Multifunctional finishing of cotton and blended fabrics treated with titanium dioxide nano-particles

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Abstract: The details of the study conducted on the synthesis and characterization of nanosized Titanium dioxide (TiO_2) particles and their application on cotton and polyester/cotton fabrics for imparting multifunctional properties (viz. Anti-bacterial protection, self-cleaning and UV protection) are reported in this paper. Titanium dioxide (TiO_2) is extensively used as a photo-catalyst due to the strong oxidizing power of its holes, high photo-stability and redox selectivity.The nano-particles of TiO_2 were produced in different conditions of temperature (100° or 120°C) and the concentration of HNO_3 using soft chemistry. These nano-particles were characterized by Fourier transformed infrared spectroscopy (FTIR), transmission electron microscopy (TEM), and X-ray powder diffractometry (XRD) for assessing the composition, their shape, size and crystallinity respectively. Then, these TiO_2 nano-particles were applied to 100%cotton and polyester/cotton samples to impart multifunctionality to the treated textiles. The effectiveness of the multifunctional finishing treatment was assessed through standardized tests available for testing the special functions such as anti-microbial protection, self-cleaning and UV protection both before and after washing of the treated samples. Consequently, it was demonstrated that the finished 100%cotton and polyester/cotton fabrics with nano TiO_2 had various functionalities, such as antimicrobial activity, self-cleaning and UV protection. The results of these tests have been collected, studied, analyzed and reported here.

Keywords: cotton fabrics, nano-particles, polyester/cotton blends, multifunctionality, TiO_2

Introduction

Traditionally, textiles were considered to belong to the low technology domain as their primary functions are protection of modesty, aesthetic and providing microclimate. With the intensification of global competition due to globalization, textile manufacturing companies and developed countries are competing for a significant share of the global market by developing new technologies or new products. Companies are trying to differentiate their products with specific and special functions. The consumers are demanding textile products with higher performances, even in the "traditional" clothing and home textiles areas as the world market of textiles is becoming highly competitive. Therefore, researchers have made many attempts to impart more functional characteristics to fabrics (in addition to the above mentioned primary functions) so as to get what are known as multifunctional textiles.

Nanotechnology is an emerging, highly interdisciplinary field, premised on the ability to manipulate structural materials on the level of individual atoms and molecules. The research interest for the use of nanotechnology in the textile industry has increased rapidly. This is mainly due to the fact that textile fabrics are some of the best platforms for deploying nanotechnology. Fibres make for optimal substrates where a large surface area is present for a given weight or volume of fabric. The synergy between nanotechnology and the textile industry judiciously exploits this property of large interfacial area and the drastic change of energetics experienced by macromolecules or supra-molecular clusters in the vicinity of a fibre when going from a wet state to a dry state (Soane *et al*., 2005).

The application of nano-particles to textile materials has been the object of several studies aimed at producing finished fabrics with different functional performances. Hee Yeon Ki *et al*. (2007) demonstrated that the finished wool fabrics with sulphur nanosilver colloid had various functionalities, such as mothproofing, antibiotic, and antistatic property. For example nano-Ag has been used for imparting antibacterial properties (Kwon *et al*., 2002; Lee *et al*., 2003) nano- TiO_2 for UV-blocking and self-cleaning properties (Dura´n *et al*., 2007; Fei *et al*., 2006; Xin *et al*., 2004) and TiO_2 nano-particles for antibacterial and UV-blocking properties (Baglioni *et al*., 2003; Qi *et al*., 2007; Vallés *et al*., 2006). Metal oxide nano-particles are more preferable than nano-silver because of cost considerations. In fact, both zinc oxide and titanium dioxide are non-toxic and chemically stable under exposure to both high temperatures and capable of photo catalytic oxidation. Furthermore, nano-particles have a large surface area to-volume ratio that results in a significant increasing of the effectiveness in photo catalytic oxidation activity when compared to bulk materials (Fujishima *et al*., 2000).

