Multiphysics Simulation of Internal Discharge in Nanodielectrics

Farzana Alam[1], Md. Afzalur Rab[2]
[1]UnitedHealth Group, Indianapolis, MN, USA
[2]Center for Materials Research, Norfolk State University, Norfolk, VA 23504

Abstract

This research work investigates the effect of inclusion of small amount (0%, 1% and 4%) of natural Nano fillers on the internal field properties and discharge characteristics of polypropylene films.2D and 3D Models are built to simulate field properties and internal charge in natural nanofillled dielectric and insulation. Internal discharge causes gradual deterioration of a dielectric material and may cause failure of the sample. So, modeling and simulation of internal field distortion in Nanodielectrics is of great interest . Numerical computation and evaluation were done on properties.

Indexing Terms: **Nanoparticle, dielectric, electric field, permittivity**

1. INTRODUCTION

Polypropylene is a commonly used material in power industry due its superior dielectric properties [1]. When polypropylene is used in power apparatus, under HV, the insulation goes through a number of issues such as internal materials degradation, internal discharges, insulation breakdown etc[2]. Discharge creates space charges that can distort internal field, and lead to degradation inside the insulating materials. Nanoparticle can solve these issues if controlled amount of nanoparticle is used[3].

To find a solution to improve dielectric properties such as decrease in space charge of Nanocomposites by building 3D model and simulate. Investigate change in internal electric field due to incorporation of Nanofiller is another objective. Then use obtained simulation results to explain real experimental results achieved from application of high voltage [4] to dielectric insulation.

2. SET UP OF SIMULATION MODEL

Isotactic Polypropylene film with organic natural Nanoparticles was used in multiphysics simulation. The thicknesses of the nanofilled micro film were 135µm. The diameter of Nanoparticles was less than 100nm. Two plane-plane copper electrodes were used to apply high voltage and ground respectively.

Figure 1 shows the built 3D model for simulation. A Plane-Plane electrode system was used to apply electrical stress to the samples. Circular samples of diameter 10cm were perfectly attached between two electrodes. The boundary conditions are top electrode, =10kV, ground electrode, V=0V.

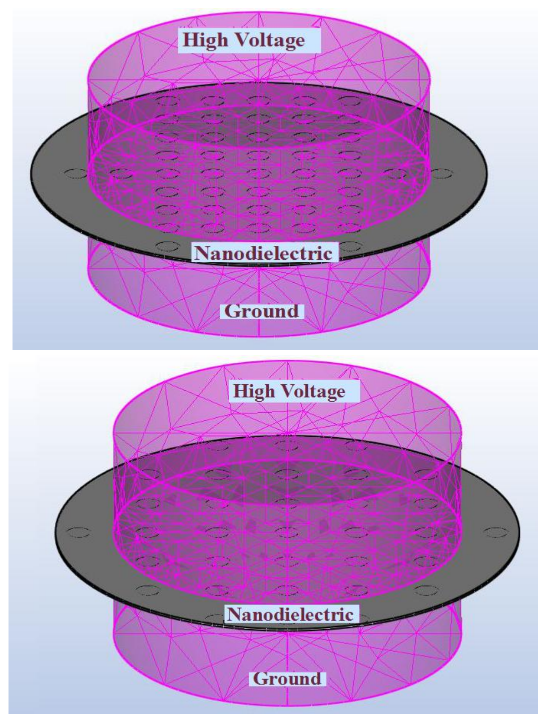

Figure 1: Meshing in Nanofillled polypropylene under HV with (a) 4% Nanoparticle and (b) 1% Nanoparticle

The second set up with a 2D plane-plane electrode system having same thin polypropylene film filled with Nanoparticles has been used. Here the thin sample is the films incorporating Nanoparticles.

