General trends of Innovation in the technical textiles' sector

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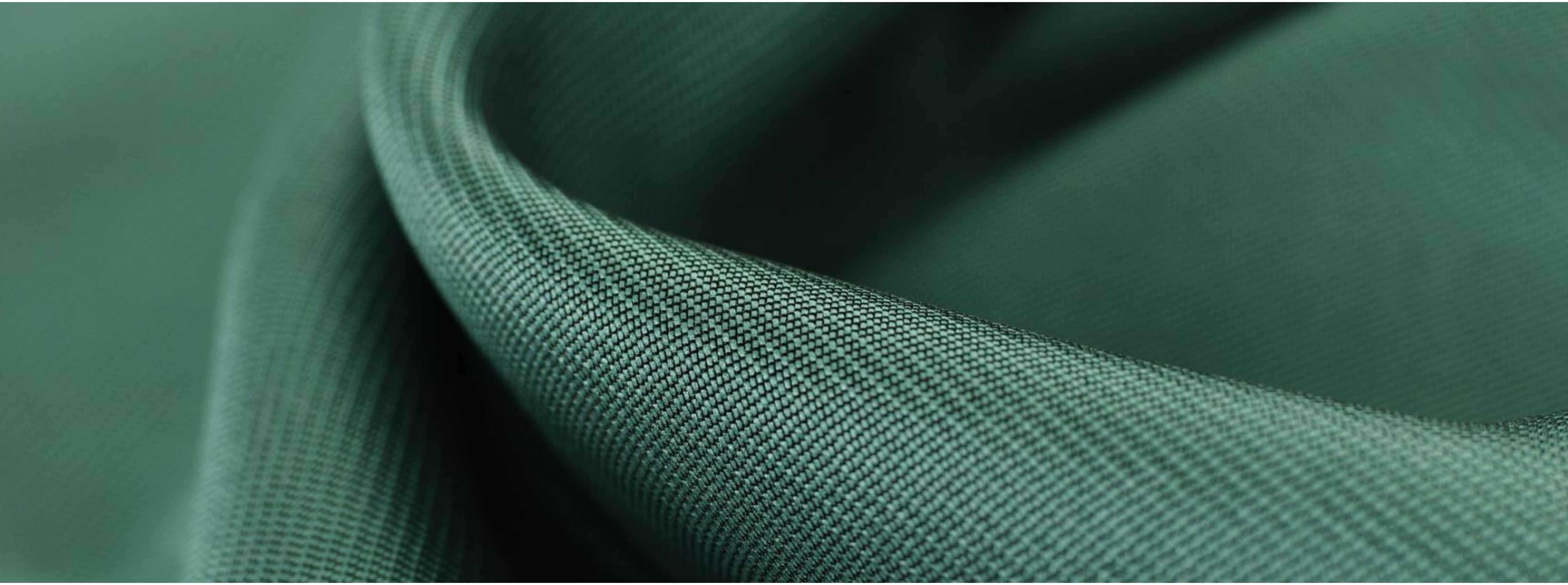

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Introduction

The first-generation textile fibres were those that were procured directly from the nature and that era lasted for 4,000 years. Many years before, science developed a second generation of new fibres, called man-made fibres. Nylon and polyester are two examples of them, a result of the efforts taken by chemists in 1950, to evolve with materials that resemble natural fibres.

Currently the research focuses mainly on finding materials that meet technical needs in various sectors. This involves the development of very specific fibres, fabrics and finishing processes, using technology to meet customer demands.

Keywords

Innovation, functionalization, plasma, electrospinning, nanotechnology, finishing processes.

Goals

Competitive intelligence is the key of a successful business strategy. However, the pace at which technology is the value of emerging technologies, strengthening useful technologies at hand, and allowing new market opportunities.

Structure

The present lecture includes:

- A general overview of trends in technical textiles
- Main research lines in materials, structures and finishing treatments
- Key challenges for the textile technology

Learning outcomes

Knowledge

- The importance of innovation in the technical textiles field.
- A general overview about the latest trends in technical textiles.
- How technology intercede in the production process.
- Stages of the life cycle of materials and manufacturing systems.
- Main research lines in yarns fabrics and finishing processes.
- Key challenges for the textile technology in the healthcare, medical, automotive, aeronautics, sports, personal protection, home and building sectors.