Conventional textile finishing methods used to impart different properties to fabrics often do not lead to permanent effects, and will lose their functions after laundering or wearing. Nano-particles can provide high durability for treated fabrics, with respect to conventional materials, because they possess large surface area and high surface energy that ensure better affinity for fabrics and lead to an increase in durability of the textile functions (Wong *et al.*, 2006). Wash fastness is a particular requirement for textiles and it is strongly correlated with the nano-particles adhesion to the fibers. In order to increase the wash fastness, the nano-particles can be applied by dipping the fabrics in a solution containing a specific binder (Baglioni *et al.*, 2003; Vallés *et al.*, 2006). Wash fastness can be further improved with the formation of covalent bonding between nano-particles and the fabrics surface. In these cases the excellent functional properties are still maintained after 45 home launderings (Daoud *et al.*, 2004).

Titania (TiO_2) has three main polymorphs *viz.* anatase, rutile and brookite. Among the three kinds of crystal structure of TiO_2, anatase TiO_2 fine particles are the most active for photo-catalysis. Titanium dioxide is widely used in different areas because of its unique photo-catalytic, electrical, electronic, optical, dermatological, and antibacterial properties (Arnold *et al.*, 2003; Behnajady *et al.*, 2006; Sawai, 2003; Tang *et al.*, 2006a;2006b; Xiong *et al.*, 2003; Yu *et al.*, 2005). For these applications, the nano-particles need to be dispersed homogeneously in the different matrices, and a number of new synthetic strategies have been developed in order to prevent particles agglomeration, and increase the stability of TiO_2 nano-particles dispersions (Guo *et al.*, 2000; Kwon *et al.*, 2002; Wang *et al.*, 2004). The wide range of applications is possible as TiO_2 has two key advantages. First, it is semiconductor, with a direct wide band gap of 3.0 eV and a large excitation binding energy (60 meV). It is an important functional oxide, exhibiting excellent photo-catalytic activity. Secondly, TiO_2 is bio-safe and biocompatible, and can be used for biomedical applications without coating. With these unique characteristics, TiO_2 could be one of the most important nanomaterials in future research and applications.

This paper deals with the various aspects of surface modification of textiles using Titanuim dioxide nano-particles to impart multifunctionality to textiles. It addresses the synthesis and characterization of TiO_2 nano-particles obtained by merely heating TiCl4 at temperatures ranging from 100 °C to 120 °C, for the formation of TiO_2 particles from aqueous $TiCl_4$ hydrolysed by HNO_3. In order to evaluate the effects of the experimental conditions on the particle size and morphology, the temperature (100 or 120°C) and the concentration of HNO_3 were changed. The particles were then characterized, by evaluating their chemical composition through FTIR spectroscopy, their crystal nature through X-ray diffractometry and their shape and size via TEM microscopy. TiO_2 nano-particles were then applied to cotton and polyester/cotton fabrics in order to evaluate the anti-bacterial activity, self-cleaning and UV protection function in the treated textiles through standardized test procedures.

Materials and methods

Synthesis

A typical procedure for making nano-crystalline TiO_2 particles was as follows. TiCl4 was hydrolyzed by adding 1.0 M HNO3 drop-wise to prepare a stock solution, in which the concentration of titanium was 5.45M.During the reaction, the yellow cakes of TiO(OH)2 were formed first, which were then dissolved with added HNO3 solution to form an aqueous TiCl4 solution. This stock solution remained in a stable state without precipitation even after 6 months at room temperature. Finally, HNO_3 solution with concentration of 4.5M HNO_3 (synthesis 1) was added to the stock solution to prepare transparent aqueous TiCl4 solutions with various concentrations of Ti4+ for precipitation. This solution was poured into reactor and placed in the oven at the temperature of 100°C for precipitation. TiO_2 precipitates were repeatedly cleaned by distilled water and dried at 70 ◦C for 48 hr or more to obtain the final particles. For synthesis 2, the same steps are repeated with the 5.5M HNO_3 at 120º C (Moroni *et al.*, 2005; Perez-Maqueda *et al.*, 1998; Salvadori & Dei, 2001).

