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Study of mechanical and thermal performances of epoxy resin filled with micro particles and nanoparticles

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Abstract

Composite insulators which are widely used in outdoor insulating systems are considered to have superior mechanical properties than conventional porcelain insulators. The hydrophobic surface of composite inhibits the water on the surface to form a water filament which may create a continuous conductive path. The lower weight of the insulators also lowers the installation and maintenance cost. Superior mechanical strength allows the insulator to support heavy conductors in transmission system. The use of additives is a very common method to enhance the properties of composite. In this study, epoxy resin is used as basic polymer matrix and SiO_2 and Al_2O_3 particles are used as additives to improve the mechanical and thermal performances of epoxy resin. The samples are prepared by planetary centrifugal mixing technique and degassed in vacuum to remove air bubbles before molding. The nanocomposite samples are prepared with 1 wt% loading of either SiO_2 fillers or Al_2O_3 fillers. The micro-composite samples are prepared with 20 wt% loading of either SiO_2 fillers or Al_2O_3 fillers. Nano-micro composite samples (either use SiO_2 or Al_2O_3 fillers) are prepared by dispersing 1 wt% nano fillers and 20 wt% micro fillers in the epoxy resin. Dynamic Mechanical Analysis (DMA) is performed on Perkin-Elmer DMA7e instrument using the tensile mode. Thermal gravimetric analysis (TGA) is also used to evaluate thermal stability property of the samples. The results show that both nano and micro composites have a superior mechanical property. The glass transition temperature of nanocomposite has improved compared with the neat epoxy. Our results show that Al_2O_3 filled nano-micro composite samples have better mechanical and thermal properties than SiO_2 filled samples.

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Keywords: Nanocomposite; Micro-composite; DMA; TGA; Epoxy Resin.

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1. Introduction

Nanocomposite as a new composite material has attracted many interests from research institutes and industry in the last decade due to the potential enhancement to the mechanical and thermal properties of composites [1-3]. It has been widely reported that the addition of nano-sized or micro-sized fillers into polymer matrix can significantly improve the mechanical property and thermal property of dielectrics [4-5]. Properties of the nanocomposite commonly depend on several factors such as the size of the fillers, the percentage loading and the dispersion of the particles [6-7]. Epoxy resin is widely used in electronic devices and insulating system in power system applications. The use of micro-sized particles as additives when manufacturing epoxy resin is already a common practice in industry. By adding nano-sized particles into micro filler reinforced epoxy resin, the properties of the material could be further improved. In this study, both nano-sized particles and micro-sized particles are used to enhance the properties of the epoxy resin. Planetary centrifugal mixing method is used to disperse the nano and micro particles. Two types of fillers, which are SiO_2 and Al_2O_3 are studied. Thermal gravimetric analysis (TGA) and dynamic mechanical analysis (DMA) are carried out 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. Epoxy resin is used as the polymer host matrix and the two-part epoxy are Araldite CW177 and Hardener Aradur HY2954. Nano SiO_2 particles are sourced from Evonik Degussa (Aerosil 300). The nano-material is hydrophilic fumed silica with a specific surface area of $300m^2/g$ and the average primary particle size is between 7 nm to 30 nm. Al_2O_3 particles are purchased from US Research Nanomaterial with an average particle size of 80 nm. Nano particles are dispersed in 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 dispersion process. Specimens are post cured at 100 degree Celsius in a 1mm thick mold. The sample preparation procedure is shown in Fig.1.

The thickness of the specimen is 0.95mm ± 0.05 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.

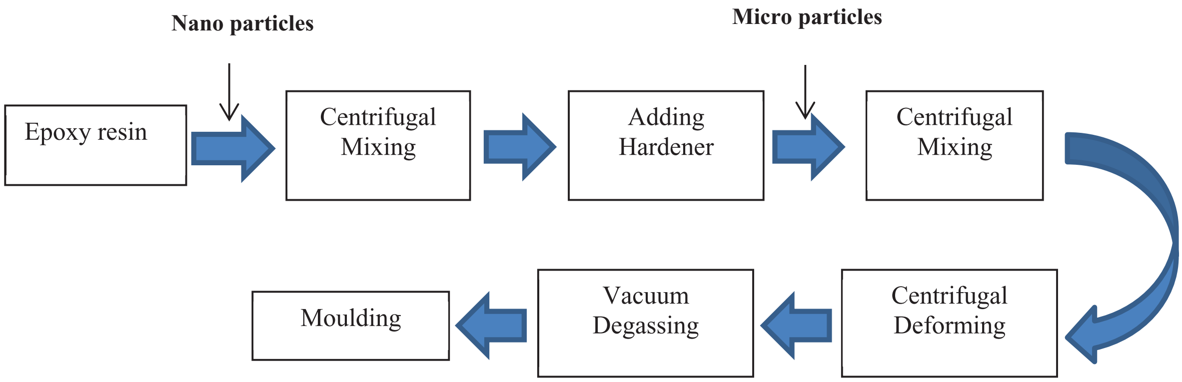

Fig. 1. Diagram of sample preparation procedure