High Performance Technical Textiles

Edited by
Roshan Paul

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1

High Performance Technical Textiles: An Overview

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1.1 Introduction

Technical textiles provide technical, functional, and performance properties, unlike textiles used in the fashion, artistic, or decorative sectors. These include textiles for households, packaging, sports, medical, protection, military, filtration, geotextiles, agriculture, construction, automotive, marine, aeronautic, and other smart applications. Synthetic as well as nanofibres – like aramid, polyolefin, polyamide, polyester (PES), viscose, glass, and ceramic fibres – are widely used for the manufacture of technical textiles. Nanofibre nonwovens can also improve the properties of textiles designed for technical applications.

Natural and bast fibres like jute, flax, hemp, coir, ramie, kenaf, and abaca are also finding applications as technical textiles for environmental reasons. They are gaining increasing importance particularly as fibre reinforced composites in automotive, construction, aerospace, and packaging industries. This is mainly due to the fact that bast fibres offer good tensile strength and stiffness compared to synthetic fibres such as polyamide, carbon, and aramid. Besides, they originate from renewable natural resources and are environmentally friendly.

1.2 Application Areas of Technical Textiles

In general, application areas of technical textiles are classified as:

- *Hometech*. Carpet components, furniture components, consumer and industrial wipes, air and water filtration, interior design, drapes, covers, ticking, composites, etc.
- *Packtech*. Bulk packaging with a predefined three-dimensional (3D) structure, scrap and disposable, spacer and tying, absorbent food pads, etc.
- *Sporttech*. Luggage components, sports equipment, sportswear, wipes, covers, disposable, and camping equipment, etc.
- *Medtech*. Drapes and gowns, sterile wrap, swabs and dressing, cleaning products, cover stock, wound care, protective apparel, bedding and sheets and masks, etc.

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- *Protech*. Chemical and biological protection, particulate protection, flame retardant, cut resistant, shields and gowns worn in emergency situations, chemical handling, hazardous waste control, cleaning, filtration, etc.
- *Clothtech*. Cleanroom garments, shoe components, insulation and structure, sewing products, interlining, leather goods applications, etc.
- *Indutech*. Electrical components, filtration and separation, satellite dishes, clothing surfacing tissues/veils, conveyor belts, reinforced plastics, polyvinyl chloride (PVC) substrates, flame barriers, noise absorbents, battery separators, antislip matting, lifting and pulling, etc.
- *Geotech*. Asphalt overlay, soil stabilization, drainage, sedimentation and erosion control, pond liner, impregnation base, drainage channel liners, separation, reinforcement, filtration, offshore land reclamation, roadside, railside, river and canal banks, reservoirs, etc.
- *Oekotech*. Environmental protection, exhaust air and waste water filtration, dust collection, oil and fuel absorbent, gas and odour removal, etc.
- *Agrotech*. Crop covers, seed blankets, weed control fabrics, greenhouse shading, root bags, biodegradable plant pots, capillary matting cover, protection and collection, fishing, etc.
- *Buildtech*. Roofing and tile underlay, underslating, thermal and noise insulation, house wrap, facings for plaster board, pipe wrap, concrete moulding layers, foundations and ground stabilization, vertical drainage, protection and display, textile construction, building components, reinforcements, high quality wallpapers, etc.
- *Mobiltech*. Boot liners, parcel shelves, heat shields, shelf trim, moulded bonnet liners, boot floor covering, fuel/oil filters, headliners, rear parcel shelves, airbags, cabin air filters, engine intake and exhaust air filters, silencer pads, insulation materials, car covers, under padding, car mats, tapes, backing for tufted carpets, seat covers, door trim and insulation, floor coverings, protection, composites, etc.

1.3 Technical Textiles by Functional Finishing

It is a general concept that technical textiles are manufactured using technical fibres, with inherent technical properties. But innovative functional finishes are creating possibilities for developing functional technical textiles by a simple finish application at the end of the textile manufacturing process. The modification of commodity fibre and fabric properties by innovative finishes can be a cheaper route to high performance than by using high cost fibres with inherent built in performance properties. In a textile industry, finishing is usually done in the final stage of textile processing. A wide variety of functional properties can be created on textiles by means of chemical or bio finishing and also it is possible to develop multifunctional textiles.