Fabric treatments

There were four types of fabric samples made with the two different compositions (100% cotton and 45/55 polyester/cotton blend and structures (woven and knitted). These fabrics were made using same yarns (100% cotton yarns and 100%

Table 1. Details of woven fabric samples

Details	Woven Fabric	
Blend composition	100% cotton	45/55% polyester/cotton
Structure	Plain weave	Plain weave
Width	48”	48”
Grams per Sq.Metres	130	130
Ends/inch	98	92
Picks/inch	72	78
Yarn count Warp & Weft	$1/40^s$	$1/40^s$

Sensura polyester yarns) by weaving/knitting. The details of their fabric constructions are given in Table 1 & 2. The two kinds of woven and knitted fabrics with different compositions were then dyed using the same dyestuff under identical conditions. The yarn counts and constructions were chosen so as to have a uniform weight per square metre of approximately 130 GSM. The constructions and the fabric weight are chosen so that these fabrics could be the ones used for shirting category.

Table 2. Details of Knitted fabric samples

Details	Knitted Fabric	
Blend composition	100% cotton	45/55% polyester/cotton
Structure	Pique	Pique
Grams per Sq.Metres	130	130
Yarn count	34^s	34^s
Gauge	26”	26”

The mass per unit surface was 130 g/m2 for cotton and polyester/cotton blend samples. The fabric samples were conditioned at constant relative humidity (65%) and temperature (21°C). The 100% cotton and 45/55 polyester/cotton blend samples (10 cm X 10 cm) were soaked for 10 min in a 2-propanol dispersion of TiO_2 nano-particles (5% w/w), under gentle magnetic stirring. The clothes were then squeezed to remove the excess dispersion, and dried in an oven at 130° C for 15 min at atmospheric pressure (dry heat). In order to evaluate the nano-particles adhesion to the textile fibers, the treated fabrics were washed five times according to a standard method (UNI EN ISO26330:1996). A model Electrolux automatic laundry machine (internal drum diameter 51.5 cm, internal drum depth 33.5 cm, heating capacity 5.4 kW) was used, and the washing cycles were performed at 30°C, with reference detergent without optical brighteners.

The drying step was carried out on a horizontal flat surface. The fabric specimens were tested before and after the washing cycles for TEM and UV spectrophotometry.

Functional testing of finished fabric samples

Functional testing of finished fabric samples: To investigate the antibacterial activity of woven and knitted fabrics impregnation was done with Titanium dioxide nano-particles in the padding mangle. Antibacterial test was carried out with Staphylococcus Aureus American type Culture collection No. 6538. Gram positive organism and Klebsiella Pneumoniae, American Type Culture Collection No. 4352, Gram negative organism. The Quantitative assessment was done by AATCC Test Method 100-2004 (2006). The percentage reduction of bacteria by the 100%cotton & 45/55% polyester/cotton treated fabrics is reported as R,

R = 100(B –A)/B. where

R = % reduction A = the number of bacteria recovered from the inoculated treated test specimen swatches in the jar incubated over 24 hours and B = the number of bacteria recovered from the inoculated treated test specimen swatches in the jar immediately after inoculation (at ‘0’ contact time).The fabric samples were tested and reported by CIRCOT, Mumbai. The results of the same are given in Table 3.

Functional testing of finished fabric samples:-stain release properties: The self cleaning properties of the treated fabrics were investigated by stain release test. The stain profiles of the untreated

Table 3. Details of antimicrobial activity testing

Titanium dioxide Nano particles	Fabric samples	Staphylococcus aureus	Klebsiella Pneumoniae
($4.5M\ HNO_3$ & $100^{\circ}C$) T1	Untreated Woven 100% cotton Woven 45/55%Polyester/Cotton Knitted 100% Cotton Knitted 45/55%Polyester/Cotton	No reduction 94% 93% 90% 89%	No reduction 94% 93% 91% 91%
($5.5M\ HNO_3$ & 120º C) T2	Untreated Woven 100% cotton Woven 45/55%Polyester/Cotton Knitted 100% Cotton Knitted 45/55%Polyester/Cotton	No reduction 97% 98% 95% 97%	No reduction 98% 99% 94% 94%

