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FUNCTIONALISED TEXTILES: AN OVERVIEW

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ABSTRACT
Articles on Functionalised textiles have reviewed and wrote brief data on an overview about different textiles which have been used for different functions from several decades. In this review, research articles on number of Antimicrobial, Anti-Ultraviolet, waterproof & moisture permeable and flame retardant textiles have been studied and summerised. This review contains information on the materials and methods used for production of different functionalised textiles along with thier characterisation data in brief.

KEYWORDS: Antimicrobial textiles, Anti-Ultraviolet textiles, Waterproof and moisture permeable textiles, Flame retardant textiles, Functionalised textiles.

INTRODUCTION

Any material made of interlacing fibres or yarns is referred to as textile. Raw fibres of wool, flax, cotton, or other materials are spun into long strands to make yarn. Fibers are woven, knitted, crocheted, knotted, or pressed together to create textiles. The usefulness and durability of a fabric as a component of a garment are referred to as its functional performance. The impact of the fabric on the following garment characteristics is considered utility: (1) shape retention, (2) appearance retention, (3) comfort, (4) ease of care, and (5) safety. Textiles with integrated control or adjustment functions, depending on their application area, are known as functional textiles. Such as Temperature control, humidity control, Control of bacterial growth, water proofing, fragrance releasing and other functions... Viscose (rayon) and polyester fibres are the most common and widely used fibres in functional textiles. Textile industry has been attracted more attention for the developement of functional textiles which can satisfy the needs of comfort and safety of consumers. Recently, durable fragrances and perfumes have been introduced into textiles to improve products these textiles are prepared by giving treatment of fragrances to fabric. Example, Z.Yang et al[2014] prepare chitosan/vanillin microcapsules and their application to cotton fabric for controlled release of fragrance through fabric.[1] Also certain other functional textiles involves antibacterial finish of textiles. It involves variety of antibacterial agents that are impregnated into textile to give textile an antimicrobial finish. There are many other biofunctional textiles that are made for prevention against vector-borne disease caused by insects, such textiles contains insect repellent chemicals or essential oil within itself.

Preparation methods of functional textiles

Basically, preparation methods of Functionalised textiles are of two types, that are

1. **To prepare functional fibre and then weave it into textile**

In this method, uniform dispersion of functional additives is formed through methods of bending and compositite spinning and added to the fibre to get functional fibre; such that firstly functional fibre is prepared and then this functional fibre is woven to obtain functional textile.

2. **To modify ordinary textile with functional groups**

This involves three types of finishing processes, that are- physical, chemical and bio-ecological finishing processes.

a) **Physical finishing process**

Physical finishing process includes Impregnation, padding and coating. The major disadvantage is that the bonding force between the finishing agent and the textiles is weak. Its strength, on the other hand, is more long-lasting, and its functionality can be preserved for a long time.

b) Chemical finishing
To create a new functional textile, the chemical finishing method involves grafting a functional monomer onto a polymer substrate. The benefit is that its functionality can be preserved for a long period of time.

c) Biological finishing
Biological finishing is a relatively new finishing technique that uses biological enzymes with biological activity in the finishing of textiles.[2]

Types of functional textiles

- **Antimicrobial textiles**

Infectious diseases caused by pathogenic microorganisms have always posed a serious health risk to humans. Avoiding or minimising contact between pathogenic bacteria and the human body is an effective way to minimise injury and prevent the occurrence and spread of infectious diseases. Ordinary textiles have no inhibitory effect on bacteria and fungi, and pathogens are prone to growing and reproducing in ordinary textiles, contacting and assaulting the human body. Antimicrobial textiles can cut off bacteria's pathways, preventing germs from spreading on textiles and effectively avoiding pathogen contact with the human body as well as reduce risk of human pathogens and cross-infection rates. Antibacterial textiles can also protect textiles from microbial erosion and inhibit odour caused by bacterial decomposition of the cloth, ensuring human health and comfort. Antimicrobial textiles are currently made primarily by coating textiles with antibacterial agents. Nanometer metal clusters (such as nano-silver), metal salts (copper and silver salts, such as copper sulphate), and certain natural polymers with antibacterial properties, such as chitosan, are all common antibacterial agents.[2]

Examples

1. Jeong et al., used the twin-screw extrusion technique to blend Ag nanoparticles into PP fibers, and then produced textiles with good antibacterial properties.[3]

2. Rukmani and sundrarajan et al [2011] grafted beta cyclodextrin onto cotton fabric using citric acid as cross linker and sodium hypophosphite as catalyst and after grafting of beta cyclodextrin, they done inclusion of antibacterial agent thymol into cyclodextrin cavities.According to their study i.e. UV visible spectral studies of beta cyclodextrin, beta cyclodextrin grafted fabric, ungrafted fabric, thymol and thymol loaded fabric etc. confirmed the inclusion of thymol on grafted fabric. They tested thymol loaded ungrafted fabric and thymol loaded grafted fabric aginst E.coli and S.aureus bacteria using agar diffusion method and they found inhibition was more pronounced against E.coli and grafted fabric shows enhanced inhibition than ungrafted fabric. This way they done grafting of beta cyclodextrin on fabric and inclusion of thymol into the cavity of beta cyclodextrin to produce durable antibacterial textile.[4]

