ABSTRACT

A survey of the literature showed the scarcity of published research work on the use and study of metal oxide nanoparticles’ treatments for imparting multifunctional finish on 100% cotton and polyester/cotton blended woven and knitted fabrics. The work described herein, is the detailed investigation of the multifunctional finishing of woven and knitted fabrics made of 100% cotton and polyester/cotton blend (45/55%) using the Titanium dioxide (TiO$_2$) and Zinc oxide (ZnO) nanoparticles. The 100% cotton plain woven fabric samples required for the research work were produced in a 122 cm (48”) width plain power loom using 100% cotton 14.8 Tex (40 Ne) single yarn as the warp and weft for the fabric with 39 ends/cm (98 ends/inch) and 28 picks/cm (72 picks/inch) so as to get a fabric areal density (weight per sq.m) of 130 gms/sq.m. Similarly, the polyester/cotton blended woven fabric samples were produced in the same power loom using 100% cotton 14.8 Tex (40 Ne) single yarn as the warp and 14.8 Tex (40 Ne) Sensura polyester spun yarn as weft for the fabric with plain weave with 36 ends/cm (92 ends/inch) and 31 picks/cm (78 picks/inch) so as to get a fabric with areal density of 130 gms/sq.m. The knitted fabric samples of pique structure were produced in a 66 cm (26”) diameter weft knitting machine. The yarns used for the knitting are 17.4 Tex (34 Ne) single yarn in the case of both cotton and polyester. The areal density of both the knitted fabric samples was chosen to be 130 gms. The fabric samples were scoured, bleached, mercerized and dyed to 3% (light blue colour) shade using reactive dye in a jigger dyeing machine under the standard conditions of dyeing. The polyester/cotton blended fabric samples were heat set after dyeing.
The first major area of the work was focused on synthesis, characterization, and application of TiO$_2$ nanoparticles on to the samples of the textile substrates followed by the functional testing of the treated fabric samples for the three functional properties viz; antimicrobial activity, UV absorption and soil release. TiO$_2$ nanoparticles were successfully synthesized at low temperature by the hydrolysis of TiCl$_4$ (Titanium tetra chloride) using HNO$_3$ (Nitric acid) solution using the soft chemistry method in the laboratory without adding any complexing agents. By using two different concentrations of HNO$_3$ (4.5M and 5.5M) in combination with two different drying temperatures (70ºC and 120ºC respectively), two sets of TiO$_2$ nanoparticles were successfully synthesized. The thus synthesized nanoparticles were then characterized using the typical methods of Fourier Transform Infrared spectrometry (FTIR), powder X-ray Diffractrometry (XRD) and Transmission Electron Microscopy (TEM). TiO$_2$ nanoparticles of two different size ranges were obtained (9 and 15 nm) as per the calculations using Scherrer’s equation. The nanoparticles were spherical in shape and mono disperse. These nanoparticles were then applied on to the sample fabrics using a hand-held spray gun. The treated fabric is cured and finished by passing it through a calendaring machine. The treated fabric samples were also characterized using the Scanning Electron Microscopy (SEM) and found to have the nanoparticles on to the fabric surfaces through the photo-micrographs of SEM.

Then, the treated fabric samples were tested for the functions of antimicrobial activity, UV absorption and soil release as per AATCC’s standardized tests. The results of these tests showed that the treated fabric samples were added with the desired functions (antimicrobial activity, UV absorption and soil release) to a considerable extent when compared with the untreated samples. The treated samples were also tested for the durability of the effect after repeated washes and found to have significant effect up to 25 washes.
The second major area of the work was focused on synthesis, characterization and application of ZnO nanoparticles on to the sample textile substrates produced for studying the functional properties such as antimicrobial activity, UV absorption and soil release. ZnO nanoparticles were successfully synthesized and obtained through a homogeneous phase reaction between zinc chloride (ZnCl₂) and sodium hydroxide (NaOH) solution at high temperature using the soft chemistry method in the laboratory without adding any complexing agents. By using the different contents of media (water and 1, 2 ethane diol) and the reaction temperatures (90°C and 150°C respectively), two differently sized ZnO nanoparticles were obtained. The thus synthesized nanoparticles were then characterized using the typical analytical methods. ZnO nanoparticles of two different size ranges were obtained (10 and 20 nm) as per the calculations of Scherrer’s equation. The nanoparticles were found to be spherical in shape and mono disperse. These nanoparticles were then applied on to the fabric samples as in the previous cases for TiO₂. The treated fabric samples were tested for the functions of antimicrobial activity, UV absorption and soil release as per AATCC’s standardized tests. The results of these tests were very similar to the test results of TiO₂ treated fabrics for all the three functions and durability of the finish. All the fabrics (both untreated and treated) were tested for their physical properties such as tensile strength, elongation, crease recovery, stiffness, air permeability and bursting strength were evaluated using the standard testing procedures and equipments. This physical testing of was done as per ASTM standards to study the effect of the treatment of nanoparticles on the physical properties of the fabrics, if any. It was seen that the treatments of the fabrics with the nanoparticles of either TiO₂ or ZnO do not affect the physical properties of the treated fabrics. Statistical analyses were done on the test results for assessing their statistical significances using TTEST function of Microsoft Excel® worksheet function. The linear regressional analysis (using the FORECAST function of the
MS Excel® worksheet function) of the test results after the $0^{th}$, $15^{th}$ and $25^{th}$ washings was done to predict the number of washes after which the functional finish was not effective.

The characterization test results of both the TiO$_2$ and ZnO were studied, analysed and compared for similarities and differences. The effects of particle size with-in and between these four (2 in TiO$_2$ and 2 in ZnO) types of nanoparticles were analysed and studied in addition to the study on the very nature of the material (TiO$_2$ and ZnO). It has been found that the treatments of the fabrics with the nanoparticles add the desired functions of antimicrobial activity, UV protection and soil release properties to the treated fabrics. It has been found that the nanoparticle size is the most important factor determining the efficacy of the finish and the durability of the same. It is interesting to note that between TiO$_2$ and ZnO, there is no significant difference in the efficacy of the finish. The effects of the fabric structure (woven/knitted) and the composition of the fabric (100% cotton and 45/55% polyester/cotton blends) have also been studied and compared. The results of these studies and tests have been analysed, discussed and reported in depth and detail with conclusions.