EFFECTS OF FILLER ORIENTATIONS ON ELECTRIC FIELD OF NANODIELECTRICS

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EFFECTS OF FILLER ORIENTATIONS ON ELECTRIC FIELD OF NANODIELECTRICS

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DEDICATION

This project report is dedicated to my supervisor and my family who encouraged and helps me throughout my journey of education.

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ABSTRACT

Composite containing fillers with at least one dimension less than 100 nm and typically less than 30 nm are called nanodielectrics, which have potential to improve the electrical performance. Micro size fillers introduction normally reduces the breakdown strength of the composites and this is due to the orientations of the fillers, which leads to reduced breakdown strength of the material. Compared to conventional composites, nanocomposites have smaller fillers which help to improve the breakdown strength. Nanoparticles can disrupt the continuity of the path provided to the charge carriers and decrease the possibility of overlapping of the local conductive regions and it is leading to an improvement in the breakdown strength. In particular, this shows that nanofiller alignment can improve the electric field breakdown strength and recoverable energy density. At the same time, filler alignment can reduce the leakage current, in these dielectric nanostructured composites. The presence of these fillers can improve the dielectric properties and electrical conductivity. This research analyses the performance of nanoclay filler in nanodielectrics through simulation using Finite Element Method Magnetics (FEMM). This is to further understand the relationship between nanodielectric and the nanoclay platelets. The analysis shows that the filler shape and orientations will result in increased electric field intensity. This is to define the effects of filler on the electric field of nanodielectrics.

ABSTRAK

Komposit yang mengandungi pengisi dengan sekurang-kurangnya satu dimensi kurang daripada 100 nm dan biasanya kurang daripada 30 nm dipanggil nanodielektrik dan berpotensi untuk meningkatkan prestasi kekuatan elektrik. Pengenalan pengisi saiz mikro biasanya mengurangkan kekuatan pecah tebat komposit dan ini disebabkan oleh orientasi pengisi, yang membawa kepada pengurangan kekuatan pecah tebat bahan. Berbanding dengan komposit konvensional, nanokomposit mempunyai pengisi yang lebih kecil dan ia meningkatkan kekuatan pecah tebat. Pengisi nano boleh mengganggu kesinambungan laluan yang disediakan kepada pembawa cas dan mengurangkan kemungkinan pertindihan kawasan konduktif tempatan dan ia membawa kepada peningkatan dalam kekuatan pecah tebat. Khususnya, ini menunjukkan bahawa penjajaran nanofiller boleh meningkatkan kekuatan pecah tebat elektrik dan ketumpatan tenaga boleh pulih. Pada masa yang sama, penjajaran pengisi boleh mengurangkan arus kebocoran, dalam komposit berstruktur nano dielektrik ini. Kehadiran pengisi ini boleh meningkatkan sifat dielektrik dan kekonduksian elektrik. Penyelidikan ini menganalisis prestasi pengisi tanah liat nano dalam nanodielektrik melalui simulasi dengan menggunakan Kaedah Elemen Terhingga Magnetik (FEMM). Ini untuk memahami lebih lanjut hubungan antara nanodielektrik dan pengisi tanah liat nano. Analisis menunjukkan bahawa bentuk pengisi dan orientasi akan menghasilkan peningkatan intensiti medan elektrik. Ini adalah untuk menentukan kesan pengisi pada medan elektrik nanodielektrik.

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LIST OF ABBREVIATIONS

FEMM	-	Finite Element Method Magnetics
2D	-	Two Dimension
GNP	-	Graphene Nanoplatelets
COMSOL	-	Cross Platform Finite Element
MATLAB	-	Matrix Laboratory
UTM	-	Universiti Teknologi Malaysia

LIST OF SYMBOLS

nm	-	Nano meter
μm	-	Micro meter
Cu	-	Copper
ZnO	-	Zinc Oxide
kV	-	Kilo Volt
Vdc	-	Direct Voltage
m	-	Meter
mm	-	Mili Meter

CHAPTER 1

INTRODUCTION

1.1 Background

Nanodielectrics are composed of multicomponent dielectrics that have nanostructures, which cause the change of some of their dielectric properties. [1]. These studies have rapidly developed since the landmark 1994 publication of Lewis [2]. Recently, the advances in characterization and preparation techniques for nanocomposites have played a significant role in making nanodielectrics more widely available especially in the field of electrical insulation. Developing a nanometric-sized filler particle will result in a dramatic increase in the interface zone generated by two dissimilar materials of nanoparticles and polymer matrix. Various studies have demonstrated that the presence of the interface influences the macroscopic behaviour of composites [3]. By modifying the microstructure and filler distribution in the polymer matrix, nanotechnology enables to modifying the dielectric properties of composites. It is thought that nanodielectrics could be applied to many different dielectric properties, including partial discharge, space charge, high energy density storage and high thermal conductivity [4-8].

Nanodielectrics have immense potential to improve the performance of applications ranging from high-voltage electrical transmission components to small-scale electronics to sensors and more. They are part of the larger field of composites consisting of a matrix or polymer and a filler. Fillers are added in a polymer to enhance its electrical and mechanical characteristics. However the addition of microfillers to the polymer matrix results in improved thermal and mechanical properties with a little degradation in electrical breakdown strength. [9]. Meanwhile the addition of nanofillers into polymer results in the improvement of both electrical and mechanical properties at the same time [10–12]. Nanocomposite dielectric is a composite having nanofillers with dimensions of less than 100 nm and typically less than 30 nm [13].

There has been an increasing interest in the use of nano-sized and type of nano filler as additives to polymers because of its superior performance in dielectric strength. It is known that an electric field in nanocomposites may be affected by the amount of the nanoparticles. It is well known that nanocomposites with smaller and oriented filler have better dielectric strength [14]. However, few manufacturers can disperse nanoparticles with small diameter. Furthermore, nanocomposites filled with smaller sized fillers may show worse characteristics in aspects other than electrical properties, such as viscosity and thermal shrinkage. Therefore, there is a need for nanocomposites with reasonable amount of well dispersed nano-particles.

1.2 Problem Statement

Composites containing fillers with at least one dimension less than 100 nm and typically less than 30 nm are called nanodielectrics. The material has potential to improve the electric field performance. Micro size fillers introduction normally reduce the breakdown strength of the composites and this is due to the orientations of the fillers, which leads to reduce breakdown strength of the material. Compared to conventional composites, nanocomposites have smaller fillers and it improves the breakdown strength. Nanoparticles can disrupt the continuity of the path provided to the charge carriers and decrease the possibility of overlapping of the local conductive regions and it is leading to an improvement in the breakdown strength. To date, many researches were done to study on the effect of nanofillers nature, size and concentration. However, very little is reported on the effect of fillers shape and their orientations on the electric field of nanodielectrics.

1.3 Objectives

Following are the objectives of this research:

i. To investigate the electric field relationship between nanodielectric and the nanoclays platelets.
ii. To characterize the effect of various fillers and orientation in electric field intensity.
iii. To analyze effects of nanoparticle permittivity and the orientations on electric field in nanodielectrics.

1.4 Research Scope

This research studies the effects of filler orientations on electric field based on nanodielectric model. The orientations of nanoclays were analysed and the relationship between electric field of nanodielectrics was investigated. The simulation using Finite Element Method Magnetics (FEMM) was carried out.

1.5 Expected Contributions

This research contributes the following matters:

i. This research analyzes nanofiller orientation to estimate the electric field under nanodielectrics.
ii. This research leads to understanding on the effect of filler orientations and shape in electric field of nanodielectrics.

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