3. J wang. Z. cai et al [2008] investigated the incorporation of antibacterial agent, miconazole nitrate into cyclodextrin cavities that are covalently bonded onto cloth fiber. They grafted beta cyclodextrin molecule using it reactive form i.e. monochlorotriazinyl beta cyclodextrin (MCT-BCD) and catalyst Na2CO3 (50-60 gm/lit) onto cotton fabric and cured the fabric at 150-160degree C for 5-8 min for thermal fixing reaction and then they treated both grafted fabric and ungrafted fabric with antibacterial agent by dipping both fabric into ethanol solution containing 5% (w/v) of the miconazole nitrate. They characterize both modified and unmodified fabric by UV spectrophotometry. Also level of miconazole nitrate entrapped in both modified and unmodified fabrics were determined by HPLC was founded to much higher (0.458%) for textile functionalized with MCT-B-CD compared to modified fabric (0.056% w/w). they test antibacterial activity measured by shaker plates method showed that antibacterial property was markedly enhanced by impregnation with miconazole nitrate of MCT-B-CD grafted textile finished fabric kept the antibacterial abilities more than 70% even after washing 10 times while antibacterial activity of unmodified textile almost lost after washings.[5]

4. M.Bajpai et al [2010] grafted cyclodextrin (CD) onto cellulose back bone of cotton fabric using citric acid as cross linker and sodium dihydrogen phosphate as catalyst. They characterize this cyclodextrin grafted cotton fabric by SEM and FTIR analysis and founded that percent grafting of CD on fabric was increase with increase in concentration of CD, citric acid and sodium dihydrogen phosphate. Then they loaded silver (Ag) ions on the grafted fabric for the purpose of obtaining a slow release device and this Ag loaded grafted fabric showed fair antibacterial property against E.coli .the release of Ag ions from CD grafted fabric was observed for a period of seven days.[6]

5. Zitao Zhang et al (2003) Cotton fabrics are treated with chitosan to impart antibacterial properties. The antibacterial function of chitosan is investigated in terms of concentration, molecular weight, and degree of deacetylation against Escherichia coli and the Hay bacillus. In this they used updated Quinn method to assess bacterial reduction and they found, at 0.3 g/l chitosan solution, Escherichia coli is effectively inhibited, while the Hay bacillus is inhibited at 0.5 g/l. The crosslinking agent glutaric dialdehyde is used to chemically bind chitosan to cloth. Cotton fabrics treated with glutaric dialdehyde and chitosan inhibit bacteria replication effectively. They also characterise the chitosan treated cotton fabric.SEM images of fibres and IR spectra of the

surface of cotton fabrics confirms the inclusion of chitosan in cotton fabric.[7]

6. S.H.Lim,S.M.Hudson et al(2004)O-acrylamidomethyl-N-[(2-hydroxy-3 trimethylammonium) propyl] chitosan chloride (NMA- HTCC), a fiber-reactive chitosan derivative, was applied to cotton fabrics using a cold pad-batch system in the presence of an alkaline catalyst to test its use as a long-lasting antimicrobial textile finish. They investigate the antimicrobial activity of NMA-HTCC treated cotton fabrics against Staphylococcus aureus quantitatively. They found that the cotton treated with NMA-HTCC at a concentration of 1% on fabric weight showed a 100% reduction in bacteria and also even after being subjected to 50 consecutive home laundering conditions, the practice was sustained at over 99 percent. They also check the effect of an anionic surfactant on antimicrobial activity of the NMA-HTCC treated fabric.[8]
7. B.Ben Fadhel et al [2012] investigate the antibacterial property of two eucalyptus leaf extract in both cotton and wool fabric. The extracts i.e. Tannins and flavonoids from E.odorata and E.cinerea are extracted via. Maceration with acetone and then extract is fixed into cotton wool fabric use in sodium sulphate as electrolyte solution for fixation.The antibacterial effect was measured against S.aureous and E.coli bacteria using agar diffusion method. Only the fabric treated with E.odorata shows antibacterial activity and which is more significant in wool fabric than cotton. The laundering durability was also evaluated showing results that antibacterial properties decreases as laundering number increases and which is also more quickly in cotton fabric than wool fabric. The treated wool fabric with E.odorata extract shows good antibacterial activity and which lasts for upto 10 washing cycles where as antibacterial activity of treated cotton fabric lasts only for 3 washing cycles.[9]

Table 1: Antibacterial medical textiles with CDs.

