Treatment of children's garments natural fabrics for protection against ultraviolet radiation

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Abstract:
In this study the researcher tries to study the possibility of protection of children clothing against UV radiation. The synthesis and characterization of nano sized zinc oxide particles and their application on natural fabric have been studied by using nanofinishing technology for the protection against UV radiation. Children are in a dynamic state of growth and therefore more susceptible to harmful effects of UV radiation and cotton is selected as its most proper fabric for children summer clothing. The effectiveness of the treatment is assessed by using standard tests and influences of the finishing by UPF test and some general textile properties tests as well as the durability of the treatment was investigated. It is found that the performance of nano Zinc oxide as UV absorber can be efficiently transferred to fabric materials through the application of ZnO nanoparticles. The UV tests indicate a significant improvement in the UV absorbing activity in the ZnO treated fabrics.

Keywords: Nanotechnology, fabric finishing, Nano textile coating, Nano Zinc oxide, Ultraviolet Protection.

1. Introduction

In spite of some beneficial effects of ultraviolet (UV) radiation on skin, radiation can cause sunburn, skin aging, allergies and even skin cancer. Textiles can provide effective protection against such damage of UV radiation. It is very important to consider the kind of textile to be used, the time of highest exposition in summer where mainly cotton is used. (Farouk, 2009)

Children are more exposed to the sun. Estimates suggest that up to 80 per cent of a person's lifetime exposure to UV is received before the age of 18. Children love playing outdoors but usually are not aware of the harmful effects of UV radiation. (WHO, 261, 2001)

Therefore, there is a growing demand in the marketplace for textile apparel that offers comfort and protection from UV-A and UV-B radiation. The purpose of this study is focused on the UV transmission of cotton fabric for children, the most common textile for summer clothes. (Abidi, 2001)

1.1 Children clothes

Until the late nineteenth century, children were dressed like miniature adults, with little thought given to designing flattering or comfortable garments for them. Children's clothes were usually made by a family member or dressmaker. Mass production of children's clothing began in the 1870s, but these early garments were simple basics with little style or imagination. (Tate 2003)

1.2 Children classification and size categories

An essential factor in understanding of a pattern grading system for children's clothes is the knowledge of how a child body grows and develops between infancy and maturity. (Cooklin 1991)

The problem in designing children's wear is very diverse. Children's sizes are arranged in groups that are typical of one body type. (Lefrancois 2001)

The demarcation lines of children's growth are defined by age groups, and although there are some small overlaps between them, the following are the generally accepted size ranges:

a) Infant – 2 months to 12 months
b) Toddlers – 1 year to 3 years
c) Young Children – 3 years to 6 years
d) Juveniles – 6 years to 11 or 12 years
e) Prepubertal – 10 years to 13 years
f) Adolescence – 13 years to approximately 18 years (Cooklin 1991)

1.3 Natural fibers

1.3.1 Cotton

Cotton and cotton blends are the fibers most widely used in children's wear because they are inexpensive, colorful, comfortable, and available in a great variety of styles and weights in both woven fabrics and knits. Pure cotton worn next to the skin is soft and absorbent, ideal for T-shirts and underwear. Cottons can be layered or quilted for greater warmth during the fall and winter. Heavyweight, durable twills, denims, and plain weaves are made into sturdy sportswear. (Tate 2003)

1.3.2 Wool

Wool is a versatile fiber that can be woven into warm, colorful fabrics appropriate for coats, dresses, and sportswear. Wool tend to be more expensive that other fibers and can be scratchy for delicate skins. Most woolens must be dry-cleaned, which is an impractical and expensive way to maintain children's clothing. Blending wool with synthetic fibers solves many of these problems. Blends of acrylic, wool and polyester are less expensive and are woven into attractive plaids appropriate for back-to-school clothes. (Tate 2003)

1.4 Requirements for children's design

Choice of style and freedom of movement must be considered together. A garment which is attractive to look at but which makes movement difficult for the child will not be popular. (Pounds 1988)

1.4.1 Design safety

Build safety into children's garments. Avoid loose strings or excess fabric that may get tangled, especially for infants. Beware of long skirts or gowns that may cause a child to trip, or very full sleeves that may catch on objects. Limit tie belts and drawstrings to short lengths, and securely fasten buttons and trims. Use fire-retardant fabrics for sleepwear. (Singer 1999)