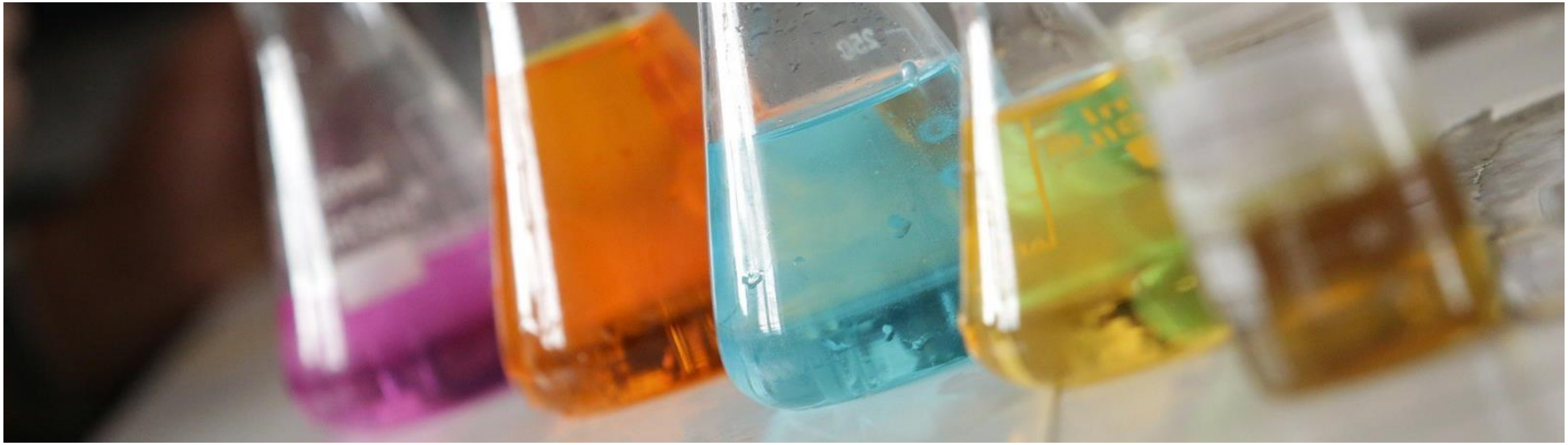
Competences

- Have a clear vision about the current trends in technical textiles.
- Be able to briefly define some concepts as nanotechnology, plasma, electrospinning.
- Be able to give some examples of the key challenges that specific sectors face nowadays.

1. Trends in technical textiles

The global technical textile market (including 3D knitting and weaving, nanotechnology...) size was estimated at USD 176.6 billion in 2019 globally, growing at a compound annual growth rate (CAGR) of 4.5 % from 2020 to 2027.

New and improved applications of technical textiles can project to propel its demand across various end-use industries including agriculture, construction, aerospace, medical or packaging, where these textiles can fit better than other solutions and they may facilitate some functions and increase the performance of the processes[2]. Nevertheless, it is important to mention that other sectors like security forces, firefighters or foundry workers, for example, depend on technical textiles, so its demand it's unlikely to decrease.



2. https://www.grandviewresearch.com/industry-analysis/technical-textiles-market

From the perspective of innovation, the continued development of new fibres or improved fibres, the new combinations or processing of existing materials, the continuous creation of new styles and designs or the increasing application of textile materials in industrial uses and in the services, have been the main engines of the textile industry in the last decades. Those have proven to be the cornerstone of European companies for improving their competitiveness in the global market.

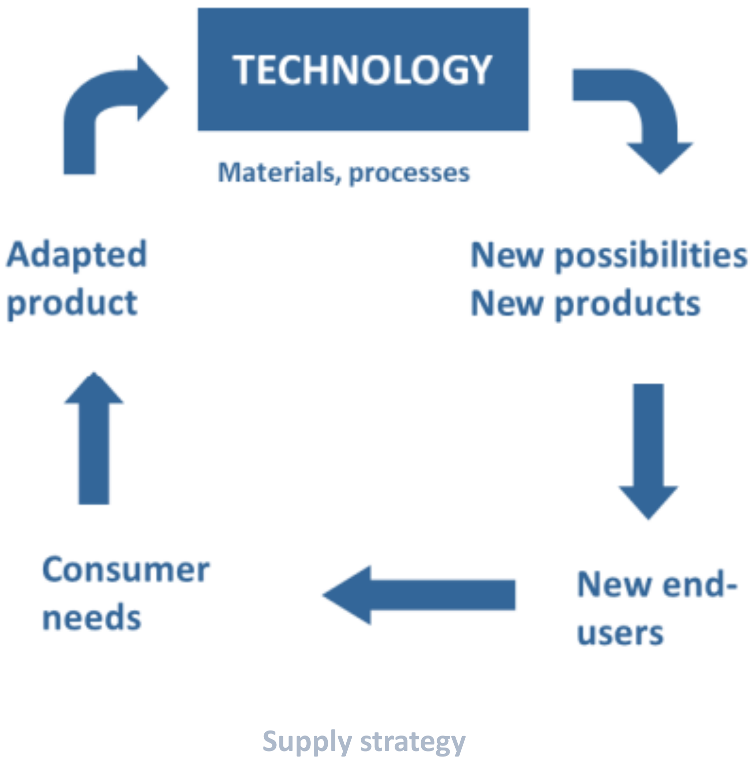
Technology used in technical textiles' production is mostly alike to the regular textile manufacturing processes in terms of equipment (except for certain products). The main difference remains in the level of requirements and the quality of the final product demanded.

3. Textile Strategy for Innovative Higher Education. Rimvydas Milašius et al.

The common trends of innovation in technical textiles can be stated as[3]:

- The **dynamism**, at the level of product development, to respond to new market-pull demand or to replace other materials in analogous functions.
- The **multiplicity of possibilities** for the selection of materials, structures, products manufacturing and their adaptation to very diverse uses.
- A slow but continuous progress of **substitution of conventional raw materials for new materials** of high cost and performance and, especially, by the application of the technological innovations of the general textile sector to articles of technical use (microfibres, new breathable finishes, grafting techniques of monomers, etc.)

