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# LDPE Partial Discharge Properties with Plasma-Treated Boron Nitride

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***Abstract***: *This paper investigates the partial discharge (PD) characteristics of the low-density polyethylene (LDPE) composite materials with plasma treated boron nitride (BN) nanoparticles. With BN, surface derivatization of BN through plasma treatment in the LDPE matrix makes nanoparticles disperse more efficiently and inter-nano compatibility. Improved interfacial bonding due to higher trapping properties and reduced charge mobility suppresses activity of PDs to a large extent. In comparison with untreated BN composites, experimental studies show great enhancement in dielectric characteristics such as PD inception voltage and discharge value. These findings indicate that plasma-treated BN can be promising to serve as a nanofiller in the insulation of polymer high-voltage designs to improve its reliability.*

***Keywords***: *Low density polyethylene, CIGRE technique, atmospheric pressure plasma, boron nitride, and partial discharge*



## I. Introduction

Low-density polyethylene (LDPE} is often used as an insulating material in high-voltage uses due to its excellent electrical, mechanical and thermal properties. With longer spans of electrical stress, there is the possibility that LDPE may experience partial discharge (PD) which is a localized dielectric breakdown that over time worsens the behavior of insulation and can cause premature failure. The incorporation of nanofillers has emerged as a feasible option on enhancing the resistance of LDPE to PD. The boron nitride (BN) nanoparticle is outstanding among the others since, owing to its high electrical insulation, stability, and thermal conductivity. But there exists a challenge of getting a high degree of interfacial bonding as well as good dispersion within the polymer matrix [1-3]. Surface modification technique in the present approach that involves use of plasma treated BN is effective as there is increased dispersion and it provides better interface quality, a factor that is brought about by increased compatibility with the polymer.

This study aims at clarifying how plasma-treated BN influences the PD behavior of LDPE nanocomposites in order to evaluate the improvements in dielectric strength and discharge resistance that may be applied in high-voltage insulation [4].

## II. Surface Modification Using Plasma

Prime requisite is the Boron nitride (BN) nanoparticle surface modification by subjecting the isolated nanoparticle suspension to plasma/vacuum treatment to enhance partial discharge (PD) intensity of the low-density polyethylene (LDPE) nanocomposites. Plasma treatment increases the surface energy and surface reactivity of particles, specifically by reacting function groups (e.g. hydroxyl, carboxyl or amine groups) to the surface of BN particles [4]. This change mitigates the agglomeration of nanoparticles, the key problem in the assembly of polymer nanocomposite, which significantly increases the dispersion and compatibility of BN within the matrix of LDPE. The more even electric field distribution and higher amount of deep trap sites at polymer-filler interface are the consequences of the better dispersion. These trap sites neutralize the charge carriers, which inhibits their flows and eliminates the formation and propagation of partial discharges.