When choosing styles for young children, avoid back fastenings, lots of fiddly button-holes, and bows or ties. Front fastenings with zippers or Velcro can help the child to dress himself at an earlier age. Double-breasted coat and blazer styles are more easily let out than single-breasted ones, because all the buttons can be re-aligned. (Mordle 1980)

1.4.2 Flammability

If Children wear dangerously flammable fabrics and they stand by an open flame, such as a heating unit, fireplace, stove, etc., the fabric can ignite and cause serious burns. (CPSC-USA, 2010)

Materials such as cotton, cotton/polyester blends, rayon and acrylic are generally more combustible than 100 per cent polyester, nylon, wool and silk. The weave is also a factor in determining flammability. Fine threads with open weaves are more combustible than heavy, closed weaves of the same material. (https://www.productsafety.gov.au, 2014)

1.4.3 Toxicity

Finished textile products can contain certain hazardous chemicals used during their manufacture, either because of their use as components of materials incorporated within the product, or due to residues remaining from the use within processes employed during manufacture. (Brigden 2013)

1.4.4 Anti UV

The UV-blocking property of a fabric is enhanced when a dye, pigment, delustrant, or ultraviolet absorber finish is present that absorbs ultraviolet radiation and blocks its transmission through a fabric to the skin. (Vigneshwaran 2006)

Metal oxides like Zinc oxide as UV-blocker are more stable when compared to organic UV-blocking agents. Hence, nano ZnO will really enhance the UV-blocking property due to their increase surface area and intense absorption in the UV region. For antibacterial finishing, ZnO nanoparticles scores over nano-silver in cost-effectiveness, whiteness, and UV-blocking property. (Vigneshwaran 2006)

1.5 Ultraviolet (UV) Protection

Exposure to ultraviolet (UV) radiation has been identified as the "most significant environmental factor" leading to skin cancer. To address concerns about increasing rates and risk of skin cancer research is directed towards understanding the mechanism(s) causing damage, and how exposure to UV radiation may be reduced. (Wilson 2006)

1.6 Nature of Ultraviolet Radiation

All radiation is a form of energy, most of which is invisible to the human eye. UV radiation is only one form of radiation and it is measured on a scientific scale called the electromagnetic (EM) spectrum. (FDA-USA, 2014)

UV radiation is only one type of EM energy you may be familiar with. Radio waves that transmit sound from a radio station's tower to your stereo, or between cell phones; microwaves, like those that heat your food in a microwave oven; visible light that is emitted from the lights in your home. UV radiation is the portion of the EM spectrum between X-rays and visible light. (FDA-USA, 2014)

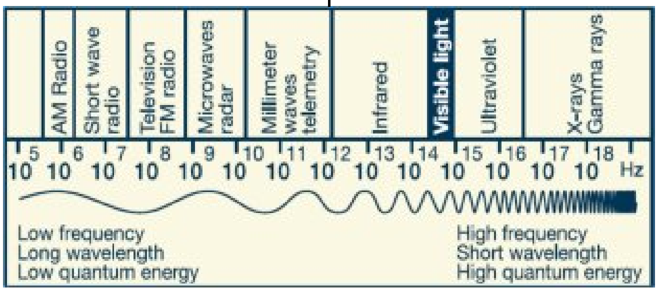

Figure 1 Electromagnetic spectrum
(WHO, 9241591056, 2003)

These radiations can be subdivided according to their range and effect on the skin into:

UV-C Radiation (100-280 nm): this type is completely absorbed by the oxygen and the ozone of the atmosphere and it does not reach the earth's surface. (Khalil 2013)

UV-B Radiation (280-315 nm): this radiation is partially absorbed by ozone layer, reaching the earth's surface as 5% of the total radiation emitted by the sun. This type of radiation is very important for the synthesis of vitamin D; however it has the highest quantum energy, thus UV-B radiation has the highest skin damage potential. Its effect varies from burns to skin cancer, collateral effects and DNA damaging, depending on the exposure dose. (Khalil 2013)

UV-A Radiation (315-400 nm): this low level of radiation are absorbed by the ozone layer, with up to 95% of the radiation emitted by the sun reaching the earth's surface. It has the same effect of UV-B, however the required does are higher. (Khalil 2013)

1.7 Solar Protection Factor (SPF)

To quantify the protective effect of textiles, the solar protection factor (SPF) is determined. The larger the SPF, the more protective the fabric is to UV radiation. In Europe and Australia, the SPF is referred to as the ultraviolet protection factor (UPF). (Khalil 2013)