3. Textile Strategy for Innovative Higher Education. Rimvydas Milašius et al.



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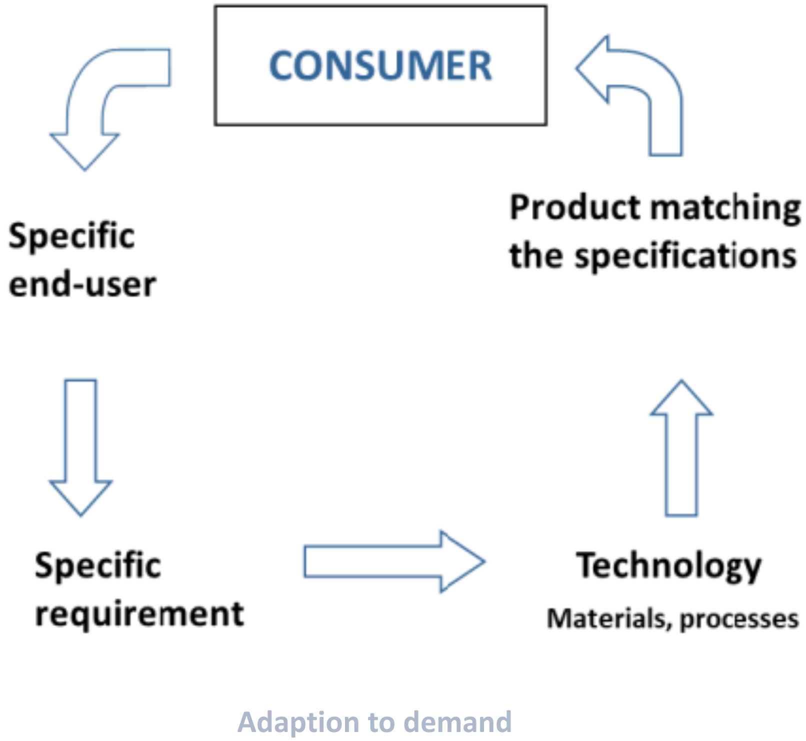

Innovation cycle for conventional textiles (Source: AEI TÈXTILS)

Innovation cycle for technical textiles (Source: AEI TÈXTILS)

2. Main research lines in materials, structures and treatments

2.1. Stages of the life cycle of materials and manufacturing systems

Different technologies used today in the textile industry can be arranged in a stages of maturity chart, depending on their technological growth and their development level.

High tech fibers are already maturing (aramids, polyetherketones, PBI, etc.) while others (e.g. PBO) are growing, along with the **ecological fibers**, due to the increasing collective sensitivity towards energy conservation and ecology aspects.

Technologies such as the **manufacture of yarns / fabrics** (weaving and knitting) are found in a decline phase. In spite of this, **electrophoresis**, derived from nanotechnology, is still in embryonic stage.

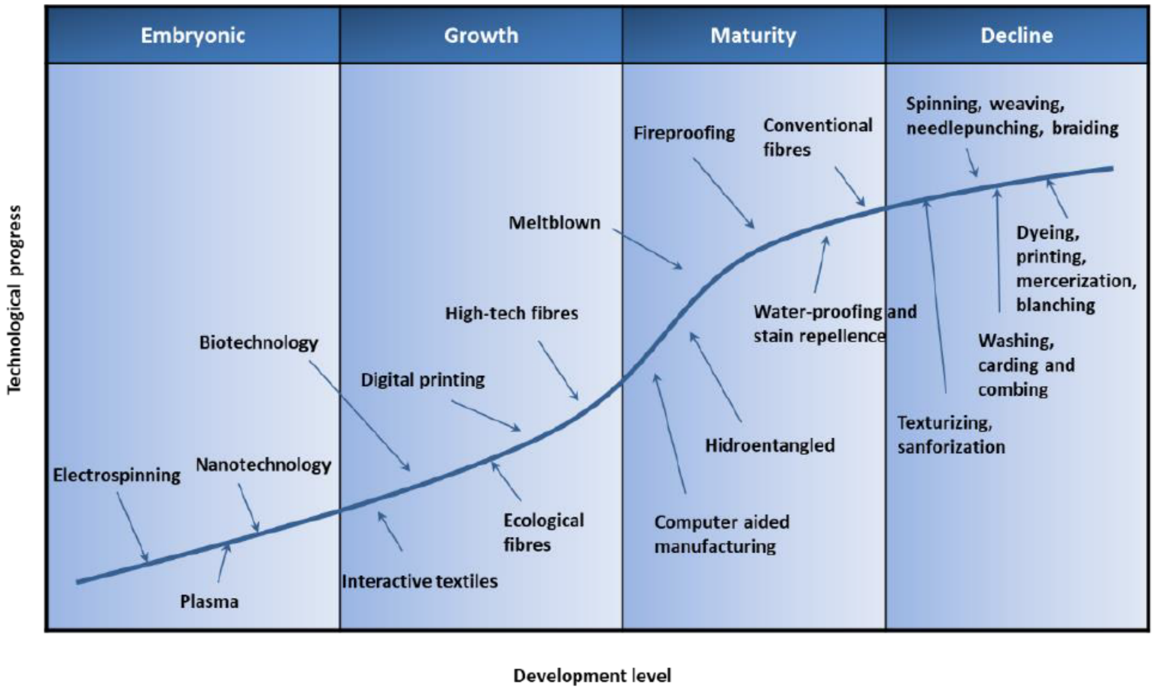

Chart: Life cycle stages of materials and manufacturing systems from a technological point of view.
(Source: Tecnitex Ingenieros)

Nanotechnology is leading to a revolution in the science of materials which will allow the textile sector to offer innovative products with new types of functional fibers, capable to respond to multiple requirements.

As for textile finishing processes, dyeing will continue to play its traditional role affected only, in terms of innovation, due to environmental conditions. It is important to mention the generalization of coating and laminating techniques who have already reached technological maturity, waiting for the possibilities offered by the products manufactured by **electrospinning**; the application of **biotechnology** (enzyme treatments) the solution of the addition of **microcapsules** or the consolidation of **nanofinishings**.

On the other hand, surface treatments **plasma technology** or **digital printing**, both in the growth stage, can pass quickly to a maturity stage without having substituted (in the first due to technical reasons and in the second one for economic reasons) the current finishing and stamping technologies, respectively, and remaining complementary to the traditional processes[3].

