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Effect of different nanoparticles based coating on the performance of textile properties

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ABSTRACT

Facile approach has been developed for synthesis of coating layer for different textile fabrics. Coating layer composed from binder and metal oxide nanoparticles prepared by one step method using ultrasonication for uniform dispersion of nanoparticles. Then, prepared coating was coated on textiles imparting multifunctional properties to the treated textile fibers. Textile coating layer was prepared based on commercial binder, TiO_2 and ZnO nanoparticles of an average particle size of 20 nm. Effect of dispersion and mass ratio of TiO_2 and ZnO nanoparticles were studied. The ultraviolet protection factor of treated fabrics was significantly enhanced achieved more than six fold and 3 fold compared to untreated and binder treated samples respectively. Antibacterial behavior against staphylococcus aureus bacteria was studied achieved 23.5 mm clear inhibition zone compared to zero for blank textiles. Furthermore, mechanical properties of the untreated and treated samples were investigated. This is in addition to evaluation of the hydrophobic properties of coated textiles achieving super-hydrophobic surface with water contact angle of 160°.

1. Introduction

Recently, the need for smart multifunctional textiles are increased for comfortable and safety properties to the end users. There are several important functions have to be inserted in textile fibers such as ultraviolet protection (UV) [1], thermal stability, flame retardancy [2], hydrophobicity [3], electrical and antibacterial properties [4,5]. However, the demand for UV protected textiles got a lot of attentions, due to the harmful effects of UV rays for human skin such as skin aging and sunburn [1,6]. The UV rays emitted by sun divide in to three regions UVA in the range of 320–400 nm UVB from 280 to 320 and UVC from 180 to 280 nm [7,8]. The UVC and some portion of UVB were filtered by ozone layer [8,9]. It was reported that, the optimum harmful effect to skin stemmed from UV rays in the wavelength range of 305–310[1,9]. There are various organic and inorganic materials have been used as UV absorbers [1,10]. The treatment of textile fibers with nanoparticles such as SiO_2, TiO_2 and ZnO has been reported for imparting the fibers with various positive functions [1,11]. Nevertheless, because of the high surface area of these nanoparticles due to their nanoscale size they are agglomerate together when coated on textile fibers. This limits their properties especially when high mass loading was used [12,13]. One of the widely used nanoparticles in fabrics finishing is TiO_2 nanoparticle (TiO_2NP) due to their excellent properties such as antibacterial, self-cleaning and UV absorber [1,5]. This is due to its ability to absorb UV rays in the range of 280–400 nm which is the range of harmful UV rays and should be blocked. The effect and mechanism of action of TiO_2NPs and ZnONPs as antibacterial, self-cleaning and UV absorber on textile fibers have been reported and studied [14–16]. However, the effect of their dispersion and agglomeration on textile fiber surface and the correlation to their antibacterial, UV-absorption, hydrophobicity and mechanical properties not yet fully studied. In our previous studies, the flammability, thermal, mechanical and electrical properties of different textile fabrics have been investigated and the effect of zero and one dimensional nanomaterials has also been studied [4,11]. This is along with our experience in synthesis, characterization of UV filter thin films [12] and different nanoparticles synthesis and applications [11,17–19]. In this study, TiO_2NPs and ZnONPs of an average particle size of 20 nm were used with commercial binder as a coating layer for different textile fibers. The effect of dispersion and mass ratio of nanoparticles on the final performance of the treated fabrics were studied. The UV shielding capacity (Ultraviolet Protection Factor: UPF), hydrophobicity, and

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Table 1
Composition of coating layer.

Sample code	Binder (wt.%)	TiO_2NP (wt.%)	ZnONP (wt.%)
C	0	0	0
C-B-2[a]	100	0	0
C-B-5[b]	100	0	0
PS	0	0	0
PS-B-5	100	0	0
W	0	0	0
W-5	100	0	0
C-B-TiO_2NP-2-2	98	2	0
C-B-ZnONP-2-2	98	0	2
C-B-ZnONP-2-5	95	0	5
C-B-TiO_2NP-2–5	95	5	0
C-B-TiO_2NP-2–10	90	10	0
C-B-TiO_2NP-2–20	80	20	0
C-B-TiO_2NP-5-2	98	2	0
C-B-TiO_2NP-5–10	90	10	0
C-B-TiO_2NP-ZnONP-5–10	90	5	5
C-B-TiO_2NP-5–20	80	20	0
W-B-TiO_2NP-5–10	90	10	0
PS-B-TiO_2NP-5–10	90	10	0
C-B-TiO_2NP-5–10-NS	90	10	0
PS-B-TiO_2NP-5–10-NS	90	10	0
W-B-TiO_2NP-5–10-NS	90	10	0

Where a and b refers to concentration of binder by 2 vol.% and 5 vol% respectively.

mechanical properties of the untreated and treated textile fibers were studied. This is in addition to their antibacterial activity evaluation.