The SPF is also used with so-called, 'sun blocking' skin creams, giving a relative measure of how much longer a person can be exposed to sunlight before skin damage occurs. Typically, a fabric with an SPF of > 40 is considered to provide excellent protection against UV radiation it is possible to realise about 80% of the theoretical maximum of SPF 200. (Khalil 2013)

1.8 Protecting Children

Children are more susceptible to UV radiation exposure because:

- Sun exposure during childhood and adolescence increases the risk of both melanoma and non-melanoma skin cancers in later life;
- a significant part of a person's lifetime UV radiation exposure occurs before age 18;
- Children have more time to develop diseases with long latency, and more years of life could be lost and more suffering endured as a result of impaired health. (WHO 9241591056, 2003)

2. Experimental work

In this experimental study we applied UV blocking and anti microbial properties, where nano zinc oxide where used to achieve these properties in natural cotton fabric which make clothes provide excellent protection against the hazards of ultraviolet rays, also create a powerful barrier against the spread of the harmful effects of micro-organisms and in reducing the risk of skin infections.

2.1 Materials

2.1.1 Fabrics

Two samples made of 100% cotton finished and unfinished woven fabric were selected as cotton is the most common fabric used in children clothes as cotton is soft, absorbent and gentle on children's skin.

Mill desized, boiled, bleached and mercerized cotton Dacron fabric was used. The fabric samples were treated with a solution containing 1 gm non-ionic detergent at 70°C for 30 minutes, thoroughly washed and dried at the ambient conditions.

2.1.2 UV absorber

Zinc oxide (ZnO) nanopowders are available as powders and dispersions. These nanoparticles exhibit antibacterial, anti-corrosive, antifungal and UV filtering properties. Zinc oxide nano particles [ZnO-NP's, dispersion, 50 wt.% in water, average particle size < 35 nm (APS)] were used.

2.2 Procedures

2.2.1 Nano Zince Oxide Treatment

a. The cotton samples were cut to the size of 50×50 cm
b. The samples are washed in a hot water bath contains 5 gm/lit of liquid soap at 90°C for 20 minutes, this step for insuring that there is no any contaminants at the samples from production process.
c. Nanotechnology were applied by using Nano Zinc Oxide as UV absorber as a coating material on both sides of the sample.
d. After treatment the fabric was rinsed at a water bath contains 4 gm/lit of liquid soap, then it was dried horizontally.

2.3 Test and Analysis

The samples were tested after treatment with Nano Zinc Oxide to see the effect on its properties, the samples were prepared in standard atmosphere for 24 hours before performing tests:

- Temperature (20 ± 2 °C).
- Humidity % (65 ± 2 %).

The tested samples were:

- Unfinished woven cotton fabric.
- Finished woven cotton fabric.
- Unfinished treated woven cotton fabric.
- Finished treated woven cotton fabric.

3. Results and discussion

3.1 Ultraviolet protection factor

UPF was measured using UV-VIS double beam spectrophotometer according to the American standard (ASTM D6604-2000) and AATCC test method [AATCC 183-2000]. The UPF was calculated using equation (1) (Sarkar, 2004; Gies *et al.*, 1994; El Tahlawy *et al.*, 2007)

$$UPF = \frac{\sum_{280\,nm}^{400\,nm} E, S, \Delta_\lambda}{\sum_{280\,nm}^{400\,nm} E, S, T, \Delta_\lambda} \qquad (1)$$

Where:

E_λ = relative erythermal effectiveness function,
S_λ = solar spectral irradiance in $Wm^{-2}\,nm^{-1}$,
T_λ = spectral transmittance of fabric,
Δ_λ = measured wavelength interval (nm),

Ultraviolet protection factor was measured by using UV-VIS double beam spectrophotometer, and we measured the undyed test samples, and the results were as the following:

Table 1 Ultraviolet protection factor of fabric after treatment with nano zinc oxide

Fabric	**Unfinished cotton**		**Finished cotton**	
Treatment	Before	After	Before	After
Sample No.	17	19	18	20
UPF	20.29	294.53	27.22	711.44

It's very obvious that after treating the fabrics with nano zinc oxide the UPF values increase very dramatically, where the bigger improvement was in the finished cotton than the unfinished cotton. This improvement is favored as it gives sufficient protection for children clothing against UV protection.