With the advent of nanotechnology, a new area has developed in the realm of textile finishing. Nanotechnology is opening new avenues in chemical finishing, resulting either in improved processes or in helping to achieve new functional properties, which were not possible with conventional finishes. Thus, the application of nanotechnology creates an expanded array of functional properties enabling textiles to be used in novel materials and products. Unlike in conventional finishing, the nanometric size of the coating will not affect negatively the hand and feel of the finished fabric.

The low temperature sol–gel techniques, as well as the new generation of polymeric resins, are offering new possibilities in textile chemical finishing.

Another important development is the plasma enhanced chemical vapour deposition (PECVD) technique. It is a finishing process which can be used to deposit thin solid polymeric films from a gas state to a solid state on a textile substrate to achieve the desired properties. The advantage of such plasma treatments is that the modification turns out to be restricted to the uppermost layers of the substrate, thus not affecting the overall bulk properties. In general, plasma treatment can be considered as a dry alternative to the wet chemical treatments and so they are environmentally friendly. Layer by layer (LbL) assembly method is another new finishing technique by which ultrathin composite films can be developed on solid surfaces like textiles. It involves an LbL adsorption of polycations and polyanions to build a multilayer ultrathin polyelectrolyte coating on a textile substrate.

1.4 High Performance Technical Textiles

This book on high performance technical textiles covers almost all the important areas of technical textiles. The book starts with household and packaging textiles, hi-tech sports textiles, and medical textiles. Further, it focuses on the protective aspects, with chapters on protective textiles, personal protective clothing, and military textiles. Industrial and filtration textiles, geotextiles, and agrotextiles are dealt with in the subsequent chapters. Important application areas like construction, automotive, marine, aeronautic, and space are covered in the following chapters. The last chapter talks exclusively about smart and responsive textiles.

1.4.1 Household and Packaging Textiles

Textiles have become an integral part of the home, both in daily use and in household installations. Household textiles include carpets, sheets, pillow cases, pillows, blankets and quilts, bedspreads, table linens, bathroom and kitchen towels, bathmats, shower curtains, readymade and custom made curtains, draperies, slipcovers, and other furniture protectors. They make life more comfortable and give home interiors a defined aesthetic characteristic.

Technological innovations have converted conventional household textiles into high performance textiles by improving their durability and by adding multiple functionalities, thus allowing them to follow trends in line with e-textiles, combining sustainable materials for easier disposal and reuse, and incorporating nanotechnology into everyday personal items. Hollow fibres with good insulation properties are broadly employed in bedding and sleeping bags. Other categories of fibre are increasingly being utilized to substitute foams in furniture because of the fear of fire and of health hazards created by such materials.

Packaging textiles include all textile packing material for industrial, agricultural, and other goods. Lightweight nonwoven and knitted materials are widely used for various wrapping and protection purposes, particularly in foodstuff industries. Growing environmental concern over reusable packages and containers is opening new opportunities for textile products in this area. Textiles have helped high performance packaging to advance as they can be engineered to have very strong weaving structures while being lightweight and more sustainable than conventional packaging materials. High performance textiles along with modern materials handling methods have permitted the innovation of more proficient handling, storing, and distribution of various powdered and granular merchandise varying from fertilizers, sand, cement, sugar, and flour to dyes and pigments. Packaging textiles have also entered a new era of active and intelligent systems which interact with their content and inform the consumer about spoilage risks or products' nonconformity.

1.4.2 Sports Textiles

Traditional applications of sports textiles are in high activity outdoor athletics, team sports, as well in less active games, for example golf. Further, they are also used in highly visible applications, including textiles for balloons, parachutes, paragliders, and sailcloth. Sportswear has also become leisure and casual clothing. High performance sports textiles are widely used in shoes, sports equipment, winter and summer sports, flying and sailing sports, climbing, angling, and cycling.