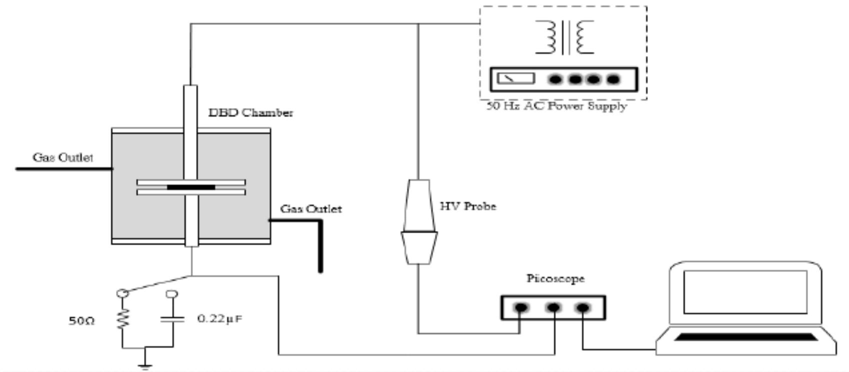


Fig 1: Atmospheric Plasma Reactor

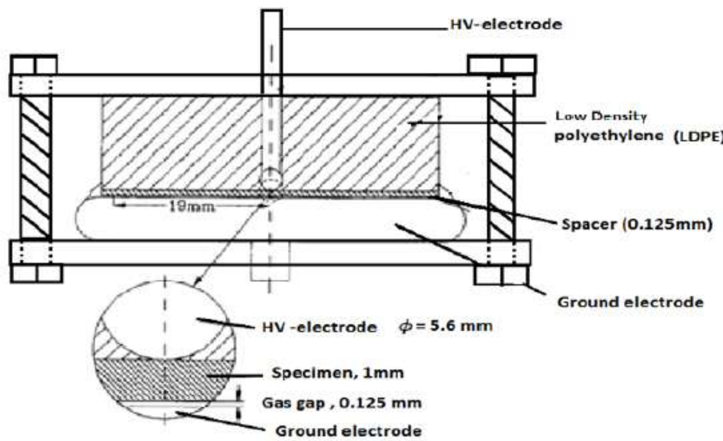


Fig 2: Electrode method configuration CIGRE

Moreover, during electrical load, stronger interfacial connection between plasma-treated BN and LDPE detains charge build-up and delays breakdown. Moreover, to its being environmentally benign, the plasma treatment process does not require the use of chemical solvents and it allows fine grained control of surface chemistry [2-3]. As a result, the LDPE nanocomposites with plasma-treated BN have a longer insulating life span, lower discharge level and higher PD inception voltage. This approach provides an effective direction towards overcoming the deficiency of polymer insulation material in high-voltage electro-related usage.

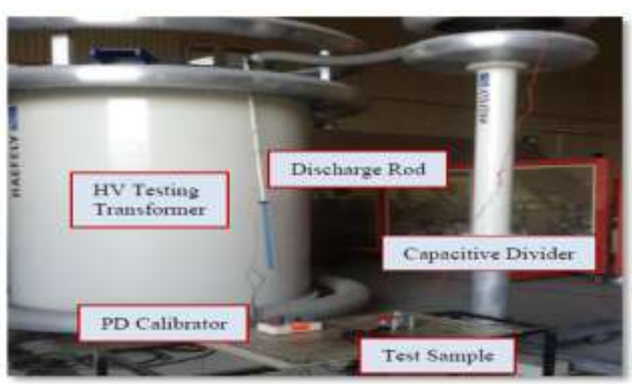


Fig 3: PD measuring system

## III. Results and Discussions

Compared with the untreated-BN LDPE and the pure LDPE, the research proved that LDPE nanocomposites with plasma-treated BN nanoparticles considerably enhanced their performance in terms of partial discharge (PD). Noticeable results of the experimental study. The LDPE composites with plasma-treated BN had a remarkable high PDIV. This implies that high dielectric strength, requires a high voltage in order to initiate discharge activity. Plasma treatment helped in minimizing fields intensification points which are normally caused by insufficient particles distribution by intensifying the interfacial interaction between BN and LDPE. The magnitude of the partial discharges presents in BN composite treated with plasma was much lower [1].

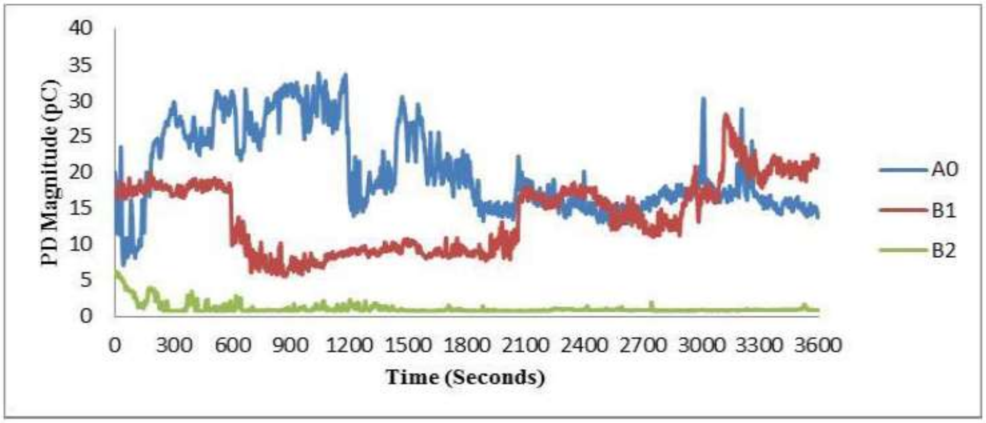


Fig 4: PD magnitude pattern

This it is attributed by the more uniform BN which generates a smoother internal field gradients and less sites of local breakdown and charge pile ups. Plasma treatment is used to add polar groups onto the BN surfaces and this enhances charge trapping at the-polymer-filler interface. The immobilization of the free electrons, decrease of the charge mobility and postponement of space charge accumulation are the reasons of lower PD activity that the traps introduce. The better dispersion of BN nanoparticle in the LDPE matrix due to the mechanochemical treatment attributed to plasma treatment was confirmed by SEM and TEM analyses [5-6]. Well dispersed nanostructure promotes better distribution of the stress and prevents generation of localized electrical hot spots. In electrical ageing ages, BN composite treated by plasma wore more slowly. In the long run, the nanofillers ensured the continuity of the insulation by serving as cracks propagators.