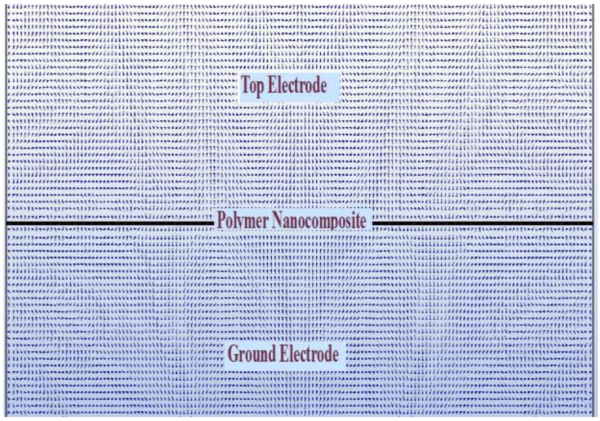

Figure 2(a). Field Arrow in 2D Model of Nanodielectrics in plane-plane electrode system

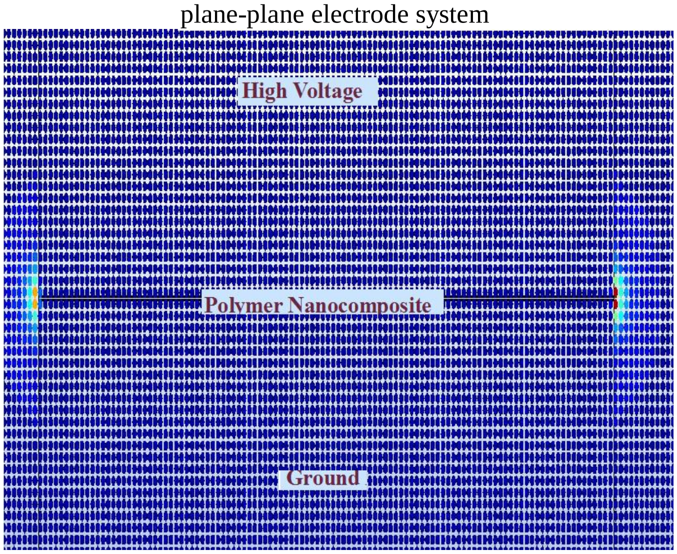

Figure 2(b). E-Field Scatter in nanoparticle filled (4%) sample

SIMULATION, RESULT AND ANALYSIS

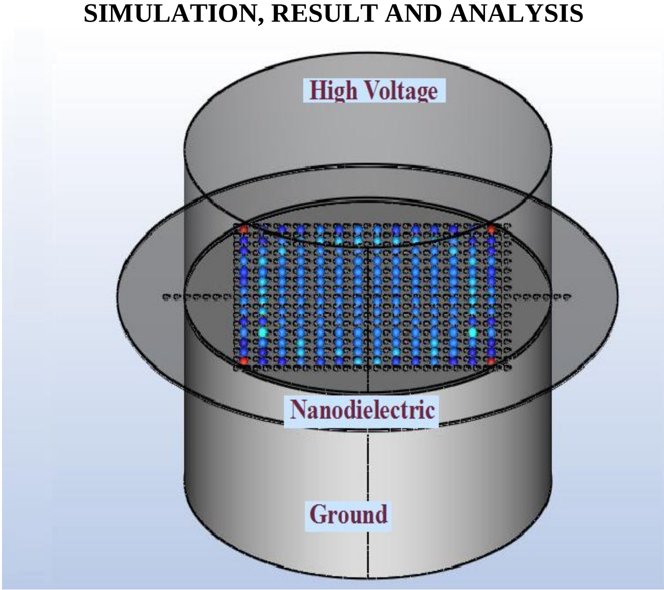

Figure 3(a). Electric Field Scatter in (a) 4% nanofillled sample

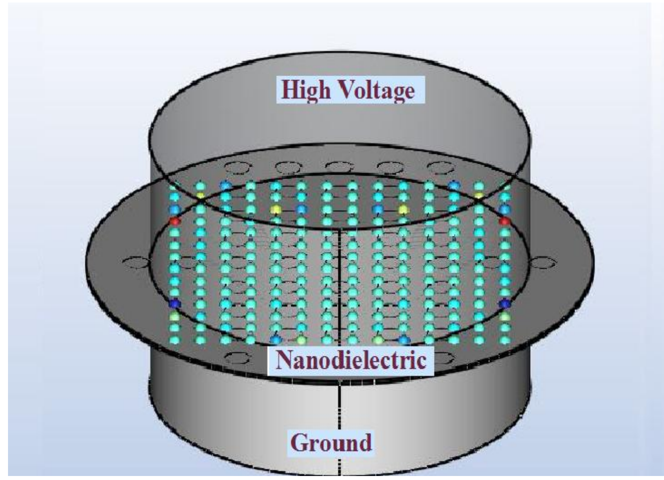

Figure 3(b). Electric Field Density under Applied Voltage

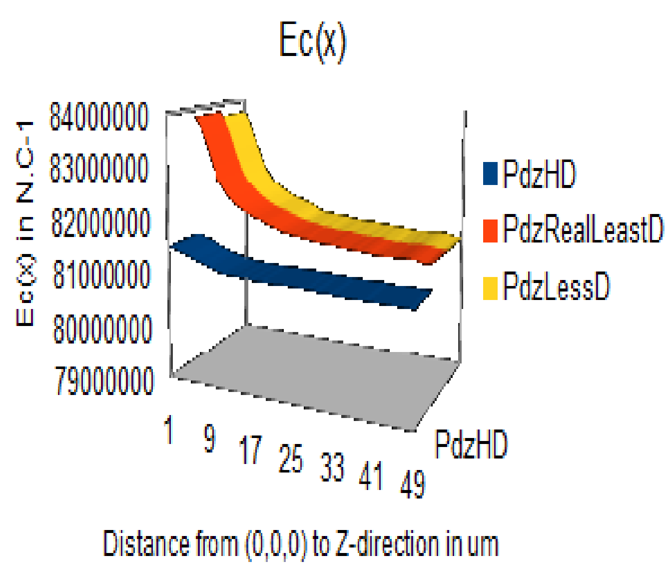

Figure 4(a). Electric Field with the presence of space charge under the Applied Voltage

