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# Nanotechnology for outdoor High voltage insulator: An experimental Investigation

**V.Dave[1,2], P.Dubey[2], H.O.Gupta[1], R.Chandra[2]**

[1]Department of Electrical Engineering, IIT Roorkee,India.
[2]Institute Instrumentation Centre, IIT Roorkee,India.

**Abstract:** Nanotechnology is an emerging technology in the scientific world. In this paper, an experimental investigation was being made to explore the use of nanotechnology for outdoor insulators. Hydrophobic coating of $HfO_2$ was deposited on ceramic insulators using DC magnetron sputtering in two inert gas environment namely argon and helium. Structural, Optical and hydrophobic properties of $HfO_2$ coatings were investigated by X ray diffractometer, UV-vis-NIR spectrophotometer and water contact angle meter respectively. The coating was found to be crystalline as well as hydrophobic. Also the coating deposited in argon atmosphere was found to be more uniform and hydrophobic ($102.1^0$) in comparison to helium ($95.5^0$). The band gap was calculated using optical data and found to be greater than 5 eV for both deposited coatings.
**Key words:** Nanotechnology, outdoor High voltage insulator, Experimental Investigation.

## I. Introduction

Nanotechnology is an emerging technology in the scientific field. Nano means having a dimension of $10^{-9}$ and technology associated with it is termed as nanotechnology[1]. While there are no universally accepted definitions, nanotechnology is generally understood to involve the manipulation of matter on a near-atomic scale to produce new structures, materials, systems, catalysts and devices that exhibit novel phenomena and properties. Nanotechnology is one of the fastest emerging fields in research. It is going to touch each corner of life eg medical, building construction, electronics etc. It offers the possibility of introducing technologies that are more efficient and environmental friendly[2,3]. In general when we say solid is in crystalline state, we mean it consist of several crystals with each crystal having atoms arranged in three dimensional patterns that repeats itself regularly. When these crystals are of nanometric size, then they are termed as nano crystals. Bulk materials obtained from the consolidation of nanocrystals are termed as nanomaterials. The average crystal size lies between 1 to 100nm. A great variety of nanocrystals are available like $Al_20_3$, $TiO_2$, $BaTiO_3$, $ZrO_2$, $SnO_2$ etc. These nanocrystals contain lesser atoms as compared to the conventional crystal. This in turn produces betterment in the property. Examples are super magnetism, ceramic super plastic, giant magneto resistance, the lotus effect[4].

Nanotechnology finds its application in electrical power engineering also. Though it sounds like a contradiction between nanotechnology and power engineering yet it is going to improve properties like electrical, mechanical, thermal and chemical of electric equipment. There are several prospects for applications in high voltage electrical engineering also. These are listed below[5].

(i) Improvement in transmission and distribution conductor to reduce losses.
(ii) Improvement in magnetic material (eg core in transformer) to reduce losses
(iii) Improvements in the properties of Insulators
(iv) Reduction in the size of equipments and components

The synthesis of nanomaterials is done through two approaches namely the bottom up approach and the top down approach. Out of the many techniques for synthesizing the nanomaterials or nanostructures, thin film technology is one of them. Thin films are fabricated by the deposition of individual atoms on a substrate. A thin film is defined as a low dimensional material created by condensing, one by one, atomic species of matter. Thin films are deposited on a substrate by various physical deposition methods which include chemical decomposition, thermal evaporation, sputtering etc. Each method has its own merits and demerits. Sputtering is widely used method for thin film coating because of many advantages associated with it. This includes uniform deposition, reproducibility and contamination free deposition[6]. Sputtering technique has been successfully applied for many electronic, optical and magnetic applications[7]. In this paper sputtering was used as a deposition technique.

## II Problems of High Voltage Insulators

In high voltage applications, the insulators used are either ceramic or non-ceramic (polymer).These insulators suffers from the problem of surface flashover due to contamination[8,9]. Various types of contamination like sand, dust, industrial pollution, salt etc get deposited on the surface of the insulators. During light rainfall or fog or mist, the deposited material becomes conducting and leakage current starts flowing through the surface of insulator. Thus dry bands are formed which ultimately results into surface breakdown. This in turn accelerates the aging of insulators. The interruption cause due to surface flashover results into great economic loss to the consumers as well as to the power company[10]. Various remedial measures have been suggested from time to time to rectify this problem. This includes cleaning, greasing and live washing. Another effective method to mitigate this problem is to put hydrophobic coating over the insulator surface. Silicone coating was done on the ceramic surface but long term stability could not achieved with this coating[11] .

