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Diagnosis of Dielectric Characteristics of Film Capacitor with nano fillers

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ABSTRACT

Capacitors have their own identification based upon their usage in various domains of Electrical and Electronics Engineering. In recent years, significant application of nano particles/filler for enhancement of electrical, thermal and mechanical properties are observed. In the present work, the dielectric and thermal properties of standard poly propylene and poly propylene-nano Zirconia composite materials are examined, which can be used as a dielectric material in capacitors. The Dielectric constant (ε), Dissipation Factor and Breakdown strength have been analyzed. It has been observed from the present analysis that 3 Wt % of ZrO_2nano filler mixed polypropylene has improved dielectric.

KEY WORDS: Poly Propylene Film Capacitor, ZrO_2 nano fillers, Dielectric Properties, Thermal Properties, AC breakdown Strength.

1. INTRODUCTION

The selection of dielectric material now days for various voltages conditions becomes a difficult task. Dielectric materials have its unique identifications in the design and performance of electrical apparatus. They can be used for insulation purposes, charge storage (as capacitive devices), in addition to other purposes like heat conduction (as in liquids in oil-transformers) and mechanical support (as in solids).

The poly propylene is a dielectric offering a higher breakdown voltage than polyester, and thus more suitable for high voltage applications such as switching power supplies. They also have low loss factors and good capacitance stability making them a good choice for high frequency applications, including oscillators and other frequency sensitive circuits. The main disadvantages are slightly higher cost and larger physical sizes over other film dielectric capacitors. Zirconia is noted for its Electrical Insulation and low thermal conductivity properties as far as Electrical application are concerned. It has various applications such as pump and valves manufacturing, cutting blade manufacturing and also usage in thermal insulating components.

The nano structured polymeric materials are objects of great interest to researchers. It is due to the fact that nanofillers provide improved surface area and enhanced thermal and electrical properties. The present work addresses the analysis of dielectric and thermal properties of standard Polypropylene and Zirconia mixed Polypropylene.

2. EXPERIMENT

2.1. Sample preparation: In this analysis, commercially available Zirconia (Assay min 99%, Iron (Fe) max 0.03%, loss of ignition 0.5%) nano powder and commercially available Polypropylene is used. The Zirconia particles are subjected to Scanning Electron Microscopy (SEM) for surface and structural property analysis. It has been observed that its value is < 45 nm in size.

2.2. Preparation of samples for testing purpose:

2.2.1. Twin screw Extrusion: The compounded samples of Polypropylene material and the Zirconia nano powders under different weight percentages i.e. 3 Wt% and 4 Wt% are extruded by the twin screw extruder machine. The basic view of a twin scerw extruder machine is depicted in the Figure 1.

The Polypropylene and the Zirconia are dropped into the hopper and the heater which is shown in the Figure 1 is used to heat the materials and under molten state the Zirconia and polypropylene is mixed by the twin screws, each of them rotate in anti-parallel direction and the extruded material is ejected through the die.

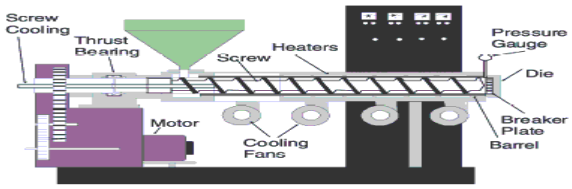

Figure.1.Typical Twin Screw Extruder

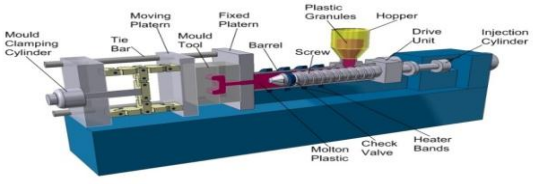

Figure.2.Typical injection moulding machine

2.2.2. Injection Moulding: The extruded compounds and the virgin Polypropylene materials are shaped into a 50 mm diameter and 3 mm thickness disc through an injection moulding machine for testing purpose. The extruded plastic granule compound is dropped into the hopper and the temperature for processing here is 200ºC which is maintained by the heaters, pressure is created by the screw and the molten compound is injected into the die of 50 mm diameter and 3 mm thickness disc at a pressure of 150 Kg/cm2.

2.3.Testing:

2.3.1. Measurement of Dielectric Constant and Dissipation Factor: This test is carried to find out the dielectric

constant and dissipation factor of the prepared sample. This test is performed according to the standard (ASTMD 150). At room temperature and 50 Hz frequency the test is performed using HP 4284A Precision LCR meter and the Capacitance and Dissipation Values are noted. Tested are conducted for Virgin Polypropylene and the three compounded samples, the electrode used for testing has the diameter of 0.038m. The Electrical Conductivity, Dielectric constant values are calculated from formulas.

2.3.2. AC Breakdown test: The Figures 3a and 3b show the testing arrangement for the determination of the breakdown field strength of foils as per standard IEC 60243–1. The breakdown test is conducted as per test procedure. The electrode setup is immersed in high dielectric liquid medium and the break down test is carried out.

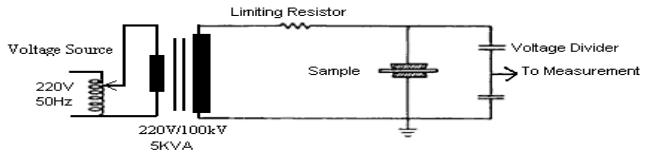

Figure.3a.Experimental Setup for the measurement of AC Breakdown Voltage

Figure.3b.Electrode Setup for the measurement of AC Breakdown Voltage

3. RESULTS AND DISCUSSION

3.1. Measurement of Dielectric Constant and Dissipation Factor: In order to ascertain the energy storage capacity and dielectric loss factor of the sample prepared the dielectric test is conducted. The result obtained using HP 4284A precision LCR meter as per ASTM D 150 standards gives Capacitance (C) and Dissipation Factor values further Dielectric constant (ε) and Electrical Conductivity (σ) values are calculated through formulas.

3.2. AC Breakdown Test: In order to know the dielectric strength of the samples prepared the AC power frequency breakdown test is conducted. The dielectric strength of the nanocomposite at different wt% of Zirconia nanofiller has been measured as per (IEC standard 60243-1) and listed in (Table III). It has been observed the 3 Wt % of ZrO2 added sample is having more AC Breakdown strength but further increase in the wt% increases in-homogeneity and hence reduces the dielectric strength. The inhomogeneity represent the non- uniform size and filling of nano fillers. The breakdown strength increases with addition of Zirconia nano fillers with base polypropylene.

Table.1.Results of dielectric constant

Sample(%wt)	Dielectric Constant (ε)	Increase in percentage
Pure	2.17	-
3	2.59	16.21 %
4	2.33	2.69 %

Table.2.Results of dissipation factor and electrical conductivity

Sample (%wt)	Dielectric loss X 10^{-3}	Electrical Conductivity(σ) in S m^{-1}
Pure	0.1325915	$8.00322*10^{-10}$
3	0.100708	$7.255275*10^{-10}$
4	0.108465	$6.725074*10^{-10}$

Table.3.Results of ac breakdown strength

Sample(%wt)	Breakdown Voltage in Kv/mm	Increase in percentage
Pure	19.48	-
3	26.37	26.12 %
4	23.02	15.37 %

4. CONCLUSION

It is concluded that AC breakdown voltage, the dielectric constant values increase by 26.12% and 16.21% respectively in the 3 Wt % of ZrO_2 and polypropylene compound with a negligible change in dissipation factor and electrical conductivity when compared with the pure sample.

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