UV protection and self-cleaning finish for cotton fabric using metal oxide nanoparticles

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Ultra-violet protection and self-cleaning action of nano zinc oxide (ZnO) and titanium di-oxide (TiO2) with acrylic binder has been assessed on the cotton fabric using pad-dry-cure method. Different precursors, such as zinc acetate and titanium tetrachloride have been used to synthesize nanoparticles. Zinc acetate is synthesized into nanoparticle by wet chemical technique and titanium tetrachloride is synthesized into nanoparticle by sol-gel technique. The synthesized nanoparticles are then characterized by using particle size analyzer, X-ray diffractometry, fourier transform infra-red spectroscopy and scanning electron microscopy. The nano ZnO and TiO2 finished cotton fabrics are tested for ultraviolet protection factor, self-cleaning action and physical properties. The wash fastness of zinc oxide and titanium di-oxide nano finished cotton fabrics for 5th, 10th, 15th and 20th washes is assessed. The self-cleaning activity is assessed for 12, 24 and 48 h duration by exposing 6% of coffee stain on the specimen fabrics to sunlight. The ZnO nanoparticle is found to be 9 nm using zinc acetate as precursor and TiO2 nanoparticle is found to be 35 nm by titanium tetra chloride as precursor. In the case of ultraviolet protection function it is found that the fabrics treated with 35 nm nanoparticles exhibit better ultraviolet protection factor values than the fabrics treated with 9 nm nanoparticles. The smaller nanoparticles (9 nm) show better results with regard to self-cleaning. The washing durability of the imparted function is found to be in between 28 washes and 48 washes for ultraviolet protection.

Keywords: Pad-dry-cure method, Self -cleaning finish, Titanium di-oxide, Ultraviolet protection, Wash fastness, Zinc oxide

1 Introduction

Nanotechnology has been well exploited for commercial applications of various products. In textiles also, nanotechnology has gained its importance in processing and finishing of textile products imparting enhanced and/or novel properties1-4. Functional textiles with the properties, such as anti-microbial, ultraviolet protection, self-cleaning activity, anti-radiation, insect resistance and fragrance have attracted much attention in recent years5. Thus, today a wide range of nanoparticles and nano structures are immobilized on fibres, which impart new properties to the final clothing products6. One of the approaches to improve the UV blocking property, anti-microbial activity and self-cleaning activity of fabrics is to coat the surface with nanoparticles7,8. Surface coating of textiles with nano-sized particles of metal oxides has gained more importance presently due to their specific advantages. Multi- functional properties like UV blocking, antibacterial, soil release and self-cleaning are achieved through nano coating. Both TiO2 and ZnO in nanoparticles form are capable of imparting self-cleaning property to textiles. Zinc oxide, titanium dioxide, zinc sulphide, tungsten oxide, strontium titanate and hematite are photo catalysis materials9. In a heterogeneous photo-catalytic system, semiconductor particles which are in close contact with a liquid or gaseous reaction medium, when exposed to light gets to excited state and initiate subsequent reaction like redox and molecular transformations. TiO2 is one such a material which exists in three crystalline forms, namely rutile, anatase and brookite10,11. Nano finishing is concerned with the control and processing technologies of coating of nanoparticles of TiO2 and ZnO. One of the important potential areas of application of semiconductor oxides such as TiO2 and ZnO is UV rays blocking. It was observed that the nano-sized TiO2 and ZnO were more efficient in absorbing and scattering UV radiation than their conventional size and were thus better able to block UV. This is due to the fact that nanoparticles have a larger surface area per unit mass and volume than the conventional materials, leading