Textile	Active principle/Drug	Host reagent	Biological tests	Ref. No.
Wool	Ag NPs,Triclosan	MCT Beta CD	After 15 washing cycles, the antibacterial efficiency exceeds75%	[43]
Cotton	Aqueous / alcohoolic extracts from:Lavandula angustifolia, Pelargonium graveolens, Pelargonium radula (Cav.) L'Hérit and Rosmarinus officinalis Linn. Rose Geranium and Rosemary oils	MCT Beta CD	Staphylococcus aureus Escherichia coli	[44] [45] [46]
Cotton	Octenidine dihydrochloride	Beta CD grafted with BTCA	Two types of bacteria and fungi/Diffusion Disk Method/over 20 washing cycles	[54]
Cotton	Silver (I)	CD grafted with CTR	E.Coli/7 days of observation	[47]
Cotton	AgNO3 reduced with NaBH4 or Beta CD-g-PAA	MCT-Beta CD-g- PAA	E.Coli /Staphylococcus aureus	[48]
Cotton	Miconazole nitrate (Antimycosis)	MCT Beta CD	Tests on Candida albicans, Aurococcus and colon bacillus	[49]
Cotton	Ag NPs	MCT Beta CD	Staphylococcus aureus, Escherichia coli	[50]
Cationized cotton	Colloid Ag NPs	MCT-Beta CD-g-PAA with EPCL/ Beta CD-g-PAA with EPCL	G+ve and G−ve bacteria	[51]
Hemp fibers	Ferulic acid, caffeic acid, ethyl ferulate , allantoin	MCT Beta CD	Microbiological analysis	[52]
PES vascular prostheses	Ciprofloxacin (Antibiotics)	Beta/Gamma/ HP Gamma / Me Beta CD	Staphylococcus aureus, Escherichia coli	[53]

➢ **Anti-ultraviolet textiles**

The wavelengths of UV light range from 40 to 400 nm. As a consequence, its energy is sufficient to inflict numerous organic material damages. The sun is the main source of UV rays in nature. Since the stratospheric ozone layer blocks most UV radiation from the sun, only UV rays with relatively long wavelengths, such as UVB (290-320 nm) and UVA (320-400 nm) reach the Earth's surface.Nonetheless, UVA and UVB rays may have detrimental effects on our bodies and other organic materials in our climate. UVA and UVB rays, for example, are related to the development of a number of diseases, including skin cancer, immune system suppression, cataracts, premature skin ageing, Alzheimer's disease, and inflammatory disorders.[27]

Excessive exposure to ultraviolet rays harms human skin and is one of the leading causes of skin cancer. Anti-UV textiles are capable of blocking UV rays and protecting the skin. The method of after-finishing determines the preparation of anti-UV fabric, and there are two main types of finishing agents.The first is to coat inorganic particles with higher UV ray reflection, such as zinc oxide and titanium dioxide; the second is to finish with an absorbent that can convert high-energy UV into heat or harmless low-energy UV radiation. ZnO nanoparticles can be immobilised onto the surface of fabric using a wet chemical method, giving it a strong anti-UV effect.[2]

➢ **Nanoparticle UV Absorbers**

UV absorbers on textiles are a relatively new area of research that aims to enhance UV defence of the skin, dyestuff, and textile itself. Despite this, a variety of organic UV absorbers have been investigated. Organic UV absorbers are relatively inexpensive and usually transparent, allowing them to be used in a wide range of colours and fabrics. However, the majority of organic absorbers are gradually killed by the UV radiation they consume, resulting in a decline in UV absorption efficiency over time. Furthermore, when organic UV absorbers are photo-decomposed, free radicals are formed, which contribute to the degradation of other organic molecules. Furthermore, since organic UV absorbers are small molecules, they can leach out of textiles, posing a health risk if they contaminate food and beverages.[24]

Inorganic UV absorbers, such as zinc oxide (ZnO), titanium dioxide (TiO_2), and cerium oxide (CeO_2), have greater light-fastness than organic UV absorbers. Inorganic UV absorbers are predicted to have a much longer UV protective effect than organic UV absorbers due to their inherent stability.The use of photon energy to excite electrons from the valence band to the conduction band is the mechanism of UV absorption in these semiconductor inorganic materials.For example,The bandgap energy of ZnO, is 3.3 eV, which corresponds to wavelengths of 375 nm. Light with enough energy to excite electrons falls below these wavelengths and is thus absorbed by ZnO. Light with a wavelength longer than the bandgap wavelength, on the other side, would not be absorbed. The absorbed light does not kill the inorganic semiconductors, but rather converts them to organic semiconductors.The inorganic semiconductors are not destroyed by the absorbed light; rather, it is converted to heat, which is negligible at room temperature. As a result, inorganic semiconductors with large bandgap absorb UV light and, if small enough, provide strong clarity to visible light.[28] Other advantages of inorganic UV absorbers over organic UV absorbers include the following. For example, zinc oxide (ZnO) has a long history of safe topical use as an anti-irritant, astringent, and skin-healing agent.

