CHAPTER 1

INTRODUCTION

Cotton, the most abundantly available natural fibre, possesses many functional properties such as high moisture regain with good absorbency, adequate strength, comfort feel during wear and easy dyeability (Shore 1995). For these reasons, cotton remains the most preferred fibre for apparel end uses. However, cotton fabrics have natural tendency to wrinkle undesirably. It is due to the rupture and reformation of hydrogen bonds during the laundering process. Further, cotton has poor smooth drying properties, low dimensional stability, higher stiffness (Morton & Hearle 1997) and easy soiling characteristics.

Cotton requires a combination of a few functional properties like crease recovery behavior with higher strength retention, soil release characteristics and lower flexural rigidity for apparel applications. Antimicrobial property and thermal resistance properties are required in specific applications like kitchen aprons and hygiene wear which can satisfy high end use customers of sophisticated society. To impart such multifunctional properties in cotton textiles, specific chemical finishing treatments are required. In the traditional approach, for imparting two or more functional properties, many chemical finishing treatments are required to be applied one after another. This consumes huge time and increases material lock-in period besides very high cost incurred in terms of chemicals, labour and energy. These limitations could be overcome, if more functional properties are imparted in the material using a single process of application, which is called polyfunctional finish.
1.1 NEED FOR FUNCTIONAL FINISHES

In today’s fast and busy world of buyer’s market with abundant choices, people expect the best in all with least maintenance. Apparels are also of no exemption. Easy-care properties like crease recovery and soil release characteristics are always expected to be present in the fabrics meant for dress materials. Flame resistance and antimicrobial properties are required for certain end uses like hygiene wear, laboratory coats and kitchen aprons. Specific functional properties like UV repellency may also be necessary on the grounds of ozone layer depletion. Outdoor sports people, fisherman and people who almost always move in the sunlight need this functionality.

Crease formation is mainly due to rupture and reformation of hydrogen bonds in the cellulose molecule of cotton during laundering process. Crease recovery depends on crosslinks which hold adjacent molecular chains together and pull them back into position after the fibre is subjected to stress and de-stress (Sahin et al 2009). As the cellulose polymers do not have strong natural crosslinks between their molecular chains except hydrogen bonds, the wrinkling tendency is all the more in cotton. Therefore, a chemical finish to crosslink the cellulosic chains, is essential. Unfortunately, crosslinking of cellulosic chains always has resulted in severe strength loss both in tensile strength and tearing strength to the tune of 50% - 60%. A crease recovery finish contains a softener in its formulation to answer this problem. Still, the strength loss is intolerably high in the range of 40%. Common crosslinking agents are based on the methylol precondensate resins, out of which the most popular one is dimethylol dihydroxy ethylene urea (DMDHEU).

Another functional property, which is very vital for making the cotton fabric easy-care in apparel use, is soil release characteristics. Soiling is quite a natural phenomenon and inevitable for textiles but the fabric should have the capacity to release it on laundering so that it can be user friendly in
clothing applications. In general, a hydrophilic fibre has better soil release characteristics compared to the hydrophobic fibres. In hydrophobic conditions, oily stains adhere heavily which makes their removal and washing off difficult (Bhat 2007). Cotton, being hydrophilic, possesses adequate soil release properties in nature. Nevertheless, the use of finishing chemicals like fixing agents, resins, softening agents etc. make cellulose lose its hydrophilicity to some extent. The soil release finish imparts hydrophilic properties in the substrate and oil and water based stains are easily washed off in normal home laundering. Fluorocarbon chemicals and acrylic and methacrylic acid ester co polymers are some of the compounds used in the industry for imparting soil release characteristics in textile materials.

Antimicrobial property is not very much essential for all kinds of apparels. But the health and safety conscious present generation expects this property also to be present in their expensive dress materials. Hygiene wears are produced nowadays which can inhibit the growth of odour causing bacteria and keeps the wearer afresh throughout the day. The antibacterial agent applied in the garments prevents physiological and psychological discomfort caused by the bacteria and create a powerful barrier against the spread of bacterial growth. Triclosan and quaternary ammonium compounds are used for the purpose.

