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REVIEW ON SIGNIFICANT CHARACTERISTICS OF FUNCTIONALIZED TEXTILE PRODUCTS

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Abstract: *The modern society is in a permanent transformation, therefore the textile industry has to continuously change and adapt their processes and products to be environmental friendly and to meet customer expectations in the today's highly technologized world. In order to meet the requirements of the actual needs of society and the technological progress, the concept of the textile products has evolved, nowadays providing benefits in a variety of application such as comfort, healthcare, protection, agriculture, information, transportation, military equipment, sporting and outdoor products etc. Functionalisation of textiles represents the process that grant to textiles properties beyond the aesthetic and decorative attributes.*
The paper presents textiles with multiple functionalities such as fibres, yarns and textile structures and their significant characteristics: water repellency/vapour permeability, heat transfer, camouflage effect, ecotoxicological properties, antimicrobial activity and flammability. The assessment of efficiency of these characteristics is performed by modern and reliable physical and chemical procedures: measurement of water vapour resistance of textiles, determination of thermal resistance, spectral reflectance measurement in infrared range, phthalates determination by gas chromatography, determination of certain carcinogen aromatic amines by high performance liquid chromatography and gas chromatography.
There are processes conducted in textile industry, from the fibre stage to fabric, that are harmful to environment. In this context, sustainability of textile industry implies manufacturing not only of competitive products but also environmentally friendly and safety products. Therefore, the content of potentially hazardous chemicals (e.g. azo dyes, formaldehyde, phthalates, pesticides, chlorinated phenols etc) is limited in finished textile.

Key words: *characteristics, multifunctional textile, eco textile, functionalization*

1. INTRODUCTION

The modern society is in a permanent transformation, therefore the textile industry has to continuously change and adapt their processes and products to be environmental friendly and to meet customer expectations in the today's highly technologized world. The textile industry is focused on developing and supplying versatile multifunctional apparel and products, the complexity of the fabrics is increasing constantly. Nowadays, textiles evolved behind the commodity materials zone, being essential in providing extended protection in arduous conditions and improved hygiene [1]. In the actual context, an advanced understanding of fabric behaviour and their characteristics is mandatory in the engineering of functional textiles [2].

Functionalisation of textiles represents the process that grant to textiles properties beyond the aesthetic and decorative attributes and can be obtained by one of the procedures listed bellow:

- fibre itself (characteristics of the polymer or additives before fibre spinning);
- the technology applied to produce the yarn, fabric or material (as example, by using various types of fibres or layers);
- textile finishing [3].

The paper presents textiles with multiple functionalities such as fibres, yarns and textile structures and their significant characteristics: water repellency/vapour permeability, heat transfer, camouflage effect, ecotoxicological properties, antimicrobial activity and flammability. The assessment of efficiency of these characteristics is performed by modern and reliable physical and chemical procedures: measurement of water vapour resistance of textiles, determination of thermal resistance, spectral reflectance measurement in infrared range, phthalates determination by gas chromatography, determination of certain carcinogen aromatic amines by high performance liquid chromatography and gas chromatography.

3. MULTIFUNCTIONAL TEXTILES

3.1 Multifunctional fibres and yarns

A wide range of functional fibres are available for the textile manufacturer: conventional fibres (natural, artificial, synthetic), higher elastic modulus and breaking resistance fibres (e.g. para-amides, ultra-high-molecular-weight polyethylene), chemical and flame resistant fibres (meta-aramides, polytetrafluorethylene), high performance inorganic fibres (carbon, glass, ceramic, boron), ultra-thin fibres and advanced fibres (microfibres less than 0.5 dtex in width, high resistant to ultraviolet radiation fibres, fibres that absorbs solar energy, thermochromic fibres, perfumed fibres, antibacterial fibres, aseptic chlorofibres, tubular fibres, anti-static fibres, flame retardant fibres etc).

In order to respond to the actual needs of society and the technological progress, the concept of the fibres evolved to being used in a variety of application such as comfort, healthcare, protection, agriculture, information, transportation, military equipment, sporting and outdoor products etc. [4]. It should be emphasized here, also the significance of conductive textiles and their extended applications in medical, space, defense, industrial fields in which they create added value [5].

The functionalities can be grouped in multiple functionalities fibres, systematised fibres and biomimetics fibres. The water vapour permeable/waterproof materials (prevents the penetration and absorption of liquid water but are permeable to water vapour and air) or flexible fibres that have high tenacity at low temperatures (high resistance to stretch) represents multiple functions fibres. For example, the systematized functionalities can be presented the fibres that store the heat (absorbs light and converts it to heat), or by the ones having antimicrobial properties (inhibits microbes spreading). The biomimetics fibres have a structure that replicates biological structures and their features. A representative case for biomimetic fibres is Morphotex® (developed by Nissan Motor, Teijin and Tanaka Kikinzoku), made of different layers of polyester and polyamide. The colour is not obtained by means of dyes or pigments, only by light interference on different fibre structures, as it was encountered at Morpho butterflies that resides in the rainforests (Figure 1) [6], [7].

In a same manner as fibres, multiple-function yarns have to meet the functional properties specific to the applications for which they are manufactured. The yarns used for protective products should have resistance to safety hazards factors such as heat, fire, chemical or mechanical damage. There are many types of yarns developed for multifunctional products manufacturing, the most frequent being: aramid filament yarns, glass filament yarns, carbon filament yarns, high-density polyethylene yarns etc [8].

