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Electrical performance of epoxy resin filled with micro particles and nanoparticles

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Abstract

Composite insulators are widely used in the overhead transmission system. Compared with porcelain products, composite has many advantages such as light in weight, hydrophobicity characteristic and superior mechanical property. However, composite products are also suffering from issues such as low tracking resistance and early failures. The use of nano or micro fillers is considered to be one of the methods that can further improve the properties of the composite product. This study is aimed to study the electrical properties of nano and micro filled epoxy resin. SiO_2 and Al_2O_3 nano and micro fillers are used in this research for comparison purposes. The host matrix, which is epoxy resin, is filled with nano particles, micro particles or both nano and micro particles. Micro particles and nano particles are dispersed into epoxy resin using planetary centrifugal mixing technique and degassed in vacuum. In total, seven types of materials are prepared in this study. These materials are (1) neat epoxy, (2) nanocomposite filled with 1 wt% nano SiO_2 fillers, (3) micro-composite filled with 20 wt% micro SiO_2 fillers, (4) micro-nano composite filled with 1 wt% nano SiO_2 and 20 wt% micro SiO_2 fillers, (5) nanocomposite filled with 1 wt% nano Al_2O_3 fillers, (6) micro-composite filled with 20 wt% micro Al_2O_3 fillers, (7) micro-nano composite filled with 1 wt% nano Al_2O_3 and 20 wt% micro Al_2O_3 fillers. In this study, AC electrical breakdown strength test are performed using a sphere-to-sphere setup. The thickness of all the samples is 1 mm ± 0.1 mm in accordance to the IEC standard. Surface partial discharge measurement is also performed to evaluate the surface property.

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Keywords: Nanocomposite; Micro-composite; Electrical Breakdown; Surface Partial Disacharge; Epoxy Resin.

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1. Introduction

Nanocomposite is known to provide a better electrical property than micro-composite or conventional composite. Nanocomposite exhibits an enhancement in electrical breakdown strength, a reduction in partial discharge and a longer breakdown time [1-3]. Many inorganic fillers such as SiO_2, Al_2O_3, BN and TiO_2 have been studied in the last 10 years. These studies show that conventional polymer filled with nano particles shows a significant improvement in the dielectric properties. A common explanation to this phenomenon is that nano particles have a tremendously large surface area compared to micro particles [4-6]. The nano particles create a large interfacial area between the particles and polymer matrix. This interface is considered to be a major factor in determining the performance of nanocomposite. Recent research showed that the properties of epoxy resin could be largely improved by adding a very small amount of nano BN particles [7]. The results presented in [7] also indicate that nano particles are not only effective at enhancing the neat epoxy but also highly loaded micro-composite. In this study, epoxy resin based nanocomposite, micro-composite and micro-nano-composite are prepared using planetary centrifugal mixer. AC breakdown strength and surface partial discharge are measured to evaluate the performance of the specimens.

2. Specimens Preparation and Experimental Method

2.1. Specimens preparation

Nanocomposite specimens used in this study are prepared in the polymer laboratory at RMIT University. Araldite CW177 with Hardener Aradur HY2954 are used to prepare the host polymer and SiO_2 nanoparticles are from Evonik Degussa. The nano-material is a hydrophilic fumed silica with a specific surface area of 300 m^2/g and the average primary particle size is between 7 nm to 30 nm. Al_2O_3 nanoparticles are purchased from US Research Nanomaterial, the average particle size is 80 nm. Nano particles are dispersed into epoxy resin via in-situ polymerization method. Planetary centrifugal mixing technique is used to achieve a uniform dispersion. The epoxy resin is degassed at 0.1 Torr in order to remove the air bubbles caused by the mixing and dispersion process. Specimens are then post cured at 100 degree Celsius in a 1 mm thick mould for 14 hours.

To fulfill the IEC requirement of electrical breakdown test, specimens are cut into squares of 20 mm × 20 mm × 1mm in dimension. The thickness of the specimens in this study varies from 0.9 mm to 1 mm. The percentage loading of both SiO_2 and Al_2O_3 nanocomposite specimens are 1 wt% (referred as NC_S and NC_A respectively) and the percentage loading of both SiO_2 and Al_2O_3 micro-composite specimens are 20 wt% (referred as MC_S and MC_A respectively). Both of the SiO_2 and Al_2O_3 nano-micro-composite specimens are filled with 20% micro sized fillers and 1% nano sized fillers (referred as NMC_S and NMC_A). Neat epoxy specimens are also prepared for comparison (referred as Neat). All the samples used in this study are listed in Table.1 .

Table 1. Matrix of Samples Types.

Samples Nomenclature	Percentage Loading	Fillers Type	Particle Size
Neat	N/A	N/A	N/A
NC_S	1 wt% nano fillers	Silica	7 - 30 nm
NC_A	1 wt% nano fillers	Alumina	80 nm
MC_S	20 wt% micro fillers	Silica	1 μm
MC_A	20 wt% micro fillers	Alumina	1 μm
NMC_S	1 wt% nano fillers and 20 wt% micro fillers	Silica	7 - 30 nm and 1 μm
NMC_A	1 wt% nano fillers and 20 wt% micro fillers	Alumina	80 nm and 1 μm