Functional sportswear has a new look as lifestyle wear, and accordingly sportswear is functionally modified and fashion elements are added to meet these new requirements. High performance sports textiles are manufactured using sophisticated raw materials and technology. The performance fibres, yarns, fabrics, and functional finishes developed for the sports sector are increasingly transferring the sportswear to the mass market in the high street. Sports textiles are also specially designed to take moisture away from the body, and attached with sensors to identify high impact stresses on joints, heart rate, temperature, and other physiological data. All these developments have made the choice of materials more pronounced and selection of them more complicated. This leads to balancing properties and functionalities with user and maintenance friendliness.

1.4.3 Medical Textiles

Medical textiles are one of the important areas within technical textiles and the use of textile materials for medical and healthcare products ranges from simple uniforms or gauze or bandage materials to scaffolds for tissue culturing and a large variety of prostheses for permanent body implants. It should provide barrier properties, comfort and water vapour transmission, along with the required mechanical properties. Disposability is the main reason hospitals and operating rooms prefer nonwovens over woven fabrics. Generally, medical nonwovens offer unique antimicrobial solutions and provide increased protection for the user and have less potential for cross-contamination. Nonwovens used in gauze swab should absorb exudates, protect from external contamination, cushion from further trauma and have good air permeability.

High performance medical textiles are in constant demand, owing to their major expansion into fields like wound healing and controlled release, bandaging and pressure garments, implantable devices, as well as medical devices, and development of new intelligent textile products. Medical textiles are clearly driving the emergence of new and improved raw materials and processes, leading to new technological solutions specifically designed to tackle the problems medical professionals and patients are daily faced with. At present, high performance medical textiles have the potential to substantially change the way patients receive medical assistance/services. Despite not being very common, the awareness of these intelligent textile systems is rising along with the number of marketed medical products.

1.4.4 Protective Textiles

Protective textiles are the technical textile materials used in the manufacturing of a wide variety of protective clothing (personal protective equipment [PPE]) for people working in hazardous situations. The diversity of protective textiles includes safety against cuts, impacts, abrasion, stabs, explosions, flame, foul weathering, severe high or low temperatures, high voltage, harmful dust and particles, and nuclear, biological, chemical, and hazardous materials. Natural fibres, specific synthetic fibres, high performance fibres, nanofibres, and other functional materials all demonstrate excellent performances in either protection or comfort of protective clothing in various environmental conditions. A combination of those high performance functional textile materials in engineered structures would help achieve desirable functionalities in specific applications.

Protective textile products have been in constant demand and the main driving force is the increasing emphasis on the reduction of occupational hazards and assurance of the health, safety, and protection of the workforce. The constant revision of legislation, governmental policies, and standards has encouraged stakeholders to take initiatives to introduce accountable measures and equipment in the prevention of hazardous events and accidents at worksites.

1.4.5 Personal Protective Clothing

Protective clothing is generally designed to enhance the worker's safety, by complying to the requirements stipulated by international regulatory bodies. Clothing plays an important role in protecting human beings from their surrounding environments. High performance PPE is widely used as advanced protective clothing – like coats, trousers, vests, etc. and body armour products like helmets, masks, aprons, gloves, socks, shoes, etc. – to protect the human body from environmental hazards. The hazards addressed by protective equipment include physical, electrical, heat, chemical, biohazards, and airborne particulate matter. PPE is also required to protect human beings from various natural hazards such as wind, cold air, rain, flash fire, etc. Protective equipment may be worn for job related occupational safety and health purposes, as well as for sports and other recreational activities.

Thus, the main purpose of PPE is to reduce human exposure to hazards when engineering controls and administrative controls are not feasible or effective to reduce these risks to acceptable levels. PPE is expected to possess high thermal protective performance under a thermal or fire hazard. At the same time, it should effectively regulate the metabolic heat and sweat vapour from the wearer's body to their surrounding environment, and this regulation will provide high thermo-physiological comfort to the wearer. Along with this functional performance, it should also possess some aesthetic features like appropriate colours and printed designs.

1.4.6 Military Textiles

Textiles for military uniforms face a complex set of challenges as they must provide protection, durability, and comfort in a wide range of hostile environments. Military and police forces are two sectors where protection and performance are paramount, as they are faced with diverse threats routinely in their employment. The main threats are ballistic, sharp weapon, flame, and chemical, biological, radiological, and nuclear (CBRN). Clothing and uniforms in these lines of work must offer a large variety of essential properties, from flexibility and breathability, to fire retardancy and body armour level protection.