***Fig. 1**: Morphotex® fibres [7]*

3.2 Multifunctional textile structures/products

Multifunctional textile structures/products are manufactured mainly for their technical performances and functional properties, and not for their decorative features. Development of products that uses textile materials designed for specific application, offers new perspectives and a transdisciplinary engineering approach.

Today, textiles serve in diverse and complexes areas, from life protection to surviving in hostile environment, leading to promotion of human health (Figure 2) and improvement of life quality.

***Fig. 2**: Protective equipment in hostile environment [9]*

The challenge in the textile innovation is to obtain the synergistic effects of functional products in order to respond to the multifaceted requirements from the domains of medicine, biotechnology, nanotechnology, physics and computing.

It has been concluded that the functional clothing can be grouped in several comprehensive classes: protective-functional (environmental hazard protective, biological, chemical and radiation hazard, NBC, protective), medical-functional (injury protective, therapeutic and rehabilitative, bio-sensing), sports-functional, vanity-functional, clothing for special needs and cross-functional assemblies (multifunctional performance, protection, life support, comfort, communication) [10].

4. SPECIFIC CHARACTERISTICS OF MULTIFUNCTIONAL TEXTILE PRODUCTS

Textile multifunctional fabrics features a large variety of specific characteristics, such as: stain resistant, self-cleaning, waterproof, oil repellent/water repellent, breathable, moisture absorption, photosensitivity/anti-adhesive, durability, anti-aging, thermal insulation, flame retardant, antistatic, non-allergenic, light, weight, UV protection, controlled release of active chemical agents (e.g. drugs, cosmetics, perfumes), antimicrobial, deodorant, non-carcinogenic etc.

Further, is enclosed a summary of the most frequent characteristics performed in order to assess the quality performance of the textile and their compliance with environmental and safety requirements.

Water repellency/ moisture vapour permeability of multifunctional apparels has a key role in protection from the environment and maintenance of thermal comfort [11]. These properties are critical for personals that perform activities ranging from rapid movement to immobilisation. The tendency of a water droplet to spread out over the fabric surface mainly depends on the contact angle of the water droplet and the fabric surface. Water repellent textiles have many uses including industrial, consumer and apparel purpose [12].

The heat transfer of complex clothing provides moisture wicking and thermal balance. The capability of a textile to wick moisture relies mainly on the size and number of capillaries in the fibre, yarn, fabric and the combination of clothing layers. Whereas, the thermal insulation is corelated to the trapped air between the fabric and the wearer's skin and/or in the interstices of the textiles [13]. Recently, thermally conductive and highly aligned boron nitride (BN)/poly(vinyl alcohol) (PVA) composite (denoted as a-BN/PVA) fibres were used to improve the thermal transport properties of textiles for personal cooling (Figure 3) [14].

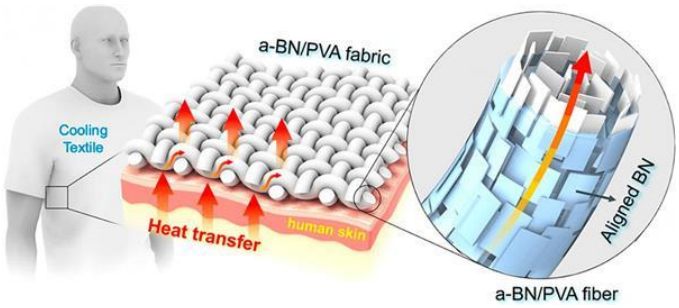

***Fig. 3**: Heat transfer through a-BN/PVA fabric/products [14]*

The camouflage properties of the textiles concealed military personnel or equipment, being critical for surviving in a hostile environment. Camouflage pattern depends on their application needs (winter, forest, desert etc.) and must cover a wide range of the electromagnetic spectrum. [15]. The investigation of the camouflage effectiveness, in the visual and near IR radiation spectral ranges was conducted by measuring the fabrics reflectance with a spectrometer and, the optimum reflectance values in the near IR spectral range for each colour of pattern were determined [16].

There are processes conducted in textile industry, from the fibre stage to fabric that are harmful to environment. In this context, sustainability of textile industry implies manufacturing not only of competitive products but also environmentally of friendly and safety products. Various dyes and solvents used by the textile industry have been found to have mutagenic and carcinogenic properties.Therefore, the content of potentially hazardous chemicals (e.g. azo dyes, formaldehyde, phthalates, pesticides, chlorinated phenols etc) is limited in finished textile [17], [18].

The development of new technologies for antimicrobial functionalization of textiles provided benefits for various applications, such as protection of textile materials from decomposition, generation of more effective wound dressings, and the prevention of infections or malodors resulting from bacterial growth, inhibiting microbes from spreading [19], [20].

The flammability hazard of textiles has a major impact in many fields (protective equipment, children wears, furniture etc), therefore correlation of the fibres composition with flammability properties were investigated [21]. Fire-retardant technical textiles have been developed from a variety of textile fibres, the choice of which is largely dependent on the cost of the fibre and its end-use.

5. CONCLUSIONS

This review focuses on recent advances and trends on multifunctional textiles characterization and applications. Textile industry play a key role in industry, social area and our environment, so safety and confidence in fabrics quality is essential. Characterisation of fabrics relies on a comprehensive knowledge of physical, mechanical and chemical properties fibres, yarns, textile structures and their correlation with textile performances and compliance with ecological requirements. Lately, the innovation in the textile field reaches remarkable performances in a very short period. By functionalization, the textile materials are provided with specific features and extended uses, beyond the common ones, for example low flammability, thermal insulation, moisture vapour permeability, water repellency, ballistic protection, antimicrobial activity.

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