1. Introduction

Clothing is one of the basic necessities for the survival of modern man and its primary objective is to protect humans from the environment. Textile has one of the longest histories of all human activities, and the history of textile spans thousands of years, with the materials changing from animal skins and leaves in early days to the plethora of yarns and fabrics today. Textile has always played a central role in the evolution of human culture, by being at the forefront of both technological and artistic development. In India, the textile industry, after agriculture, has generated enormous employment for both skilled and unskilled labor. Thus the textile industry continues to be the second largest employment generating sector in India, providing direct employment to around 20 million people (Desrani, 2013).

In the evolution from a primitive species to the modern society, humans snatch every available opportunity to make conditions better for their survival, and the onset of the information era is now pushing the technological developments beyond the limits. Even though the primary objective of textile is to protect human’s against hostile climatic conditions such as extreme heat or cold, modern day textile is expected to offer more than these original functional properties, as the people’s quality of life improves with technological advancements. Pollution and population explosion have made the conditions harsher for survival, which consequently triggered the need for more advanced and value added textile. Also, the consumer’s attitude towards hygiene and active lifestyle has created a rapidly accelerating market for multifunctional textile. Worldwide, textile industry occupies a significant part of the economy which drives a massive inflow of funds for intensive research and development activities. Especially, the Indian textile industry is one of the largest contributors to meet the world’s textile demand. It was able to make its mark on the global scenario, penetrating to the market both in terms of range of products and countries. It is expected to grow from US$ 70 billion in 2010 to US$ 220 billion by 2020. Textile and clothing exports account for one-third of the total value of exports from the country (Dhanabhakyam & Shanthi, 2013). Indian textile industry with its intrinsic strength and the aid of several promoting factors, comprises of 70% apparel, 23% technical textile and 7% home furnishing and decors. Compared to the apparel, technical textile is also one of the emerging areas for investment in India because it has immense potential to gear up the traditional textile industry (Chaudhary & Shahid 2013).

In recent years, research and development activities are oriented more towards the development of multifunctional textile, to satisfy the demands of modern society. One of the basic properties of the textile is its flexibility towards imparting additional
functionalities. Textile functionalization can be done at various stages of fabric development such as fiber formation (in polymerization and before spinning), changing the material construction (types of fiber, fabric or weaving and knitting) and textile finishing (either surface modification or fixation of active molecules on to textile). Thus the term textile finishing, covers an extremely wide range of activities performed on textile before they arrive at the customer’s hands. Textile finished with functional properties like antimicrobial, UV protection, self-cleaning, antistatic, water repellent, fire retardant and fragrance finished products has attracted more consumer attention (Kaihong Qi, 2008). Various factors such as proper formulations for finishing, type of textile, functional or chemical agents, compatibility with other ingredients, available machinery as well as economic and ecological aspects, and innovative technologies are taken into consideration for imparting functional finishes into the fabric (Zgondek et al., 2008).

In contrast to the moderate development of conventional textile, functional high-grade textile shows logarithmic market growth. The importance of multifunctional textile is closely connected with recent changes in the textile industry. Development of the multifunctional textile seems to offer the textile and apparel industry new challenges and benefits for the future. Functional textile can significantly improve the applications and extend its range of utilization. Functional garments should meet consumer demands in terms of comfort, easy care, health and hygiene while ensuring protection against mechanical, thermal, UV rays, chemical and biological attacks. Moreover, functional coatings enable considerable improvements in performance and durability of the textile (Mahltig et al., 2005).

