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12. Advances in Textile Finishing

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12.1 Introduction:

Textile industries contribute significantly to the economy of many developing countries. Every year, these countries export textile products to developed countries. However, textile industries use expensive and corrosive chemicals that pose a significant threat to environmental quality and public health. This has led to serious concerns and necessitated the inclusion of safer and environmentally friendly alternatives. Textile industries are regularly in search of a technology; explore environmental friendly, less water consuming, replacement with special auxiliaries, known as unconventional technologies. The textile industry has been developing rapidly and newer technologies are introduced and the only formula for survival is encapsulating those innovations into the manufacturing process and making the best of use them for increasing the productivity and quality. A lot of interesting advancements have been witnessed within the last two decades in the clothing and textile industry. Finishing is the processing operations applied to grey fabrics to enhance their appearance and hand properties to improve appearance, like luster, whiteness etc. and it also improves feel which depends on the handle of the fabric and its softness, to improve the wearing qualities, likes non-sailing anti-crease etc. It imparts the serviceability of the material promotion of dimensional stability of the material hence finishing is important for a textile goods before they are placed on the market all that part comes under the conventional finishing process. Tons of interesting advancements are witnessed within the last twenty years within the clothing and textile industry. Whereas the conventional methods of finishing including wet and dry finishing techniques are still being practiced on cotton and woolen fabrics, advanced textile finishing techniques may include functionalization using nano-coatings, surface modification using hydrolyzable silanes, enzymes, plasma technology, and the strengthening of synthetic fibres with nano-coatings and nano-clays, to mention but a few. These techniques induce different textures and performance characteristics onto the textile materials, making them textile materials for the future, otherwise "futuristic" textiles from apparels and garments to technical textiles that respond effectively to changes within the environment and human body. This would make it possible for futuristic textiles to be widely applied in a variety of situations and environments.

12.2 Use of Enzyme Technology in Textile Finishing:

The use of enzymes in the textile industry is an example of white/industrial biotechnology, which allows the development of environmentally friendly technologies in fibre processing and strategies to improve the final product quality. The consumption of energy and raw-materials, as well as increased awareness of environmental concerns related to the use and disposal of chemicals into landfills, water or release into the air during chemical processing of textiles are the principal reasons for the application of enzymes in finishing of textile materials **(O'Neill *et al.* 1999).** The rise in the level of various kinds of pollutions has created a major awareness among the consumers for using eco-friendly products. Governments of many countries have also imposed limitations on release of pollutants. This in turn has resulted in a rise in demand for green and clean processes.

One of the sectors of industry that holds a major share in the global pollution is textile industry. Therefore use of enzymes on textiles play a key role as an alternative process for textile processing and have become an integral part of the textile processing industry.

The process of use of enzymes is energy saving and does not require any special equipment for heat resistance, pressure or corrosion. Their efficiency, high biodegradability and the mild conditions of working mark their use in a wide range of industrial applications. Enzymes work only on renewable raw materials.

Fruit, cereals, milk, fats, cotton, leather and wood are some typical candidates for enzymatic conversion in industry**.** Out of the 7000 enzymes known, only about 75 are used in the textile industry **(Quandt & Kuhl 2001).**

Enzymes are biocatalyst and can speed up the chemical process without even being consumed in the process. Usually most enzymes are not reusable after a reaction but some enzymes can be released again and mark their use in another reaction also.

Mainly two types of enzymes are used in textile processing industry. The desizing process includes the use of Amylases and in the finishing area cellulases are used for softening, bio-stoning and reducing of pilling propensity for cotton goods. The other enzymes used in the processing of textiles are pectinases, lipases, proteases, catalases, xylanases etc.

12.2.1 Application of Enzymes on Textiles:

In textile industry, there is a wide use of enzymes because of their beneficial nature **(Uhlig, 1991; Ruttloff, 1994):**

- They accelerate reactions,
- Act only on specific substrates,
- Operate under mild conditions,
- Safe and easy to control,
- Can replace harsh chemicals
- Are biologically degradable i.e. biodegradable
- Save water, energy and chemicals
- Increase productivity
- Produce high quality textile products

The various applications of enzymes in textile area includes the effect of fading of denim and non-denim, bio-scouring, bio-polishing, wool finishing, peroxide removal, decolourization of dyestuff, etc **(Cavaco-Paulo *et al.*, 1998).**

A. Desizing: One of the various steps of textile processing is weaving which includes the interlacing of warp and weft yarns. This process results in the exposure of warp threads to considerable mechanical strain. Therefore, to prevent the warp threads from breaking during weaving, a gelatinous substance is used to coat them. This process is known as Sizing and the substance is known as Size. In the weaving of cotton blend fabrics, the commonly used material to size the yarn contains starch in native or modified form, sometimes in combination with other polymers such as polyvinyl alcohol (PVA), polyacrylic acid (PAA) or carboxymethyl cellulose (CMC). Small amounts of fats or oils may be also added to the size, with the aim of lubricating the warp coat surface. Because of this process, the sized warp yarns of the fabrics are unable to absorb water or finishing agents to a sufficient degree. This in turn necessitates the removal of the size before dyeing or finishing of the fabric. In most cases, the Desizing treatment given to the fabric to get the desired effect consumes huge amount of water & different types of hazardous chemicals resulting in large amount of effluent and high pressure on environment**.** The widely used enzyme for desizing process is a hydrolytic enzyme called Amylase. It catalyses the breakdown of dietary starch to short chain sugars, dextrin and maltose which gives uniform wet processing. The advantage of these enzymes is that they are specific for starch, removing without damaging to the support fabric. An amylase enzyme can be used for desizing processes at low-temperature (30- 60ºC) and optimum pH is 5,5-6,5 **(Cavaco-Paulo and Gübitz, 2003).**

