CHAPTER 10

SUMMARY AND CONCLUSIONS

10.1 SUMMARY

Comprehensive studies of the multifunctional finishings of textiles treated with metal oxide nanoparticles were undertaken and in view of the large amount of experimental investigations, it will be meaningful to present a general summary of the research work. Although the research works on the use of metal oxide nanoparticles were started more than 10 years before, there is a paucity of data on the subject. The main aim of the research study was to investigate the multifunctional finishing of textiles treated with metal oxide nanoparticles (TiO$_2$ and ZnO individually).

In the present study, the syntheses, characterization and application of metal oxide nanoparticles of TiO$_2$ and ZnO for multifunctional finishing of 100% cotton and P/C blended woven and knitted fabrics have been investigated. The metal oxide nanoparticles of TiO$_2$ and ZnO have been synthesized using soft chemistry and the synthesized nanoparticles have been investigated for characterization using the advanced techniques of FTIR, XRD and TEM. These nanoparticles have been characterized on the fabric after the treatment using SEM.

Studies have also been made on imparting multifunctional characteristics to the fabrics treated with the nanoparticles of TiO$_2$ and ZnO separately for the different types of fabrics. In this case, the nature of the
nanoparticles, the effect of their size and the treatments have been investigated. 100% cotton and 45/55% P/C blends have been used in the study. The most commonly used woven (plain) and knitted (pique) fabric structures were used for making the fabrics for the study. The effects of blend composition, fabric structure on the treatment and the functional properties have also been studied.

The treated fabrics were tested for the three important functional properties viz. antimicrobial activity, UV protection and soil release function. The durability characteristics of the multifunctional treatments of the treated fabrics have also been studied. The influence of the surface treatment of nanoparticles on the mechanical properties of the treated fabrics has also been examined.

10.2 CONCLUSIONS

The following conclusions have been drawn from the research work:

i. In the synthesis of ZnO, the change of the medium and increase of the temperature of the synthesis is responsible for the reduction in the particle size (10 nm) than the other method (20 nm). This is in line with the result of TiO$_2$ synthesis mentioned above. It can be understood that the higher energy input in to the synthesis systems of both the cases (higher temperature) is responsible for the reduction in the sizes of the nanoparticles. It is logical to conclude that the higher energy put into the syntheses has been consumed in the reduction of the particle size during the syntheses.

ii. Both the woven and knitted fabrics can be imparted with the desired functions of antimicrobial activity, UV protection and
soil release function by treating these fabrics with the nanoparticles of TiO$_2$/ZnO.

iii. In the case of antimicrobial activity function, it has been seen that the fabrics that are treated with smaller sized (9 nm) TiO$_2$ nanoparticles (T$_2$) show better results than the fabrics treated with slightly large sized (15 nm) TiO$_2$ nanoparticles (T$_1$). This is in partial (as a comparison is made with TiO$_2$ nanoparticles with ZnO nanoparticles) confirmation with the established fact that the smaller ZnO particles have a better antibacterial activity (Sawai et al 1996; Yamamoto 2001; Makhluf et al 2005).

iv. In the case of UV protection function, it is interesting to see that all the fabrics treated with slightly larger sized (15 nm) TiO$_2$ nanoparticles (T$_1$) have higher UPF values than the fabrics that are treated with smaller sized (9 nm) TiO$_2$ nanoparticles (T$_2$).

v. The established fact that P/C blended fabrics (both woven and knitted) have better soil release property than the 100% cotton fabrics (both woven and knitted) has been confirmed with the soil release test results.

vi. In the case of antimicrobial activity function, it has been seen that the fabrics that are treated with smaller sized (10 nm) ZnO nanoparticles (Z$_2$) show better results than the fabrics treated with slightly large sized (20 nm) ZnO nanoparticles (Z$_1$). This is in full confirmation with the established fact that the smaller ZnO particles have a better antibacterial activity (Sawai et al 1996; Yamamoto 2001; Makhluf et al 2005).
vii. In the case of UV protection function, it is interesting to see that all the fabrics treated with slightly larger sized (20 nm) ZnO nanoparticles ($Z_1$) have higher UPF values than the fabrics that are treated with smaller sized (10 nm) ZnO nanoparticles ($Z_2$). This is in line with that of TiO$_2$ particles for the function of UV absorption. This confirms the Raleigh’s scattering theory’s statement that the scattering was strongly dependent upon the wavelength, where the scattering was inversely proportional to the wavelength to the fourth power. This theory predicted that in order to scatter UV radiation between 200 and 400 nm, the optimum particle size will be between 20 and 40 nm (Burniston and Bygott 2004).

viii. Both TiO$_2$ and ZnO nanoparticles show comparable performances of the three desired functions as their band-gap energy difference is very low. ZnO is preferable due to its lower cost.

ix. In the case of the soil release function of the fabric samples treated by both TiO$_2$ and ZnO nanoparticles, it is observed that the smaller sized nanoparticles give better soil release when compared to the larger sized nanoparticles. This behaviour is similar to that of the antibacterial effect and size where such size and effect relationship has been noted. The existences of similarities in the cases of the antibacterial and soil release functions indirectly suggest that both these functions are governed by a common mechanism.

x. The durability of the imparted functions were in the range of 27 to 40 washes with variability with in the particles because of the changes in size of the nanoparticles and between the
fabrics because of fibre composition. Fabrics having the polyester component in the blend performed better than the 100% cotton fabrics. The results imply that with an accurate control over the size distribution of the nanoparticles, it may be possible to control and improve the durability of the imparted functions. The wash fastness test results indicate that there is significant difference between the wash fastness values of the soil release function in the cases of TiO$_2$ nanoparticles finishing as this function is influenced by all the four factors namely fabric type, particle type, size and the fibre composition of the fabric.

xi. The physical properties such as strength, elongation, stiffness etc of the treated fabrics do not get affected by the treatments of nanoparticles.

10.3 SPECIAL CONTRIBUTIONS

This research work had been novel in its approach because of the following unique aspects.

i. Multifunctional finishing has been done with a single finishing treatment.

ii. Multifunctional finishing has been done for the three most important functions.

iii. Multifunctional finishing studies have been done for both woven and knitted fabrics.

iv. Multifunctional comparative studies have been done for both 100% cotton fabrics and P/C blends.
v. The multifunctional performances of both TiO$_2$ and ZnO have been studied.

As the findings of this research work have very good potential for the development of sportswear fabrics, there are very good prospects of commercial application of the same after the industrial trials and further development work.

10.4 RECOMMENDATIONS FOR FUTURE WORK

The present investigations have paved the way for further research on the following aspects:

i. The low stress mechanical properties of the treated fabrics can be evaluated and compared to study the influence of the nanoparticles treatments, if any.

ii. By controlling the size distribution of the synthesized nanoparticles, the durability of the functions imparted can be improved.

iii. The studies can be extended to cover the nonwoven fabrics as the structures of nonwovens are very much different than that of the wovens and knitted fabrics.

iv. The studies can be extended to cover the other popular natural fibres such as silk, wool and their blends.

v. The studies can also be extended to cover the other popular synthetic fibres such as nylon, polypropylene and semi synthetic fibres such as viscose rayon and lyocell.

vi. Visible light photo-catalysts can be used in the place of TiO$_2$ and ZnO.

vii. Doping of the nanoparticles for improved performances.