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to the effectiveness of blocking UV radiation. A thin layer of TiO$_2$ and ZnO is formed on the surface of the treated cotton fabric which provides excellent UV protection. TiO$_2$ is a semiconductor material which on illuminating with ultraviolet band gap light becomes a powerful radix catalyst capable of killing bacteria$^{12}$. Nano ZnO provides effective photo catalytic properties once it is illuminated by light and so it is employed to impart anti-bacterial and self-cleaning properties to textiles. The functional performances in textiles required by consumer include antibacterial activity, UV protection, self-cleaning and stain resistance, which allows partially decomposed stain/dirt residues on the surface to be washed away easily$^{13,14}$. This radiation is composed of three types namely UV-A, UV-B and UV-C ranging respectively between 320 nm and 400 nm, between 290 nm and 320 nm, and between 100 nm and 290 nm. The UV-C radiation is completely absorbed by the ozone layer. However, the UV-A and UV-B reach the earth’s surface and cause series of health problems, particularly skin cancer, sun burn, photo-aging, acne, photo toxic reaction to drug, skin reddening, eye damage and DNA damage$^{15,16}$. Photocatalytic titanium dioxide is exposed to sunlight, and it exhibits super-hydrophilic behaviour, which allows partially decomposed stain/dirt residues on the surface to be washed away easily$^{17,18}$. In this work, two sets of precursors such as zinc acetate and titanium tetrachloride have been synthesized into nanoparticles by wet chemical and sol-gel technique respectively. The synthesized nanoparticles/sols are then characterized using PSA, XRD, FTIR and SEM. These nanoparticles are then applied on to the cotton fabric samples using a pad-dry-cure method. Then, the treated fabric samples are tested for the functions of UPF and self-cleaning activity. The treated samples were also tested for the durability of the effect after repeated washes.

2 Materials and Methods

2.1 Materials

The bleached cotton plain woven fabric, having the specifications 40 Ne (14.8 tex) count in both warp and weft, 38 ends/cm & 38 picks/cm cloth set and 118 gsm fabric mass was purchased from the market and used. The precursors zinc acetate (AR grade) was procured from M/s Fisher Scientific, Thermo electron LLS India (P) Ltd, Mumbai and titanium tetrachloride (AR grade, molecular mass 189.679 g/mole, density 1.726 g/cm$^3$) was procured from M/s. Hi-media Laboratories (P) Ltd, Mumbai. Lissapol-N non-ionic was used as surfactant for dispersion of nanoparticles in acrylic binder (Texacryl binder SLN). De-ionized water was used for the hydrolysis of zinc oxide (ZnO) and titanium dioxide (TiO$_2$) and for preparation of solution.

2.2 Methods

Two different precursors namely zinc acetate and titanium tetra chloride were used for synthesis of ZnO and TiO$_2$ nanoparticle by adopting wet chemical and sol-gel technique.

Synthesis of ZnO Nanoparticle (Procedure I)

Synthesis of ZnO nanoparticles was done using zinc acetate precursor dissolved in 120 mL of H$_2$O$_2$ (3%, v/v aqueous solution). The pH of solution was adjusted at 10.0 with dilute ammonia. The resultant solution was refluxed at 100 °C for 12 h. The ZnO nano crystals formed at this stage were cooled to room temperature and subjected to repeated washing and centrifuging (20 min at 1100 rpm). The material was dried at 80 °C for 3 h and ZnO nano powder was produced by using micro grinding equipment. The yield was found to be 36%.

Synthesis of TiO$_2$ Nanoparticle (Procedure II)

Titanium tetrachloride (TiCl$_4$) was hydrolysed by adding 1.0M ammonia 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 ammonia solution to form an aqueous TiCl$_4$ solution. This stock solution remained in a stable state without precipitation even after 5 months at room temperature. Finally, ammonia solution with a concentration of 4.5M HNO$_3$ was added to the stock solution to prepare transparent aqueous TiCl$_4$ solutions with various concentrations of Ti$^{4+}$ for precipitation. This solution was poured into reactor and placed in oven at 90 °C for precipitation. TiO$_2$ precipitates were repeatedly cleaned by distilled water and dried at 80 °C for 6 h.

