USING NANOMATERIAL TO ENHANCE THE PERFORMANCE OF MEDIUM VOLTAGE INSULATORS AND STREET LIGHTS CONSIDERING ENVIRONMENTAL IMPACTS

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ABSTRACT

Nanoparticles are small objects that their size, in at least one dimension, is between 1 and 100 nanometers. Nanomaterials characteristics are completely different from larger particles. Therefore, Nanotechnology can be used to enhance the properties of many products. Although it is possible to use nanotechnology to improve the performance and life cycle of various electric components, Alborz Electric Power Distribution Company (AEPDC) efforts have been focused on using TiO_2 nanoparticles in street lamps as well as medium voltage silicon rubber insulators. In current paper, the properties of titanium dioxide (TiO_2) nanoparticle were described. Then the applications of this nanomaterial in insulators and lamps were explained. Finally, the possible impacts of using it on environment were discussed.

INTRODUCTION

Nowadays, nanotechnology is widely used for improving the performance of electrical components in energy sector. Improving the surface characteristics of medium voltage silicon rubber insulators and developing self-cleaning street lights are two applications of nanotechnology that will be used in Alborz Electric Power Distribution Company (AEPDC) in near future. In the former usage, silicon rubber insulators are covered by a thin layer of titanium dioxide nanoparticles. This enhancement not only increase the long-term performance of the insulators but also reduce the amount of dirt on the surface of them. In the latter application, tin film of titanium is applied to glass in order to make a self-cleaning lamp.

However, installed components will be worn out in a few decades. Old components have not proper characteristics which are needed for reliable utilization. Hence, power distribution companies replace old insulators and lamps with new ones. The old components usually stack up in the inventory as waste. Periodically, the pile of unrecyclable components buried in a remote place which is allocated to landfill. Electrical components which have been modified with nanomaterials have not been used in distribution network widely in Alborz province and consequently none of them have been buried in the landfill. However, it is necessary to assess the environmental risks of using them. Unfortunately, reliable documents that predict the flows of engineered nanomaterials in silicon rubber insulators and lamps in the environment are not available. Therefore, it is necessary to conduct researches to understand how nanomaterials, which cover electrical components such as insulators, will be released to the surrounding environment.

Alborz Electric Power Distribution Company (AEPDC) have decided to examine the risk of nanomaterials to the environment before any irreparable damage is inflicted.

In current essay, the practices of AEPDC in using nanotechnology to enhance the performance of insulators and lamps will be introduced and the possible environmental impacts of disposing this components will be discussed.

THE PROPERTIES OF TITANIUM DIOXIDE NANOPARTICLE

Titanium dioxide is available in many forms and sizes including microscale powder and nanoparticle. Microscale TiO2 has high diffraction index and light scattering properties. Therefore, it has been used as white pigment. However Nanoscale titanium dioxide does not scatter light. Crystals of TiO2 particles can be found in many main different forms.

Titanium dioxide has three different crystal structures, anatase, rutile and brookite, as well as amorphous structure. Amorphous titanium dioxide shows very little photoactivity but this property is much more evident in crystal form, especially anatase. Mean diameter of anatase nanoparticles are less than visible light wavelength, thus they are transparent when they are applied on a substrate [1].

Titanium dioxide, especially in the anatase form, has photocatalystic properties in the presence of ultraviolet light. In recent years, scientists have developed many techniques like electron beam treatment [2] and doping with nitrogen ions or metal oxide like tungsten trioxide [3] in order to make visible light-active nanoparticles that can used effectively as photocatalyst in the presence of visible light as well.

The TiO2 is not only a photocatalyst but also a super-hydrophilic substance in the presence of UV light. Therefore, its water contact angle is reduced under ultraviolet exposure and consequently a uniform water film on the treated surface is created which prevents contact between dirt and surface. The combination of these two properties is the fundamental of self-cleaning ability of titanium dioxide [1].

APPLICATION OF NANOTECHNOLOGY AT AEPDC

Street lamps are situated along the street. Dirt usually covers the outer surface of the lamps especially in urban and industrial regions and consequently reduces the amount of light emitted from the lamps. Manual cleaning of the street lights is not only costly and time consuming but also causes traffic congestion. Therefore, increasing the time between cleaning and maintenance of the lamps can increase the profitability of the company. Nanoparticles are widely used to make glass and concrete self-cleaning.

Alborz Electric Power Distribution Company (AEPDC) has signed a contract to develop a self-cleaning lamp. The enhanced glass cleans itself in two stages. In the first stage which is called "photocatalytic" stage, organic dirt is broken down using ultraviolet light of the sun. It make glass superhydrophilic. In the second stage, rain washes away the dirt without any streaks. Many methods can be used to prepare and coat titanium dioxide nanoparticle on glass. One of these approaches is employing coating solution that contains TiO_2 nanoparticles. In order to fix nanoparticles on the surface, thermal treatment can be used. Similar project is being conducted to improve the performance of medium voltage silicon rubber insulators.

EFFECT OF USING TITANIUM DIOXIDE NANOPARTICLES ON HEALTH

The effects of nanoparticles inside of the human body are not completely identified and many researches have been conducted in order to understand them. Nanotoxicology is the study of the toxicity of nanomaterials. Generally, Chemical activity of nanomaterials is usually much higher than larger particles. Any harmful material must be absorbed in enough quantity in order to pose health and safety risks. The surface area to volume ratio of nanoparticles is very high. Therefore, the absorption rate of these materials through the skin, lung and digestive tracts can be much more than normal materials [4]. When TiO_2 nanoparticles enter the human body, they accumulate in different organs and there is no mechanism in the human body to eliminate them.