The increasing consumption of fabric and the change in lifestyle have created a demand in production of fabrics that lead the industry to blend natural with various other fibers (Wong et al., 2006). Combination of natural and synthetic fibers generally have different characteristics, which make them ideally suitable mainly for apparel construction. Polyester/Cotton is most popular and common among the blended fabrics and it is used throughout the world in a wide range of fields such as apparel industry, household textile and furnishings, medical items, industrial uses and technical products. This blend exhibit the properties of both fibers providing easy care qualities of polyester as well as the comfort afforded by the moisture absorption characteristics of cotton, but the overall performance depend on the blend ratio. The combined properties of the polyester/cotton blended fabric, make them a sole choice of material for textile with added functionalities. These advantages permit an increased variety of products to be made, and yield a stronger marketing advantage. Also, polyester/cotton can be easily functionalized and suitable for lots of high end applications.
Textile is vulnerable to microbes during production, usage or storage, which leads to loss in quality, change of color, reduction in strength and formation of unpleasant odor (Heine et al., 2007). The inherent properties of the textile fibers provide an excellent medium for the adherence, transfer and propagation of microbial species causing infection (Gupta & Bhaumik, 2007), and the pathogens may be able to survive on the fabric for periods ranging from few minutes to several months (Langenhove, 2009). It was also shown that bacteria and fungi can survive for prolonged periods in hospital fabrics (Neely & Maley, 2000) and it is one of the most probable causes of hospital infections (Isabel, 2010). As the consumers are now increasingly aware of the hygienic lifestyle, there is a need for textile products finished with antimicrobial properties. This awareness triggered the apparel and clothing industry to develop more protective clothing for day-to-day textile needs. These antimicrobial finished textile products typically include compounds such as silver, quaternary ammonium halides, aromatic halogen compounds, chitosan, metals and metal oxides (Kenawy et al., 2007; Simoncic & Tomsic, 2010).

Recent research studies reveal that textile plays an essential role in protecting the human skin from the harmful UV rays of the sun. UV rays reaching the earth’s surface have wavelength ranging from 280 nm to 400 nm. Long term exposure of human skin to UV rays results in damages like skin ageing, photo dermatitis, erythema, (skin reddening), sun-burn, skin cancer, eye damage and DNA damage / alteration (Menezes, 2009). The National Institutes of Health, USA reported that the main cause of skin cancer is UV radiation from the sun and 90% of skin cancer cases can be prevented by way of sun protection. Textile is an excellent medium to protect the skin from UV rays, as it can absorb, reflect and scatter UV rays. UV protection finish is the single major influencing factor that decides the ability of textile to block UV rays. On the other hand, the radiation from the sun is capable of degrading the organic bonds of the dirt molecules present on the fabric. Self-cleaning textile is the new developments in this direction. It is based on the fact that the textile are capable of cleaning itself to some extent under certain conditions. They are able to free themselves from dirt and stains. No detergents or chemicals are needed in such cleaning process. In the modern day living, consumers prefer multifunctional textile with all the above antimicrobial, UV protective and self-cleaning properties.

Nanotechnology is an emerging field which extends its arms in all the disciplines and aids their development. Nanotechnology has gained increasing worldwide consideration because of its huge benefits in a wide range of end utilities with the distinctive and new properties. The advancements of nanotechnology can also be utilized in the textile industry (Gouda & Aljaafari, 2012). Recent developments of nanotechnology in the textile industry takes place in fibers, yarns, fabrics, nonwovens, finishing, coating,
electronic textile, fiber modification and value added applications. Imparting nano finishes on to the fabric will highly increase the performance of the finished fabrics. Application of nanotechnology in textile industry has tremendous advantages. This is mainly due to the fact that conventional methods used to impart different properties to fabrics often do not lead to permanent effects, and will lose their functions after laundering or wearing, but this technology can provide high durability for fabrics, because, nanoparticles have a large surface area-to-volume ratio and high surface energy, thus presenting better affinity for fabrics, leading to an increase in durability of the function.

Specifically, metals and metal oxide nanoparticles attracted more interest because of their wide spectrum of functionalities. At the same time, metal oxides are also more stable in harsh conditions like exposure to sunlight and washing detergents, making the metal oxide nanoparticles an ideal choice for the fabrication of multifunctional textile. Metals and their oxides have been used as antimicrobial agents since antiquity, but throughout most of history their modes of action have remained unclear. Recent studies indicate that different metal oxides like TiO₂, ZnO, Fe₂O₃ and CuO cause discrete and distinct types of damages to microbial cells, as a result of oxidative stress, protein dysfunction or membrane damage, thus leading to death of the microbes (Chakraborty et al., 2010).