Table 4. Stain release rating for the different samples Test method: AATCC: 175

Sample particulars	Stain release values
Untreated 100%Cotton (woven)	3
Untreated 100%Cotton (Knitted)	2
Untreated P/C blend (woven)	4
Untreated P/C blend (Knitted)	3
100%Cotton (woven) with nano-TiO2 (T1)	7
100%Cotton (woven) with nano-TiO2(T2)	8
P/C blend (woven) with nano-TiO2(T1)	8
P/C blend (woven) with nano-TiO2(T2)	9
100%Cotton (knitted) with nano-TiO2 (T1)	6
100%Cotton (Knitted) with nano-TiO2(T2)	7
P/C blend (knitted) with nano-TiO2(T1)	7
P/C blend (Knitted) with nano-TiO2(T2)	8

The samples are exposed to direct sun light for 15 minutes before simple rinsing with water. Rating: 1.Severe staining (poor stain release) 10.No staining (the best stain release).

samples were compared to the ones collected from the same fabrics treated with TiO_2 nano-particles, and the effectiveness in self cleaning and stain release was compared with the AATCC ratings as per test procedure: 175-2004 (2006). Table 4 shows the results of Stain release rating for the different samples.

UV absorption properties: The UV-screen properties of the treated fabrics were investigated by absorption spectroscopy using a UV-Vis spectrophotometer (Perkin-Elmer Lambda 35, equipped with a 60-mm integrating sphere). The blank reference was air. The UV profiles of the untreated samples were compared to the spectra collected from the same fabrics treated with TiO_2 nano-particles, and the effectiveness in shielding UV radiation was evaluated by measuring the UV absorption, transmission and reflection. Each measurement is the average of four scans obtained by rotating the sample by 90º. The transmission data were used to calculate the UPF (ultraviolet protection factor) and the percent UV transmission, according to the following equations (Gambichler *et al.*, 2001; 2002): E (λ) is the relative erythemal spectral effectiveness, S (λ) is the solar spectral irradiance in W m-2 nm-1, and T (λ) is the spectral transmission of the specimen obtained from UV spectrophotometric experiments.

$$\mathrm{UPF} = \frac{\int_{\lambda_1}^{\lambda_2} E(\lambda)\, S(\lambda) * d\lambda}{\int_{\lambda_1}^{\lambda_2} E(\lambda)\, S(\lambda) * T d\lambda} \quad (1)$$

$$\text{Percent UV transmission} = \frac{\sum_{\lambda_1}^{\lambda_2} T(\lambda)}{(\lambda_2 - \lambda_1)} \quad (2)$$

The values of E (k) and S (k) were obtained from the National Oceanic and Atmospheric Administration database (NOAA). The UPF value was calculated for UV-A in the range 315-400 nm, and for UV-B in between 295 and 315 nm. The percent UV transmission, obtained from Eq. 2, was determined for UV-A and UV-B radiation from the transmission spectra of the fabric samples. Table 5 gives the values of UPF for the different samples for UV-A (315-400 nm) and UV-B (295- 315 nm) radiation.

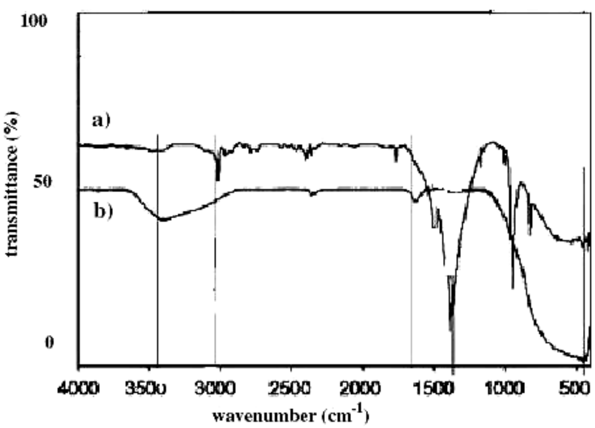
Physical and physico-chemical characterization