Moreover, some nanoparticles can enter human bodies via inhalation, ingestion or even directly from skin and move from deposition organs to other part of body such as bone marrow, liver and brain [5][6] [7]. Finally, they can cross biological membranes that protect cells, tissue and organs [8]. Previous studies have shown that nanomaterial can be toxic because they are able to enter mitochondria and nucleus of body cells that can cause major structural damage and DNA mutation[9] [10].

Titanium dioxide is widely used in cosmetic products such as sunblock creams. Therefore, majority of researches which are pertinent to the health and safety impacts of this material have focused on cosmetic products. However, their result can help us to understand possible risks of using titanium dioxide nanoparticles in the power distribution network.

International Agency for Research on Cancer (IARC) has classified titanium dioxide as an IARC Group 2B carcinogen "possibly carcinogen to humans". Previous studies have shown that high concentrations of ultrafine titanium dioxide dust caused respiratory tract cancer in rats [11]. In another study which was conducted by researchers at UCLA's Jonsson Comprehensive Cancer Center showed that the TiO_2 nanoparticles induced single- and double-strand DNA breaks and caused chromosomal damage and inflammation [2]. In a research which was conducted in Swedish Karolinska Institute, the effects of various nanoparticles on human lung epithelial cells were studied. The result showed that titanium dioxide caused DNA damage. However, in that research only copper oxide nanoparticles was identified as a clear health risk [12].

Although the observation of cancer in animals implies the considerable risk for human health, no association between exposure to titanium dioxide and an increased risk for cancer has been found in recent studies [11].

INVIRONMENTAL ASPECTS OF USING NANOPARTICLES IN POWER GRID

According to British Standard Guide PD 6699-2, there are four types of nanomaterial-related waste streams:

1- Pure nanoparticles.

2- Items contaminated with nanoparticles

3- Liquid suspensions containing nanomaterials

4- Solid matrices with nanoparticles that can be easily crumbled or have a nanostructure loosely attached the surface.

In figure 1 the transmission of titanium dioxide nanoparticle in the supply chain and utilization of silicon rubber insulators was depicted.

The properties of nanomaterials and their impacts on environment vary according to their size. These properties Comprise reactivity, solubility, conductivity, redox and many more characteristics. Therefore, understanding of their behaviours in the environment is extraordinarily complex [13].

Old or damaged electric components are usually dumped on land and in a few cases disposed in a landfill. The methods of disposal vary from controlled and engineered landfills to uncontrolled site. Landfill design, site condition, complexity of control and weather determine the potential release of pollutant through landfill gas and leachate. Sophisticated landfills use synthetic barrier and collection systems for leachate and landfill gases. These collection systems capture and treat leachate and landfill gases. In other words, they prevent the release of untreated landfill gases to the atmosphere and leachate to ground/surface water [14].

There is not any documented reference that show how titanium dioxide nanoparticles move from the electrical components dumped on a surface of land or buried in a landfill to the environment. However, a few researches

have been conducted that showed how nanoparticles released though landfill leachate. A research conducted by Dulger et al [15] showed that titanium dioxide nanoparticles that are used in consumer goods like cosmetics and textile can be found in leachate of municipal solid waste. The leachate characteristics such as pH, ionic strength and natural organic matter concentration play an important role in how titanium dioxide nanoparticles are released and transported [16].
The release of titanium dioxide nanoparticles in the environment has negative impacts on waste water treatment as well. Previous studies showed that the presence of nano-titanium dioxide can decrease nitrogen and phosphorus removal efficiency [16].

CONCLUSION

Nanotechnology can improve the performance of many electrical components which are used in power distribution network. AEPDC not only has started a two distinct projects to improve the performance of silicon rubber insulators and street lights but also aware about the environmental aspects of this development. Although modified components have not been widely used in Alborz distribution network and it is not possible to measure the environmental impacts of using TiO_2 nanoparticles, in current paper the risk of using these nanoparticles was explained. We hope that in near future the result of field study will be published.

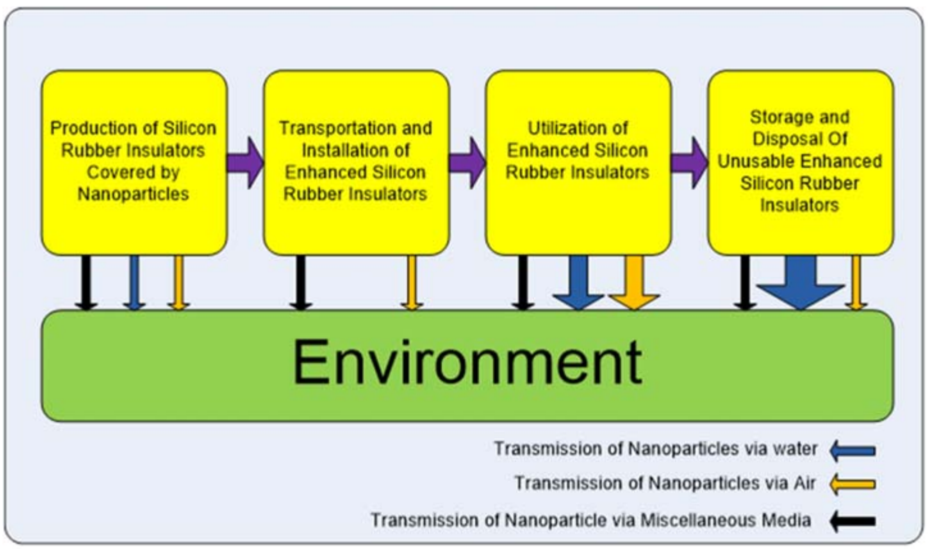

Figure 1: The flow of titanium dioxide nanoparticles which are used for enhancing medium voltage silicon rubber insulators (Thicker arrows represent more important flows)

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