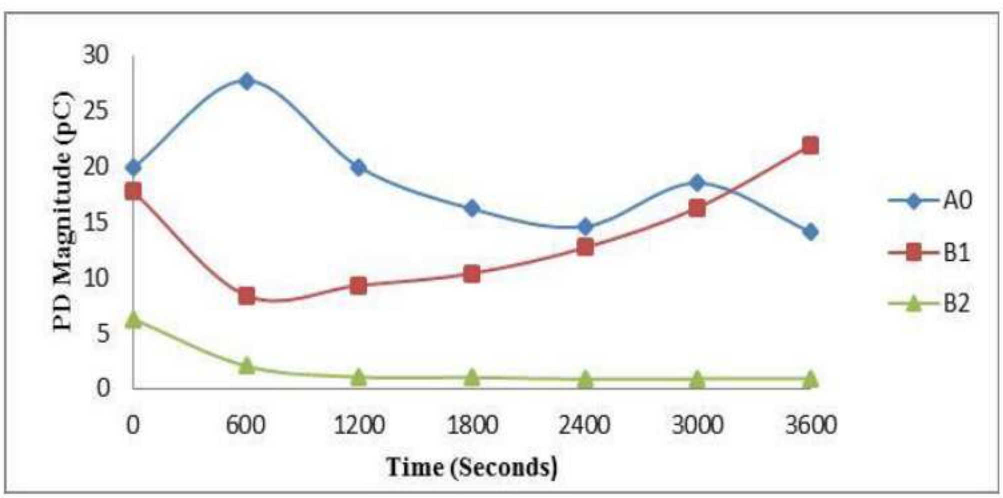


Fig 5: Average PD magnitude

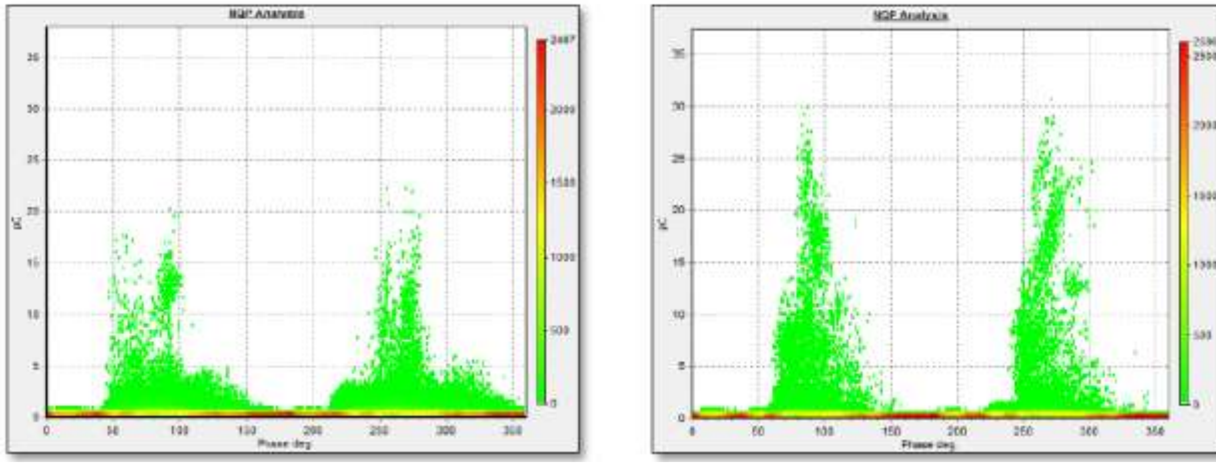

Fig 6: Ppattern of LDPE-BN and NQP nanocomposite

## IV. Conclusion

The results of the study showed that when plasma-treated boron nitride (BN) nanoparticles were introduced into low-density polyethylene (LDPE), they significantly enhanced the global dielectric behavior as well as partial discharge (PD) tolerance of the material. The effects of plasma treatment are the increased PD inception voltage, reduced discharge magnitude, and enhanced charge trapping in addition to enhanced BN dispersion and interfacial bonding in the polymer matrix. Two advantages of these upgrades are the greater insulating reliability and long-term stable behavior under high-voltage stress. Based on the findings, it is possible to note that plasma-treated composite BN LDPE are promising candidates in advanced electrical insulating sites because plasma surface treatment is an effective and sustainable process of insulation nanocomposites optimisation.

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