Improvements in Dielectric Properties of Varnish filled with Al_2O_3 and Nano fillers

[1]M. Murugan, [2] K. Muthukumar,
[1, 2] BE-IV Year Student
Department of Electrical and Electronics Engineering,
Sree Sowdambika College of Engineering,
Aruppukottai, India.

[3] M. Muthukumaran
[3]Assistant Professor,
Department of Electrical and Electronics Engineering,
Sree Sowdambika College of Engineering,
Aruppukottai, India.

***Abstract* - In the recent years, it was examined that the nano fillers play an important role on the enhancement of the properties of the varnish used in electrical machines. The physical, chemical, electrical, thermal and magnetic properties of the varnish used in the electrical apparatuses were improved by the addition of the nano fillers to the varnish. Only a few dielectric properties were discussed in this research paper. The investigation includes the study of insulating resistance, dipole moment and internal field of the varnish, varnish mixed with nano fillers of alumina taken in different proportions. The various parameters were studied and the results were compared with each other.**

Key words – Al_2O_3, Nano fillers, varnish, Electrical machines, Dielectric studies

1. INTRODUCTION

Solid insulating materials should have

1. Reduced dielectric loss,

2. Improved mechanical strength,

3. It should be free from gaseous inclusions, moisture and be resistant to thermal and chemical deterioration.

Generally, they were used in all kinds of electrical apparatuses to insulate the conductors. Some of the solid insulating materials such as polymers, enamels and varnishes were mostly subjected to tracking. The formation of continuous conducting paths across the surface of the polymeric insulation mainly due to moisture and surface erosion was known as tracking.

In general, an insulating material should have following properties:

1. Dielectric strength should be greater.
2. Mechanical strength should be as high as possible.
3. Fire proofing qualities should be larger.
4. Volume and surface resistivity should be greater.
5. It should have highly appreciated thermal conductivity.
6. Chemical inertness should be as high as possible.
7. Water proofing quality should be good.
8. It should have reduced thermal expansion.

Nano fillers added to the polymeric insulation would have the following advantages:

1. Higher resistance to partial discharge
2. Enhanced thermal properties
3. Lacking of erosion resistance
4. Matching of coefficient of thermal expansion
5. Thermal conductivity enhancement
6. Improved mechanical reinforcement
7. Increased abrasion resistance
8. Improved life time

2. SYNTHESIS AND CHARACTERIZATION OF ALUMINA NANO FILLER

2.1 SYNTHESIS OF ALUMINA NANO FILLER

Different methods were used for the nano particle preparation. The micro powders of alumina were converted into nano particles by means of the ball mill method. The micro particles were crushed by the small balls present inside the ball mill for nearly 40 hours. Then the nano powders of alumina were obtained effectively. This method was also economic. So it was used for the nano particle preparation. Then the prepared nano particles of alumina were subjected to SEM analysis to augment and confirm the particle size of the prepared nano powders. The following Figure 1 shows the image of Ball mill.

Figure 1 Ball Mill

2.2 Characterization of Alumina Nano Filler

The alumina particles were subjected to scanning electron microscopy studies to analyze the surface and structure of the particles. The principle of scanning electron microscopy and the obtained SEM pictures and their interpretations were explained clearly. The samples must be conducting (in order to accelerate electrons into the sample) and hence a biological sample must have a gold layer deposited on its surface if it is to be investigated by SEM or STEM. In SEM, the image may be produced in a number of ways from variations in the intensity of secondary electrons back–scattered from the specimen through to X-ray emission produced by inelastic collisions of the primary beam with bound electrons in the specimen. The following Figure 2 shows the image of Hitachi SU- 1510 Scanning Electron Microscope.

Figure 2 Hitachi SU- 1510 Scanning Electron Microscope

From the analyzed SEM image the particles were in the form of nano metric range varies for one area to other. The sizes of the particles were in the range from 50 to 120 nm size. The SEM analysis of alumina was shown in Figure 3 and 4.