2.3 Characterization of Nanoparticles

The nano particles were characterized for their size, shape, chemical and physical structures using the following techniques.
**X-ray Diffraction (XRD)**

The crystallinity of the nanoparticles was determined by XRD using a SHIMADZU – XRD 6000 advanced X-rays Diffractometer equipped with a Cu Kα radiation, \( \lambda = 1.5406\AA \), applied voltage 30 kV and current 30 mA. The dried nanoparticles were deposited as a randomly oriented powder onto a plexiglass sample container, and the XRD patterns were recorded at angles 10° - 80°, with a scan speed of 5°/min, sampling pitch of 0.02° and preset time of 0.24 s. The crystallite domain diameters (D) were obtained from XRD peaks according to the Debye-Scherrer’s equation, as shown below:

\[
D = \frac{0.99 \times \lambda}{\Delta W \cos \theta}
\]

where \( \lambda \) is the wavelength of the incident X-ray beam (1.5406 Å for the Cu Kα); \( \theta \), the Bragg’s diffraction angle; and \( \Delta W \), the full width of the X-ray pattern line at half peak-height in radians.

**Fourier Transform Infrared Spectroscopy (FTIR)**

SHIMADZU - FTIR 8400S with a spectral range of 4000 - 400 cm\(^{-1}\) was used. Spectra were collected with a resolution of 0.9-1.0 cm\(^{-1}\) and given as ratio of 200 single beam scans to the same number of background scans in pure KBr (IR grade supplied by Alrich). KBr was ground to fine powder and mixed with samples [2% weight by weight (w/w)].

**Particle Size Analysis (PSA)**

The size distribution of nanoparticles was determined using particle size analyzer. The size of the nanoparticles was obtained through PSA, using a Sympatec GmbH, NANOPHOTON (0143 P). The conditions were nanoparticles measuring duration 150.10 s, temperature 27º C, laser power 75% and measuring range 1 - 1000 nm.

**Scanning Electron Microscopy (SEM)**

The fabric samples treated with the nanoparticles were mounted on a specimen stub with double-sided adhesive tape, coated with gold in a sputter coater and finally examined using a scanning electron microscope (JEOL - JSM-6360).

2.4 Coating of Nanoparticles on Fabric

Before coating, the fabric was dried at 100 °C for 5 min in oven to remove the moisture content. The cotton fabric was immersed for 1 min in aqueous nano-solution with 0.5% acrylic binder in padding mangle.

Fabrics were treated with the nano solution at different concentration levels such as 1.0, 1.5 and 2.0%. Zinc oxide nano solution and titanium dioxide nano solution were separately coated on the fabric by pad-dry-cure method. The nanoparticle was uniformly coated using laboratory padding mangle at speed of 15 m/min with pressure of 15 kg/cm\(^2\). After padding the fabric was dried at 70 °C for 5 min and cured at 120 °C for 3 min using curing chamber.

2.5 Ultraviolet Protection Factor (UPF)

**In-vitro** method was used to assess the UV protection of the cotton fabric as per the AATCC-183 (2004) test method. It measures the transmittance or blocking of UV radiation through fabrics by UV-VIS Spectrophotometer (Varian, Cary 5000). The UV profiles of the untreated samples were compared with the spectra collected from the same fabrics treated with nanoparticles, and the effectiveness in shielding UV radiation was evaluated by measuring the UV protection, transmission and reflection. Each measurement is the average of four scans obtained by rotating the sample by 90°. The transmission data was used to calculate the UPF, according to the following equation:

\[
\text{UPF} = \frac{\sum_{\lambda=280}^{400} E\lambda \times S\lambda \times \Delta\lambda}{\sum_{\lambda=280}^{400} (E\lambda \times S\lambda \times T\lambda \times \Delta\lambda)} \quad \ldots(2)
\]

where \( E\lambda \) is the relative erythemal spectral effectiveness; \( S\lambda \), the solar spectral ir-radiance in Wm\(^{-2}\) nm\(^{-1}\); \( T\lambda \), the spectral transmission of specimen obtained from UV spectrophotometer experiments; and \( \Delta\lambda \), the band width in nm.