This enzyme works by converting the starch mixture to soluble dextrin and then more slowly convert this to reducing substances and sugar, such as maltose. The two types of amylase enzymes used for removing size materials from warp yarn of woven fabric are α-amylase and β- amylase.The α -Amylases are produced by a variety fungi, yeasts and bacteria, butenzymes from filamentous fungal and bacterial sources are the most commonly used in industrial sectors **(Pandey *et al.* 2000).** Nowadays amylases are commercialized and preferred for desizing due to their high efficiency and specificity, completely removing the size without any harmful effects on the fabric **(Etters and Annis 1998; Cegarra 1996).** The starch is randomly cleaved into water soluble dextrins that can be then removed by washing. This also reduced the discharge of waste chemicals to the environment and improved working conditions.

B. Enzymatic Scouring (Bioscouring) Scouring means the removal of non-cellulosic material, which is responsible for water repellency of cotton, present on the surface of the cotton. Enzymes cellulase and pectinase are combined and used for Bioscouring. Pectinase destroy the cotton cuticle structure by digesting the pectin and removing the connection between the cuticle and the body of cotton fibre whereas Cellulase destroys the cuticle structure by digesting the primary wall cellulose immediately under the cuticle of cotton. This is done by using a specific degradation process in delicate pH and temperature and then removing the natural impurities with a successive hot wash and rinse. The traditional scouring of cotton includes the use of hazardous chemicals that increase biological oxygen demand (BOD), chemical oxygen demand (COD) & total dissolved solid (TDS) in waste water increasing overall cost & pollution of environment**.** Enzymatic scouring results in very soft handle compared to harsh feel in alkaline scouring process. It also minimizes health risks hence operators are not exposed to aggressive chemicals**.**

C. Enzymatic Bleaching: Cotton bleaching is done to decolourise natural pigments and give a pure white appearance to the fibres. Mainly flavonoids are responsible for the colour of cotton. Generally for bleaching, H2O2 is used and its residues must be removed in order to obtain the most efficient dyeing & to reduce the complexity of treatment. The traditional processing of cotton requires high amounts of alkaline chemicals and generates huge quantities of rinse water. Therefore, the conventional bleaching agent hydrogen peroxide can be replaced by an enzymatic bleaching system which would result in a better product quality due to less fibre damage and savings on washing water needed for the removal of hydrogen peroxide. With the use of enzymes, dyeing can be carried out in the same bath resulting in reduced water consumption which in turn requires less power to dye fabric eventually lowering the amount of effluent produced.

Therefore, we can save on the use of water, energy and chemicals. For this procedure, Amyloglucosidases, pectinases, and glucose oxidases are used as they are compatible concerning their active pH and temperature range.

D. Bio polishing: A finishing process to improve fabric quality and reduce fuzziness and pilling property of the cellulosic fibre is called Bio polishing. This process involves the action of cellulose enzyme in order to discard micro fibrils of cotton.

E. Enzymatic treatment to denim: Many garments are subjected to a wash treatment to give them a slightly worn look, e.g. stonewashing of denim jean, in which the blue denim is faded by the abrasive action of pumice stones on the garment surface. Owing to the introduction of cellulases, the jeans industry can reduce or even eliminate the use of stones, resulting in less damage to the garment and machine, and less pumice dust in the laundry environment. Productivity can also be increased because laundry machines contain fewer stones or none at all, and more garments. Denim garments are dyed with indigo, which adheres to the surface of the yarn. The cellulase hydrolyses exposed fibrils on the surface of the yarn in a process known as 'Bio- Stonewashing', leaving the interior part of the cotton fibre intact. Partial hydrolysis of the surface of the fibre removes some of the indigo is creating light areas. There are a number of cellulases available, each with their own special properties. These can be used either alone or in combination in order to obtain a specific look. A fading effect is given to the denim in its finishing process. The conventional method of giving this finish was done using sodium hypochlorite or potassium permanganate was used called as pumice stones**.** Denim is heavy grade cotton and the dye is mainly adsorbed on the surface of the fibre due to which fading can be achieved without considerable loss of strength. The use of pumice stone carries some disadvantages with it like:

- Pumice stones cause large amount of back-staining.
- Pumice stones are required in very large amount.
- They cause considerable wear and tear of machine.

The enzymatic finishing of denim fabric is done with cellulase enzyme as it loosens the indigo dye on the surface of denim. This process is known as "Bio-Stonewashing". A small dose of enzyme can replace several kilograms of pumice stones. This process results in less damage to garment, machine and less pumice dust in the laundry environment. More recently, some authors showed that laccase was an effective agent for stone-washing effects of denim fabric with and without using a mediator **(Campos *et al.*, 2001; Pazarloglu *et al.*, 2005).**

F. Enzymes for wool and silk finishing:

The bio blasting of cotton and other fibers based on cellulose came first, but in 1995 enzymes were also introduced for the bio blasting of wool. Wool is made up of protein and requires a treatment to modify the fibres known as Bio-blasting which uses protease enzyme. The enzymatic treatment reduces "Facing up" (a trade term used for the ruffling up of the surface of wool garments by abrasive action during dyeing) resulting as increased softness and improved piling performance. As reported, the enzymatic finishing of wool also improves shrink resistance, tensile strength retention, handle, softness, wettability, dye uptake, reduced felting tendency and protection from damage caused by the use of common detergents **(Cortez et al. 2004)**.