3. La I+D en el sector tèxtil. Estat actual, tendències. Ariadna Detrell i Sergi Artigas.

2.2. Research lines in materials / fibres

In the 60s, the fundamental advances in the field of textile fibers were based on the improvement of primary functions of already known fibrous materials (high tensile strength, improved feel, etc.). From the 1970s to the present, there has been remarkable progress in the design of new fibers, developing polymers with improved properties (high toughness, non-flammability, fibers with functional additives, breathability, etc.). Microfibers, waterproof and breathable laminates lyocell-type viscose fibers, organic fibers or inorganic heat-resistant, generalization of the use of elastomeric yarns, etc., are some examples of the milestones achieved during this period.

In the fiber market, innovative solutions appear thanks to the development of bio-component fibers, formed by two different polymers that take advantage of the qualities of both and allow get differentiated threads in their behavior.

Knowledge of the science of textile materials, coupled with the progress of industrialization, has allowed the manufacturers obtain fibers with dazzling optical effects or hollow fibers with heat-insulating properties, etc. On the other hand, the different shape of the fibers sections promotes the evacuation of sweat perspiration to the outside of the garments.

Also, the rising ecological sensitivity of the consumers is increasingly considered, and fiber-producing companies are directing their research towards the development of fiber that doesn't harm the environment. New fibers appear, such as so-called organic fibers, which belong to the family of synthetic, artificial fibers (protein or cellulosic) or natural, such as milk protein fibers, soy protein fibers and bamboo fibers, among others.

Finally, it is worthy to mention the introduction of graphene as new material in the textile sector, for its properties excellent (hardness, lightness, thermal conductivity, etc.). Several research projects are currently underway focusing on the transformation of insulating tissues into fabrics with conductive properties or obtaining electronic textiles, among others[3].

Thus, the main innovations in the field of materials, in recent years, have been based on:

- Provide new properties and functionalities by means of:
  - New and improved polymers and additives
  - Multicomponent fibers and multifilament
  - New fiber surfaces
  - New shapes / dimensions of the fibers (micro / nanofibers)
- New or improved fiber blends
- Innovative uses for conventional fibers
- Improving the sustainability of fibers (recyclable, renewable fibers / biopolymers)

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2.2. Research lines in materials / fibres

Technological area:	Materials / fibres
Main lines of research:	• Deployment and exploitation of technical capacity from current fibres. • Development of adaptable fibres, capable to regulate their functionality according to the surrounding environment. • Production of super-mimetic fibres, with a deployment functionalities alike living beings.

The fiber and yarn sector is an integral part of the textile and garment industries. To stay competitive, these industries are striving for continuous improvement and therefore are constantly looking for innovative solutions to meet the changing demands and industry standards. These standards are geared mainly towards sustainable solutions such as recycling, waste reduction, production efficiency and closed-loop production. With increasing involvement from governments, these standards now are becoming crucial for trade and businesses.

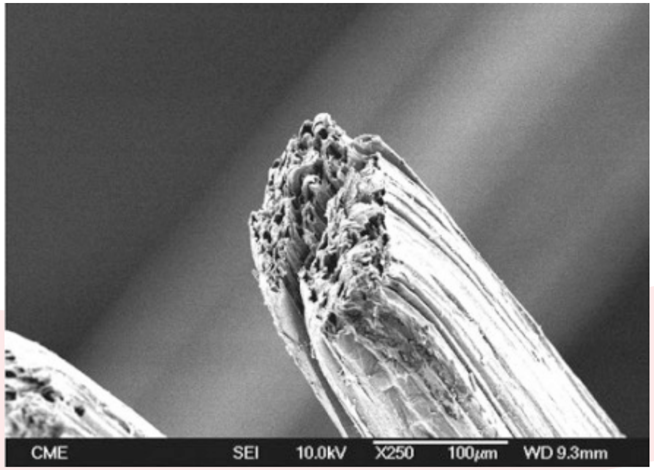

Image: Electron microscope photograph of a banana fibre for its use in composites, developed in the BAN-TEX project (Source: LEITAT).

It is obvious that sustainability is a rising concern of brands, equipment and fabric manufacturers, and consumers. The industry is still very recycled-centric, which is clearly not enough. There has been a greater push for water savings, durability and waste management, as well as reduced emissions, water pollution, and carbon footprint[4].

4. https://www.textileworld.com/textile-world/features/2020/05/new-developments-in-fibres-yarns-fabrics/

2.3. Research lines in structures

Some related lines of research with textile structures are briefly explained in the following lines:

- **Composites**: composite materials reinforced with structures textiles, made of a polymeric material, metal or ceramic (matrix) with a textile structure in fiber, yarn, braid or cloth form. Research work focus on obtaining more durable and lighter composites, as well as improving manufacturing processes. Also, noteworthy is the research into the use of natural fibers for composites production; these fabrics (linen, sisal, etc.) are used as fiber substitutes of glass in some technical applications.
- **3D structures**: creation of new structures using high-tech fibers, new manufacturing processes (machinery), new applications (aeronautics, sport, construction, etc.)
- **Seamless fabrics**: manufacturing technology of seamless knitting allows the direct obtaining of ready-made pieces. Knitted fabrics with minimal seams have been in the market for many years. In this topic the fully-fashion technique must be mentioned, which aim is to get directly required garments the minimum finishes.

In the field of fabric manufacturing machinery, innovation focus on obtaining equipment that offer more production, lower energy consumption, a product with a higher quality, the trend to the “Zero defect” and, above all, “smart manufacturing” is pursued. “smart manufacturing” aim is the production efficiency and its automation.