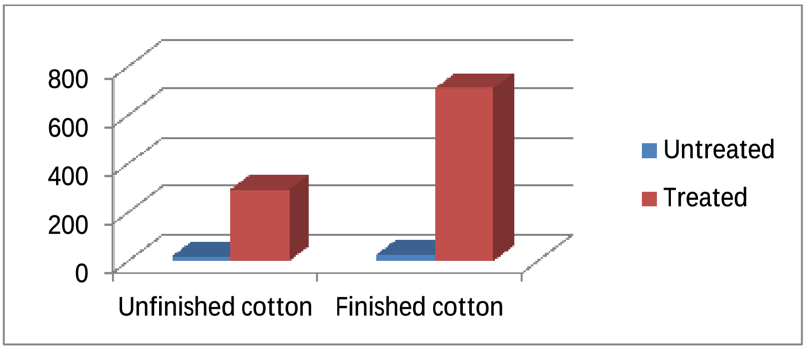

Figure 2 Comparing results for ultraviolet protection factor results

3.2 Textile Tensile Strength and elongation test

The tensile strength was determined directly by the tensile strength gauge, while the elongation was calculated by using equation (2):

$$\text{Elongation\%} = \frac{\text{Recorded Elongation Reading}}{\text{Original Sample Length}} \times 100\% \qquad (2)$$

The test was performed for warp and weft by using a tensile testing machine, and the results were as the following:

Table 2 Tensile strength and elongation for warp after treatment with nano zinc oxide

Fabric	**Unfinished cotton**		**Finished cotton**	
Treatment	Before	After	Before	After
Sample No.	17	19	18	20
Tensile Strength (Kg/cm)	772	850	841	862
Elongation %	31.68%	35.20%	22.72%	24.00%

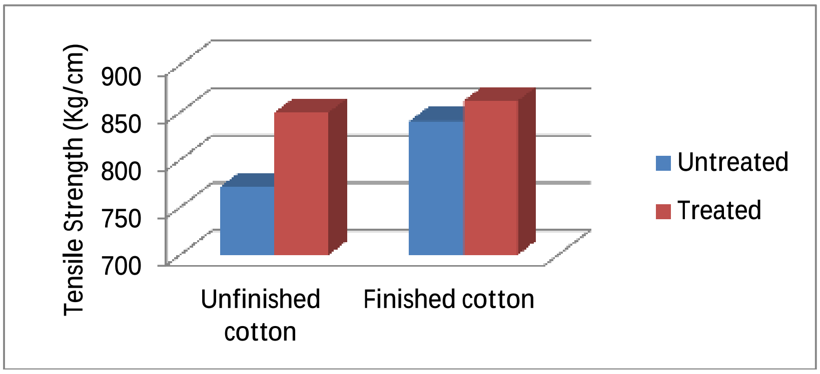

Figure 3 Tensile strength for warp after treatment with nano zinc oxide

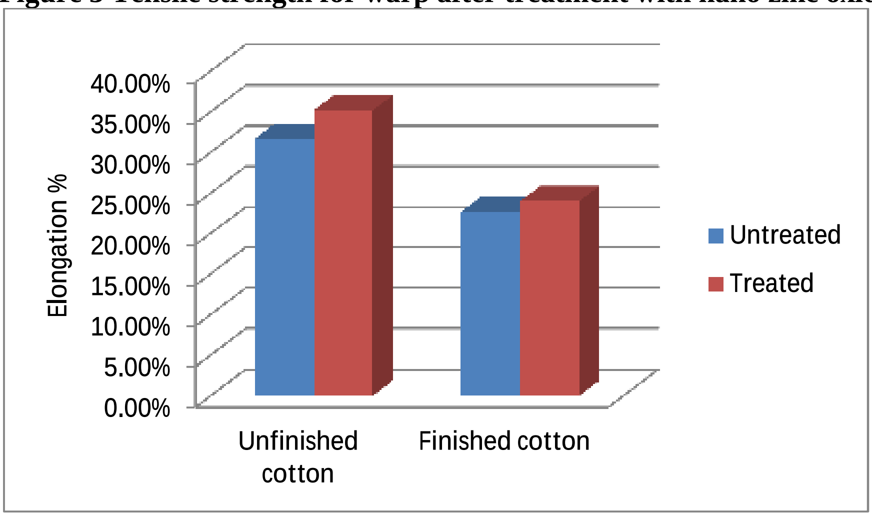

Figure 4 Elongation for warp after treatment with nano zinc oxide

Table 3 Tensile strength and elongation for weft after treatment with nano zinc oxide