2.6 Self-cleaning Action

The self-cleaning action of the ZnO and TiO\(_2\) treated cotton fabric was investigated by exposing the samples with adsorbed coffee stain to visible radiation. Measured quantity of 6% coffee solution was introduced on the cotton fabric and was allowed to spread. One half of each stain on the fabric was exposed to sun light for 12-48 h, while the other half was covered with a black paper to prevent its radiation from sunlight. The exposed part of the stain was compared with that of the covered part for self-cleaning action. Premier colour scan SS 5100ASpectrophotometer was used to measure the photo degradation of coffee stain. The self-
cleaning action was quantified by comparing K/S values of the exposed and un-exposed portions of the same stain as shown below:

\[
\% \text{ Decrease in } K/S \text{ of exposed part } = \frac{(K/S)_{\text{unexposed}} - (K/S)_{\text{exposed}}}{(K/S)_{\text{unexposed}}} \times 100 \quad \ldots(3)
\]

where K is the absorption; and S, the scattering.

2.7 Washing Fastness Test

The wash fastness of ZnO and TiO\(_2\) nanoparticles coating on fabric was tested by AATCC method 61(1996) test no.2A using LEF Atlas launder-O-meter instrument.

2.8 Physical Testing of Fabrics

The physical properties of the 100% cotton woven fabric such as fabric mass (ASTM D3776:2009), thickness (ASTM D1777:2007), crease recovery (AATCC 66:2008), drape co-efficient (ASTM D6193:92(2004)), tensile strength and elongation (ASTM D 5035:2006), air permeability (ASTM D737:2008), tearing strength (ASTM D1424:2009) and whiteness index (ASTM E 313 : 1998) of both untreated and treated samples were evaluated after conditioning the specimens at 65% RH and 27±2°C for 24 h by bringing them to approximate moisture equilibrium in the standard atmosphere for preconditioning textiles as directed in Practice D 1776 in an environmental chamber (ASTM 2008).

3 Results and Discussion

3.1 Characterization of ZnO and TiO\(_2\) Nanoparticles

The results analysis and interpretations of the various tests have been used to characterize the ZnO (Z\(_1\)) and TiO\(_2\) (T\(_1\)) nanoparticles synthesized. These analytical tests include particle size analyzer (PSA), X-ray diffraction (XRD), fourier transform infrared spectroscopy (FTIR) and scanning electron microscopy (SEM).

3.1.1 Particle Size Analysis (PSA)

The particle size distribution of nano ZnO and TiO\(_2\) synthesized was determined using PSA and are shown in the Figs 1 (a) and (b). Zinc oxide nanoparticle of the size 9 nm (Z\(_1\)) is obtained from synthesis of zinc acetate as a precursor at 100 °C temperature and titanium dioxide nanoparticle of the size 35 nm (T\(_1\)) is obtained from the synthesis of titanium tetrachloride as a precursor at 30 °C temperature. The density distribution for the maximum peak is 1.4.

3.1.2 X-Ray Diffraction (XRD)

The X-ray diffraction (XRD) spectogram of ZnO nanoparticles synthesized using zinc acetate shows distinctive ZnO peaks at 37.11 (100), 43.31 (101), 62.46 (220), 66.23 (110) and 75.0 (311) respectively. The X-ray diffraction (XRD) spectogram of TiO\(_2\) nanoparticles synthesized using titanium tetrachloride shows four distinctive TiO\(_2\) peaks at 29.91(101), 47.87(111), 56.94 (200) and 74.79 (102) respectively. The exhibited peaks similar to those reported for ZnO and TiO\(_2\) suggest the formation of ZnO and TiO\(_2\) nanoparticles in anatase form. The XRD pattern for ZnO and TiO\(_2\) nanoparticles obtained shows much sharp peaks. This means that the Z\(_1\) and T\(_1\) nanoparticles are more crystalline.