In the routine apparel applications, flame retardant finish plays a minimum role. But it is necessary in special applications like kitchen aprons, laboratory coats and overcoats for personnel working in fire risk industries. A complete protection from fire is required for dress materials meant for professionals like firefighters, petroleum industry field operators and those working in industries manufacturing explosives. Phosphorous and nitrogen based compounds are helpful in producing low flammable fabrics
(Schindler & Hauser 2000). Borax and tetrakis hydroxy methyl phosphonium chloride (THPC) are useful in such applications.

1.2 CROSSLINKING AND FUNCTIONAL FINISHES

Cross linking of cellulose polymer chains using dimethylol precondensate resins can reduce the swelling of cellulosic fibres by moisture. It can render easy-care properties such as wrinkle resistance, smooth drying and crease retention properties on cotton. Conventional resin crosslinking process uses predominantly DMDHEU resin which gives excellent wrinkle recovery properties and durable press finish. But the drawbacks (Schindler & Hauser 2004) are more in dimethylol based resins. Resin crosslinking prevents the movement of the fibre molecules causing severe strength loss and reduction in flexibility of the treated fabric. Further, most of these resins release formaldehyde, a suspected human carcinogen, causes severe irritation to mucous membranes, induced cough and difficulties in breathing. Non formaldehyde based resins were also developed and tried. One such example is N,N’-dimethyl-4,5-dihydroxy ethylene urea (DMeDHEU).

DMeDHEU does not contain formaldehyde. But for crosslinking reaction with cellulose, stronger catalysts and harsher curing conditions are required as compared to DMDHEU. Further DMeDHEU costs about twice as much as DMDHEU and nearly twice the amount of chemical has to be added to achieve the result comparable to that of DMDHEU treated fabrics. For these reasons, their usage is restricted.

There has been a search for a long time for alternative safe crosslinking system. Polycarboxylic acids (PCAs) are nowadays considered as a successful crosslinking agents which can impart excellent crease recovery behavior with better strength retention and good whiteness retention
properties. They can also be exploited for achieving a few other properties like soil release, lower stiffness and flame resistance, which make the cotton fabric more functional.

1.3 ROLE OF POLYCARBOXYLIC ACIDS IN IMPARTING FUNCTIONAL FINISHES

Cross linking resins can be substituted by polycarboxylic acids. PCAs can form ester crosslinks between cellulosic chains through the formation of cyclic anhydride intermediates (Welch 1988, 1989, 1992, 1994 and Yang & Wang 1996b). The advantages of using PCAs over resins are manifold. PCAs do not release poisonous formaldehyde and found to be safer. They form strong ester crosslinks between cellulosic chains and these crosslinks are softer than the crosslinks formed by resins (Yang et al 1998). Therefore, PCAs treated fabrics exhibit better easy-care properties with greater strength retention percentage. 1,2,3,4 butane tetracarboxylic acid (BTCA) is proven to be the most promising PCA for crosslinking cellulose (Welch & Andrews 1990 and Andrews 1990) but its exorbitant cost has prevented it from commercial applications.

PCAs crosslinking can also impart other functional properties like improved soil release and lowered flexural rigidity to make the fabric perfectly easy-care. BTCA and sodium hypophosphite treatment has reduced the susceptibility of the treated fabrics to particulate soil (Yatagi & Takahashi 2006). Other PCAs like 1,2,3 propane tri carboxylic acid, citric acid and maleic acid have also been found to possess adequate cross linking capability and found to impart easy-care properties. In research works carried out so far using PCAs, the main objective was to use them as alternate crosslinking agents to improve crease recovery behavior and to impart durable press finish properties. Only a few researchers have reported improvement in one or two
of the other functional properties like strength retention, dimensional stability and whiteness retention properties as additional benefits obtained.

In this research work, four PCAs which were scarcely used in the earlier researches viz., itaconic acid, tartaric acid, maleic acid and citric acid were applied on cotton fabric solely in the first part of the study and in the second part, combinations of these PCAs were applied on cotton to impart multiple functional properties like improved crease recovery behavior with greater strength retention percentage, excellent soil release characteristics, good whiteness retention and reduced flexural rigidity in a single process of application.