There is always a compromise between the protection offered by a clothing system and the ability to complete the task, i.e. between survivability and mobility. The optimum design of high performance protective clothing systems requires subject matter expert knowledge of the threats faced, the tasks to be completed, the anthropometric properties of the persons to be protected, the fabrics that might be used, integration with other fabrics and equipment, and knowledge of appropriate clothing manufacturing techniques and test methods.

1.4.7 Industrial and Filtration Textiles

Industrial textiles are widely used for chemical, mechanical, and electrical engineering purposes, such as filtration, plasma screens, lifting machines, transportation, sound proofing, roller covering, grinding equipment, insulation, and fuel cells. These textiles are generally strongly woven with high tenacity PES and/or polyamide yarns. This area of technical textiles offers solutions and products for different industries like paper, carbon, metal, ceramic, glass fibre, plastic, etc.

High performance industrial textiles play a major role in filtration media and are widely employed to separate and clean industrial goods, gases, and effluents. A wide variety of fibres, DREF yarns, nonwoven fabrics, multifilament and monofilament woven fabrics, and in some cases blends or combinations of more than one of the above are used in filtration applications. Depending on the filtration purpose, several requirements and standards must be fulfilled for the production of filters. Sometimes it is required to merge different filtration media to better fit the application's requirements, such as filter fabric and membrane.

1.4.8 Geotextiles and Environmental Protection Textiles

Geotextiles are permeable fabrics, and when used in association with soil have the ability to separate, filter, reinforce, protect, or drain. They are widely used in supporting embankments, bridges, and drainage systems. They are also employed for soil reinforcement, erosion control, and filters. Typically made from polypropylene (PP) or PES, geotextile fabrics come in three basic forms: woven, needle punched, or heat bonded. Geotextile composites have also been developed, and products such as geogrids and meshes are available commercially. A woven geotextile could be manufactured from monofilament, multifilament, or fibrillated fibres. A nonwoven geotextile could be fabricated from either continuous filaments or staple fibres. Nonwovens resistant to tear, soil chemicals, puncture, UV light exposure, mildew, rot, freeze/thaw conditions, etc. are an ideal choice for high performance geotextile applications.

Each configuration of geotextiles like geonets, geosynthetic clay liners, geogrids, geotextile tubes, etc. are able to yield benefits in geotechnical and environmental engineering design. The three main properties which are required and specified for geotextiles are mechanical responses, filtration ability, and chemical resistance. They should be able to withstand several high stress situations, be durable, and be able to soften an undesired fall. The environmental protection textiles are widely used for protection of environment and ecology. This is not a well-defined sector yet, though it overlaps with numerous other application areas of technical textiles. They are also used for environmental protection such as floor sealing, erosion protection, oil spill management, air and water filters, and waste handling.

1.4.9 Agrotextiles

Agrotextiles offer advantages like flexibility, breathability, and greater ease of installation as compared to polymer films and are widely used for crop protection and for promoting crop development. The most important requirements of agrotextiles are weather resistance and resistance to microorganisms, in order to protect the plants against temperature extremes by day and by night. They are characterized by strength, elongation, stiffness, porosity, sunlight and toxic environment protection, and biodegradation. The use of agrotextiles to improve the conditions under which crops are grown or developed is increasing. They include all the woven, nonwoven, and knitted fabrics applied for agricultural and horticultural uses including livestock protection, shading, weed and insect control, and extension of the growing season.

Lightweight spunbonded fleeces are employed for a range of products such as shading, thermal insulating, and weed suppression. Heavyweight nonwoven, knitted, and woven textiles are used for wind and hail shelters. Capillary nonwoven mats are employed for horticulture to spread moisture to rising plants. The type of fibre used in the development of high performance agrotextiles is important to ensure that the textile fulfils its protective functions efficiently and that it will withstand the environmental conditions. As the synthetic fibres such as PP, polyethylene (PE), polyethylene terephthalate (PET), and polyamide (PA) comply with these requirements, these fibres have been for many years the primary option for producing agrotextiles; however, these fibres are not biodegradable and have a significant impact on the environment once their useful life ends.