3.1.3 Fourier Transform Infrared Spectroscopy (FTIR)

The FTIR spectra clearly show the ZnO and TiO\(_2\) absorption band near 440 cm\(^{-1}\) and 482 cm\(^{-1}\). The FTIR spectra of untreated sample do not show any peak at 440 cm\(^{-1}\) and 482 cm\(^{-1}\), which confirms the presence of ZnO and TiO\(_2\) in the treated samples. The peaks at 3,450 and 2,350 cm\(^{-1}\) and 3,000 and 1,200 cm\(^{-1}\) indicate the presence of –OH and C=O residues, probably due to atmospheric moisture and CO\(_2\) respectively.

![Fig. 1—Particle size analysis of (a) ZnO nanoparticles (Z\(_1\)) and (b) TiO\(_2\) nanoparticles (T\(_1\))](image-url)
3.1.4 Scanning Electron Microscopy (SEM)

Figure 2 (a) shows the SEM image of untreated 100% cotton woven fabric. Figures 2(b) and (c) show the nano-scaled ZnO and TiO$_2$ nanoparticles on cotton fabric samples. The nanoparticles are well dispersed on the fibre surfaces in both cases and are finely dispersed and embedded. From Fig. 2(b) it is possible to observe that Z$_1$ type nanoparticles are more uniformly distributed over the fabric surface than fabric treated with T$_1$ type nanoparticles [Fig. 2(c)], where uneven and agglomerated patchy coating is seen due to larger nanoparticles size. The particles size plays a primary role in determining their adhesion to the fibres. It is reasonable to expect that the larger particle agglomeration will be easily removed from the fibre surface, while the smaller particles will penetrate deeper and adhere strongly into the fabric matrix.

3.2 Ultraviolet Protection Factor (UPF)

Table 1 shows the values of UPF for both the fabrics against UV-A (320–400 nm) and UV-B (290–320 nm) radiations. The results show that the UPF values of the treated fabric has better UV protection than the untreated fabrics. T$_1$ type of sample shows better UPF value than the Z$_1$ type of sample. According to Raleigh’s scattering theory, the scattering of light is inversely proportional to the fourth power of wavelength. The optimum particle size for scattering the radiation is calculated as 15 - 40 nm. This clearly indicates that nanoparticles nearer to the range of 20 - 40 nm exhibit better scattering of UV rays. Hence, the UV protection factor value for T$_1$ is more than that for Z$_1$.

3.2.1 UPF Value for Repeated Washes

The test results of the UV protection testing for the first use, and after 5$^{th}$, 10$^{th}$, 15$^{th}$ and 20$^{th}$ washes are given in Table 2. The results show that the UPF values of all the treated fabrics have better UV protection as compared to the untreated fabric. The results indicate that the efficiency of finish gradually reduces with the increase in number of washes.

It is clear that the predicted number of washes for (to reach untreated UPF value of 1.6) Z$_1$ type of nanoparticles treated fabrics are found to be 48 for 1, 1.5 and 2% concentration levels and that for T$_1$ type of nanoparticles treated fabrics are found to be 28 for 1, 1.5 and 2% concentration levels.

<table>
<thead>
<tr>
<th>Treated sample</th>
<th>Control sample</th>
<th>UPF values</th>
<th>UV-A</th>
<th>1%</th>
<th>1.5%</th>
<th>2%</th>
<th>UV-A</th>
<th>1%</th>
<th>1.5%</th>
<th>2%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z$_1$</td>
<td>1.54</td>
<td>1.6</td>
<td>30.62</td>
<td>32.6</td>
<td>33.8</td>
<td>31.83</td>
<td>33.7</td>
<td>35.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T$_1$</td>
<td>1.54</td>
<td>1.6</td>
<td>35.8</td>
<td>28.6</td>
<td>39.0</td>
<td>36.6</td>
<td>38.7</td>
<td>39.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. 1.5 and 2% are the concentrations of the respective nanoparticles in terms of on weight of material.
### Table 3—Linear regression equation for Z1 and T1 nanoparticle samples