### 1.4 ROLE OF CHITOSAN IN IMPARTING FUNCTIONAL FINISHES

Increasing public awareness about the risks of microbial infection has increased the demand for products which possess antimicrobial properties. Most of the existing antimicrobial agents used in the industry are chlorine based compounds. These are non eco-friendly and not safe to human health causing skin allergies and dermatitis. Chitosan, a deacetylated derivative of chitin, is a natural, non-toxic, microbial resistant and biodegradable polymer which can be safe and ecofriendly. It has active amino groups in its structure. It has been used as a successful antimicrobial agent in many research works (Dutta et al 2004, Gao & Cranston 2008 and Kong et al 2010). Chitosan has been used in many studies mainly to impart the antimicrobial characteristics in the textile substrates. Few works have reported its effect on other characteristics like strength properties and flammability of the substrates (Tahlawy 2008 and Tahlawy et al 2008). Chitosan, when applied alone, can impart number of functional properties like antimicrobial finish, low flammability and slightly improved crease recovery behavior with much reduced strength loss.
In the studies carried out so far using the combination of PCAs and chitosan, PCAs have been used only for crosslinking chitosan with cellulose to improve the durability of antimicrobial activity (Tahlawy 2005 and Montazer & Afjeh 2007). These works have not given much emphasis in studying the other functional properties that could be achieved like improved crease recovery, low flammability, soil release properties and reduced flexural rigidity.

In the present research work, cotton fabric was finished with different concentrations of chitosan solely, in one part of the study and in the final part of the study; cotton fabric was finished with combination of chitosan and PCAs. A comprehensive analysis of the finished samples for all the functional properties like antimicrobial property, flame retardancy, soil release characteristic, crease recovery behavior, strength retention properties and flexural rigidity has been accomplished.

1.5 OBJECTIVES OF THE RESEARCH

To impart functional properties like improved crease recovery, greater tensile strength retention and tearing strength retention, excellent soil release characteristics, very good whiteness retention percentage and reduced flexural rigidity in cotton by finishing with polycarboxylic acids such as maleic acid, citric acid, itaconic acid and tartaric acid in individual applications.

To impart these functional properties in cotton by applying binary combinations and ternary combinations of the above PCAs.

To make a comparative study of the behavior of PCAs in single and in combinations in influencing the functional properties imparted in cotton.
To impart functional properties like antimicrobial characteristics, low flammability and improved crease recovery behavior with much lower strength loss in cotton by finishing with chitosan.

To impart multiple functional properties like durable antimicrobial properties, crease recovery with greater strength retention, very good flame resistance characteristics, excellent soil release characteristics and reduced flexural rigidity in cotton by finishing with select combinations of chitosan and polycarboxylic acid.

In all these studies, the results are analysed statistically wherever applicable to arrive at a decision on whether the parameters chosen influence the properties significantly or not.

1.6 STRUCTURE OF THESIS

The thesis is divided into 8 chapters. Each chapter has a brief introduction about its contents. Tables and Figures are given in the necessary places to substantiate the analysis and the claims made in this work.

Chapter 1 gives the introduction to the subject, polyfunctional finishes, need for functional finishes in cotton textiles and the scope and objectives of the research.

Chapter 2 deals with an extensive literature survey, which serves as the background for the entire research work.

Chapter 3 provides complete information about the materials and chemicals used for the study and the actual methods of finishing cotton with the chosen chemicals. It also explains the procedure used for testing various functional properties as per international standards.
From chapter 4 to chapter 7, results obtained from the different studies are discussed and analysed in detail. Inferences deduced are reported. Accordingly, chapter 4 deals with the study of finishing of cotton fabric with polycarboxylic acids viz., maleic acid, itaconic acid, citric acid and tartaric acid. These PCAs are applied on cotton fabric samples individually in different concentrations. The effect of the type of PCAs and their concentrations on functional properties imparted in cotton is discussed.

Both binary combinations and ternary combinations of the above PCAs are applied on cotton fabric samples. The effect of combination of these PCAs on imparting functional properties in cotton is discussed in chapter 5. Further, a comparative analysis of the behavior of PCAs in single and in combinations in influencing the functional properties imparted in cotton has been made.

Chapter 6 deals with the study of finishing of cotton with chitosan in different concentrations and at different curing conditions. Further, the effect of concentration of chitosan on imparting different functional properties in cotton is described. The effect of different curing conditions on the functionality of chitosan in each concentration is also discussed.

Different combinations of chitosan and PCAs have been applied on cotton. The effect of different combinations of chitosan and polycarboxylic acids on imparting an optimum blend of all the functional properties in cotton is discussed in Chapter 7.

Summary of the entire study and the conclusions drawn on this research work with suggestions for future work are elaborated in chapter 8.