It should be noted that the characteristics of the behavior of the textile structures are conditioned, in addition to the geometry of the structure itself, also by the chemical nature of the fibers used and, in many cases, by the operations that are applied to them[3].

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2.3. Research lines in structures

Technological area:	Structures
Main lines of research:	• More resistant composites, including lightweight and improved manufacturing processes • Creation of 3D structures using high technological value yarns, new manufacturing processes for new applications • Seamless products

Image: seamless machines (Source: apparelresources.com)

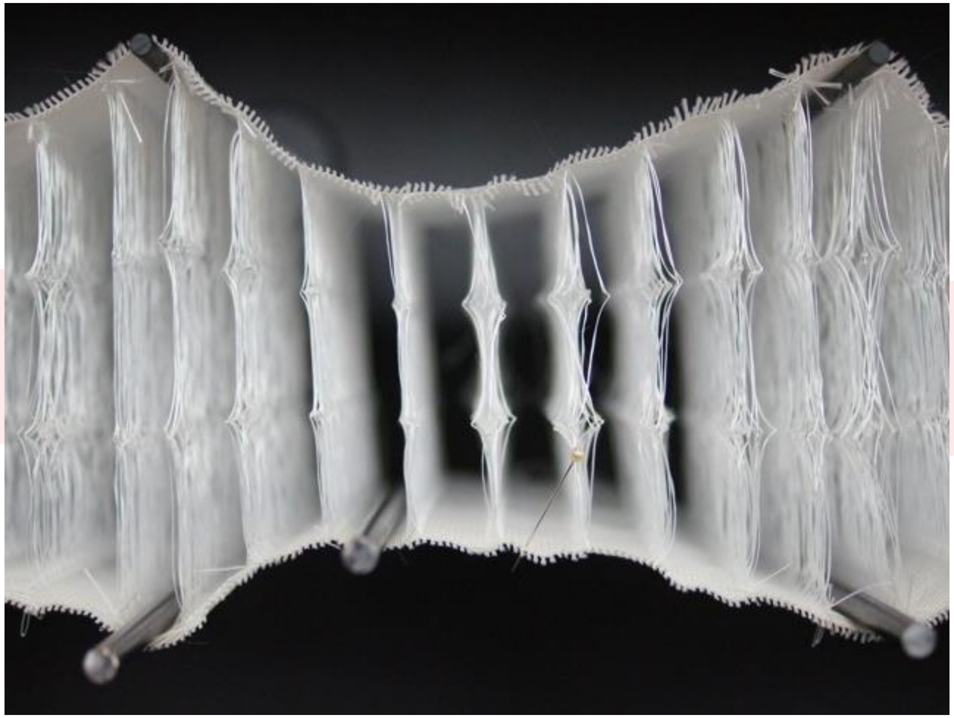

Image: 3d spacer fabric (Source: 3dweaving.com)

2.4. Research lines in functionalization treatments: plasma

Plasma is an ionized gas made up of electrons, ions, photons, atoms and gas molecules in any state of excitation. The plasma state, also called the fourth state of matter, has a zero electric charge. This means that, in plasma, there are an identical number of components with positive and negative charge, regardless of the charge density, the presence of neutral components and the emission or absorption of electromagnetic radiation.

The reactive components contained in plasma (ions, neutrons and free radicals) are formed from processes of ionization, fragmentation and / or excitation produced, due to collisions of electrons accelerated by the field electrical with other components present in the plasma.

During the plasma state, a wide variety of dissociation and recombination reactions occurs, even for simple chemical compounds.

In the recent literature, it is often still attributed to plasma treatment the condition of alternative to traditional preparation processes; the reality is that technology of plasma treatment is an emerging option with possibilities already consolidated such as the achievement of liquid repellent effects, the improvement of the fixation of the dye molecules or the adhesion of coatings and laminates, among others.

This technology still requires remarkable research effort; for this reason the costs for its implementation are high[3].

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2.4. Research lines in functionalization treatments: plasma

Functionalization treatments (embryonic technologies)	Plasma
Main lines of research:	• Anti-aging of wool. • Treatment prior to dyeing (improvement of dye absorption). • Plasma induced grafts (creation of surface active centers that bind covalently to chemical compounds applied later to confer different properties (antimicrobial, hydrophilic / hydrophobic, etc.).

Plasma is a novel dry processing technique and provides a solution to reduce the use of chemicals, water and energy. It is an environmentally and worker-friendly method to achieve surface alteration without modifying the bulk properties of textile substrate[5]. Plasma technology is replacing numerous conventional wet-chemical methods in laboratories and industries, with a huge positive impact in:

- renewable energy;
- environmental protection;
- biomedical applications;
- functionalization of textiles;
- microelectronics, and other fields.