➢ **Anti-UV finish of textile by nanoparticle coating**

1. TiO_2 Nanoparticles

Xin et al. (2004) investigated the effects of TiO_2 on UV blocking properties in cotton fabrics. In ethanol, a sol-gel process was used to create the coating. On the fibre surfaces, a thin layer of TiO_2 with a thickness of 100 nm formed. The films were nanograined continuous films rather than scattered nanoparticulates. Nonetheless, the cotton fabrics' UV safety factor (UPF) increased from 10 to 50+. Even after 55 home launderings, the high UPF value was retained.[29]

Fei et al. (2006) The synthesis of TiO_2 nanoparticles directly onto fabrics has been studied.Nanosized TiO_2 particles containing granular anatase and brookite, as well as rod-like rutile, were first synthesised. Using a dip-pad-cure technique, the peptized TiO_2 sols were then adsorbed onto cellulose fabrics. As a result, a homogeneous film of nanocrystallites formed on the cotton fibres, consisting of nanoparticles and nanorods smaller than 100 nm. There was no agglomeration because the nanoparticles and nanorods covered the entire surface of the fibres. A promising bactericidal photocatalytic activity was achieved, as well as excellent UV radiation safety.[30]

Daoud et al. (2005) The synthesis of TiO_2 nanoparticles directly onto fabrics has been studied.Using a dip-pad-cure process, we dipped knitted cotton substrates into a titanium tetraisopropoxide solution in absolute ethanol at a pH of 1–2. The process produced a uniform coating of TiO_2 nanoparticles with a near spherical grain morphology and a diameter of 15–20 nm. The UPF ranking went from 10 to 50+. The UPF rating did not deteriorate after twenty washings.[31]

Yu et al. (2008) Developed a system for applying UV-blocking treatment to cotton fabrics in one bath and two phases by dyeing and finishing the fabric. As an inorganic anti-UV agent and an adhesive, industrial nano-TiO_2 with a diameter of less than 50 nm was used; poly vinyl pyrrolidone (PVP) was used to increase the wet fastness.The dyestuff solution was enriched with nano-TiO2 and PVP before being applied to fabrics at 70°C, followed by cleaning, soaping, washing, and drying. The UPF values increased from 15 to 35 when

the TiO_2 content in the treatment solution was increased from 0 percent to 1.5 percent. They discovered that treating the cotton fabric with nano-TiO2 has no impact on the fabric's wearability.[32]

2. ZnO Nanoparticles

Wang et al. (2004, 2005) investigated ZnO crystallites derived from sol-gel for UV defence of textiles.A dip-pad-cure process was used to apply transparent solutions of zinc acetate and triethenamine in 2-methoxyethanol, equal to 3 wt percent ZnO, to cotton fabrics twice, followed by curing at up to 400 ^{0}C. Cotton fabrics were used to develop Dumbbell-shaped ZnO crystallites larger than 500 nm. A UPF of more than 400 was achieved when a curing temperature of at least 150^{o}C was used. UV-blocking wavelengths ranged from 352-280 nm. After a washing process that was equal to 5 cycles of home laundry, this finishing process offered consistent wash-fastness.[33,34]

Yadav et al. (2006) used ZnO nanoparticles to enhance the UV blocking properties of cotton fabrics. A simple method was used to coat fabrics with ZnO nanoparticles in their analysis.Zinc nitrate and sodium hydroxide were used as precursors, and soluble starch was used as a stabilising agent, in a wet chemical process to make ZnO. An acrylic binder was used to coat these nanoparticles, which have an average size of 40 nm, onto bleached cotton fabrics (plain weave, 30 s count). Around 75% of the incident UV light was blocked by the nano-ZnO (2%) coated cotton fabric.[35]

A method for impregnating ZnO–soluble starch nanocomposites was developed by Vigneshwaran et al. (2006). From zinc nitrate hexahydrate and sodium hydroxide in water, ZnO nanoparticles with a diameter of 38 nm were synthesised using water as a solvent and soluble starch as a stabiliser. Using a pad-dry-cure process, nano-ZnO was impregnated into cotton fabrics. The coated fabrics provided better UV protection; the transmittance at 350 nm was reduced from 80% to 20%.[36]

Becheri et al. (2008) used zinc chloride and sodium hydroxide solutions to make peptised ZnO nanoparticles, which they then applied to cotton and wool fabrics. Under gentle magnetic stirring, the wool and cotton samples were soaked for 10 minutes in a 2-propanol dispersion of ZnO nanoparticles (5 percent w/w). After that, the clothes were squeezed to eliminate excess dispersion before being dried in an oven at 130°C for 15 minutes at atmospheric pressure. At 350 nm, the UV transmittance of the fabrics was reduced from 90 percent to 20%. Despite the fact that the nanoparticles were not covalently grafted to the fabric materials, the large agglomerates were removed from the textile surface after 5 launderings, and more than 50% of their initial volume remained on the fabric.[37]

