IMPROVEMENT OF PHYSICAL PROPERTIES OF VISCOSE USING NANO GeO_2 AS DOPING MATERIAL

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Abstract:

The properties of viscose/ TiO_2 and viscose/ TiO_2 /germanium dioxide (GeO_2) are investigated and compared. The elemental mapping analysis using a field emission scanning electron microscope (FESEM) shows the excellent distribution of nanomaterials, while the energy dispersive X-ray (EDX) confirms its existence. The 500 s cycle of rubbing test indicates that the abrasion resistance of treated samples improves significantly. In addition, the doping of nano GeO_2 enhances the strength of the treated samples. Furthermore, the thermal behavior of the treated samples, characterized by differential scanning calorimeter (DSC), results in a higher crystallization temperature and doping GeO_2 increases the thermal properties of viscose in comparison with nano TiO_2 . The study of ultraviolet blocking indicates that doping GeO_2 can improve the transmission of ultraviolet even from TiO_2 .

Keywords:

Germania, viscose, physical properties

1. Introduction

In the past decade, researches have been conducted on immobilizing nanomaterials and nanostructures on fiber or fabric to obtain new properties in the final product. Recently, the ultraviolet (UV) protection activity of fibers or fabrics has gained much attention because of its ability to prevent diseases [1–6]. Many studies have reported the UV protection activity of nano titania and its virtuous properties on fabrics [7–9]. This paper has made an attempt to enhance this property.

The main application of titania is as an adsorbent, catalytic support, and in pigments. This nanomaterial has many applications such as in photo degradation, as a bactericidal, and for its UV blocking property and low toxicity [10–14].

Germanium dioxide (Germania; GeO_2) is an inorganic compound which forms a passive layer on pure germanium in contact with oxygen with low toxicity, as well as consists of a hexagonal and tetragonal crystalline morphology. There is a lack of scientific research on the effect of Germania on textile property; this study has made an attempt to study and investigate the physical properties of viscose crosslinked with Germania [15–18]. In the crosslink method, free carboxylic groups (two groups) must be available to interlink the nanoparticle and cellulose. In this method, a covalent ester bond is set up and a hydroxyl group of cellulose will perform esterification by one carboxylic group of the crosslink factor while the other carboxylic group of the crosslink factor connects to the nanoparticles [19].

Viscose is regenerated natural fiber, whose physical properties [20–22] are used as a renewable resource for the development

of environment friendly, biocompatible, and functional materials. Viscose is made of cellulose and the cellulosic textiles present a polar surface which is associated with the hydroxylated nature constituting of hydroglucose units. This property is responsible for the high hydrophilicity of cellulose, which enables the establishment of strong hydrogen bonding between fibers and the setting up of three-dimensional fiber-based structures. It is worth mentioning that the existence of these hydrophilic groups can develop nucleation and the formation of inorganic phases like titania and metal oxides, helping in generating the multifunctional properties of viscose [23–26]. The thermal behavior of viscose is of importance in the textile industry. The differential scanning calorimetry (DSC) is a thermos analytical method which measures the difference in the amount of heat needed to enhance the temperature of a specimen as a function of temperature [27–30].

2. Materials, methods, and characterization

GeO_2 (CAS Number 1310538) nanopowder at a density of 4.23 g/cm^3 was purchased from Sigma Aldrich. In addition, P-25 nano titanium dioxide was prepared from Degussa. The 100% plain weave bleached viscose fabric with a warp density of 24 yarn/cm and 20 yarn/cm weft and fabric weight of 119.5 g/m^2 was prepared by the Yazdbaf Company. Sodium hypo-phosphate and succinic acid were purchased from Merck.

Initially, the viscose fabric was washed with distilled water to remove any impurities. The crosslink method was used to conjugate the nanomaterials and fabric; 3%w/w succinic acid and 2%w/w sodium hypo-phosphate were prepared and the

washed viscose fabric was immersed in this solution for 60 min. Then the sample was dried in an oven at a temperature of 170 °C for 2 min. Meanwhile, the GeO_2 and TiO_2 nanopowders were sonicated in an ultrasonic bath (Euronda ultrasonic bath model Eurosonic 4D, 350 W, 50/60 Hz, Italy) at 40 °C for 50 min at 1% and 2% respectively. The treated fabric immersed in nano solution was sonicated again at 50 °C for 30 min. Later, the finished fabric was heated at 100 °C in an oven for 5 min to fix the nanoparticles on the fabric. Then, the sample was washed with distilled water to remove the unbounded particles. This process was repeated with only nano TiO_2 . Therefore, two samples of viscose/ TiO_2 and viscose/ TiO_2 / GeO_2 were prepared.

The morphology of the treated samples was investigated by a field emission scanning electron microscope (FESEM; MIRA3-TESCAN). UV transmission of the treated samples was examined by the Perkin Elmer Lambda ultraviolet-visible (UV-vis) spectrophotometer. DSC analyses were conducted by Shimadzu DSC-50 at a heating rate of 10 °C/min.