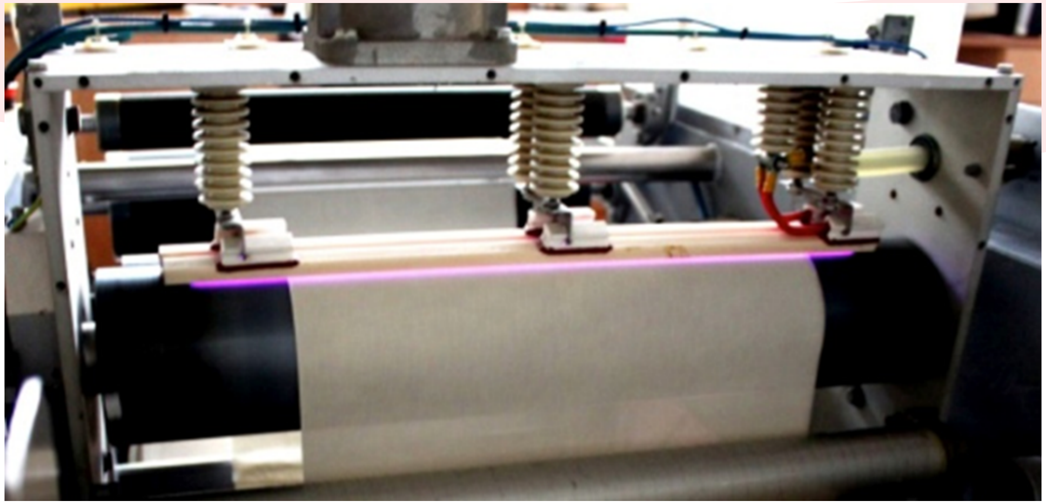

Image: semi-industrial prototype of direct barrier discharge plasma (Source: Plasma technology for textiles. Surdu, Lilioara et al.)

5. Plasma technology for textiles. Surdu, Lilioara et al.

2.5. Research lines in functionalization treatments: nanotechnology

The term nanofiber is used to define fibers with diameters less than 0.5 microns, which are made through electrospinning processes. These nanofibers have a large surface area per unit mass and a very small pore size, and this means that their main applications can include, among others, filtration, protective clothing, nanocomposites or drug release mechanisms.

Conventional methods used to give different properties in textiles do not entail permanent effects, but these are lost as a result of washing or use processes. In addition, the conventional finishing processes can increase the rigidity and modify the breathability of the textile materials. In contrast, nanotechnology entails a high durability for textiles as well as nanoparticles have a high affinity for textile fibres due to the fact that they have a high area / volume ratio and high surface energy.

In addition, nanoscale coatings on textiles do not affect the properties associated with user comfort such as vapor permeability and touch. These advantages raise a growing interest in the textile sector for the potential commercial applications of nanotechnology.

Nanotechnology can be applied in any of the phases of the textile-clothing chain, from the extrusion process of a polymer to which nanoparticles can be added, through the spinning process by electrospinning and in the finishing process, where it is normally applied most nanotechnology, through plasma, grafting, coatings etc.

Currently, the most general applications of nanotechnology are those that involve the use of nano or microparticles (larger size, 2 to 5 μm) for encapsulation active substances and confer to various tissues properties: antibacterial, cosmetic, etc[3].

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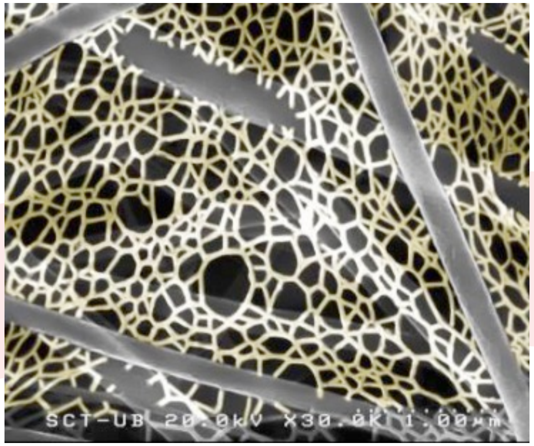
2.5. Research lines in functionalization treatments: nanotechnology

Functionalization treatment (embryonic technologies)	Nanotechnology
Main lines of research:	• Sol-gel nano-finishing • Thermo-chromic and photo-chromic microcapsules resistant to high temperature • High durability PCMs • Microencapsulation of bug repellent and natural antimicrobial products, reducing toxic biocides • Drug microencapsulation in medical textiles • Halogenated-free fire retardant microcapsules • Kinetic control of microcapsule release of active compound • Formulations of micro- and nano-capsules finishing with improved fastness • New methods of application, including surface modification • Determination of nanomaterials' health and environmental impact



Nanotechnology is driving a revolution in material science as for example with fiber forming polymers. This would allow the textile sector to offer innovative products with new types of functional fibers ready to cover a large variety of needs.

Image: nanofibre web (Source: Leitat).

2.6. Research lines in functionalization treatments: electrospinning

Electrospinning is a process in which small diameter fibers (the microfibers already mentioned) are obtained from of a polymer dissolved in an electrically charged solution as a result of the application of an electric field between two electrodes.

The nanofibers obtained are deposited on the surface of the collector textile substrate, in the form of a veil or homogeneous membrane of low thickness and weight.

It is an economical and efficient method for the fibers manufacturing on a micro and nanometer scale, which allows you to select and properly combine components, allowing to effectively adapt the fibers properties to obtain the desired morphologies and functionalities.

Although the benefits of electrospinning still need to be improved on an industrial scale in the following aspects:

- high volume processing
- precision and reproducibility at all stages of manufacturing
- related aspects with safety and environmental

Currently, several companies offer laboratory equipment as well as components and industrial electrospinning machinery.

New technologies are expected to appear in the future for the manufacture of nanofibers, becoming this one of the most important trends in the science of materials in our century[3].