Proteases are also used to treat silk. The finishing of silk includes the removal of sericin, a proteinaceous substance that covers the silk fiber. This process is called degumming of silk fibers. The traditional method of degumming of silk is a harsh treatment that destroys fibrin as it is done in an alkaline solution containing soap **(Araujo *et al.* 2008).** On the other hand, the proteolytic enzymatic finishing is a better method as it removes the sericin without attacking the fibrin. Tests with high concentrations of enzymes show that there is no fiber damage and the silk threads are stronger.

12.3 Use of Nanotechnology in Textile Industry:

The term nanotechnology (sometimes shortened to "nanotech") comes from nanometer – a unit of measure of one billionth of a meter of length. The concept of Nanotechnology was given by Nobel Laureate Physicist Richard Feynman, in 1959.

Nanotechnology is defined as the understanding, manipulation, and control of matter at the length scale on nanometer, such that the physical, chemical, and biological properties of materials (individual atoms, molecules and bulk matter) can be engineered, synthesized or altered to develop the next generations of improved materials, devices, structures, and systems**.**

Generally, nanotechnology deals with structures that are sized between 1 to 100 nm in at least one dimension and involves developing materials or devices possessing dimension within that size. Nanotechnology creates structure that have excellent properties by controlling atoms and molecules, functional materials, devices and systems on the nanometer scale by involving precise placement of individual atoms**.** The textile industry certainly has the biggest customer base in the world. Therefore, the advances in the customer oriented products will be the main focus for future NT applications, and the textile industry is expected to be one of the main beneficiaries. There are many ways in which the surface properties of a fabric can be manipulated and enhanced, by implementing appropriate surface finishing, coating, and/ or altering techniques, using nanotechnology. A few representative applications of fabric finishing using NT are schematically displayed in. NT provides plenty of efficient tools and techniques to produce desirable fabric attributes, mainly by engineering modifications of the fabric surface. For example, the prevention of fluid wetting towards the development of water or stain-resistant fabrics has always been of great concern in textile manufacturing.

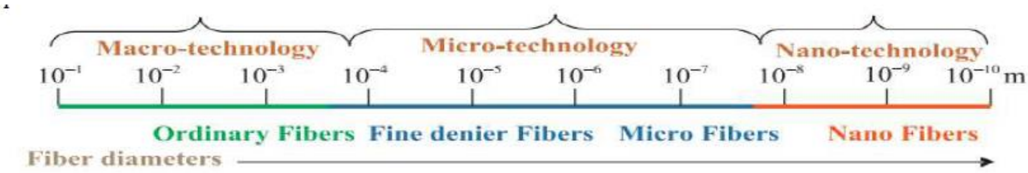

Figure 1 Fiber size and associated manufacturing/processing technologies

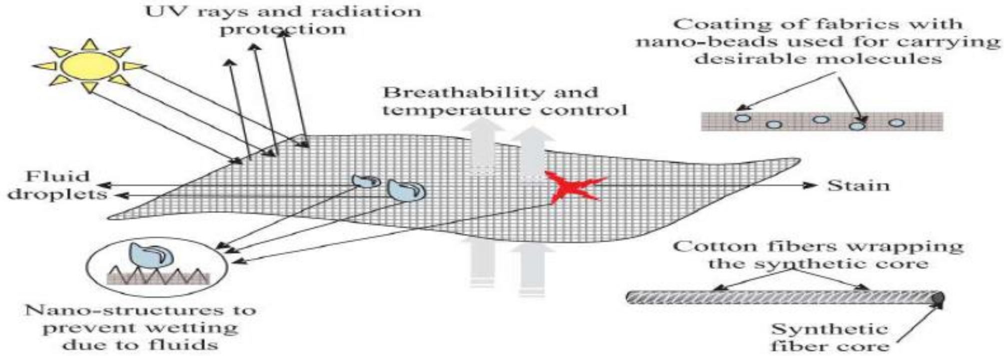

Figure 12.1: Fabric Finishing for Enhanced Properties and Performance

Now textile industries have already been prospered as a result of advancement in nanotechnology. Improvement in the performance of textiles and accomplishment of extraordinary functions of textiles are the outcomes of nanotechnology. The key benefit of nanotechnology is based on the nanostructure, nanoscale additives, nanoscale thin membranes, engineered nanomaterials and nanoscale transistors etc. Materials that can efficiently be produced by nanotechnology is more durable, sieve like, lighter in weight, conductive, stronger and may possess many other individualities.

