International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 16 (2017) pp. 6155-6158

Health effects of nanomaterials with sportswear applications

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Abstract

Recently, nanotechnology has received great interest in a global sportswear industry. Nanotechnology is becoming an essential key for special functions of sportswear. Impact of nanotechnology on the sportswear industry is getting bigger. Ultimate purposes of highly functional sportswear based on nanotechnology are to increase safety against mechanical, chemical, physical, optical, and thermal destruction and to improve water repellency, oil recovery and anti-fouling functions. Moreover, nanotechnology can improve functions sportswear such as reflection and absorption of UV and IR, shielding of electromagnetic waves, and etc. In addition, appearance, touch, and durability of color can be improved as well. Several types of nanomaterials have been used to enhance functionalities of sportswear. Mostly used nanomaterials are ZnO, TiO_2, Ag, SiO_2, carbon black, and carbon nanotubes. Although nanomaterials can provide many conveniences when used in sportswear, but the health effects on human is a major hindrance for actual industrial use. In this study, we study the health effects of nanomaterials with sportswear applications.

Keywords: Nanomaterial, Textile, Toxicity, Functional textile, Health effect

INTRODUCTION

Recently, nanotechnology has received great interest in a global sportswear industry. Nanotechnology is becoming an essential key for special functions of sportswear. Impact of nanotechnology on the sportswear industry is getting bigger. The nanotechnology applied functional apparel will take up to 25 percent of total US apparel industry in five years. In addition, many apparel experts believe that nanotechnology based innovations (eg, anti-stain, wrinkle-free and antibacterial clothes) will attract more consumers' interest.

By using nanotechnology, companies can achieve better performances of sportswear. Changing the properties of the sportswear means that the market for nanotechnology-enhanced sportswear can be grown up much further.

Ultimate purposes of highly functional sportswear based on nanotechnology are to increase safety against mechanical, chemical, physical, optical, and thermal destruction and to improve water repellency, oil recovery and anti-fouling functions. Moreover, nanotechnology can improve functions sportswear such as reflection and absorption of UV and IR, shielding of electromagnetic waves, and etc. In addition, appearance, touch, and durability of color can be improved as well.

Several types of nanomaterials have been used to enhance functionalities of sportswear. Mostly used nanomaterials are ZnO, TiO_2, Ag, SiO_2, Carbon black, and carbon nanotubes. These nanomaterials can provide some prominent functions such as increasing strength of the sportswear, preventing bacterial growth, increasing a thermal conductivity. For example, polymer nanocomposites are based on carbon nanomaterials and utilize the superior properties of carbon nanomaterials. Carbon nanomaterials are used in various forms such as films, fibers, nanofiber webs and etc., and have been studied for various applications to improve mechanical, electrical, thermal and optical properties of the composite. However, the research on carbon nanocomposites is still not enough to understand the dispersion and behavior of carbon nanomaterials and the mechanism of physical properties in the complex. Moreover, the study of the carbon nanofiber material itself is still required for some applications.

Although nanomaterials can provide many conveniences when used in sportswear, but the health effects on human is a major hindrance for actual industrial use. Therefore, it is very important to address it.

Health effect of nanomaterials using in textile

Over recent decades, sportswear that has improved exercise performance, enhanced functionality and convenience by using advanced nanotechnology is attracting great research attentions. As an example, nanomaterials have been studied for sportswear applications. The sportswear is the boundary between the human body and the environment, and heat is transferred through conduction, convection, radiation, evaporation, and breathing processes between the human body and the environment. As a condition of sports clothing according to climate change, since a lot of heat is divergent during heavy exercise, low insulation effect, quick moisture transmission and low moisture absorption should be performed, and in low temperature environment, water absorption must be achieved. The functions can be achieved or improved by adoption of nanomaterials on the sportswear.

When nanomaterials are used in textile, they can give significant health effects on humans. For example, direct contact with the skin, ingestion or adsorption to the lungs can cause health problems. When nanomaterials are used in textile, it can serve many conveniences and provide new and exciting features. However, the health issues are a major hindrance for actual industrial applications and therefore it is very important to pinpoint and solve them. Many studies have been conducted to analyze the effects of nanomaterials on human health, but there are still a lot of deficiencies and more researches are needed. In this study, we summarize the health effects of the most applicable nanomatierlas in textile, including SiO_2, TiO_2, Ag, ZnO, and carbon nanoparticles including carbon nanotubes.