The main advantages of nanofibers obtained by electrospinning are:

- Elevated surface area
- High porosity
- High filtration efficiency
- Low relative cost

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2.6. Research lines in functionalization treatments: electrospinning

Functionalization treatment (embryonic technologies)	Electrospinning
Main lines of research:	• Scale-up to large volumes • Precision and reproducibility during the whole manufacturing process • Safety and environmental aspects

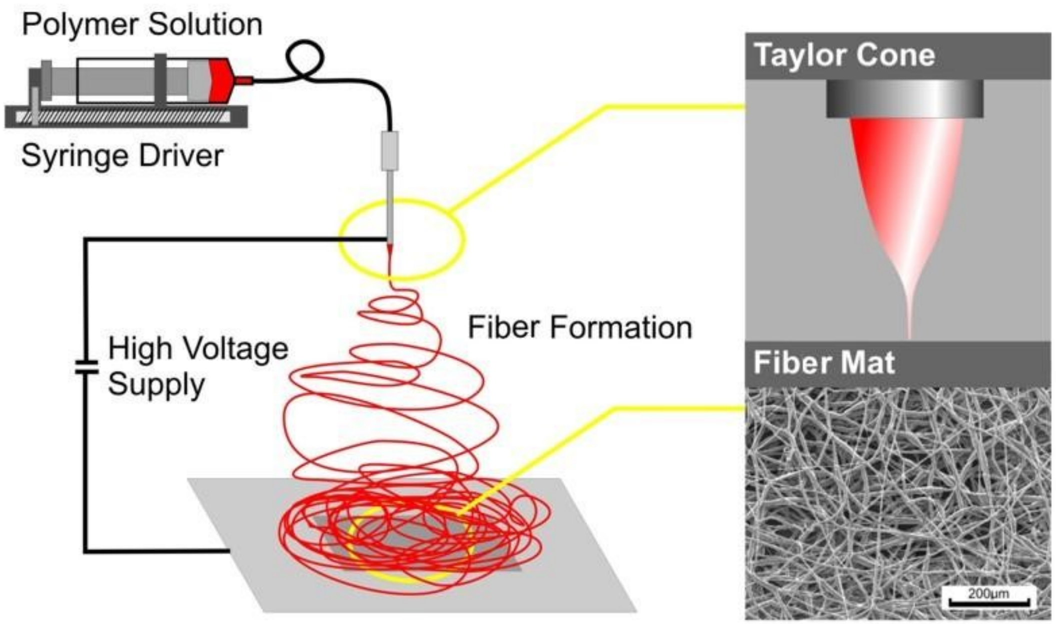


Image: electrospinning process (Source: oxolutia.com).

By using electrospinning technologies, it is possible to design robust, light, porous and high surface area materials from polymer nanofibers which composition, diameter, aspect and morphology can be easily and cost-effectively tuned. Thus, electrospinning is probably the most versatile process to produce polymer fibers from almost any polymer which can be solved or melt. Applications of these materials are currently focused on biomedicine and filtration technologies, but the results obtained as materials in renewable energies are very promising for near future uses[6].

6. Electrospinning: una técnica fascinante para la obtención de nanofibras poliméricas. Núria Garcia Garcia.

2.7. Research lines in functionalization treatments: finishing processes

Regarding the finishing processes, dyeing will keep its important and traditional role, although this will be slightly affected by innovation due to environmental aspects. There is a trend of generalization of coating and laminating systems reaching maturity and awaiting the impact of developments in electro-spinning; the use of biotechnology with finishing based on the application of enzymes; the solution to the current problem of adding microcapsules or the consolidation of nano finishing.

On the other hand, the still growing technologies of surface finishing through plasma technology or digital printing can quickly reach a stadium of maturity without becoming real substitutes to the current technologies but rather occupying a complementary role due to technological and economic reasons.

Other considerations regarding the last trends in the finishing sector:

- Ecological consideration in finishing products (e.g. fluorine free).
- Novelties in water-repellent finishes but not in oil-repellents (there is no alternative to fluorocarbons)
- Insect repellent, antimicrobial, etc. finishes. which increase the number of washes that hold the property.
- Dyeing auxiliaries to reduce water and process time

