



ACADEMIC YEAR 2025-2026, SEMESTER – VI  
STUDY MATERIAL FOR B.Sc. FASHION TECHNOLOGY  
TECHNICAL TEXTILES



STUDY MATERIAL FOR B.Sc. FASHION TECHNOLOGY

TECHNICAL TEXTILES

SEMESTER – VI



ACADEMIC YEAR 2025-26

PREPARED BY

FASHION TECHNOLOGY DEPARTMENT



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**SYLLABUS**

**UNIT: 1 - Introduction to Technical Textiles**

Introduction to Technical textiles, definition and scope of technical textiles, developments in fibres Natural fibres, polyamide, polyester, viscose rayon, polyolefin, high performance fibres and glass and ceramics, Application of technical textiles.

**UNIT: 2 - Functional Apparels and Medical Textiles**

Functional apparels: Design and engineering of functional clothing, requirements, smart characteristics: structural, aesthetic, functional, comfort and fit for clothing. Medical textile: Materials used and classification. Requirements and application. Textiles for Health care and Hygiene products.

**UNIT: 3 - Protective Wear**

Selection of materials, requirements and functions of flame resistant, chemical, mechanical, Electrical and radiation protective clothing.

**UNIT: 4 - Sports Wear**

Sportswear requirements-functional fibers, yarns and fabrics suitable for sportswear- Sweat management for sports application. Footwear Clothing: Fabric requirements, finishing adaptability.

**UNIT: 5 - Smart and Intelligent Textiles**

Smart fibers: Nano fibers, Photo adaptive fibers, Chameleon fibers, Conductive fibers – properties and applications in textiles and apparels. Phase change materials: properties and applications. Shape memory polymers and properties. Stimuli sensitive intelligent textiles.



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UNIT - I

TECHNICAL TEXTILES

INTRODUCTION

Technical textiles are manufactured using both natural as well as man-made fibres such as Nomex, Kevlar, Spandex, Twaron which have superior functional properties such as higher tensile strength, insulation, weather resistance etc. Various industries like automobile, healthcare, aerospace, defence etc extensively use Develop a holistic understanding of the various sectors in technical textile industry

- Enable them to gain knowledge about the significance of technical textile products in human life
- Understand about the progress of Indian technical textile industry

DEFINITION

Textile materials created chiefly for specific scientific functions and industrial applications than for its look and beauty is describe as technical textiles. It is also explained as non- aesthetic textile products in the free encyclopedia- Wikipedia. In a nut shell technical textiles is any fiber, yarn or fabric produced with a particular process and finish for a well-defined end use. Example –hundred percent cotton plain weave fabrics with antimicrobial finish as medical textiles whereas the same the same hundred percent cotton plain weave fabrics with fragrance finish as cloth textiles.





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### Introduction to Technical Textiles

- Technical textile are textile products manufactured for non-aesthetic purposes.
- Technical textiles are 'advanced materials' for which the technical performance and physical properties are more important than features such as colour, pattern and price. This industry encompasses a vast array of materials, manufacturing processes and end use markets.
- Its growth and evolution is driven by the combination of sector lead by R&D and collaboration with other industries.
- They are used for automotive applications, medical usages, crop protection, protective clothing etc.
- Textile technical means "Textile materials and products manufactured primarily for their technical and performance properties rather than their aesthetic or decorative characteristics".
- Textile that is primarily used for its performance or functional properties
- And not for its appearance or aesthetics is known as technical textiles.
- The industrial fabric that are used for various industrial applications are
- Also classified as technical textiles.
- Some textile academicians also include finished products such as ropes or tarpaulins, and parts of other products, such as tyre cord for tyres or cover stock for diapers, in the definition of technical textile.
- Technical textiles are used individually or as a component/part of another product.
- They can be used individually to satisfy specific functions, as a component or part of another product, to enhance the strength, performance or other functional properties of that product.
- They are also used as accessories in processes to manufacture other products.
- Other terms used for technical textiles are Industrial textiles, Functional textiles, Performance textiles, Engineering textiles, Hi-tech textiles etc.
- Their wide range of applications, lack of competition and growing consumer and industrial demands make it a big opportunity area and an attractive option to invest in.
- Though India is the 2nd largest textile economy in the world after China; its contribution in the global technical textile industry is only 9% to the total consumption.



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### Major Segments of Technical Textiles

The technical textile is broadly grouped under the following 12 segments based on the functional applicability.