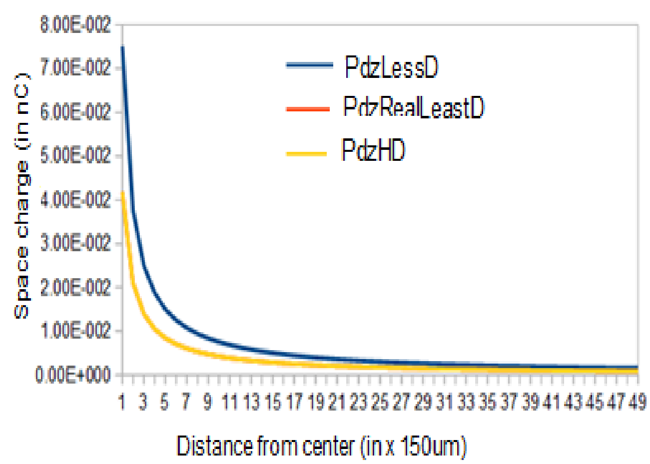

Figure 4(b). Space charge under the Applied Voltage

In figure 2(b) field scatter is exhibited in edges of sample only.

In figure 3, blue color indicates less scatter in electric field and green color indicates high scatter in electric field.

In figure 4(a), internal field becomes lowest for 4% nanoparticle concentration and higher for least or 0% concentration

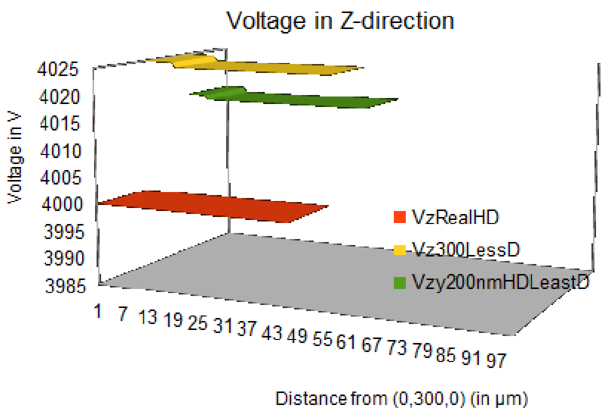

Figure 5(a). Voltage from (0, 0,300nm) to Z-directions in samples in presence of space charge