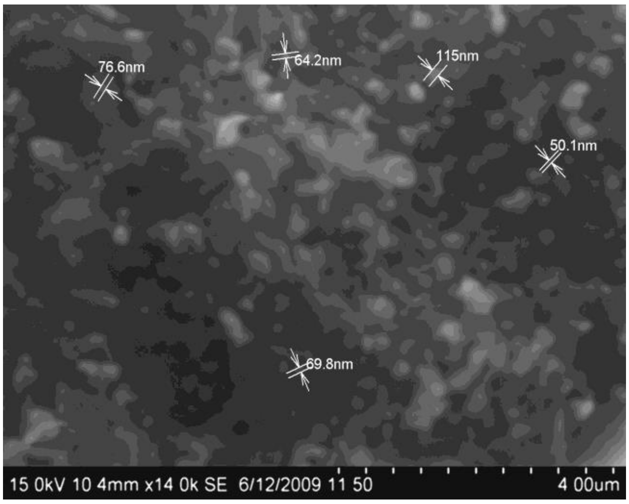

Figure 3 SEM analysis of alumina at 4μm

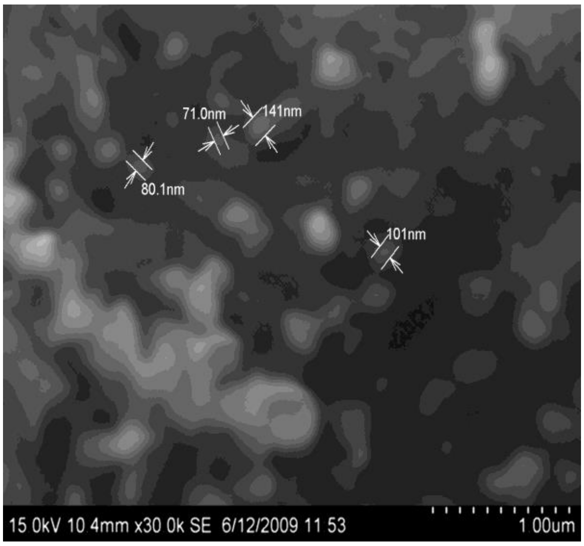

Figure 4 SEM analysis of alumina at 1μm

3 SAMPLE PREPARATIONS

The organic varnish used in the motors was in the fluid nature having high viscosity. So it was difficult to study the electrical and thermal properties of it.. The process of conversion of varnish from its fluid state to solid was done as per the chemical standards without affecting the internal properties of the varnish.The nano composite samples were prepared by radical initiator curing method. 80% of organic varnish having phenolic base and 20% of epoxy resins were taken. DDM (Diamino Diphenyl Methane) was taken as the curing agent. 0.3 g of DDM was taken for 1g of resin. The DDM was melted for 10 minutes at 60-80°C using magnetic mantle. Then the varnish, resin and melted DDM were taken in a beaker. The die should be coated by anabond 666 before pouring the mixture. Then it was placed in an oven at a temperature of 80°C for 1 hour. After the mixture was poured in to the die which was coated by a Teflon sheet, it was heated at 80° C for 2 hours for epoxy curing and 120° C for 3 hours. After this time period it was cooled for 1 hour to obtain a solid nano composite sample. Four series of specimens were produced, each one with different filler content, starting from 0 wt% (pure varnish), 1, 3 and 5wt% weight.

4. EXPERIMENTAL RESULTS

Dielectric spectroscopy also known as Electrochemical Impedance Spectroscopy was used to measure the dielectric properties of a medium as a function of frequency. It was based on the interaction of an external field with the electric dipole moment of the sample, often expressed by permittivity. Here the dielectric measurements were carried out by Impedance spectroscopy (LCR HITESTER 3532-50) measuring instrument. It was also an experimental method of characterizing electrochemical systems. This technique was also used to measure the impedance of a system over a range of frequencies, and the frequency response of the system including the energy storage and dissipation properties. The prepared nano composite sample was sliced to an area of 0.5×0.5 cm^2 then it was placed between the electrodes of dielectric spectroscopy at various temperatures for the frequency range of 0 – 5 MHz. Dielectric Spectroscopy was used to obtain the various electrical parameters like impedance, admittance, impedance phase angle, static capacitance in series, static capacitance in parallel, loss coefficient, inductance in series, inductance in parallel, Q factor, effective resistance in series, effective resistance in parallel.

4.1 Dipole moment of the varnish filled with alumina nano fillers

The strength of the electric dipole moment is proportional to the strength of the electric field. Dipole moment is used to find the amount of polarization and the type of polarization occurring in the insulating materials. Dielectric spectroscopy is used to find the different dielectric properties of the insulating materials.