New production techniques, the advancement of modern materials, and the use of ecological bast fibres have led to the development of sustainable high performance agrotextiles. These additional performance features can increase the productivity and quality of agricultural goods and thus help to effectively tackle the growing challenges currently experienced by the agricultural sector.

1.4.10 Building and Construction Textiles

Textiles in fibre, yarn, or fabric form combine excellent strength, resilience, and flexibility with low weight, resulting in desirable construction materials for multitudinous functions and appearances. They should offer mechanical properties such as lightness, strength, and resilience as well as resistance to many factors such as creep, degradation by chemicals and pollutants in the air or rain, and other construction material, as well as the effects of sunlight and acid.

Construction textiles are widely employed in building construction, including textile reinforced concrete, house wrap, frontispiece, interior structures, sun protection, heat and noise insulation, water- and fireproofing, air conditioning, wall reinforcement, aesthetic, safety, sewer and pipe, and linings. They are also used for temporary constructions such as tents, marquees, and awnings. Such temporary use textile materials should be characterized by lightweight, strength, rot resistance, sunlight protective, flame retardant, and weatherproof.

The application of new sustainable materials with high performance properties, together with a better understanding of textile structures and their mechanics, has led to new applications of these materials in construction. Architectural fabric structures are becoming an integral part of commercial construction, because of their energy efficiency and potential for creating a form of architecture. Similarly, insulation and house wraps are being improved to offer more efficient, comfortable, and sustainable structures.

1.4.11 Automotive Textiles

Automotive textiles are that area of technical textiles which are widely used in transportation vehicles and systems, including cars, trains, buses, ships, and aeroplanes. These textiles range from seats, carpets, belts, tyres, hose reinforcement, and air bags to reinforced composites for automotive and aircraft bodies, filters, battery separators, wings, and engine components, etc. Among all these applications, the major part constitutes seat upholstery and roof covering. They should not only cover isolation and safety aspects but also focus on comfort, style, and a wide range of functionalities. Other applications include solutions for engineering problems in the form of composites, tyre reinforcement, sound insulation, and vibration control.

Textile reinforced composites and 3D woven solid structures are now widely used in the automotive sector replacing metallic parts, thus leading to weight reduction and fuel efficiency. Increasing complexity of product specifications and the requirement of high performance end uses have led to the adoption of sustainable, lightweight, durable, low cost, and more accurately engineered yarns, textiles, and nonwovens in the automotive sector.

1.4.12 Marine Textiles

As in other application areas, textiles are used in functional as well as decorative applications in the marine industry. Marine textiles play an integral role on every vessel, from protection to upholstery. They are the preferred choice for making hoods, tarpaulins, protective covers, rear closures, but also for decorating and boat furnishings. Textile reinforced composites are being increasingly used for navigational aids.

Marine textiles are specialized technical textiles because of the high performance specifications and special properties required. Marine textiles have to withstand a much higher exposure to sunlight, seawater, and potential damage from ultraviolet radiation. In addition, safety features like flame retardant behaviour are crucial, and weight reduction and antifouling are also other important technical requirements. Owing to the highly aggressive environment, marine textiles developed from natural and synthetic materials are then reinforced with different functional materials and techniques. In a marine environment, the comfort, design, and appearance of textiles are important for providing users with a relaxing atmosphere. In order to satisfy the high performance requirements, numerous advanced materials and technologies are being developed for marine applications.

1.4.13 Aeronautic and Space Textiles

From clothing to complicated aeroplane parts, textiles are found everywhere in aircraft. Aeronautic and space textiles include specially crafted lightweight structures as well as engineered textiles. The application of high performance textile composites in space shuttles and other aerospace products needs to be completely defect free. The use of textile reinforced composites reduces fuel consumption in aircraft and space shuttles, without any compromise on the strength. These products are mainly manufactured with high performance textile fibres, which require additional properties as compared to conventional fibres.

Apart from aircraft applications, textile structures are widely used in the manufacturing of specialized space suits. Various new materials are used for making the space suit, including fabrics made from different functional polymers. Typically, the innermost layer of the suit is made up of a nylon tricot material, the second layer is manufactured with spandex which gives elasticity in the suit, and the next layer is made up of urethane coated nylon. Thermo-physiological comfort aspects are also considered while designing the spacesuits.