<table>
<thead>
<tr>
<th>Nanoparticles</th>
<th>Concentration %</th>
<th>Equation</th>
<th>R² value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z₁</td>
<td>1</td>
<td>y = -0.666x + 33.06</td>
<td>0.879</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>y = -0.708x + 35.02</td>
<td>0.881</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>y = -0.738x + 36.54</td>
<td>0.878</td>
</tr>
<tr>
<td>T₁</td>
<td>1</td>
<td>y = -1.308x + 38.16</td>
<td>0.963</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>y = -1.398x + 40.74</td>
<td>0.962</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>y = -1.428x + 41.52</td>
<td>0.964</td>
</tr>
</tbody>
</table>

Table 3 shows a good correlation in Z₁ and T₁ nanoparticles for ultraviolet protection factor having R² value from 0.878 to 0.964 with the equation from y = -0.738x + 36.54 to y = -1.428x + 41.52; this shows a insignificant correlation among 1, 1.5 and 2% concentration levels.

#### 3.2.2 Evaluation of Self-cleaning Action of ZnO and TiO₂ Treated Fabric

The self-cleaning property of ZnO treated cotton textile is based on the highly oxidative intermediates generated at the cotton surface. The K/S values (absorption to scattering coefficient) of exposed and unexposed parts of the samples were measured after 12, 24 and 48 h. The comparison of K/S values of different test sample is shown in the Fig. 3. The percentage decrease in K/S value for the exposed samples in comparison to unexposed sample is measured to quantify the self-cleaning activity. The rate of degradation of coffee stain is faster in first 12 h of exposure. In the nanoparticle treated samples, no visual deterioration in the properties of cotton fabric is observed up to 48 h of exposure. The nanoparticles of smaller size have more surface area and exhibits superior self-cleaning action. The smaller nanoparticles of Z₁ (9 nm) shows better self-cleaning activity then T₁ (35 nm). The sample treated with Z₁ nanoparticles shows a better self-cleaning activity then that treated with T₁ nanoparticles.

#### 3.3 Physical Properties of Untreated and Treated Fabrics

The physical properties of untreated, ZnO treated and TiO₂ treated cotton fabrics were analyzed as per AATCC and ASTM standard methods and their test results are given in Table 4. The textile fabrics as such has the variability in all the basic properties such as fabric mass, thickness, crease recovery, drape coefficient, tensile strength, elongation, air permeability and tearing strength. This is due to the inherent nature of variation in EPI, PPI, cover factor, number of fibre in the yarn cross-section, and variation in the yarn thickness. Therefore, the observed variation in the measured fabric properties such as mechanical properties, physical properties can be attributed for such inherent variations. Further, a slight reduction in whiteness of treated fabric is observed, mainly due to the added ammonia.

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**Fig. 3**—Percentage decrease in K/S values of coffee stained cotton fabrics

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**Table 2—UPF value of fabrics for repeated washes**

<table>
<thead>
<tr>
<th>Treated sample</th>
<th>Untreated sample</th>
<th>Before wash</th>
<th>After 5 wash</th>
<th>After 10 wash</th>
<th>After 15 wash</th>
<th>After 20 wash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z₁</td>
<td>1%</td>
<td>1.6</td>
<td>31.2</td>
<td>33.1</td>
<td>34.5</td>
<td>30.2</td>
</tr>
<tr>
<td></td>
<td>1.5%</td>
<td>0.678</td>
<td>0.570</td>
<td>0.604</td>
<td>0.652</td>
<td>0.583</td>
</tr>
<tr>
<td>T₁</td>
<td>1%</td>
<td>36.2</td>
<td>39.4</td>
<td>32.2</td>
<td>34.4</td>
<td>35.0</td>
</tr>
<tr>
<td></td>
<td>1.5%</td>
<td>0.442</td>
<td>0.579</td>
<td>0.548</td>
<td>0.485</td>
<td>0.561</td>
</tr>
</tbody>
</table>
Table 4—Physical properties of untreated, ZnO treated and TiO$_2$ treated cotton fabrics