Nanotechnology also has a great influence in textile finishing. It not only introduced the new finishes but also developed new application methods in textiles. Smooth, controllable and highly functional chemical finishes have been made. Nanoparticles finishes can pass through the localized sites on textiles through technical and electrostatic approach. Nano-coating is applied usually on the smooth and the planer substance. Nanostructured surfaces are of great interest, due to their large surface area, which might yield high functionality. Nanocoating refers to the covering of materials with a layer on the nanometer scale (10 - 100 nm in thickness) or covering of a nanoscale entity to form nanocomposite and structured materials. Nanocoatings on Textiles have recently been explored using mainly processes such as plasma-assisted polymerization, self-assembly, sol-gel nanocoating and electrochemical deposition. Nano-coating is done by various techniques i.e. sol gel coating, electro deposition, microwave heating method, dip coating, electrochemical deposition, spin coating and vacuum evaporation. Each method has some limitations and its application depends upon the end use. The adhesive forces between the material being used for coating and coating are electrostatic, covalent bonding and hydrogen bonding. Semi-conductor ceramics and metallic oxides nano-finishes can be applied on textiles to get specific properties i.e. flame retardency, water repellency, oil repellency, thermal resistivity and antimicrobial properties etc. Nanoparticles of Fe, pd/pt and Ag are manipulated into textile products to achieve conductive heating, conductive and magnetic properties. Nano-finishes are also used for medical purposes. Nanofibers can be made by different techniques. Electrospinning is an uprising technique for the production of nanofibers. Electrospun nanofibers have applications in many fields. These fibers have capability to absorb (VOC) volatile organic compound. Activated carbon is used for many years to the remove the toxic chemicals by absorption. Electrospun nanofibers replaced conventional activated carbons for desorption and absorption of toxic chemical and VOC.

12.3.1 Use of Nanotechnology in Textile Finishing:

A. Water and Oil Repellent (Hydrophobic) Nanofinishes: The premier range of Nano Care® and NanoPel® nanofinishes marketed by NanoTex Inc. USA are the next generation easy care finishes based on nanotechnology. These finishes which come under Resist spills TM Category protect the fabric against both water and oil based liquid stains / soils. Tiny whiskers aligned by proprietary “spines” are designed to repel liquids and are attached to the fibers utilizing molecular "hooks”. These whiskers and hooks are very-very small in fact no more than 1/1000th the size of cotton fiber. These whiskers cause the liquids or semisolids to roll off the fabric thus cause minimal staining, which can be removed with simple washing. Since the attached whiskers are of nanoscale size, they do not affect the hand, breathability of fabric and can withstand 50 home launderings.

B. Super Hydrophobic: Self Cleaning Nano Finishes: Many plants in nature including the Lotus leaf exhibit unusual wetting characteristic of super hydrophobicity. A superhydrophobic surface is the one that can bead off water droplets completely; such surfaces exhibit water droplet advancing angles of 150^{o} degree or higher. A self-cleaning surface thus results since the rolling water droplets across the surface can easily pick up the dirt particles to leave behind a clean surface. Taking the inspiration from the nature there have been several approaches researched to create super hydrophobic surfaces on textiles, which mimic the nano structured Lotus leaf and therefore exhibit self-cleaning properties. Nano Sphere ®, a Lotus effect based textile finish has been developed, patented and commercialized by Schoeller Texil AG of Switzerland. Super hydrophobic silica coating film on cotton substrates, which are transparent and durable have been reported by W.A.Daud and coworkers of the Hong Kong Polytechnique University using low temperature sol-gel coating based on a low temperature process. This nanocomposite coating has new applications in daily use material and such as plastics or textiles and is an eco-friendly substitute for fluorocarbon based water repellant finish. There is less than 5% decrease in textile strength and tearing strength. The air permeability of the fabric remains unchanged. The washing durability of the coatings is also good.

C. Hydrophilic Nano Finishes: The poor moisture absorption property of synthetic fabrics such as polyester and polyamides limits its applications in the apparel sector. The new range of hydrophilic nanofinishes 'Cotton Touch’ TM and ‘Coolest Comfort’ TM commercialized by NanoTex, USA makes the synthetic fabric look and feel like cotton. “Nanotouch ® gives durable cellulose wrapping over synthetic fibers such as polyester and polyamides. Cellulosic sheath and synthetic core together form a concentric structure to bring overall solutions to the drawbacks of synthetics such as static discharge, harsh handle and glaring luster. It can also last 50 launderings and expected to eliminate the decline in demand of synthetic microfiber and broaden the use of synthetics to new applications. 'Nano Dry ®. Finish provides break through moisture wicking to draw moisture away from body while drying quickly. It improves the moisture absorption of polyamides and polyesters making them hydrophilic and comfortable. The main applications are in sportswear and close to body garments that require perspiration absorbency. The finish lasts 50 launderings.

D. Antibacterial Nanofinishes based on Nanosilver: A range of antimicrobial textile finishes and products have been reported and quite a few have been commercialized, which are based on much superior antimicrobial properties of silver in nanoform. Nano silver particles containing antimicrobial dressings have been incorporated in wound care and have gained wide acceptance in medical industry, as a safe and effective means of controlling microbial growth in the wound, often resulting in improved healing. Ag nanoparticles applied on textiles through padding technique possessing excellent laundering ability. Antimicrobial filters are made by manipulation of antimicrobial agents (Ag with nanofibers). Many nanofiber membranes like cellulose, PAN, (polyacrylonitrile) and PVC (polyvinyl chloride) containing Ag nanoparticles possessing antimicrobial properties. Engineered nanomaterials containing Ag and Ag+ nanoparticles are utilized as antimicrobial filters with sufficient transport properties.