1.4.14 Smart and Responsive Textiles

Active and responsive textile materials providing functional and high performance properties are generally termed smart textiles. Smart textiles are thus the textile materials or products that can discern and deduce changes in their surroundings and respond appropriately. Smart textiles act as both sensors and actuators and thus stand differently from the other existing multifunctional textiles that behave as mere passive materials with enhanced properties. Major end uses of high performance smart textiles include architecture, automotive, fashion, entertainment, military or protection, healthcare, sport or fitness, and others.

Developments in smart and responsive textiles have made a great impact on human lives in recent years. They have a wide range of applications like wearable electronics, shape memory materials, barrier membranes, phase change materials, optical materials, and other functional textiles, which provide convenience and comfort required for a smart life.

1.5 Conclusion

A wide variety of high performance technical textiles can be developed either from technical fibres or through the functional finishing of conventional fibres. Technical textiles, textile reinforced composites, and 3D woven solid structures have a wide range of applications in different industrial sectors, offering multifunctional properties which are not possible to achieve by using conventional materials. On the other hand, smart and responsive textiles are contributing towards a smarter way of life.

Sustainability and recyclability of technical textiles is becoming a significant concern in every area of its application. A major reason for reduced recyclability of technical textiles is the use of nonbiodegradable fibres. Hence, there is a great research focus to develop sustainable and biodegradable technical textile materials, which should be far simpler to recycle and reuse.

2

Household and Packaging Textiles

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2.1 Introduction

In a constantly technologically advancing world, homes are continuously turning 'smarter' and often 'greener', equipped with high performance household materials. Textiles are integral part of a household's built and daily dynamics as they are sensed by the whole body and are related to every basic human need. Towels are used to dry the hands, cleansing wipes to clean the face, bed linen and duvets to cover the body, carpets to step on with the feet, food in textile packaging to alleviate the feeling of hunger, tents as a roof above the head to sleep in outdoors or as protective shades from excessive sun at home, and of course homewear clothing to shield oneself against weather conditions.

As people worldwide become more educated and have access to opportunities for realizing a higher income, the information, knowledge, and financial independence that they have acquired drive their will to turn their houses into homes with high technology products which offer higher living standards and enhance performance, durability, comfort, hygienic conditions, and even aesthetics. Therefore, smart design solutions combined with high performance attributes are part of the package of modern-day household and packaging textiles.

This chapter offers an overview of the types of such textiles, as well as of their properties, engineering processes, testing methods, and applications. Sustainability aspects are also discussed before the chapter concludes.

2.2 Textile Materials, Properties, and Manufacturing

Like in any other category of high performance textiles, both natural and synthetic fibres are used in household and packaging textile-based materials. Such fibres originate from the same sources used for common fabrics, such as wool (e.g. for carpets), cotton (e.g. for towels), jute (e.g. for food sacks), polyester (e.g. for curtains), and polyamide (e.g. for packaging bags). The key to their advanced properties is the type of finish and coating, the type of combination in composites, and even the structural

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engineering of the textiles produced. Bast (i.e. woody, cellulosic, plant) fibres, for instance, have been used for decades in the manufacturing of wrapping and bagging materials from hemp, ramie, and flax. Nowadays, they are used in polymer matrix composites which exhibit improved mechanical properties, such as tensile and flexural strength. Examples include the use of bamboo, kenaf, and sisal fibres combined with glass fibres in epoxy matrices to produce hybrid materials that are lighter with an increased impact energy [1]. Altering the layering sequence of bast fibre plies or varying the fibre content with different weight ratios are techniques to manufacture such high performance textile-based composites. Lamination with various stacking sequences can be achieved by using regular vacuum bagging methods and post-curing of composite laminates in an autoclave.