Direct growth of ZnO nanoparticles on silicon dioxide (SiO2) coated cotton fabrics was reported by Mao et al. (2009). The cotton fabric was coated with needle-shaped ZnO nanorods with a diameter of 24 nm after hydrothermal processing. The UV-blocking properties of the coated fabrics were excellent, with a UPF value of over 50. After 5 times laundering, the UPF was reduced to 50% of its original value.[38]

Other nanoparticles

Grancari et al. (2009) used white cotton and polyester fabrics to apply natural zeolite nanoparticles with a diameter of 200 nm. Zeolites are hydrates of aluminosilicate that are porous. They don't absorb UV light, but they can scatter or diffuse it like other white mineral particles. The UPF values of textiles coated with zeolilte nanoparticles increased to 160. Despite the fact that natural zeolites are yellowish, the coatings had little effect on the fabric's whiteness.[39]

Other examples of Anti-ultraviolet textiles

1. **Hossam E. Emam et.al (2017):** In this research, Outdoor employees need to wear protective textiles against harmful solar radiation to protect their skin from a variety of diseases. The current research focuses on the use of nano metal organic structures to produce anti-ultraviolet radiation (UVR) textiles (n-MOFs). Using a one-pot technique, two different MIL-MOFs, namely MIL-68(In)-NH2 and MIL-125(Ti)-NH2, were produced in nano size within natural textiles (cotton and silk) matrix. Using an electron microscope and X-ray diffraction, the formation of n-MIL-MOFs within textiles was confirmed. Depending on the textile form, different sizes and morphologies were observed, indicating that the chemical composition of the textile plays a role in the existence of prepared MIL-MOFs. Particles with a size range of 70.6–44.5 nm in cotton and 81.3–52.2 nm in silk were found in MIL-68(In)-NH2. Within textiles, a crystalline disc of MIL-125(Ti)-NH2 could be seen.After alteration, natural textiles showed complete UVR blocking, and the UV safety factor (UPF) was linearly proportional to MIL-MOFs and metal content. Direct incorporation of MIL-MOF contents 10.4 g/kg, regardless of metal form, was necessary to achieve excellent UV blocking properties.Despite the fact that 38.5–41.0 percent of MIL-MOFs were lost after 5 washings, the washed samples had a high blocking rate (UPF = 26.7–36.2), indicating strong laundering durability.[25]

2. **Yao-Yu Wang et.al (2019):** In this article, Anti-UV radiation surface coating is a powerful method for producing practical textile materials that are required for outdoor workers to protect their skin from a variety of diseases. However, achieving such anti-UV radiation coating with a simple method remains difficult, as existing fabrication protocols typically necessitate complex machinery, complicated

procedures, and the use of toxic chemicals. A novel coating technology involving in situ self-assembly of metal–organic frameworks is described in this paper for fabricating anti-UV radiation fabrics using a single solid-phase hot-pressing stage. InOF-1 nanocrystalline microparticles are securely placed on the surface of three types of fabrics (cotton, polyester, and aramid), resulting in a major improvement in UV-blocking property with light robustness loss.[26]

- **Waterproof & Moisture-permeable textiles**

Waterproof and moisture-permeable textiles can prevent water from penetrating the fabric under certain pressures while also allowing water vapour to pass through the fabric quickly, resulting in "breathable fabric." Laminating and coating are two common processing processes. Laminated fabric is currently the most popular, consisting primarily of multiporous Teflon film, PU film, and fabric composite lamination. Gore-Tex fabric is a more established product with a sizable market share in outdoor sportswear fabrics. Directly grafting hydrophobic groups onto cotton fabrics can introduce the cotton waterproof function while preserving the cotton's original comfortable and breathable characteristics, and has promising application potential. In this area, a research group at the SINAP, CAS, has conducted extensive research.[2]

Types of waterproof breathable fabric

These can be divided into three groups:

1. Densely Woven Fabrics
2. Membranes

a) Microporous Membrane.
b) Hydrophilic Membranes.

3. Coatings

a) Micro Porous Coatings.
b) Foam Coating.
c) Hydrophilic Coatings.

Examples of Waterproof & Moisture-permeable textiles

Das et al (2016) To create a moisture vapour permeable waterproof coating, cotton fabric was coated with an aqueous dispersion containing a mixture of natural rubber latex (NRL), polyvinyl alcohol (PVA), and starch using a knife-over-roll technique.Coating cotton with a formulation containing NRL, 15% aqueous PVA, and tamarind kernel seed powder as starch in a 1:3:0.3 ratio in the presence of a traditional sulphur curing method, accompanied by drying the coated fabric at 95°C for 5 minutes and subsequent vulcanization at 120°C for 2 hours.Waterproofness, breathability as measured by moisture vapour transmission rate, coating adhesion, tensile properties, abrasion resistance, and flex endurance were among the properties of the coated fabric that saw the most balanced improvements. The addition of PVA to the coating makes it permeable to moisture vapour, and the inclusion of starch in the coating formulation enhances this property. SEM analysis of the surface morphology of vulcanised coatings showed that poly vinyl alcohol crystals formed clusters in the rubber matrix with dimensions of just a few microns. Such PVA clusters acted as conduits for moisture vapour to pass through the NRL film while also serving as an effective barrier to liquid water droplets.[40]