The chemical composition of the synthesized materials was checked by FTIR spectroscopy with a Biorad FTS-40 spectrometer. The crystallinity was determined by XRD using a Bruker D8 Advance Xrays Diffractometer equipped with a Cu Ka (k = 1.54 A °) source (applied voltage 40 kV, current 40 mA). About 0.5 g of the dried particles were deposited as a randomly oriented powder onto a Plexiglass sample container, and the XRD patterns were recorded at angles between 20° and 80°, with a scan rate of 1.5°/min. The crystallite domain diameters (D) were obtained from XRD peaks according to the Scherrer's equation (Jenkins & Snyder, 1996).

$$D = \frac{0.89 * \lambda}{\Delta W * \cos\theta}$$

Where λ is the wavelength of the incident X-ray beam, θ is the Bragg's diffraction angle and ΔW is the width of the X-ray pattern line at half peak-height in radians. The shape and size of the particles were obtained through TEM, using a Philips EM201C apparatus operating at 80 kV. The samples for TEM measurements were placed on carbon-coated copper grids. The samples for TEM measurements were prepared from much diluted dispersions of the particles in 2-propanol. The TiO_2-treated fabrics were analyzed through scanning electron microscopy (SEM), using a Stereoscan S360 Oxford-Cambridge. The samples were previously coated with a thin layer of gold deposited by sputtering under vacuum.

Fig. 1. FTIR spectrum of TiO_2 nano-particles obtained from (a) synthesis 1 and (b) synthesis 2



Results and discussions

FTIR & XRD

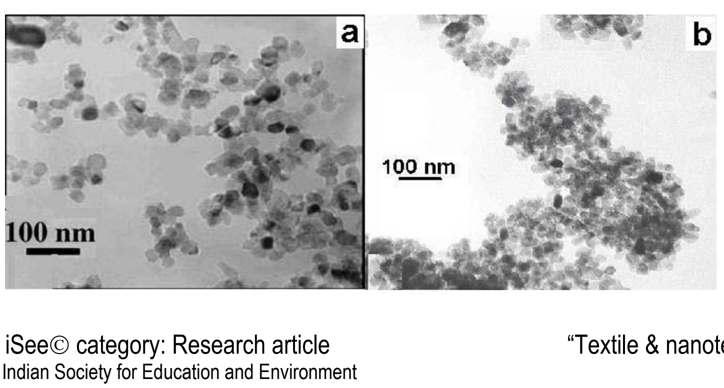
Fig.1 shows the FTIR spectra of the synthesized nanomaterials. The spectrum of the material obtained from synthesis 1 (4.5M HNO_3, at 100°C; Fig. 1a) clearly shows the The wave number of 480 cm_1 in Fig. 2(a) indicates the absorption band for Ti-O bond. The peaks at 3,450 and 2,350 cm-1 indicate the presence of -OH and C=O residues, probably due to atmospheric moisture and CO2 respectively. The same spectrum was obtained from the nanomaterial produced via synthesis 2 (5.5M HNO_3, at 120°C, see Fig. 1b). TEM images of the TiO_2 nano-particles are shown in Fig. 2. Nano-particles are nearly spherical and quite monodisperse. However, there are some larger aggregates in the sample obtained from synthesis 1 (Fig. 2a), because of the high surface energy of TiO_2 nano-particles that results in aggregation, especially when the synthesis is carried out in an aqueous medium. Particles obtained from synthesis 2 are more monodisperse and isolated than the particles obtained from synthesis 1.