A representative example of exploiting textile structures to achieve high performance is a recent study performed on woven polyester fabrics used to manufacture curtains as sound absorbers [2]. Four types of fabrics were investigated, all lightweight, contrary to the old practice of heavy velvet curtains used for sound absorption. Three to five different types of yarns with various linear mass densities and different weaving patterns were employed to produce fabrics of increasing area density, specific airflow resistance, and cut-off frequency. The fabrics were tested, both folded and unfolded, as well as with and without a rigid backing material (a wall), to distinguish among good or poor sound absorbance.

2.2.1 Household Textiles

2.2.1.1 Types and Properties

In the global market of technical textiles, household textiles contribute with a share of 7% [3]. Examples include soft furnishings (carpets, rugs, upholstered furniture, cushions, curtains, blinds, bed linen, blankets, duvets, and pillows); bath towels and kitchen cloths (oven gloves, tea towels, etc.); fibrefill (e.g. polyester staple fibres); nonwoven wipes for house cleaning and personal hygiene; and textile-based filters for vacuum cleaners, heating, ventilation, and air-conditioning systems, mosquito nets, even stuffed toys (Figure 2.1). Home products like impregnated fabric wipes have been developed decades ago [4] but technological progress has broadened the field of textile-for-house applications to uses beyond imagination. Knitted fabrics can be used to reinforce wall coverings, both outside and inside, as a lighter material than steel [5].

Solar textiles, inspired by biological archetypes such as polar bear fur, are used for the translucent thermal insulation of buildings. The sun shines through a transparent front sheet and warms up a dark absorber sheet lying behind. The absorber convects the heat to the brick wall and thus into the house. Insulation is achieved through a coated flexible spacer textile with smooth foils on both sides, the top one for self-cleaning purposes functioning according to the lotus effect and the bottom one in the form of a black pigmented coating to absorb sunlight and transform it into heat [6]. Insulating textiles are becoming an integral part of wall constructions as they are flexible and lightweight. Novel systems, such as aerogel impregnated textiles that can act as the insulating core, can easily be installed in combination with suitable fabric finishes [7]. Even though such textiles (solar and wall covers) do not fall strictly under the category ‘household’ or ‘home’ but rather under ‘construction building’ textiles, it is evident that hundreds of square metres could be covered by textiles in a house.

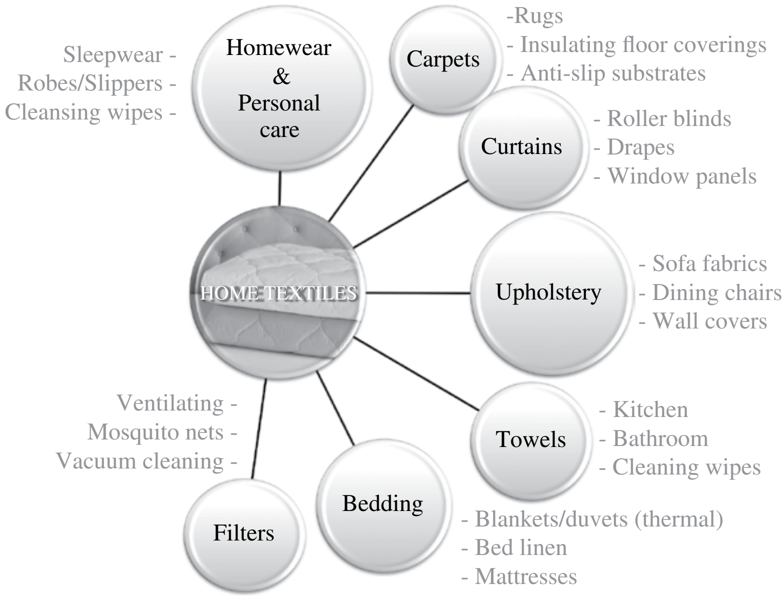

Figure 2.1 An overview of household or home textiles.

Owing to the large impact a home has on daily life, choosing household textiles is dictated by very concrete parameters, such as cost, durability, ease of cleaning, functional properties, and of course colour and fashion style. For instance, curtains play an important multiple role in a house – they provide privacy, they retain warmth, they protect from the sun, and they add to the decoration – so choosing them is a matter not just of taste but also of functionality. Lined curtains have better drape, provide insulation, and are less likely to fade with time and under the effect of sunlight so they may be preferred over nonlined ones. At the same time, it is good if they are also fire-resistant. The same general attributes apply to upholstery fabrics, i.e. the outer fabrics which cover furniture. Duvets consist of an insulating material, such as down, feathers, or polyester wadding, to be warm but light. Carpets should be durable, fire-resistant, moth proofed, and easy to clean, be able to absorb sound, and also add warmth. Therefore, the general properties of household textiles are mechanical strength, elasticity to avoid deformation, antistatic properties, hypoallergenic properties, soil releasing, flame retardancy, and insect repellence [8].