V. M. DESAI AND V. D. ATHAWALE (1995), Polyurethane (PU) coatings with high moisture permeability and water repellency properties have been developed for nylon fabrics. These PU coatings are made by reacting the -caprolactam-4,4'-diphenyl methane diisocyanate(MDI) adduct with hydrophobic polyols, then deblocking the -caprolactam with different molecular weight polyethylene glycol (PEG) at room temperature. To achieve the best moisture permeability properties, the hydrophobic and hydrophilic segment balance was changed by adjusting the molecular weight of PEG.[41]

N. S. SAVE ET AL(2002), Polyacrylamide-based breathable coatings for cotton fabrics have been developed. The coatings have a high water vapour permeability while also having good resistance to air and liquid water penetration. These polyacrylamide-based coatings were created by coating the fabric with a 4 percent polyacrylamide solution containing citric acid as a crosslinker (5–50 mol%) and sodium hypophosphite (0.3 mol%) as a catalyst followed by drying at 90C and curing at 150C. Crosslinks are formed between the polymer chains as well as between the polymer and the cotton fabric during the curing reaction. The crosslinked polyacrylamide coating was found to have good integrity. In comparison to the control fabric, the resistance to hydrostatic head for double and triple-coated samples with cross-linker concentrations of 50 and 20 mol percent was found to be in the range of 800–1280 mm, whereas the air-permeability values were significantly reduced by two orders of magnitude. These samples' water vapour transmission rates (WVTR) were found to be outstanding, with only a 5-23% reduction. As compared to the values shown by control cotton cloth, the water vapour transmission rate (WVTR) values for these samples were found to be excellent, with just a 5-23% reduction. FTIR and NMR spectroscopy is used to investigate the mechanism of the reaction that leads to the formation of crosslinks.[42]

- **Flame retardant textiles**

In industrial goods, flame-retardant fabric with fire-retardant properties is commonly used. There are two ways to achieve the flame-retardant property of textiles. First, the flame retardant is weakly bonded to the textile in the finishing of flame-retardant textiles, and the flame-retardant property will gradually deteriorate as the service life and washing times increase. Second, the flame-retardant fibre is synthesised first, followed by weaving into the flame-retardant textile. The flame-retardant property of the material will then be preserved for a long time.[2]

Non-durable and semi-durable flame retardants based primarily on phosphate or phosphonate salts are still used on rarely washed or disposable items, and recent improvements have been made to impart better 'hand' or limited wash resistance. On charrable fabrics, backcoating with insoluble ammonium polyphosphate, usually with additives and binders for intumescence, has been found to be effective. The leading backcoating, however, is decabromodiphenyl ether plus antimony oxide, which is effective on a wider range of fabrics, including synthetics and mixes. Polymers and copolymers of pentabromobenzyl acrylate are newer candidates for textile coating growth. The most durable finish for cellulosic fibres has been based on tetrakis(hydroxymethyl)phosphonium salts reacted with urea and cured with gaseous ammonia for about 50 years. Chemical or process modifications, as well as specific fibre blends, have increasingly been used to create softer versions. On cellulosic fabrics, phosphonic ester methylolamide finishes are used, which are less durable and do not require gaseous curing. Other washable phosphorus-based finishes for cellulosics and blends are currently being developed. In a 'thermosol' process, polyesters are still flame retarded with phosphonate or hexabromocyclododecane. As specialty fabrics, polyesters with built-in phosphinate structures are available.In polyester, a dialkylphosphinate salt was recently introduced as a melt spinning additive. For polypropylene fibre, a tribromoneopentyl phosphate melt spinning additive has been developed. (E. D. WEIL AND S. V. LEVCHIK.et al).[10]

The history of flame retardant textiles

Chemical flame retardant textiles have been patented in England since at least 1735, when borax, vitreol (a metal sulphate), and other mineral substances were patented for flame retarding canvas and linen.[13] It's worth noting that non-durable flame retarding of tent fabric is still popular, and certain sulphates (such as ammonium and occasionally alum) are still used in non-durable flame retarding. The first systematic research was conducted at the request of the French government to flame retard theatre curtains, with Gay-Lussac identifying ammonium phosphate (still used!) as highly effective in 1821. Military laboratories performed experiments on a wide variety of inorganic additives and treatment methods at the time of World War II. Most of this work is outlined in an excellent monograph by Little,[14] which is also useful for avoiding duplication of previous work. Lyons' monograph on flame retardants[15] contains useful discussions of textile applications. Albright & Wilson (UK), Hooker Chemical Co. (Niagara Falls, NY), the US Department of Agriculture Southern Regional Laboratory (New Orleans, LA), and American Cyanamid Co. (Stamford, CT) worked hard in the mid-twentieth century to develop durable flame retardant cotton fabrics, as did Ciba in Europe. The need to flame-retard cotton work clothing was one driving factor, and the Federal children's sleepwear rule was another later.