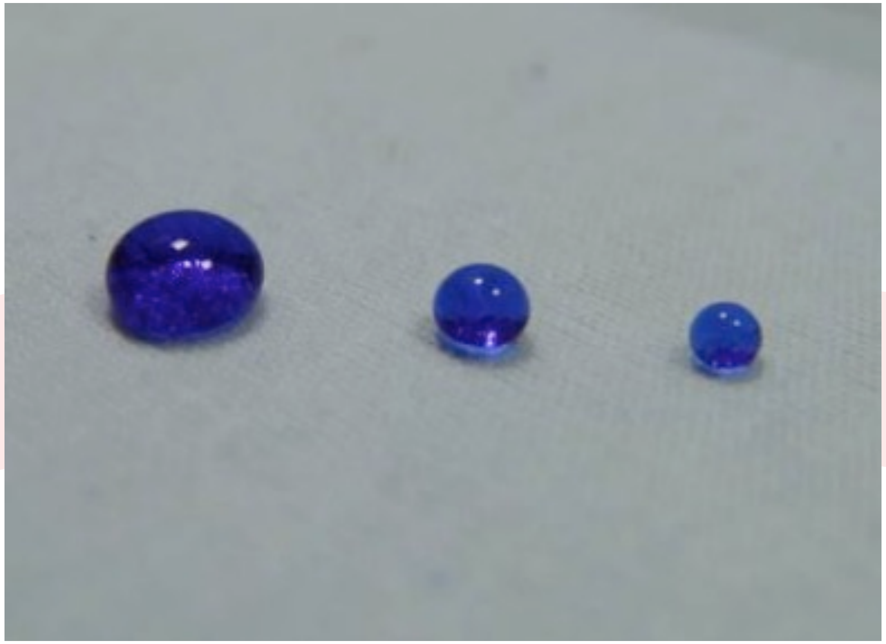
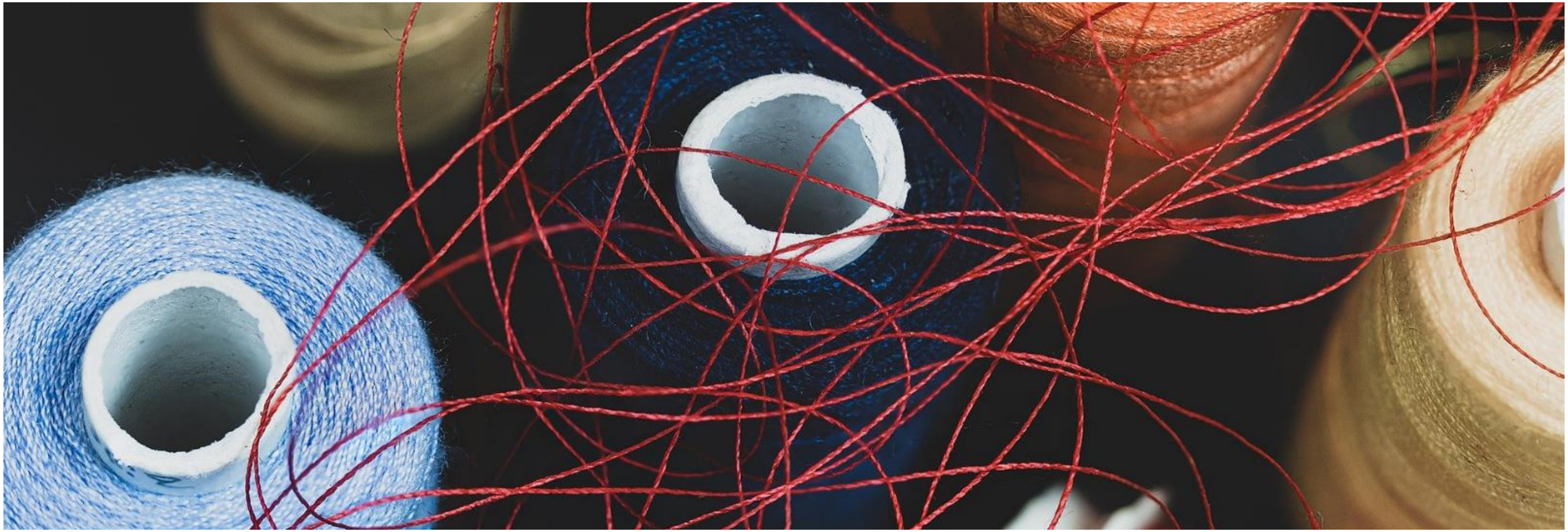


Image: *Hydrophobic cotton* fabric *(Source: LEITAT).*

Image: *digital printer (Source: fibre2fashion.com).*

3. Key challenges for the textile technology industry

Textile technology is an enabling technology for numerous fields and can make important contributions to new solutions for effective and affordable health care, highly functional sportswear and goods and smart personal protection. All these are rapidly growing markets and targeted by the European societal challenges of active ageing and safety and security. CONTEXT Cost Action proposers defined the technological challenges described in this chapter for textile materials in the healthcare and medical, automotive and aeronautic, sports, personal protection and building and living sectors.



3.1. Key challenges in the healthcare and medical sector:

- development of controlled drug release fiber and textile structures for therapeutics of different skin conditions
- development of garments and home textile products with fully integrated bio-monitoring, active systems to improve life quality and ICT systems enabling remote monitoring of patients and assisted living services for “better ageing concepts”
- development of fiber and textile structures with enhanced thermal/breathability electro-active properties with integration of new surface functionalities for improving barrier (antiviral and antibacterial) properties

3.2. Key challenges in the automotive and aeronautics sector

- integration of fully integrated and printed electro active and interactive sensors and actuators that enable the development of ubiquitous sensing and interactive surfaces, while also integrating fully embedded (or printed and/or fiber and yarn integrated) haptic feedback systems via both lighting integration and mechanical stimuli responses
- integration of fully customizable self- lighting materials based on active fibers and yarns, and integration or programmable textile matrixes for interactive sensing
- light and resistant structure with PTFE membrane for architecture
- separating tissues for growing vegetables

3.3. Key challenges in the sports sector

- development of light weight performance garments having new textile surface coatings enhancing thermal management (insulation), controlled drug release for muscle care, and also proving optimized comfort, low pill, low shrink and fast drying
- integration of low power/autonomous bio-monitoring and/or integrated ICT and IoT communication systems for training monitoring and performance assistance and integration concepts of training analytics, always connected and data sharing for garment/textile structures “peripherals”

3.4. Key challenges in the personal protection sector:

- the integration of geo tracking and personal GPS systems (Global Positioning Systems), physiological and biometric monitoring, embedded and integrated communications and energy harvesting, with all data monitoring systems sharing data in real-time
- integration of cooling/heating systems into garments

3.5. Key challenges in building and living:

- development of new functional textile materials using nano materials and industrial waste, eco-friendly technologies (like ultrasonic deposition, bi/tri- component fibers, UV curing coatings), considering multilayer approaches
- focus on high thermal performance (applying eco-efficient heating and cooling systems, together with low thermal conductivity and diffusivity coatings and additives, infrared reflective and phase change materials), in order to achieve Net Zero Energy Buildings (NZEB)
- textile functionalization with smart and efficient systems like adding sensors, communication systems and actuators, considering printing electronics approaches, in order to maximize comfort, well-being
- develop interoperability between connected devices

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