Fig.3 shows the XRD spectra of the TiO_2 nanomaterials. The spectra show well-defined peaks typical of TiO_2 in the crystal structure of titania. This indicates crystallinity of the synthesized solids. Traditionally, the broadening of the peaks in the XRD patterns of solids is attributed to particle size effects (Moroni *et al.*, 2005). The mean crystallite size of a powder sample was estimated from the full width at half-maximum of the diffraction peak according to the Scherrer equation. An interesting feature is that the peaks from synthesis 2 (Fig. 3b) are sharper than the peaks from synthesis 1 (Fig. 3a). This result suggests that the particles obtained from synthesis 2 are smaller than the particles obtained from synthesis 1, as confirmed by TEM micrographs (Fig. 2), and reflects the effects due to the experimental conditions on the nucleation and growth of the crystal nuclei. The particles size calculated on the basis of Scherrer's equation agrees quite well with the value obtained through TEM micrographs.

Electron microscopy

The surfaces of the treated fabrics were observed by SEM microscopy. In Fig. 4, SEM micrographs show the nanoscaled TiO_2 particles on polyester/cotton (a-before washing) and (b-after washing) samples. The nano-particles are well dispersed on the fiber surface in both cases, although some aggregated nano-particles are still visible. The particles size plays a primary role in determining their adhesion to the fibers: it is reasonable to expect that the largest particle agglomerates will be easily removed from the fiber surface, while the smaller particles will penetrate deeper and adhere strongly into the fabric matrix. SEM images (Fig. 4b) confirm that the large agglomerates are removed from the textile surface

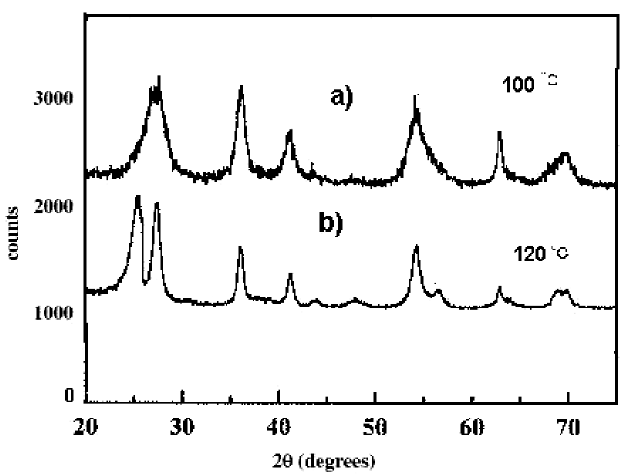
Fig. 2. TEM micrographs on the materials obtained from synthesis 1 (a) and synthesis 2 (b) after three peptizations.



after washing. Instead, although the nano-particles are not covalently grafted to the fabric materials, preliminary gravimetric essays show that more than 50% of their initial amount remains bound to the fibers surface after washing.

Antibacterial activity of fabrics: The woven cotton fabric treated with 1.0 % Titanium dioxide nano-particles (synthesis 1) solution shows better antibacterial property (93%,94%) when compared to the knitted cotton fabric (90%,91%) for both the types of bacteria respectively. Similarly, the woven 45/55% polyester/cotton fabric treated with 1.0 % Titanium dioxide nano-particles (synthesis 1) solution shows better antibacterial property(93%,93%) when compared to the knitted 45/55% polyester/cotton fabric (89%,91%). Fabrics treated with Titanium dioxide nano-particles (synthesis 2) show antibacterial property to a much higher extent than the Titanium dioxide nano-particles (synthesis 1). The woven fabrics show much higher antibacterial activity (97%, 98%) when compared to the knitted fabrics (95%, 94%) treated with synthesis 2. Between the two different sizes of nano-particles synthesized in two different synthesis conditions 1 & 2 , fabrics treated with Titanium dioxide (prepared by synthesis 2) are better than fabrics treated with 1.0 % Titanium dioxide (prepared by synthesis 1) in respect of all the types of the fabrics. The antibacterial activities of all the treated samples remained at the same level even after repeated washings up to 45 washes.

Fig. 3. XRD patterns of the material obtained from (a) synthesis 1; (b) synthesis 2.