Table 1 Dipole moment in C – m at 50^o C

Sample	Frequency in Hz						
	50	100	1000	10000	100000	1000000	5000000
5% Nano Al_2O_3 mixed varnish	9.8 x 10^{-14}	9.98 x 10^{-14}	7.76 x 10^{-14}	5.96 x 10^{-14}	5.32 x 10^{-14}	4.2 x 10^{-14}	4.9 x 10^{-14}
3% Nano Al_2O_3 varnish	3.3 x 10^{-13}	1.01 x 10^{-13}	5.88 x 10^{-13}	7.32 x 10^{-14}	6.64 x 10^{-14}	6.6 x 10^{-14}	6.76 x 10^{-14}
1% Nano Al_2O_3 varnish	7.2 x 10^{-14}	4.8 x 10^{-14}	1.28 x 10^{-14}	4.4 x 10^{-14}	4.8 x 10^{-14}	4.8 x 10^{-14}	6.2 x 10^{-14}
varnish	1.7 x 10^{-13}	9.2 x 10^{-14}	7.2 x 10^{-14}	5.28 x 10^{-14}	4.6 x 10^{-14}	4.52 x 10^{-14}	5.28 x 10^{-14}

4.2 Internal Field or Local Field of the varnish filled with alumina nano fillers

The space and the time average of the electric field intensity acting on a particular molecule are called as local field or internal field. The local field intensity is higher than the macroscopic intensity. Lorentz method is used for finding the internal field for the cubic structure.

Table 2 Internal field of the varnish filled with alumina nano fillers in V/m at 50^o C

Sample	Frequency in Hz						
	50	100	1000	10000	100000	1000000	5000000
5% Nano Al_2O_3 mixed varnish	28591.72	19226.76	7233.645	5251.74	4573.53	4375.95	5195.13
3% Nano Al_2O_3 varnish	231112.75	7428.454	6099.78	4545.78	3980.79	3895.32	4743.36
1% Nano Al_2O_3 varnish	194460.63	3641.13	1527.69	4516.92	4743.36	4772.22	6128.64
varnish	143800.38	10424.34	7061.04	5139.63	4432.56	4291.59	4940.94

4.3 Insulation Resistance of the varnish filled with alumina nano fillers

Resistance dissipates energy in the form of heat energy. When the resistance of the insulation is high, the dielectric losses would be less. The temperature rise of the insulating material depends upon the rate of generation and dissipation of the heat by it. If the rate of generation is greater than the rate of dissipation, the temperature goes on rising and vice versa. The sources of heat for the insulating materials are

1. Core loss,
2. Dielectric losses,
3. Harmonic losses and
4. Copper losses

Insulating material should dissipate the heat to the surroundings. Insulation resistance is defined as the opposition offered by the insulating materials to the leakage current. The insulating materials are subjected to dielectric stress in the form of electrostatic forces.

Table 3 Insulation Resistance in Ω at 50° C

Sample	Frequency in Hz						
	50	100	1000	10000	100000	1000000	5000000
5% Nano Al_2O_3 mixed varnish	63.58 x 10^6	13.20 x 10^6	1.76 x 10^6	183.41 x10^3	10.23 x10^3	839.29	146.88
3% Nano Al_2O_3 varnish	54.68 x 10^6	12.49 x 10^6	1.66 x 10^6	165.32 x10^3	9.05 x10^3	621.31	93.85
1% Nano Al_2O_3 varnish	14.05 x 10^6	13.73 x 10^6	1.34 x 10^6	159.15 x10^3	9.41 x10^3	665.27	65.14
varnish	19.22 x 10^6	17.79 x 10^6	1.52 x 10^6	172.87 x10^3	9.14 x10^3	775.25	71.50

5. CONCLUSION

From this research, it was observed that the values of dipole moment, insulation resistance and internal field of the varnish vary with temperature, filler concentration and frequency. From these researches, it was also found that the 5% of Nano alumina mixed varnish sample has the highest value of the internal field when compared to all the samples at the temperature of 50° C. It was examined that the 5% of Nano alumina mixed varnish sample has the highest value of dipole moment and insulation resistance for the temperature of 50° C at 50 Hz.

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