1. **Agrotech:** Textiles used in agriculture, horticulture, and forestry.
2. **Buildtech:** Performance-driven fabrics for building and construction, such as insulation and concrete reinforcement.
3. **Clothtech:** Technical components used in shoes and clothing, including accessories like handbags and scarves.
4. **Geotech:** Geotextiles used in civil engineering for support, drainage, and soil stabilization.
5. **Homotech:** Specialized fabrics for furniture, floor coverings, and household textiles like flame-retardant curtains.
6. **Indutech:** Industrial textiles used for filtration, cleaning, and heavy manufacturing processes.
7. **Medtech:** Hygiene and medical textiles, including bandages, sutures, and surgical gowns.
8. **Mobiltech:** Textiles applied in automobiles, shipping, railways, and aerospace.
9. **Oekotech:** Materials used for environmental protection.
10. **Pactech:** Packaging textiles ranging from heavyweight bags to lightweight tea bags.
11. **Protech:** Protective wear designed for personal and property protection against hazards like fire or chemicals.
12. **Sportech:** Specialized fabrics for sports and leisure that offer performance benefits like moisture-wicking and breathability.

### Construction Textiles:

Construction Textiles, are performance-driven fabrics used in construction and civil engineering for purposes like concrete reinforcement, insulation, drainage, and roofing membranes. Common examples include geotextiles for soil stabilization, architectural membranes for roofs and facades, and safety nets for scaffolding. These textiles enhance a project's durability and performance, using materials like polyester, glass fiber, and PVC-coated fabrics.

### Construction Textiles

- Building and construction textiles
- Kevlar, nomex, carbon fibers.....





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**AgroTextiles(Agrotech):**

- These are the Agro-textiles, also known as Agrotex, that are used in agricultural applications related to growing and harvesting of crops and animals.
- Not only crop production, they are also used in forestry, horticulture, as well as animal and poultry rearing including animal clothing.
- Agro-textiles have to be strong, elongated, stiff, bio- degradable, resistant to sunlight and toxic environment.

Agro Textiles ➤ Agriculture, horticulture, forestry and aquaculture textiles  
➤ Polypropylene, polyester, polyethylene etc.....



**Cloth tech:** This sector comprises of all type of clothing and accessories used for personal grooming like dresses, both basics or intimate wear, casual, formal and party wears, clothing materials and accessories like slippers, handbags and scarf symbolically represented by a picture of a shirt without collars. Freudenberg Non-woven India, Ashima Limited, Ahmedabad, Pasupathi Spinning and weaving Mills, Sky Industries Limited, Vardhaman Yarn Threads Limited are the outstanding producers of cloth textiles.

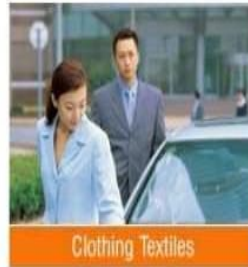


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## Clothing Textiles

- Technical components of shoes and clothing  
e.g. linings
- All the natural, man made and Synthetic Fibers



"Indutech" refers to industrial textiles, while "Hometech" refers to technical textiles for home applications. Indutech includes items like conveyor belts, filters, and ropes used in manufacturing and heavy industry, valued for strength and durability. Hometech involves specialized fabrics for domestic use that go beyond simple aesthetics, such as flame-retardant curtains, antimicrobial bedding, and UV-protective materials, as explained by [Kripa Drishti Publications](#) and [Textile School](#).

### Indutech (Industrial Textiles)

- **Definition:** Functional fabrics designed for industrial and technical uses.
- **Key characteristics:** High durability, heat and chemical resistance, and strength.
- **Examples:**
  - Conveyor belts and drive belts
  - Filters for industrial processes
  - Ropes for shipping and heavy lifting
  - Anti-friction felts and protective clothing
  - Computer printer ribbons and refills



## Home Textiles

- Technical components of furniture, household textiles & floorcoverings
- Acetates, acrylics, polyester, natural fibers.....



### Geo Textiles (Geotech):

In the context of technical textiles, Geotextiles (also known as Geotech) are specialized fabrics used at or below ground level for civil engineering and environmental applications.

#### Key Characteristics

- **Fabric Types:** They are manufactured as woven, non-woven, or knitted fabrics.
- **Material Composition:** Common synthetic fibers used include polypropylene, acrylic, and glass fiber.
- **Performance Properties:** These materials are valued for their high strength, durability, thickness, and low moisture absorption.

#### Primary Functions

Geotextiles are engineered to perform several critical roles in infrastructure projects:



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- **Support & Stabilization:** Providing structural reinforcement to the ground.
- **Drainage:** Allowing water to flow through while keeping soil in place.
- **Separation:** Preventing different layers of soil or materials from mixing.
- **Crack Prevention:** In building materials, specialized fibers (like glass or polypropylene) are added to prevent cracking in concrete and plastics.

### Major Application Areas

These textiles are used extensively in the following fields:

- **Civil Engineering:** Roads, earth construction, and dam engineering.
- **Coastal Engineering:** Protection and stabilization of coastlines.
- **Environmental Protection:** Soil sealing and specialized drainage systems.

**Geo textiles** > Geotextiles and civil engineering materials  
> Jute, coir, Polypropylene, Polyester,  
Polyethylene, polyvinyl chloride, Polyamide,  
Aramids



### Industrial Textiles (Indutech)

- **Definition:** A category of technical textiles used in industrial processes, equipment, and systems.
- **Purpose:** Unlike aesthetic fabrics, these are performance-focused, providing properties like mechanical strength, chemical resistance, and thermal resistance.
- **Examples:** Filters, conveyor belts, wipes, and felts used in various industries such as construction, manufacturing, and the chemical industry.