TiO_2 nanoparticles

TiO_2 has been studied extensively because of its wide range of usability. Most of the studies showed that TiO_2 is inert and adverse effects on human health are negligible in general usage.

Functionalized and not functionalized TiO_2 were investigated for lung cell damage at low doses condition. [1] Rats were exposed through instillation with several types of untreated TiO_2 and functionalized hydrophobic TiO_2 particles. After 3, 21 and 90 days, inflammatory signs for cells, protein, tumor necrosis factor-α, fibronectin, and surfactant phospholipids were examined. As results, DNA damage was at a level of control and the both types of TiO_2 nanoparticles are inert at applied doses.

Damages on lungs by inhaled TiO_2 nanoparticles were examined. [2] Rats were exposed to aerosols of TiO_2 nanoparticles, median diameter of 22 nm, for 1 hour. The aerosol nanoparticles in a lung tissue were identified by electron energy loss spectroscopy. The nanoparticles were found in the cell as small clusters and size distribution of the cluster was found to be a median diameter of 29 nm which indicates no severe clustering of the inhaled nanoparticles.

In other study, TiO_2 nanoparticles aerosol with median diameter of 22 nm were inhaled by rats and their lungs were examined. [3] The inhaled TiO_2 nanoparticles were found from all major lung tissue compartments and cells and within capillaries.

In other study, toxicity of TiO_2 nanoparticles in cell was characterized under ambient condition. [4] At relatively high concentrations of the TiO_2 nanoparticles, 100 ug/ml, showed cytotoxicity and inflammation and the damages were increased with time of exposure. The effects were not dependent on sample surface area but phase composition. The anatase TiO_2 nanoparticles were 100 times more toxic than the rutile TiO_2 nanoparticles. The most cytotoxic nanoparticles were also the most effective at generating reactive oxygen species, in other words, the most efficient for photocatalysis.

In contrary to the previous study, inhaled smaller TiO_2 nanoparticles showed higher toxicity than larger TiO_2 nanoparticles in rats. [5]

ZnO nanoparticles

ZnO nanoparticles are an element that a certain amount is needed for human every day. However, other problems may arise if human has overdose of ZnO, or if you have skin or other ways of exposure. ZnO nanoparticles are widely used in sunscreen creams and can be easily absorbed into skin.

Toxicity of ZnO nanoparticles in cells was examined. [6] ZnO nanoparticles generated reactive oxygen species resulted in an oxidant injury, excitation of inflammation and cell death. The ZnO nanoparticles could be dissolved in culture medium and endosomes, but not dissolved ZnO nanoparticles were found in cells.

Cytotoxic effect of ZnO nanoparticles on various human cancer and normal cells were investigated. [7] The cancer cells were resulted to death with the ZnO nanoparticles but the normal cells got no major effect observed.

Some different sizes and shapes of ZnO nanoparticles were investigated for cytotoxicity in rats. [8] As results, there was no significant impact on cytotoxicity by size of ZnO nanoparticles, but there is high impact by the shape of the nanoparticles.

SiO_2 nanoparticles

SiO_2 nanoparticles can be in form of amorphous or crystalline structures, but the amorphous structures are mostly used. Cytotoxicity of two structures were compared and chronic inhalation of crystalline SiO_2 nanoparticles showed higher cytotoxicity on lung cells in rats compared to amorphous SiO_2 nanoparticles. [9]

Effect of amorphous SiO_2 inhalation on health was studied. [10] The results showed that partially reversible inflammation, granuloma formation and emphysema could be possibly happened, but no progressive fibrosis of lung cells was happened by SiO_2.

Most studies have shown that amorphous SiO_2 is safer, and crystalline SiO_2 is more toxic. However, it is difficult to completely separate amorphous SiO_2 and crystalline SiO_2 nanoparticles, and a small amount of crystalline SiO_2 should be contained, so caution is required when using amorphous SiO_2 nanoparticles.