A range of nano silver based medical textiles for health and hygiene has been developed and commercialized. For imparting anti-bacterial properties, nano-sized silver, titanium dioxide and zinc oxide are used. Metallic ions and metallic compounds display a certain degree of sterilizing effect. The part of oxygen in the air or water turned into active oxygen by means of catalysis with metallic ions thereby dissolving the organic substance to create a sterilizing effect.

E. UV Protective Nanofinishes*:* It is also known that nanosized TiO2 and ZnO particles are more efficient at absorbing and scattering UV radiation than the conventional size particles and thus were better able to block UV radiation as have much larger surface area to volume ratio. Semiconductor oxides such as TiO2, ZnO, SiO2 and Al2O3 are known to have UV blocking property. It is also known that nanosized TiO2 and ZnO particles are more efficient at absorbing and scattering UV radiation than the conventional size particles and thus were better able to block UV radiation as have much larger surface area to volume ratio. A lot of efforts have been made on the application UV bulking treatment to fabrics using nanotechnology. UV blocking treatments for cotton fabric has been developed using sol-gel method by Xin and coworkers. A thin layer of TiO2 nanoparticle is formed, on the surface of treated cotton fabric, which provides excellent UV protection, the finish is durable up to 50 home launderings. Apart from TiO2, ZnO nanorods of 10 to 50 nm in length were also applied to cotton fabric to provide UV protection. The rods exhibited excellent UV protection. To minimize interaction of UV rays to skin metal oxide nanoparticles are made. Titanium oxide, magnesium oxide, zinc oxide and aluminum oxide are the metal oxides that inhabit the UV absorption, photocatalytic, electrical conductivity and photo-oxidizing capability. Nanoparticles of these metal oxides work against the biological and chemical toxic agents. Mostly zinc oxide and titanium oxide nanoparticles are used as UV blockers.

F. Antistatic Nanofinishes: Synthetic fibers such as Nylon and polyester are prone to static charge accumulation as they absorb less water. It has been reported that nanosized TiO2, ZnO whiskers, nanoantimony-doped tin oxide (ATO) and silane nanosol could impart antistatic properties to synthetic fibers. TiO2, ZnO and TiO2 nanoparticles are electrically conductive materials and help dissipate the static charge in these fibers.

G. Nano Matrix: Self Assembly based nanocoatings: Toray Industries, Inc. have succeeded in developing a "nanoscale processing technology" that allows the formation of molecular arrangement and molecular assembly necessary to bring out further advanced functionalities in textile processing. This "nano-scale processing technology" named "NanoMATRIX" forms the functional material coating (10-30 nm) consisting of nano-scale molecular assembly on each of the monofilament that forms the fabric (woven / knitted fabric). "Nano-matrix" is based on the concept of "self-organization" by controlling the conditions like temperature, pressure, magnetic field, electrical field, humidity, additives etc. The application of this technology is expected to lead to development of new functionalities as well as remarkable improvements in the existing functions (quality, durability, feel etc) without losing the fabric's texture.

12.3.2 Areas of Nanotechnology Application:

A. Fileration and Self cleaning textile: Nylon nanofibers coated with silver has antibacterial properties against gram negative E.coli and staphylococcus aureus bacteria. Electrospun nylon 6 nanofibers coated on cotton/nylon woven fabrics are used for filtration purpose. 99.5% efficiency is achieved without any surrendering in pressure drop and loss in air permeability by using nylon 6 nanofibers. Nylon fabric coated with electrospun nanofibers incorporating the nanoparticles of ZnO, SrTiO3 and TiO2 possessing self-cleaning features. It has been proved by characterization techniques that fabrics treated with such nylon (polyamide66) nanofibers retaining high photo activity after repeated wash and dye degradation.

B. Conductive textiles: Inherently conductive polymers (ICPs) have exclusive properties of actuation and sensing. The unique chain structure comprised by the conjugated double bonds is responsible for the electrical conductance of these polymers. Conductive polymers like polyaniline, polyacetylene, polythiophene and polypyrrol (PPy) are incorporated into the textile materials and work as sensing and actuating materials. PPy-based fabricated supercapacitors were reported with cycling stability in recent past. Electrical conductivity changes in polymers like polypyrrol, polyacetylene and poly 3, 4-ethylenedioxythiophene (PEDOT) etc as a result of reasons, osmotic removal or transfer of solvent in/out and change in polymer structure backbone. Mostly polypyrrol is used as conductive polymers due to its high elasticity and high mechanical strength. It never destroys the texture and shape of the textile materials. So organic piezo-resistive sensors developed by using the conductive polymers. They can be used as artificial muscles due to their ability to work on physiological fluids by exerting the mechanical force as a result of electrochemical reactions. This mechanical sensing ability is of extreme importance with respect to tissue engineering owing to its influence on the behavior of cells. A polypyrrol based actuator system can be incorporated on a chip based on mechanical stimulation. This actuator system is responsible for transformation of mechanical signals to epithelial cells. They are also used as micro-grippers and blood vessel sealers. Inherently conductive polymers are light weight and actuators can produce the mechanical response of 1 mega Pascal as a result of electrical force of 1 volt. Their capability to work at surprisingly low voltage (1 volt) makes them an ideal material to use for tissue scaffolds. Nanoparticles finishes can convert a material into sensor based material. For instance, piezoceramic particles that are operated into the textiles can detect the pulse and heart beat by conversion of mechanical force into electrical signals.