Self cleaning activity of fabrics: The results of the stain release testing are given in the form of Table.4. From that it can be seen that the untreated 100% cotton fabric has got the lowest stain release property as the knitted fabric is bulkier than the stiff woven fabric. The untreated 100% cotton woven fabric and untreated P/C blended knitted fabric have the same stain release property as seen from their ratings. The untreated P/C blended woven fabric has the best stain release property amongst all the untreated fabrics. The blended fabrics have better stain release property than the 100% cotton fabrics mainly because of the hydrophobic nature of the polyester component.

When we compare the ratings of untreated 100% cotton woven fabric with that of the 100%Cotton (woven) with TiO_2, it can be seen that there is a substantial increase in stain release rating by 4/5 units (3 to 7, 8 by T1 and T2 respectively). When a similar comparison is done for the 100% cotton knitted fabric, the same trend is equally maintained here. (2 to 6, 7). In the case of P/C blend woven fabric, the increase in stain release rating is identical between the untreated to treated category. (4to8 for T1 and 4 to9 for T2). An identical trend is followed in the P/C blended knitted fabric between the untreated to treated category (3 to7 and 3 to 8). From these results, we can find that the improvement in stain release rating is uniform for both the 100% cotton and blended fabrics and also it is the same for both the types of the fabrics viz. woven and knitted. From this, it can be concluded that the improvement in stain release is because of the nano-topological application of TiO_2, the effect is uniform irrespective of the substrate variations either due to the composition or due to the structure. With the smaller size of the nano-particles, (as in the case T2 when compared with T1), there is an improvement of the self-cleaning function of the Titanium dioxide.

Sunscreen activity of fabrics: The solar UV radiation is actually composed of UVA (400-315 nm), UV-B (315-290 nm) and UV-C (290-200 nm). These radiations are present in natural terrestrial sunlight in different amounts, due to the filtering activity of the upper atmosphere, and to local conditions (latitude, altitude, clouds, etc.). UV-C and most of UV-B are filtered by the ozone layer. UV spectra were performed on the untreated and treated fabrics, by measuring the absorbance, transmission and reflection. Untreated cotton does not absorb UV radiation while untreated polyester strongly absorbs in the UV region between 200 and 300 nm. The application of nanosized TiO_2 particles on the cotton and polyester/cotton blended fabrics increases the absorption of UV light over the entire investigated UV spectrum.

Fig. 4. SEM images of TiO_2 nano-particles from synthesis 1 on: P/C blend (a) before washing, (b) after washing.

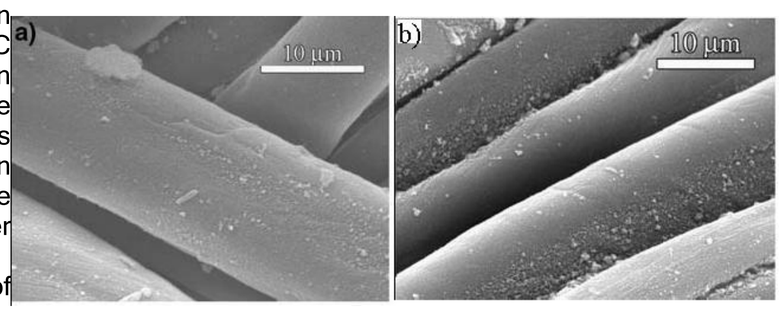


Table 5. UPF for the different samples for UV-A (315-400 nm) and UV-B (295-315 nm) radiation.

Sample	UPF values	
Untreated 100%Cotton (woven)	1.05	1.07
Untreated 100%Cotton (Knitted)	0.98	1.00
Untreated P/C blend (woven)	2.30	5.50
Untreated P/C blend (Knitted)	1.80	4.40
100%Cotton (woven) with T1	4.92	5.23
100%Cotton (woven) with T2	8.45	10.29
100%Cotton (Knitted) with T1	4.00	4.70
100%Cotton (Knitted) with T2	8.80	9.50
P/C blend (woven) with T1	10.23	15.76
P/C blend (woven) with T2	11.80	16.20
P/C blend (Knitted) with T1	9.62	14.53
P/C blend (Knitted) with T2	11.10	15.87

The values of the ultraviolet protection factor (UPF) and the percent of UV transmission for UV-A and UV-B ranges were calculated according to Eqs. 1 and 2, respectively, and are listed in Table 5. The data reflect the higher protection against UV radiation provided by the TiO_2-treated fabrics, particularly for the cotton samples loaded with Titanium dioxide nano-particles synthesized according to procedure 2, while in the case of P/C blends the nano-particles produced with the two different methodologies gave comparable results.