Fabric	Unfinished cotton		Finished cotton	
Treatment	Before	After	Before	After
Sample No.	17	19	18	20
Tensile Strength (Kg/cm)	423.5	437.5	415.5	441
Elongation %	21.80%	24.20%	14.50%	16.40%

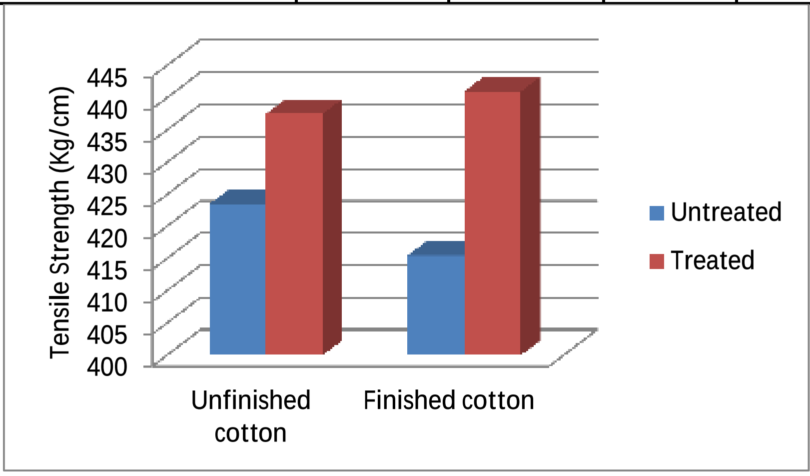

Figure 5 Tensile strength for weft after treatment with nano zinc oxide

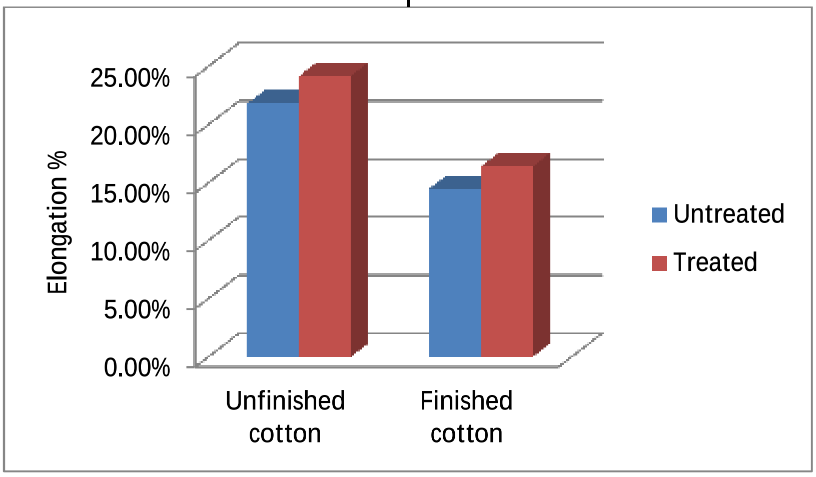

Figure 6 Elongation for weft after treatment with nano zinc oxide

The obtained results show that there is an increase in the tensile strength and elongation of the treated fabrics compared to the untreated ones in the wrap; which is good for enhancing fabric properties and decrease its chances for cuttings.

3.3 Physical properties

3.3.1 Fabric thickness

Thickness test was measured by using the micrometer, and we measured the test samples, and the results were as the following:

Table 4 Thickness of fabric after treatment with nano zinc oxide

Fabric	Unfinished cotton		Finished cotton	
Treatment	Before	After	Before	After
Sample No.	1	2	3	4
Thickness (mm)	0.25	0.28	0.28	0.32