Particularly in the case of fire resistance and flame retardation, depending on the type of fibre used, each textile has different grades of flammability. Wool, for example, does not burn that easily, but synthetic fabrics like polyester could easily catch fire. To enhance their performance and safety features, flame-retardant agents are used, especially for products like carpets and curtains. The new generation of such agents is halogen-free, owing to environmental and health considerations. Silicon, nitrogen, and phosphorus based compounds are mainly employed with the ideal aim to produce only char and no toxic fumes while burning [9]. The burning behaviour of commercial polyester curtains treated with flame retardants has been reported in a study [10]. Fabrics had various weights in the range of 300–550 $g\,m^{-2}$ and their flammability was investigated using cone calorimetry. Apart from the efficiency of the flame retardant itself, the physical characteristics of the fabrics, such as the weight per unit area, were found to be of importance influencing the rate of heat and smoke release, among other parameters [11].

Last but not least, fashion design and decoration are integral components of household textiles, particularly for furniture and drapes. Furnishing fabric designers use fancy yarns for decorative purposes but there are certain practical aspects to consider, such as formability and risk of deformation from daily usage, abrasion resistance, soft handle, insect repellence, etc. A material often used for furniture by designers is chenille yarn for its shiny appearance, reflection effect, and softness. A study on the performance of chenille for upholstery fabrics showed that pile length is one of the properties of the chenille yarn which affects resistance to abrasion [12]. As the pile length increases, the pile loss decreases because it is harder to remove long fibres incorporated into the twists of the chenille yarns than short fibres. Also, the appearance rate of chenille yarns on the surface of upholstery fabrics due to abrasion is related to weaving constructions [12].

2.2.1.2 Manufacturing

One of the most modern types of high performance household textiles is that which offers protection from electromagnetic radiation. Such an attribute can be achieved by using electroconductive covers which can generate and transport free charges. There are two main paths for the production of such covers: (i) metallization of textile materials and (ii) coating textiles with conductive polymers. The most widely used metals are silver, copper, and stainless steel. However, conductive polymers, such as polypyrrole or polyaniline, and dispersed additives, such as carbon nanotubes or graphene, can be also used to increase conductivity. Traditionally, sewing or stitching metallic yarns was used to create conductive patterns. More recent application techniques include metal fibre staple spinning, vapour deposition, sputter deposition, plasma-assisted coating, sol–gel processes, and even inkjet printing with conductive inks, which enable the production of stable coatings in the nanoscale [13–15]. Particularly for sample collections, inkjet printing is cost-effective (very accurate usage of colour pastes) and time saving (production from two months down to two weeks) while it offers high pattern repeatability [8]. Another method is electroless metal plating which is a nonelectrolytic method of deposition of metal from solution and has some advantages such as coherent metal deposition, excellent conductivity, and shielding effectiveness [13].

In the case of coating with conductive polymers, there are various techniques, including *in situ* chemical polymerization, *in situ* electrochemical polymerization in a one-compartment cell with two electrodes connected with an external power supply, *in situ* vapour phase polymerization, solution coating process, and *in situ* polymerization in a supercritical fluid. The conductive polymer coated composites manufactured by these methods function on the principle of absorption of electromagnetic rays rather than reflection [14]. A commercial example of conductive polymer coated yarn is the E-glass/polypropylene commingled yarn produced by the P-D FibreGlass Group (Germany) and used for the production of poly(3,4-ethylenedioxythiophene): poly(styrene sulfonate) (PEDOT: PSS)-coated yarns as strain sensors [16]. Also, it has been reported that an increasing number of laminating layers increases the electromagnetic shielding effectiveness of woven polyester fabrics with stainless steel staple blended yarns and