Although the calculated UPF are significantly lower (for 100% cotton fabrics) than the standard values required for classifying the clothing as "excellent" in UV-shielding, these results confirm the protection against UV radiation produced by the treatment with nanosized TiO_2 on the fabrics. Higher values of UV absorbance were obtained when TiO_2 nano-particles from synthesis 2 were applied both on 100% cotton and polyester/cotton blends. It can be seen that in all cases, the woven fabrics showed better UV blocking properties than the knitted fabrics (for both 100% cotton and Polyester/cotton blends. That is, woven Polyester /cotton blends showed better UV absorption characteristics than the knitted fabric of the same composition. A similar trend can be seen in the case of 100% cotton fabrics. Polyester /cotton blends showed better UV absorption characteristics than 100% cotton samples because of the better UV absorption characteristics of the polyester component in the blend. The application of nanosized TiO_2 on polyester/cotton blended fabric increases UV light absorbance in region between 300 and 400 nm when compared to the untreated blended fabric. The results imply that the effectiveness in shielding UV radiation is due to the UV absorption capacity of TiO_2 nano-particles on the fabrics surface.

Conclusions

We reported the synthesis of Titanium dioxide nano-particles through a hydrolytic reaction starting from Titanium tetra chloride and HNO_3 at different temperatures at concentrations. The reaction with higher HNO_3 concentration at 120ºC results in the formation of smaller nano-particles with respect to the reaction carried out with lower HNO_3 concentration at 100ºC. In both cases, the nano-particles appear to be nearly spherical and with a quite narrow size range. Nano-particles were analyzed through electron microscopy, X-ray diffraction and FTIR spectroscopy. The homogeneous phase reaction processes offer a valid alternative for an industrial-scale production of TiO_2 nano-particles for many applications. The antibacterial activity performance of TiO_2 nano-particles (arising out of its photo-catalytic activity), can be efficiently transferred to fabric materials through the application of TiO_2 nano-particles on the surface of both woven and knitted cotton and polyester/cotton blended fabrics. The woven fabrics are more receptive to antibacterial finishing than the knitted fabrics. Similarly, 100% cotton fabrics are better textile substrates for antibacterial finishing than the polyester/cotton blended fabrics. The antibacterial tests indicate a significant and considerable increment of the antibacterial activity in the TiO_2-treated fabrics. Such results can be exploited for the commercialization in the case of consumer textiles. The performance of TiO_2 nano-particles as photo-catalytic oxidizing agent can be efficiently transferred to fabric materials through the application of TiO_2 nano-particles on the surface of cotton and polyester/cotton blended fabrics. The self-cleaning and stain release tests indicate a significant increment of the self cleaning activity in the TiO_2-treated fabrics. From the study conducted, it can be concluded that there was substantial increase in self cleaning or stain release property of the nano TiO_2 treated fabrics. It could also be seen that the self cleaning effect obtained by the nano-surface modification is independent of the nature of the substrate [material composition (cotton/blend) / fabric structure (woven/knitted)]. It has been seen that the intensity of self cleaning changes due to the changes in the size characteristics of the TiO_2 nano-particles. The performance of TiO_2 nano-particles as UV-absorbers can be efficiently transferred to fabric materials through the application of TiO_2 nano-particles on the surface of cotton and polyester/cotton blended fabrics. The UV tests indicate a significant increment of the UV absorbing activity in the TiO_2-treated fabrics. Such result can be exploited for the protection of the body against solar radiation and for other technological applications. Thus, it could be seen that the 100%cotton and polyester/cotton fabrics treated with nano TiO_2 had various functionalities, such as antimicrobial activity, self-cleaning and UV protection functions.

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