Similarly, as metal oxide nanoparticles are semiconductors, they have a strong absorption towards UV radiation, and also, the nano size of the particles highly contribute to the scattering of the incident UV light. Metal oxides with band gap energy, lesser than or equal to the UV light, effectively absorb the UVA as well as UVB radiation. The photons shining on the metal oxides excite the electrons from the valence band to the conduction band. This excited electron will produce free radicals by reacting with the nearby atoms and catalyze the degradation of the organic dirt materials by photocatalytic process, thus facilitating the self-cleaning action. Each metal oxide has its own area of action and exhibit high efficiency to specific processes.

In this work, it is aimed to blend different metal oxide nanoparticles with specific functionalities into single nanocomposite, to synergistically harvest the potential of individual metal oxides. Various reports on usage of different nanocomposites like TiO₂/ SiO₂ and TiO₂/ZnO for multifunctional finishing of textile are available in the literature (Qi et al., 2006). An easy and economical way of preparing nanocomposites is by ball milling. Ball milling is one of the widely adapted processes in the industries and this method is capable of producing large quantities of nanocomposites. Adherence of the functional materials to the fabrics is a major problem in the functional textile. Even though the nanomaterials have good adherence to the fibers due to their high surface-to-volume
ratio, the adhesion can be further improved by removing the impurities and adding some functional groups on to the fiber surface by specific pretreatment processes. Various pretreatment methods such as plasma technology and cationization are available for modifying the surface of the fabrics.

During recent years, there has been increasing interest towards eco-friendly textile processing techniques like plasma technology in order to achieve improved fabric functionalities and performance properties. Plasma surface treatments show distinct advantages, because they are able to modify the surface properties of inert materials without affecting their bulk properties. Plasma treatment is an environment friendly technology which does not use water or any chemical for the surface modification. Plasma is a partially ionized gas, composed of highly excited atomic, molecular, ionic and radical species with free electrons and photons. This plasma reacts with the surface of the textile fiber and induces desirable modifications improving the material absorption. Three main effects such as cleaning effect, increase in micro-roughness and production of radicals to obtain hydrophilic surfaces can be attained by varying the treatment conditions.

Cationization is a process of treating the fabrics, using a cationic agent, which will impart a positive charge on the fabric surface, thus increasing the affinity towards anionic substances, such as metal ions and dye. Modifying cotton fibers with cationic charges prior to coating of metal oxide nanoparticles is an attractive route for improving the adsorption of nanoparticle on to the fabric (Kim & Choi, 2014). Plasma treatment and cationization can improve the fabric characteristics such as wettability, adhesive bonding, printability, dyeability, etc., hence both pretreatment methodologies are adapted widely in the textile industries.

In the current research work, fabrication of multifunctional textile was done by applying nanomaterials on to the polyester/cotton blended fabrics. The fabrics were pretreated with plasma and cationic agent to improve the material adhesion on to the textile. Although some researchers have already worked in the field of multifunctional finishing of textile, a survey of literature revealed that there is lot of works yet to be done in this field of multifunctional finishing of textile. A thorough and critical examination of the literature shows that the some aspects of the research works were not well addressed by any of the researchers so far. This includes, multifunctional finishing of the fabrics, using nanocomposites melded from both UV light active as well as visible light active metal oxide nanoparticles, optimization of the blending ratio of nanoparticles for the preparation of nanocomposites, and analyzing the comparative performance of pretreatment of textile using plasma, cationization and co-treatment using both the pretreatment processes.
The main objective of the present study is to develop multifunctional textile with antimicrobial, UV protection and self-cleaning properties, and the research work is planned with the following specific objectives:

- To synthesis and characterize TiO$_2$, ZnO, CuO, Fe$_2$O$_3$, MgO and Al$_2$O$_3$ nanoparticles, using hydrothermal method,
- To optimize the preparation of nanocomposites by Box-Behnken design,
- To optimize the process parameters of DC air plasma and cationization for the pretreatment of polyester/cotton fabric by Box-Behnken design,
- To impart multifunctional finish on pretreated fabrics, using metal oxide nanocomposites,
- To compare and validate the treated and untreated fabrics for their multifunctional properties, using standard test methods,
- To determine the skin irritation potential of the treated fabrics by HET CAM test, and
- To assess the wash durability and physical properties of the finished fabrics using standard test methods.