Modes of action

The scope of this analysis does not allow for a thorough discussion of mode of action; instead, the reader is directed to the authors' chapters in.[11,12] To simplify a complicated issue, halogen and halogen–antimony systems are flame inhibitors, phosphorus and boron systems enhance charring and the formation of surface barrier layers, and metal hydroxides are endothermic water-releasing systems. Some additives in thermoplastic textiles, such as PET, help extinguishment by improving melt flow. Many naturally flame retardant fibres and fabrics, on the other hand, form a char when exposed to flames.[10]

Examples of flame retardant textiles

1. Kaynak et al(2020), In this research, Wool and wool-polyamide blended yarns (88.6% wool–11.4% polyamide 6,6 and 78.5 percent wool–21.5 percent polyamide 6,6) were knitted, and the resulting fabrics were treated with zirconium complexes using the exhaustion process. The researchers looked at six separate baths containing potassium hexafluorozirconate and zirconium acetate.The spread of flame, heat release, and smoke release rate were all used to assess the flammability danger. Untreated fabrics failed the vertical flammability test regardless of the blend composition. Just 1% potassium hexafluorozirconate and 10% zirconium acetate solution could pass the vertical flammability test on 100% wool fabric. For the blended fabrics to pass the vertical flammability test, higher metal complex compositions were needed. In a cone calorimeter test, 100 percent wool treated with 5% potassium hexafluorozirconate and 10% zirconium acetate solution provided the lowest peak heat release and smoke release rates, with 146.4kW/m^2 and 1.2 s1 respectively.[16]

2. Mohd Yusuf(2020) In this chapter, Due to increased understanding of environmental issues, flame retardants (FRs) focused on eco-friendliness, eco-viability, and durability have become one of the most common areas of research interest in recent years. In this regard, strategies for textiles and other substrates are considered, as well as their applicability and selectivity. Because of its flexibility, phosphorus-based FRs provide a basis for the guided design of nontoxic FRs. For example, it may function in both the condensed and gas phase, as an additive or a reactive part, in various oxidisation states, and in synergy with a variety of adjuvant elements. Various P-moieties and combinations, including elemental, inorganic salts, and organophosphorus compounds, contribute significantly. This chapter provides an overview of phosphorus-based flame retardants for polymeric structures, as well as potential research and development opportunities.[17]

3. LEWIS et al.(2020), In this research, The reaction of potassium salts of phosphorous-containing acids with cotton cellulose in the presence of urea under thermosol conditions (pH 5, 185 °C) to esterify the cellulose and create a flame-retardant effect is investigated in this article.Chemical modification of cotton cellulose was verified using attenuated total reflectance Fourier-transform infrared (ATR-FTIR) spectroscopy, with only the phosphite salt forming a covalently bound cellulose ester (confirmed by flammability tests). Urea is essential because it decomposes into ammonia and isocyanic acid (the reactive intermediate), and it is the isocyanic acid/phosphite anion addition compound that interacts with the hydroxyl groups on cellulose to form the ester.Phosphate and hypophosphite salts did not react with cellulose, according to ATR-FTIR analysis, and thus had no flame resist impact. Although the esterification of cellulose adds phosphorous to the cellulose, it was important to add a nitrogen species with the addition of a cationic polymer to meet more stringent work-wear laundry requirements. The possibility of simultaneously bonding nitrogen via carbodimide chemistry is investigated in order to develop a one-shot "all-in" process, with preliminary promising trials demonstrated. Many dyed-fabric after-treatments will result in colour shifts due to interactions with the chromophores. Azo dyes, for example, are especially vulnerable to formaldehyde generated during the Pyrovatex process or the reducing nature of the Proban process, both of which result in colour change. The novel phosphite/urea flame-retardant system presented here has the advantage of being less aggressive, allowing for the use of reactive dyes to create a bright and broad shade range, as demonstrated by the results.[18]

4. Sidra Saleemi et.al (2020) Functional textiles have gotten a lot of attention in recent years because of their health and safety benefits. As a result, this research used a sol-gel finishing technique to examine the flame retardancy of cotton (COT) and polyester-cotton (PC) fabrics treated with different concentrations of silica and zinc nanoparticles. The characterization of coated fabric samples was done using FTIR, SEM, and TGA. The FTIR and SEM study of Pristine and Treated Cotton and PC fabrics showed that the SiO_2 (silica dioxide) and ZnO (zinc oxide) nanoparticles were uniformly attached to the fibre surface, leading to improved thermal stability.For the COT-2 cotton substrate, the starting thermal degradation increased from 320 to 350 °C, and the maximum degradation was observed from 400 to 428 °C. However, for the PC substrate PC-2, the initial thermal degradation improved from 310 to 319 °C, and the fastest degradation improved from 500 to 524 °C. The results showed that silica has a greater effect on the thermal properties of COT and PC fabrication.The treated samples' tensile strength and flexural rigidity were also increased, despite a slight reduction in air permeability.[19]