2. Experimental section

2.1. Materials

Cotton/polyester blend of 65/35 respectively (C) and polyester/cotton blend of 80/20 respectively (PS), and wool (W) were supplied by Al Mahalla Co., Algharbia, Egypt. Commercial binder coded as MTP acrylate based used in the preparation of coating layer was purchased from market. TiO_2 and ZnO nanoparticles of an average particle size of 20 nm were obtained from Sigma Aldrich Chemie GMBH, Germany. Toluene used in the preparation of coating was purchased from El Nasr Pharmaceutical Chemicals Co., Egypt.

2.2. Synthesis of coating dispersion B-TiO_2NPs and B-ZnONPs

In a beaker containing toluene (100 ml) dissolve 2 and 5 vol% of binder (B) individually. Then, individually disperse different mass loading of TiO_2NPs and ZnONPs of 2, 5, 10 and 20 wt.% (40, 100, 200 and 400 mg respectively) based on final wt. of B-NPs composites in the previous solution as tabulated in Table 1. This followed by ultrasonication at 50% output for 30 min to prepare well dispersed dispersion of B-TiO_2NPs and B-ZnONPs. The coating dispersion without ultrasonication was also prepared as a blank.

2.3. Preparation of textile- B-TiO_2NPs and textile-B- ZnONPs composites

The textile samples of dimension of 20 cm × 20 cm were immersed in beaker containing different coating dispersion prepared in the step 2.2 individually for 10 min. Then, removed and squeeze out, this step repeated three times. Afterwards, the samples were dried in air followed by curing in oven at 130 °C for 5 min. Final samples coded as C-B-TiO_2NP-2-2 where C refer to cotton blend, B refer to binder, TiO_2NP refers to nanoparticles and first number to binder concentration and second number relate to the concentration of nanoparticles.

2.4. Characterization

The SEM images were obtained using a scanning electron microscope (Quanta FEG-250, operating at a voltage of 20 kV). A UV spectrum was measured using a UV–vis Spectrophotometer – Shimadzu UV 3101PC in the wavelength range 190–400 nm in transmittance mode. The mechanical properties were tested using tensile testing machine model H1-5KT/S using standard test method EN ISO 13934-1:1999 [20] and results were the average of three replicate samples and young modulus were calculated. Furthermore, the antibacterial activity was investigated using the AATCC standard test method 147–2004[21]. The antibacterial against *staphylococcus aureus* bacteria was tested by measuring the average clear inhibition zone of three replicates based on W = (T-D)/2. W is the width of the clear inhibition zone in mm, T is the total diameter of both test specimen and clear zone in mm and D is width of the test specimen itself in mm. The water contact angle (WCA) was calculated based on the standard test methods and results were the average of three replicate measurements [22,23].

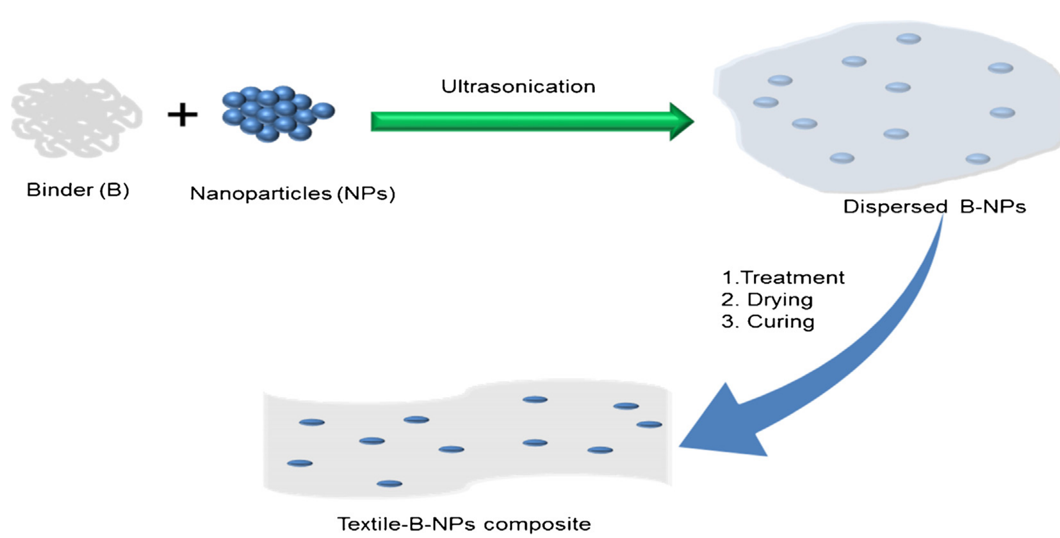

Fig. 1. Schematic diagram showing the synthesis of coating dispersion and treatment on textile fabrics.