Ag nanoparticles

Ag is well known as the most toxic substance. Therefore, using of Ag nanoparticles in textile should be considered very carefully. A pulmonary and systemic distribution of inhaled Ag nanoparticles was investigated. [11] After exposure of rats with Ag nanoparticles, 15 nm modal diameter, the particles were detected from all over the body. However, the amounts of Ag in the lungs, liver, kidney, spleen, brain, blood, and heart were decreased rapidly with time.

The other research showed that Ag nanoparticles may give damage on mitochondria. [12]

Toxicity of Ag nanoparticles on a human lung cell and glioblastoma cell was studied. [13] The toxicity was evaluated by cell morphology, cell viability, metabolic activity, and oxidative stress. The result showed that Ag nanoparticles can damage to mitochondria and increase production of reactive oxygen species. Moreover, it can give damage to DNA.

However, studies couldn't distinguish the toxicity of Ag nanoparticles and the toxicity of Ag^{+} ions. Researches about origin of the toxicity are insufficient and further researches are required.

Carbon nanotubes

Toxicity of carbon nanotubes have relatively higher research attentions compared to other nanomaterials, however, clear results have not come out till now. There are various structures for carbon nanotubes such as various aspect ratios, diameters and number of walls. Moreover, the carbon nanotubes have various contaminants and it make difficult to come out a clear explanations of toxicity. In other words, there are several contradictory research results.

Intratracheal instillation effects of carbon nanotubes on lung cell in guinea pig were studied. [14] Three months intratracheal exposure of carbon nanotubes caused organizing pneumonitis.

A respiratory toxicity of multi walled carbon nanotubes was studied. [15] A biological reactivity of purified multi walled carbon nanotubes in rat lung was characterized. The carbon nanotubes were still remained in the lung cells after 60 days and induced inflammatory and fibrotic reactions. The carbon nanotubes were dispersed in the lung parenchyma and induced inflammatory and fibrotic responses.

Other research compared presence of contaminants on carbon nanotubes and they explained that toxicity of carbon nanotubes are mainly depending on the contaminants. [16]

Carbon nanotubes are frequently functionalized, for example, functionalization to improve dispersibility, and the functionalization can greatly change properties of carbon nanotubes. Analysis of toxicity of the functionalized carbon nanotubes revealed that the toxicity thereof was greatly lowered. [17] We summarized the health effects of nanomaterials discussed in Table 1.

Table 1. Health effects of nanomaterials in textiles

Material	Health effect
ZnO nanoparticles	Biological effects detectable
Ag nanoparticles	Toxic but weak evidence
TiO_2 nanoparticles	Negligible in general usage Toxicity increased with time of exposure
SiO_2 nanoparticles	Amorphous SiO_2 is rather safe Crystalline SiO_2 is more toxic
Carbon nanotubes	Uncertainty due to weak evidence

CONCLUSION

Ultimate purposes of highly functional sportswear based on nanotechnology are to increase safety against mechanical, chemical, physical, optical, and thermal destruction and to improve water repellency, oil recovery and anti-fouling functions. Moreover, nanotechnology can improve functions sportswear such as reflection and absorption of UV and IR, shielding of electromagnetic waves, and etc. In addition, appearance, touch, and durability of color can be improved as well. Several types of nanomaterials have been used to enhance functionalities of sportswear. Mostly used nanomaterials are ZnO, TiO_2, Ag, SiO_2, carbon black, and carbon nanotubes. These nanomaterials can provide some prominent functions such as increasing strength of the sportswear, preventing bacterial growth, increasing a thermal conductivity. Development and application of nanomaterials are important, but research on toxicity is important as well. When nanomaterials are used in textiles, they may be inhaled on human skin, nose, mouse, or through other paths. Toxicity studies based on a shape, structure, and chemistry of nanomaterials should be done more systematically, and further theoretical researches such as mechanism of toxicity expression are needed before actively applying nanomaterials to textile industry.

ACKNOWLEDGEMENT

This research was supported by Hallym University Research fund, 2015(HRF-201512-015).

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