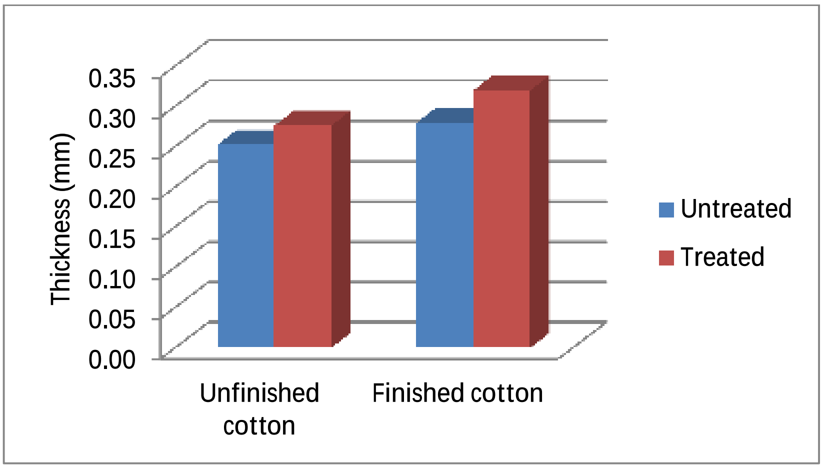

Figure 7 Thickness of test samples after treatment

There was a slight increase on thickness of fabric after treatment with nano zinc oxide, which is a good result as it will not affect the appearance of the fabric.

3.3.2 Fabric weight

The test was done by using a a weight balance with sensitivity 0.001 gm, an average of 5 samples was taken to get the following results:

Table 5 Weight of fabric after treatment with nano zinc oxide

Fabric	**Unfinished cotton**		**Finished cotton**	
Treatment	Before	After	Before	After
Sample No.	1	2	3	4
Weight (gm/m^2)	1.045	1.235	1.390	1.675

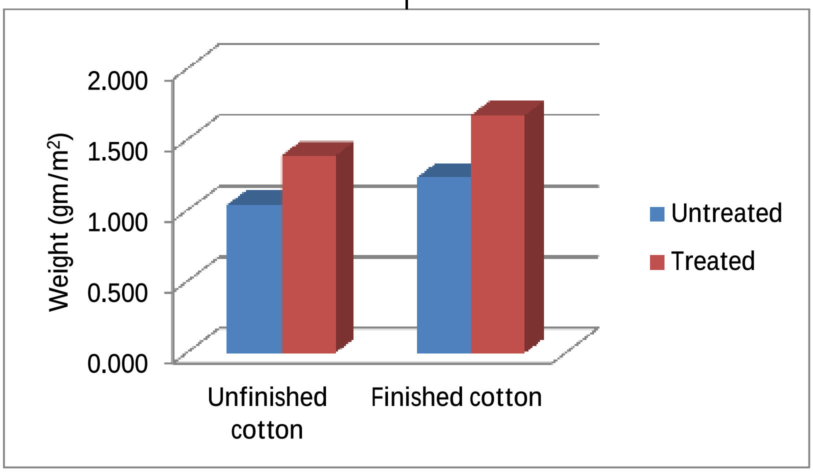

Figure 8 Weight of test samples after treatment

The obtained results show that there is an increase in the weight of the treated fabrics compared to the untreated ones; which is reasonable as the fabric absorbed the nano zinc oxide which affects its weight.

3.3.3 Antimicrobial test

The test was performed by using a modified Kirby-Bauer disc diffusion method, and the results are as shown on the below table:

Table 6 Results for antimicrobial activity Disc diffusion method

Fabric		**Unfinished cotton**		**Finished cotton**	
Sample No.		**1**	**2**	**3**	**4**
Inhibition zone diameter (mm / 1 cm Sample)	**Escherichia coli (G^-)**	0	20	0	20
	Staphylococcus aureus (G^+)	0	19	0	20

As shown from the results for the two untreated samples (1) and (3) they don't have any effect on the antimicrobial activity, while for Samples (2) and (4) we can see the diameters of the inhibition zones measured in millimeters was ranging from 19 – 20 mm indicates improvement in antimicrobial activity for the treated samples.

3.3.4 Scanning electron microscope (SEM)

The test was performed by using a scanning electron microscope produced by "JEOL" at power 35 Kilovolts, the below photographs show the scanning electron microscope photographs of the unfinished and finished woven cotton fabric, and unfinished and unfinished treated woven cotton fabric.

Comparing the SEM photographs of the cotton fabrics, it's clear that by adding the nano zinc oxide particles the fibers became completely covered by the nano particles onto the top layer of the treated fabric samples leading to noticeable white particles.