Polymer insulation was put forward as a solution of this problem as they possess good hydrophobic properties because of low surface energy. The other advantages includes light weight which results in economic design, higher mechanical strength to weight ratio which enables longer spans of the towers and better withstand voltage. The known polymers used for insulation purposes are silicone rubber (SIR), ethylene-propylene-diene monomer (EPDM) and alloys of silicon-EPDM. However these polymers do not possess sufficient mechanical strength, they are subjected to chemical changes and suffer from erosion and tracking[12].

Hence for last one decade research was focussed on developing new insulating materials which exhibit most of the good properties of ceramic as well as non ceramic insulating materials. This research got acceleration with the emergence of nanotechnology as nanomaterial has better property in comparison to their bulk counterpart.

In this paper, we are investigating the structural, optical hydrophobic and electrical property of $HfO_2$ coating over ceramic insulator. The coating was deposited by DC magnetron sputtering.

## III Experiment

A sputter target of hafnium (2 inch diameter and 5 mm thick) was used for depositing hafnium oxide on ceramic (porcelain) and quartz substrates by reactive magnetron DC sputtering. Before deposition the substrates were cleaned in ultrasonic baths of acetone and then dried in nitrogen atmosphere. This is done in order to make the substrate contamination free. After drying, the substrate was mounted onto the substrate holder placed in the deposition chamber. The chamber was evacuated to about $10^{-6}$ Torr with a Turbo Molecular pump backed by a rotary pump. Thereafter the hafnium oxide was deposited on ceramic substrates using reactive gas oxygen in two different inert gas environments namely argon and helium. The flow rate of oxygen was kept 20sccm while that of inert gas argon or helium was kept 40 sccm. The target to substrate distance was kept 41mm.The deposition was carried at sputtering pressure of 15mtorr, the DC power was kept 50 W and the deposition time was 60 minutes.

The structural analysis of the deposited hafnium oxide film was done by Bruker D8 Grazing incidence X-ray diffractometer (XRD). The average crystallite size was calculated from the XRD pattern using well known scherrer formula[13].

$$d = \frac{0.9\lambda}{B\cos\theta_B} \qquad (1)$$

The morphology and the surface roughness was investigated using atomic force microscopy(NT-MDT Ntegra). The hydrophobicity was determined using contact angle meter (Kruss DSA 100 Easy drop). The optical study was carried out using UV-vis NIR spectrophotometer. The transmission and absorption spectrum of the coating was obtained through spectrophotometer. The bandgap of the coating was calculated using Tauc relation[14].

$$\alpha h\nu = B(h\nu - E_g)^r \qquad (2)$$

The bandgap was calculated to verify the dielectric property of $HfO_2$.

## IV Results and discussion

The XRD pattern of deposited hafnium oxide in argon as well as helium atmosphere is shown in figure 1.The XRD pattern in argon as well as in helium case exhibit a single peak at approximately $2\theta=28^o$ indicating the presence of a $HfO_2$ crystalline phase[15]. The XRD patterns clearly reveals that peak broadening is more in helium case in comparison to argon case which indicate that particle size is smaller in helium case.

The calculated crystallite size is shown in Table I. It was observed that films deposited in argon atmosphere has bigger particle size as compare to those deposited in He atmosphere ,thus confirming our visual observation as discussed earlier.

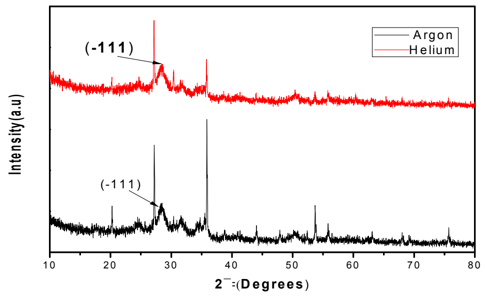


**Fig 1 XRD pattern of Hafnium oxide coating deposited in argon and helium atmosphere**

**Table I Parameters of hafnium oxide coating**

| Sputtering gas | Crystallite Size(nm) | Surface Roughness (nm) | Contact angle($^o$) |
|---|---|---|---|
| Argon | 42 | 4.02 | 102.1 |
| Helium | 31 | 3.34 | 95.5 |

The surface morphology was studied using 3D AFM micrographs as shown in figure 2.The AFM micrographs reveals that the particles grown in the argon atmosphere are more uniform in comparison to the helium atmosphere. The rms value of surface roughness is calculated using software attached with AFM. The surface roughness as shown in table I was found to be more in hafnium oxide deposited in argon atmosphere. The contact angle of coating deposited in argon as well in helium atmosphere was found be greater than $90^o$. Such surfaces are termed as hydrophobic else hydrophilic. The contact angle of deposited hafnium oxide surface in both argon as well as helium case is shown in Table I. The surface is found to be hydrophobic in both case. However coating deposited in argon environment is more hydrophobic in comparison to helium environment. The reason may be attributed to the surface roughness of the deposited coating. . The surface roughness plays an important role in determining the hydrophobicity of a coating. Wenzel through its equation justified that the surface roughness produces a physical enhancement of hydrophobicity[16].