<table>
<thead>
<tr>
<th>Property</th>
<th>Untreated fabric</th>
<th>$Z_t$</th>
<th>$T_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabric mass, g/m$^2$</td>
<td>118±2.065</td>
<td>118.4±1.847</td>
<td>119.4±2.101</td>
</tr>
<tr>
<td>Fabric thickness, mm</td>
<td>0.168±0.003</td>
<td>0.174±0.004</td>
<td>0.176±0.004</td>
</tr>
<tr>
<td>Crease recovery angle, deg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warp</td>
<td>68.5±1.200</td>
<td>70.5±1.332</td>
<td>71.0±1.491</td>
</tr>
<tr>
<td>Weft</td>
<td>62.3±1.090</td>
<td>64.3±1.273</td>
<td>64.8±1.283</td>
</tr>
<tr>
<td>Drape coefficient</td>
<td>0.504±0.012</td>
<td>0.590±0.015</td>
<td>0.602±0.014</td>
</tr>
<tr>
<td>Tensile strength, kgf</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warp</td>
<td>29.66±0.593</td>
<td>29.66±0.660</td>
<td>29.68±0.731</td>
</tr>
<tr>
<td>Weft</td>
<td>25.41±0.635</td>
<td>25.41±0.565</td>
<td>25.44±0.563</td>
</tr>
<tr>
<td>Elongation, %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warp</td>
<td>11.7±0.293</td>
<td>11.9±0.278</td>
<td>11.9±0.278</td>
</tr>
<tr>
<td>Weft</td>
<td>13.3±0.299</td>
<td>13.3±0.288</td>
<td>13.4±0.261</td>
</tr>
<tr>
<td>Air permeability, cm$^3$/cm$^2$/s</td>
<td>37.42±0.842</td>
<td>37.24±0.782</td>
<td>37.2±0.901</td>
</tr>
<tr>
<td>Tearing strength, kgf</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warp</td>
<td>17.7±0.398</td>
<td>17.7±0.391</td>
<td>17.7±0.391</td>
</tr>
<tr>
<td>Weft</td>
<td>18.6±0.418</td>
<td>18.6±0.416</td>
<td>18.6±0.416</td>
</tr>
<tr>
<td>Whiteness index</td>
<td>100</td>
<td>98.4</td>
<td>98.2</td>
</tr>
</tbody>
</table>

4 Conclusion

ZnO and TiO$_2$ nanoparticles were synthesized with average particle size of 9 nm and 35 nm respectively. In FTIR analysis the presence of an IR band in the region 440 cm$^{-1}$ and 482 cm$^{-1}$ in the finished product indicates the presence of ZnO and TiO$_2$ in the treated fabric. In XRD spectra of the ZnO and TiO$_2$ nanoparticle the presence of well-defined peaks indicates the more crystalline structure. The particle size plays a primary role in determining adhesion of particles to the fibres. It is observed that the larger particle agglomerates are easily removed from the fabric surface, while the smaller particle penetrates deeper and adhere strongly into the fabric matrix. In the case of UV protection function, the fabrics treated with larger sized TiO$_2$ nanoparticles ($T_t$) have better UPF value than the fabrics treated with smaller sized ZnO nanoparticles ($Z_t$). In the case of self-cleaning action, the smaller nanoparticle size in-situ coating of ZnO derived using wet chemical technique ($Z_t$) shows better self-cleaning activity as compared to larger nanoparticle of $T_t$ treated fabric. The physical and mechanical properties of cotton fabrics have practically no effect after finishing with ZnO and TiO$_2$. The UV protection factor (UPF) value increases enormously after nano ZnO and TiO$_2$ finishing on cotton when compared to untreated fabric and retain until 10 washes; beyond 15 washes there is deterioration in UV protection factor values.

The ZnO and TiO$_2$ nanoparticles finishing of cotton fabric not only imparts the UV protection and self-cleaning characteristics to the treated fabrics but also adds two more functional properties like antimicrobial activity and soil release action. Thus, finishing of textiles with ZnO and TiO$_2$ nanoparticles opens up the possibility of multifunctional finishing of textiles with a single treatment process.

References