Abrasion test was done through AATCC TM93. The samples were driven by a rotor along a zigzag course in a circular orbit within a cylindrical chamber, so that it repeatedly impinged on the walls and the abrading liner of the chamber, while at the same time being continuously subjected to rapid, high-velocity

impacts. Rubbing test of 500 cycles was done for each sample and the difference in mass of the samples was calculated.

3. Results and discussion

3.1. FESEM, map images, and EDX analysis

The FESEM method was implemented to study the morphology of nanomaterials coated on the surface of fabric. The voltage and magnification of the device was set to 15 kV and 500x, respectively. Figure 1(a) shows the excellent distribution of nanomaterials and with the absence of aggregation or agglomeration of nanoparticles. It also demonstrates 30 nm as the average particle size of nanomaterials. Therefore, the coating of nanomaterials on the fabric surface is acceptable. However, the energy dispersive X-ray (EDX) spectra of the treated sample show the presence of nano TiO_2 and GeO_2 (Figure2). FESEM also demonstrates the distribution of nanoparticles by elemental mapping analysis. Figure 1(B–D), respectively, shows the FESEM of the treated sample; indicates its elemental mapping of Ge; and indicates the elemental mapping of Ti. As shown, the presence and distribution of these two nanoparticles on the surface of fabric is good and monotone.

Figure 1. FESEM images of (A) treated sample, (B) map of the treated sample, (C) elemental mapping of Ge, and (D) elemental mapping of Ti.

Figure 2. EDX image of the treated sample. EDX, energy dispersive X-ray.

3.2. Abrasion resistance and strength analysis

Abrasion assessment was done using the rub tester. For the treated and untreated samples, 500 cycles of rubbing test was performed and the weight difference before and after abrasion was calculated. Table 1 illustrates the mean data and abrasion resistance. The results show that the abrasion resistance of the treated sample is higher than that of the untreated sample. Additionally, the abrasion resistance of viscose\TiO₂\GeO₂ is higher than viscose\TiO₂. This can be explained by the mechanical properties of GeO₂, which is clearly visible from the FESEM figures, showing that all the surfaces of the treated sample are coated uniformly by nanoparticles. The tensile force of the treated or untreated samples was calculated by ISO 5079-breaking strength test. The results indicate that using nanomaterials increases the strength of viscose (Figure 3). It is worth mentioning that the strength of viscose\TiO₂\GeO₂ is greater than viscose\TiO₂, which indicates that doping of GeO₂ can improve the physical properties of fabric.

3.3. DSC analysis

The DSC method was used to analyze the treated and untreated samples. In this test, the treated and untreated fabrics were rapidly heated to 230 °C and maintained at this temperature for 3 min (to remove any thermal history and stresses). The samples were later cooled at room temperature of 10 °C/min. Figure 4 illustrates the DSC curve of samples. As shown, the exotherms maxima are at 182 °C for the untreated and 187 °C for the treated sample. The crystallization curves occurred while cooling. Comparison of the two spectra reveals that the crystallization peak is shifted toward the high temperature for the treated sample, which contains nanoparticles.

Table 1. Abrasion resistance of samples

Sample	Fabric weight before abrasion (g)	Fabric weight after abrasion (g)	Abrasion resistance (%)
Raw viscose	3.013	2.486	82.50
Viscose\TiO ₂	2.891	2.464	85.23
Viscose\TiO ₂ \GeO ₂	2.836	2.578	90.90

Figure 3. Strength of sample.

Figure 4. DSC spectra of samples. DSC, differential scanning calorimeter.

3.4. UV/Vis transmission property

UV/Vis transmission of the raw and treated samples was investigated based on the AATCC Test method 183-2004. Figure 5 illustrates the spectra. The irradiation wavelength of 200–800 nm shows that the raw sample has higher transmittance in comparison to the contained nanomaterials. It means that UV protection of the treated samples is better than that of the raw sample. Furthermore, doping GeO₂ to the viscose\TiO₂ improves the UV blocking remarkably. This is due to the synergetic UV absorption of nano GeO₂.

4. Conclusion

Viscose fabric containing nano TiO₂ and GeO₂ was produced by the crosslink method. Raw sample, viscose\TiO₂ and viscose\TiO₂\GeO₂ were characterized by FESEM. The nanomaterial

Figure 5. UV/Vis transmission of samples.

particle size was about 30 nm and the EDX analysis proved their existence. Elemental mapping analysis of the samples by FESEM indicates the good distribution of nanoparticles on the surface of viscose fabric. Meanwhile, the thermal behavior of the treated samples was characterized by DSC, resulting in a higher crystallization temperature. The doping of nano GeO_2 enhances the thermal properties of viscose in comparison to nano TiO_2 . Also, the result of the transmission spectrophotometer shows good UV blocking of the viscose/ TiO_2 / GeO_2 composite; however, the blank sample does not have suitable UV blocking, but by doping nano GeO_2 , its UV blocking property enhances greatly in comparison to viscose/ TiO_2 . This is because of the UV-blocking property of nano GeO_2 and its synergetic UV adsorption. Furthermore, the abrasion resistance and strength of the treated samples improved significantly.

Data availability statement

The data used for this study are available on request from the corresponding author.

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