C. Stretchable Circuits as Conductive Inks: Now-a-days it is possible to construct electronic connections in textiles that are harmless and portable. Garment can be made conductive at any site. Conductive ink applied by screen and ink jet printing creates conductive areas on textiles. Inks can be made conductive by adding metals as nickel, carbon, gold, silver and copper to conventional printing inks to make them conductive. The printed areas on textiles can be utilized as pressure pads or electronic switches. Conductive ink can be used in medical field as monitoring device and as excellent active wear. These inks are quite cheaper, flexible and comfortable with respect to other conductive materials i.e. conductive yarn and polymers. Now focus is shifted towards dielectric encapsulated and Ag based conductive inks. Ag based conductive inks are made up of polyurethane film that manipulated silver flakes are treated at 120°C. There electrical resistivity is very low. To cover or wrap wires (containing conductive inks) insulated inks are also used. Stretchable circuits are formed by the combination of insulated and conductive inks. To monitor the human body bio signals are used that are easily detected by conductive inks. Electronic inks have been developed on textiles by some companies. Such kind of inks printed on textiles is connected to some sensory elements that monitor the stress level, breathing rate and heartbeat. Battery module which is in wireless connection with some smart device using the sensory elements embedded on the shirts can detect the signals coming from the body.

D. Optical Fibers: Optical fibers are produced by the combination of liquefied glass and sand particles. In this combination particular diameter/thickness is achieved and liquefied glass is taken out from the tiny openings (bushings) as filaments by cooling with cold air/ water. These filaments are sized with particular chemical (in liquid form) to protect the filaments. Finally optical fibers are winded and packaged. Optical fibers are incorporated into the textile materials for many purposes. Plastic optical fibers are quite famous for incorporation into textiles. Plastic optical wires are used widely owing to its resistance against electromagnetic radiations and heat. These optical fibers perform multi-functions in textiles i.e. deformation detection due to strain and stress, light transmission, chemical sensing and data transmission. Plastic optical fibers areweaved into the textiles and are responsible for transmission of the light. This kind of optical fibers are used in fashion industry and data transmission applications. For aesthetic appeal and as a therapy, flexible assortments of LEDs are incorporated in the fabric. This type fabric falls into the category of light emitting textiles that can transfer images, messages, information and graphics. These textiles are used as a therapy to affect the mood of individual and to optimize the positive behavior.

E. Medical Use: Ag is very important with biological point of view. It has been used in bio-treatment for more than hundred years ago. Silver has natural anti-fungal and anti-bacterial features. Polyester non-woven and colloids treated with nano-silver particles are highly bacteriostatic. Prohibition of bacterial growth in nano-silver particles makes it useful to use in socks. These nanoparticles are widely used in wound, scald and burn dressings. Electrostatic, thermal and padding methods are utilized to apply nano-finishes on textiles.

Ag nanoparticles, titanium oxide and magnesium oxide nanoparticles are also used as biological protective agents. They can be manipulated by electrostatic methods and spray coatings. Phase change materials can store, release and absorb heat as the material melts or freezes. Thermoregulation of human body is maintained by the phase change materials. Phase change materials are protected in the polymer shells by microencapsulation. These polymers are then applied as coatings or finishes on the textiles during production. Such materials made the cloths adoptive to human body temperature. These cloths maintain human body temperature i.e. when it is cold it retains the body heat (such as embrace baby blanket) and keeps body cool when outside is hot vice versa. They can replace the incubators owing to their ability to maintain the human body temperature.

F. Military/Security: There is a real need of protection and comfort in risky and life threatening environment. Enhanced performance and unique functionality are the key objectives to tackle the emergency and hazardous situation specifically for military and security purposes. Much advancement has been made in the field of defense e.g. a T- shirt is designed on which optical fibers are integrated which works like a computer on conductive fabric. Affected locations and wounds are precisely detected with the help of optical fibers (that are integrated into the garment of armor). Wireless communication utilizing conductive wires makes it possible to detect the variations in human body during combat situations. Now focus is shifted to design special jumpsuits that can be used as light weight bullet proof textiles. These jumpsuits will be used in battlefields to detect injuries, health issues and pulse rate. Conductive polymers that are incorporated onto woven textile material worked as chemical sensors. These are formed to monitor hazards that may affect the health of an individual. For toxic gases i.e. nitrogen dioxide and ammonia less detection of ppm are devised.

G. Sports Wear: Sports industry is researching to achieve individual comfort and performance. Many products are designed to achieve the desired comfort level i.e. moisture management fabrics and waterproof breathable fabrics. For moisture management a membrane of PTFE polytetrafluoroethylene is used. To achieve the desire comfort level a fabric with proper evaporation, wicking properties and breathable properties is required. Natural fibers absorb the moisture; hence they have poor moisture management properties. To achieve proper moisture management synthetic micro fibrils are used. These synthetic fibers have good wicking properties. Now-a-days textiles are designed to adopt the human body changes, hence fulfilling needs of the users and the essential comfort properties. Special kinds of shoes are designed with motor and a microprocessor that can sense the user’s running style and adjust its shock absorbing features. Likewise some textiles are also designed that have wireless connections with the smart devices to trace the pace, distance, time and calories burned.