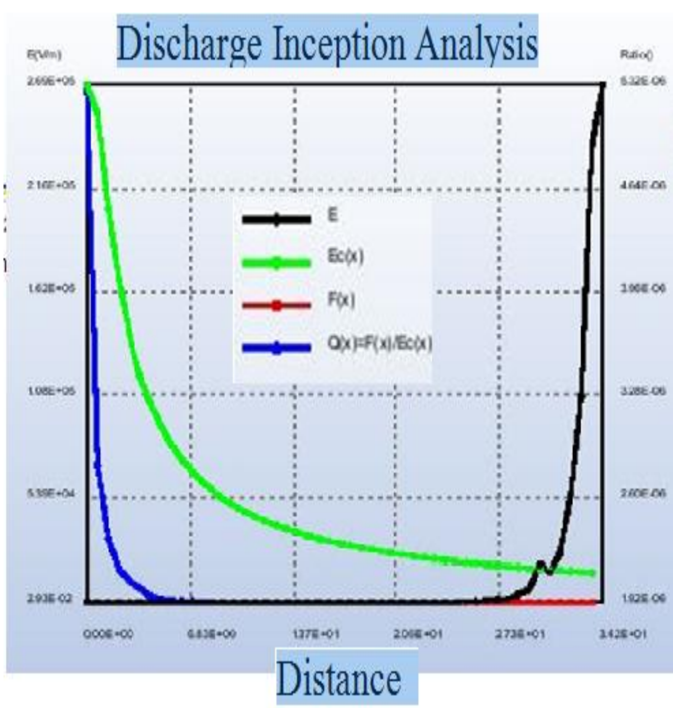

Figure 5(b): Discharge inception, Electric field and Force relationship

HV was applied from top plane electrode to the nanofillled micrometer thick sample and variation in output voltage within the sample for different concentration of nanoparticle has been investigated. Results indicate that for 4% concentration the internal voltage becomes lower. Higher concentration can sustain higher electrical stress [5][6].

Internal discharge inception analysis shows relationship among space charge, internal field and electrostatic force. From sample center to the edges in Z direction, both Q(x) and Ec(x) decreases with increases in distance. The relationship is observed at a certain applied voltage which is greater than 4kV [7][8]. Below that voltage, no discharges occur[9][10]. This is why; it is kwon as inception analysis.

THEORETICAL ANALYSIS OF ELECTRIC FIELD DISTORTION

In unfilled nanofillled samples, space charges occur under high electrical stress. These space charges tend to distort main applied field and enhance it which is not expected. In order to reduce the local field enhancement it is required to find a mechanism to reduce space charges. Nanoparticle introduces a mechanism by introducing traps in nanofillled dielectric [11][12].

Trap is a location that restricts movement of carriers- electrons or holes. Trap consists of either a chemical impurities or an imperfection of regular spacing of atoms that make up solid. In our unfilled polypropylene samples, traps are generated by physical or chemical defects[5][6]. In nanofillled samples, Interface zone between nanoparticle and polymer generates a new potential barrier. This interacts with original trap sites in polymer, results to an increase in deep traps in nanocomposites. Both trap density and energy of trap increase with controlled increase in nanofiller.

These deep traps distribute from internal layer to outside layer of nanoparticle-polymer interface zone. In this way, nanoparticle acts as nucleating agents to alter the morphology of polymer and increase in deep traps[2][3]. Since, traps restrict carrier movement, increased deep traps leads to a reduced conduction in nanofillled insulation. Such it decrease charge mobility, suppress space charge accumulation, decrease the mean free path that the electrons accelerate [7][8].

Since, space charges are reduced by traps, local electric field distortion is reduced significantly and in some case vanish it. This enhances the potential resistivity of the material against partial discharge attack. Also, it is one of the reasons why breakdown strength increased in nanofillled samples.

CONCLUSIONS

Summarily, both 2D and 3D models were developed to investigate local electric field reduction in nanoparticle field dielectric polypropylene insulation. The motive was to explain experimental results that showed that space charges were reduced in nanofillled sample. Since space charges distort local field, it is expected that nanoparticle can reduce local electric field also. So, we did some simulation in COMSOL by building models of nanocomposites and applied high electrical stress to these nanofillled samples. Our result indicated that nanoparticle reduced local field when a controlled amount of nanoparticle was introduced.

- 2D and 3D models of Nanodielectrics for internal discharge simulation are built
- Boundary conditions were applied at top cylindrical electrode=any HV, ground=0V.
- Various electrical properties such as voltage contour, electric field density, voltage scatter, electric field contour have been simulated.
- Simulated results are shown.
- Analysis has been performed.

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