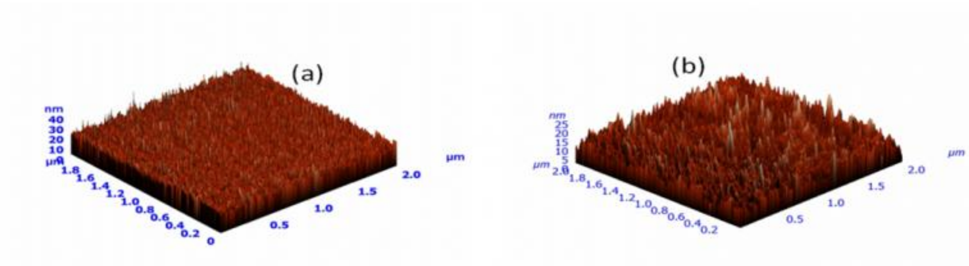


**Fig. 2 AFM micrographs deposited in (a) Argon atmosphere (b) Helium atmosphere.**

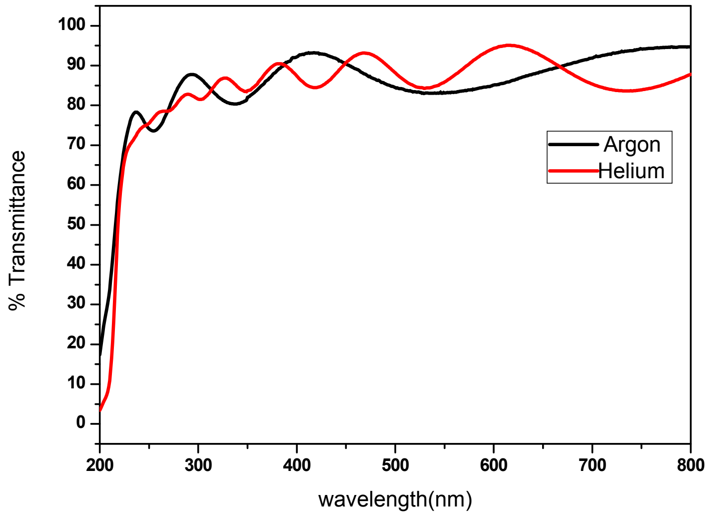


**Fig 3 Transmittance curve of hafnium deposited in argon and helium atmosphere**

The transmittance spectra of hafnium oxide coating in argon as well as helium spectrum are shown in figure 3. It is clear that average transmission in coating deposited in helium atmosphere is more in comparison to those of argon atmosphere. From the viewpoint of surface roughness, hydrophobicity and transparency have inverse relationship. Surface roughness introduces sources of light scattering. When the roughness increases, the hydrophobicity also increases, whereas the transparency decreases.

Where hν is the energy of the incident photons and Eg is the value of the optical band gap corresponding to transitions indicated by the value r which is characteristic of the type of the optical transition process and was taken 2 for $HfO_2$ coating. The bandgap of $HfO_2$ was found to be 5.05 eV in argon case and 5.21 eV in helium case[17]. Higher band gap of the coating ensures dielectric property of the films.

## V Conclusion

Thus hydrophobic $HfO_2$ coating was successfully deposited on ceramic insulator in both argon as well as helium atmosphere. However $HfO_2$ coating in argon atmosphere is found to be more hydrophobic in comparison to helium atmosphere. The AFM images confers the uniform deposition of coating. The optical analysis also confers the dielectric nature of the coating and band gap value closely matches with the theoretical value (5.7 eV). Thus in this paper the use of nanotechnology was shown in the form of nanostructured hydrophobic coating of $HfO_2$ for outdoor insulators. In future further investigation is required to obtain best value of contact angle by varying sputtering parameters. In addition to this, the properties like mechanical and electrical are also need to be investigated to utilize the coating for commercial purpose.

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