H. Fashion/Lifestyle: Expansion and uprising of advanced textiles to achieve improved performance and enhanced functionality lead the textiles into the world of fashion and esthetics. Designers always find a way to create inspiration and art into textile. Optical fibers are utilized for data and light transmission. At the same time they are used in fashion industry to produce esthetic and decorative textiles. It is the part of the lifestyle to have a digital camera, advanced featured wrist watch, MP3 player and mini-laptop. Nanotechnology made it possible by converting the macrostructures into the nanostructures. Thin film technology makes the electronics into very thin and flexible films that can be integrated into the textiles. Touch pads, fabric, snowboarding jackets, electronic switches and pressure pads can be integrated into textiles. Musical jeans developed in 1997. Now it has new features with advanced textiles incorporation. It has a fabric keyboard made up of polyester composite yarns and conductive fibers of stainless steel. The polyester yarns and stainless steels are joined by embroidery. Fabric keyboard is manipulated in jeans. This keyboard is highly responsive and sensitive to touch. On mechanical impact it produces music, rhythms and may connect with internet MP3 file. It has a control unit which takes energy from wind, solar and mechanical impact.

I. High performance textiles: Carbon nanotubes are used as fillers in different polymers that enhanced the mechanical, heating and chemical properties of polymers. Carbon nanotubes based polymers composites are used as sensing materials against stimulus comprising of pH, gasses, temperature, pressure, chemical vapors, light, strain and liquid. Carbon doped polymers have are used as piezoelectric materials that works as stretch actuators. For high performance textiles, sensing garments are made by the combination of carbon black powder and silicone. In electric blankets previously heating coils are used, now it can be modified by using carbon doped polymers. Now it is possible to make the whole surface of the fabric conductive by making the carbon based fabrics. In this way heating elements are created in the garments. CNTs coatings are used now on textiles for sensing applications for example general cotton yarns are converted into e-textiles by coating of carbon nanotubes. Basically polyelectrolyte based coating of carbon nanotubes is done on the cotton yarns. Now it is possible to detect the blood protein (albumin) with the help of CNTs coated cotton yarns. Not only on the threads/ yarns can carbon nanotubes be coated on the fabrics and polymers. They may be utilized as lithium ion battery. Development of self powering energy textile was also reported that transform solar energy into electrical energy from CNTs.

12.4 Use of Plasma Technology in Textile Finishing:

Partially ionized gas composed of electrons, ions, photons, atoms and molecules, with negative global electric charge. It is called as Plasma Technology. Irving Langmuir first used the term plasma in 1926. Describe the inner region of an electrical discharge. Plasma, as a very reactive material, can be used to modify the surface of a certain substrate typically known as plasma activation or plasma modification. The Recent development in the plasma treatment of textile materials has revealed that it has an enormous potential as an alternate technology for the textile processing in terms of cost saving, water saving and eco friendliness. Plasma technology is applicable to most of textile materials for surface treatment and is beneficial over the conventional process, since it do not alter the inherent properties of the textile materials, It is dry textile treatment processing without any expenses on effluent treatment, It is a green process and it is simple process. This technology can generate more novel products to satisfy customer's need and requirement.

12.4.1 Principles of Plasma Treatment:

The atmosphere of plasma contains free electrons, radicals, ions, UV – radiations and lot of different excited particles in dependence of the used gas. So the gas plasma treatment differs in nature to the specific gas or gases, e.g. air, ammonia, argon etc. the textile placed near the plasma gas containing mixture of species that can react with, can lead to a various surface modifications. Type and adduction of surface modification depends on (i) nature of the gas mixture, (ii) type of textile fibre, (iii) machine parameters such, (iv) treatment temperature and time, and (v) the frequency and power of the electrical supply.

12.4.2 Effect of plasma on textile surface:

There are three major effects: surface activation, etching, and deposition. Surface activation by plasma is nothing but a chemical grafting. It always present with surface cleaning. In this phenomenon, plasma reacts with contamination present on substrate surface, loosely bound hydrocarbons. Both H and C will react with oxygen and will leave the substrate surface in the form of volatile H2O and CO2.

This contaminated free surface is ready to react with oxygen for forming carbonyl-, carboxyl- or hydroxyl functional groups on the substrate surface. The effect of grafting carbonyl-groups onto a surface of PP, polyethylene (PE), or polyesters such as polyethyleneterephthalate (PET) or polybutyleneterephthalate (PBT) gives rise to an increase in surface energy to levels higher than 68 mN/m immediately after the plasma treatment. This effect has a certain shelf-life. Plasma activation is being used in several fabric and nonwoven applications in the textile industry:

- Fabrics for automotive and medical applications
- Pre-treatment before dyeing
- Activation of transportation textile before application of flame-retardant chemistry

12.4.3 Etching by plasma:

Direct plasma is used to create an efficient etching process. The substrate is bombarded with charged particles (ions and electrons) and apart from a purely chemical effect; the substrate is subjected also to a physical sputtering effect. In the case of textiles and nonwovens, this effect of plasma treatment is not often used. A plasma etching enhances a controlled Nano- or micro-roughness, increasing diffuse reflectance and minimising the specular component.