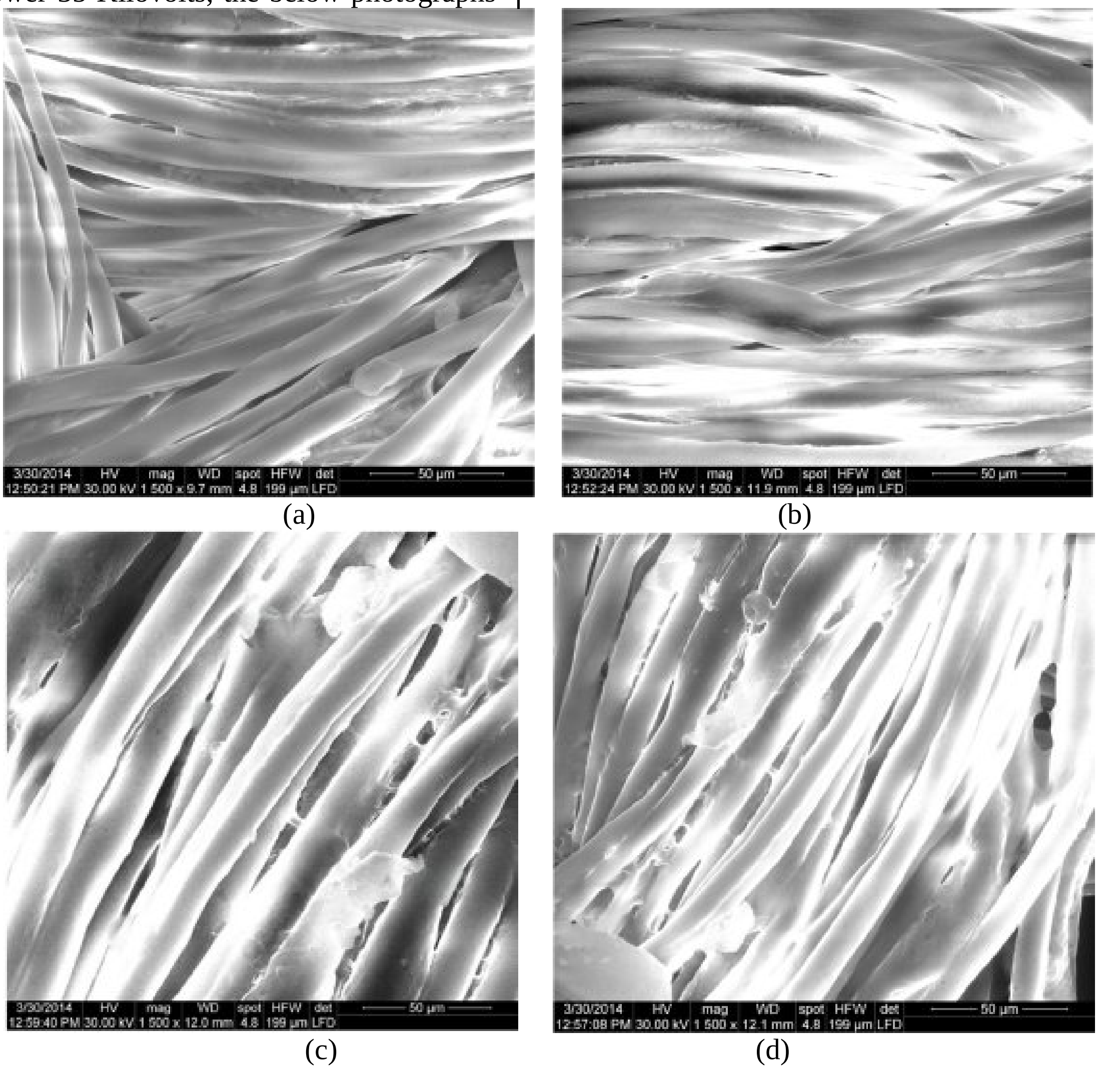

Figure 9 SEM graphs for (a) unfinished untreated (b) finished untreated (c) unfinished treated (d) finished treated

Conclusion

The performance of ZnO nanoparticles as UV absorber can be efficiently transferred to fabric through application of ZnO nanoparticles on the surface of cotton. The UV blocking and anti microbial properties has successfully achieved after treatment.

On industrial purpose the treated samples have a good impact on tensile strength and elongation of the fabric, with slight difference on the fabric thickness and weight. Thus, finishing of fabrics with ZnO nanoparticels gives the possibility of multipurpose finishing with a single treatment.

From these results it was clearly concluded that there is a big advantage from coating cotton fabrics with ZnO nanoparticles which have a good impact on the functional properties of the garment. This it can be used for making UV blocking clothing for children and adults for their summer wear.

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