin/palm kernel shell.

3.3 Discharge Current Data

Discharge current measurement process on solid insulating material composites with a current probe is complex because these discharge pulses can cause distortion on an oscilloscope. To obtain the optimal results, it needs to be done with the current probe cable wrapping a layer of aluminum which is then connected to ground. For further research in measuring the discharge current pulses on solid composite insulators will require measurement techniques without signal interference (noise) by using LED (light emitting diode) and an optical cable that is connected to the photodiode [21]. Figure 7, 8, and 9 are the discharge current curve in pure resin, resin/palm kernel shell and resin/alumina.

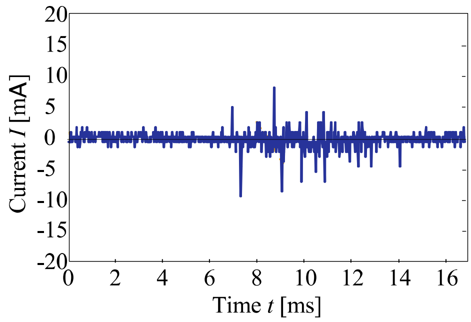

Figure 7: Discharge current curve of the pure resin.

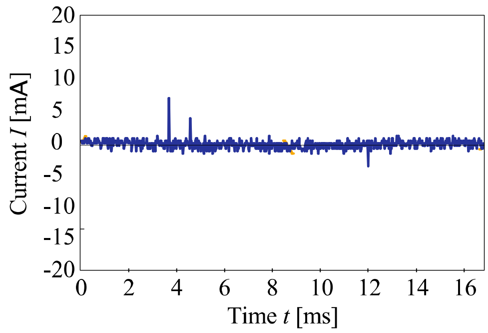

Figure 8: Discharge current of he resin/palm kernel shell of 8 wt% .

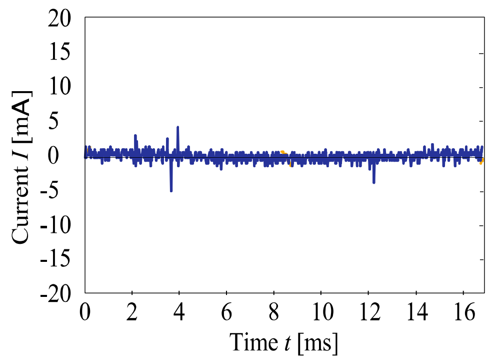

Figure 9: Discharge current curve of the resin/alumina of 17 wt%

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In Figure 7 looks at conditions approximating the breakdown event on composite electrical insulator, discharge current pulses have a lot and the amplitude is higher when compared with the figure 8 and 9. This happens because the solid composite insulators still have a high insulation resistance. At the time of approaching breakdown event, the solid composite insulators have current pulses that indicate that the resistance of composite solid insulator has gone down as a result of exposure to high alternating fields. High electric fields created by the needle electrodes can also trigger a process of polarization in the solid insulation that follows the polarity of the alternating current, known as a dielectric loss. Dielectric losses can generate heat in a solid insulating material that can accelerate the aging of insulation materials, and this led to a decrease in insulation resistance.

4.0 CONCLUSION

From these results it can be concluded that:

1. The breakdown voltage of epoxy resin/palm kernel shells is higher than pure resin. The highest breakdown voltage occurred in the resin/palm kernel shells (8 wt%) is 76 kV. While the highest breakdown voltage that occurred in the epoxy resin/alumina (17 wt%) is 57.15 kV. Breakdown voltages of both samples are higher than pure epoxy resin of 36 kV.
2. The maximum electric field density (Emax) in pure resin is 0.24 MV/cm lower than the resin/palm kernel shell (8 wt%) of 0.51 MV/cm and the resin/alumina (17 wt%) of 0.38 MV/cm.
3. Discharge current has a lot of pulses when all solid insulation approached the breakdown event. However, the current pulses in pure resin are higher than in both resin/palm kernel shell and resin/alumina.
4. The epoxy resin mixture with palm kernel shells can be used as a new solid insulator.

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