12.4.4 Thin film deposition by plasma polymerisation:

A very important usage of low-pressure vacuum plasma technology is thin film coating deposition by plasma polymerisation. In this technique, gases are polymerising on the surface of substrate. The precursor gases are broken into radicals that react with each other on the substrate surface. The nature of the precursor gases will very much determine the properties of the deposited coating. Coating thickness is normally in the 10–50 nm range (5–30 molecular layers).

12.4.5 Application of plasma technology in Textile:

As quoted by *The Hindu,* Plasma technologies present an environmentally-friendly and versatile way of treating textile materials in order to enhance a variety of properties such as wettability, liquid repellency, dyeability and coating adhesion. Recent advances made in commercially viable plasma systems have greatly increased the potential of using plasma technology in industrial textile finishing. In India too, efforts have been made at laboratory levels at Indian Institute of Technology, Delhi, Bombay Textile Research Association (BTRA), Mumbai, Wool Research Association (WRA), Mumbai, and Central Silk Technology Research Institute (CSTRI), Bangalore. Plasma technology can improve surface modification for enhancing various textile wet processes, viz., fabric preparation, colouration, finishing. Table reports summery of some of the properties that plasma treatments can impart to material textiles.

A. Desizing of cotton fabric: sizing material like PVA from cotton can be remove by using plasma technology. In conventional desizing process we use chemicals and hot water to remove size. But desizing with plasma technology we can use either O2/He plasma or Air/He plasma. This treatment break downs chains of PVA making them more soluble. Of the two gas mixtures that were studied, the results also indicate that O2/He plasma has a greater effect on PVA surface chemical changes than Air/He plasma.

B. Dyeing: Several studies have shown that colouration of textiles can be markedly improved by plasma treatments. It has been reported that plasma treatment on cotton in presence of air or argon gas increases its water absorbency which in turn increase both the rate of dyeing and the direct dye uptake in the absence of electrolyte in the dye bath. This happens due to, the change of the fabric surface area per unit, the etching effect of the plasma effect, the chemical changes in the cotton fibre surface. The dye exhaustion rate of plasma treated wool has been shown to increase by nearly 50%. It has been shown that O2 plasma treatment increases the wetability of wool fabric thus leading to a dramatic increase in its wicking properties. In the synthetic fibres, plasma causes etching of the fibre and the introduction of polar groups leading to improvement in dyeability. The researchers believe that this technique can lead to a continuous flow system, low energy consumption, and more environmentally friendly consumption, low temperature dyeing technology on polyester substrates. Polyamide (nylon6) fabrics have been treated with tetra fluoro methane low temperature plasma and then dyed with commercially available acid and dispersed dyes. Dyeing results showed that the plasma treatment slows down the rate of exhaustion but does not reduce the amount of absorption of acid dyes. The dyeing properties of disperse dyes on plasma treated nylon fabric charged markedly when compared with untreated fabric. A slight improvement in colorfastness was seen with the treated sample.

C. Anti felting of wool*:* In regular conventional processes, wool tends to shrink, can be cover up by oxidation using a suitable plasma treatment. Surface oxidation induces by plasma prior to wool coating by plasma polymerisation reduces, wool fibre shrinkage and consequent felting. But plasma deposited on wool fibre reduces the wetablity of surface, which reduces the dye uptake.

D. Water repellent fabric: Cotton or hemp fabric usually absorbs water immediately. Applying a low-pressure plasma process, the fibre’s surface can be altered to make it repel water. After the treatment, drops run freely over the surface while mechanical properties, the visual appearance, and the permeability for water vapour remain unchanged. The surface modification is limited to a very thin layer. A treatment as short as 2 seconds can be sufficient to achieve this effect in a batch process. Continuous treatments with a speed of more than 20 m/min are conceivable. The stability of the modification can be seen in intermitted washing cycles of fluorocarbon treated cotton fabric.

***E. Flame retardant fabric**:* Currently, halogen-containing flame retardants are being banned for ecological reasons. The new kinds of flame-retardant chemistry, e.g. based on organic phosphonate derivatives, are much more expensive. Therefore, their usage should be limited to the absolute minimum. It has been shown that, in the case of plasma-activated fabrics consisting of both natural fibres and polymers, the concentration of flame-retardant chemicals can be reduced considerably without influencing the flame-retardant properties of the treated web. This again leads to considerable cost savings.

F. Ink Jet Printing: Inkjet printing is becoming increasingly widespread for the printing of textiles. Ink jet printed fabrics have demonstrated improved properties over the traditional textile printing methods, such as roller, screen and transfer printing. It displays excellent pattern quality, considerably little pollution, and especially a faster response to the frequent fashion changes. An atmospheric plasma surface pre-treatment of PET fabrics with air and argon for pigment printing, the results showed better colour yield and drawing sharpness on the pre-treated polyester fabrics. Others plasmas types, such as radio frequency and DBD discharge have been employed for the pre-treatment of PET fabric before printing with pigment showing superior wettability in final properties of the printed polyester. A wool/polyester blended fabric (45/55) pre-treated with an atmospheric DBD plasma has been printed using two different dye mixtures. The experimental results indicated that the wettability and colour strength of treated fabrics are enhanced. Moreover, changes in surface morphology of treated samples are also observed. The quality of a digitally printed polypropylene fabrics pre-treated with low-temperature plasma discharge, Polypropylene is known as very hard-to-print and hard-to-dye material. It is clear that plasma pre-treatment is able to provide added value to inkjet printing on polypropylene.

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