5. Bin Zhao et.al (2020) In this article,To reduce the chance of fires, there is a need for long-lasting flame retardant treatments for cotton fabrics. Toxic halogenated organic flame retardants or formaldehyde-evolving chemistry are used in many modern industrial treatments. Based on a spontaneous crosslinking reaction between branched polyethyleneimine (PEI) and hexachlorocyclotriphosphazene, a simple two-step process for coating cotton fabric is described (HCCP).The cotton fabric has a high limiting oxygen index (33.8%), self-extinguishing activity in open flame testing, and an 85 percent reduction in peak heat release rate thanks to a coating made from 10 percent PEI and 5 percent HCCP solutions.After a simulated washing test, this treated fabric retains its self-extinguishing behaviour. This one-of-a-kind combination of properties is due to a tightly networked coating that intumesces when burned. This treatment's ease of use and formaldehyde-free chemistry make it a viable alternative to organohalogen and formaldehyde-evolving treatments.[20]

6. Xian-Wei Cheng, Jin-Ping Guan, Xu-Hong Yang, Ren-Cheng Tang In this article, Natural phytic acid (PA), titanium dioxide (TiO2) nanoparticles, and 1,2,3,4-butanetetracarboxylic acid were used to create a novel and long-lasting organic-inorganic flame retardant (FR) method for wool fabric (BTCA).An additional exhaustion method was used instead of the conventional pad-dry-cure protocol to resolve the diffusion barrier action of wool fibre to the FR agents. The treated fabrics' flame retardancy, heat release, smoke production, thermal stability, and washing durability were discussed. Wool fabric was given excellent flame retardancy and washing durability thanks to the PA/TiO2/BTCA system. After 30 washing cycles, the treated fabric was still able to self-extinguish. Furthermore, the FR system effectively decreased the potential for smoke generation. Thermogravimetry testing revealed that the FR method changed the thermal decomposition behaviour of wool, with the formation of thermal protective intumescent char accounting for the majority of the improved flame retardancy, indicating a substantial condensed-phase FR mechanism in the treated wool.[21]

7. E. Kaynak et al. (2019), In this research, Padding was used on wool and wool/nylon blended yarns that had been knitted and treated with a phosphorus sulphur dependent agent. The probability of flammability was measured using parameters such as flame spread, heat release, and smoke emission. The FAR/CS 25.853 12 Second Vertical Bunsen Burner test protocol was used to determine the flame

distribution of fabrics. The fabrics treated with the flame retardant (90 percent add-on) will meet the vertical flammability criteria for aircraft materials regardless of the blend ratio. The cone calorimeter measures important flammability parameters including heat release rate and peak heat release rate. Fabrics that have been treated with FR have been found to be efficient in reducing heat release and thus fire risks. Both a cone calorimeter and an NBS smoke density chamber were used to assess the smoke created by the materials during flaming combustion.[22]

8. S. Wazed Ali et.al (2019) In this paper, On cotton cloth, sodium lignin sulfonate (SLS) has been investigated as a fire retardant finishing agent. The LOI value of 30 percent [w/v] SLS treated cotton fabric was 28.5 with a minimum char length of 4 cm (self-extinguishment), while the control cotton fabric burned out with flame and afterglow in 1 minute. Thermo-gravimetry of the treated cotton fabric revealed 35 percent mass retention at 500 C, while the control cotton fabric had just 8% char mass left at the same temperature. The GC–MS technique was used to analyse volatile species released during the burning process, demonstrating that the SLS treated fabric prevented the development of flammable gases that SLS treatment imparts a natural attractive yellow colour to the treated fabric as well as UV protection without compromising the fabric's physical strength, which can be considered an added benefit over the flame retardant effect.[23]

CONCLUSION

Based on the functions performed by various textiles, they can be categorised as Antimicrobial textiles, Anti-ultraviolet Textiles, Waterproof & Moisture-permeable Textiles and Flame Retardant Textiles. All these textiles have great functions to use it accordingly to the need. Antimicrobial textiles protect users from source of infection i.e microbial or pathogenic organisms and keeps user safe from infection. Anti-UV Textiles protect user from ultraviolet radiations and keeps them undamaged from sunlight and other UV radiations. Waterproof and Moisture permeable textiles keeps user resistance from water and keeps them breathable. Flame redardant textiles retards flame hence improves safety of user in flame and performs key role for firemens. Such a way that all textiles accordingly to their functions are categorized and described. This review is an overview on functionalised textiles. This review paper gives idea and brief information on functionalised textiles.

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