### The Company (InduTech GmbH)

- **Description:** A company based in Germany that develops and manufactures high-precision, non-contact online process measurement technology.



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- **Products:** Analyzers like the OXEA® – Online X-Ray / XRF Elemental Analyzer and PMD® – Precision Microwave Device.
- **Services:** Offers worldwide support, including remote and on-field service, as well as consulting to improve processes.

**Industrial Textiles (Indutech):**

- These are the Industrial Textiles, also known as Indu tex.
- These are used in different ways by many industries for activities such as separating and purifying industrial products,
- Cleaning gases and effluents,
- Transporting materials between processes and
- Acting as substrates for abrasive sheets and other coated products.
- They range from light weight nonwoven filters, knitted nets and
- Brushes to heavy weight coated conveyor belts.

**Industrial textiles**

- Filtration, conveying, cleaning etc
- Nylon, polyester, polypropylene, glass fibers....





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Industrial Textiles, or Indutech, are specially engineered textiles used for functional, non-decorative purposes across various industries like construction, chemical, and manufacturing. These fabrics provide essential properties such as high strength, heat resistance, and durability for applications including conveyor belts, filtration, insulation, and protective gear. Indutech is a sub-category of technical textiles and its products are vital for industrial processes, from separation and purification to material transport and reinforcement.

### Key characteristics

**Engineered for performance:** Unlike traditional textiles, Indutech is designed for specific industrial functions and environments, not aesthetics.

**High durability and strength:** Fabrics must withstand heavy use, high pressure, and wear and tear.

**Functional properties:** Indutech materials often exhibit properties like heat resistance, chemical stability, high absorption capacity, and flexibility.

**Variety of forms:** These can be woven fabrics, non-woven materials, or knitted fabrics.

### Medical Textiles (Medtech):

Medical textiles, also known as Medtech or Medtex, represent a critical sector of technical textiles focused on fiber-based products used for healthcare applications such as prevention, care, and hygiene. These materials range from simple consumer products like bandages to advanced medical implants and tissue engineering.

## Medical Textiles

- Hygiene and medical products
- Polyester, Cotton, polypropylene, silk etc...



Alloplastic cruciate ligament





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**Classification of Medical Textiles**

Medical textiles are categorized based on their intended use within the medical field:

Category	Typical Products
<b>Non-implantable materials</b>	Wound dressings, various bandages, and plasters.
<b>Hygiene and healthcare products</b>	Surgical gowns, uniforms, caps, masks, wipes, and hospital bed linens.
<b>Implantable materials</b>	Surgical sutures, vascular grafts, artificial joints, and ligaments.
<b>Extracorporeal devices</b>	Components for artificial organs like the lung, liver, and kidney

**Extracorporeal devices-** artificial kidney, liver, heart pacer and lung



Type Fibre	Appication	Function
Hollow polyester fibre, hollow viscose	Artificial kidney	Remove waste products from patients' blood
Hollow viscose	Artificial liver	Separate and dispose of patients' plasma and supply fresh plasma
Hollow polypropylene fibre, hollow silicone membrane	Mechanical lung	Remove carbon dioxide from patients' blood and supply fresh oxygen

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Implantable materials- sutures, vascular grafts, artificial ligaments, cartilages, artificial joints, heart valves etc

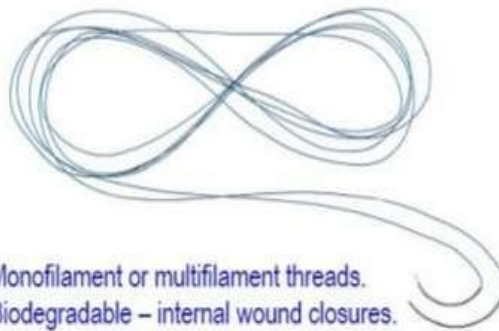


### Vascular grafts

Used in surgery to replace damaged arteries.  
Woven or knitted PET or PTFE.  
Crimped to prevent kinks.  
Velour surface promotes tissue growth.  
Collagen impregnation to prevent blood leakage.

"Extreme Textiles: Designing for High Performance"  
Boston Scientific Company Inc.

### Sutures



Monofilament or multifilament threads.  
Biodegradable – internal wound closures.  
Non biodegradable – external.  
Biocompatible.

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**Packaging Textiles (Packtech):**

- These are the Packaging Textiles, also known as Packtex.
- Textiles have been used for packagings in ceages.
- It ranges from heavy weight woven fabrics used for bags,
- Packaging sacks,
- Flexible Intermediate Bulk Carriers (FIBCs) and
- Wrappings for textile bales and carpets to the light weight nonwovens used as durable papers, teabags and other food and industrial product wrappings.

Packaging Textiles

➤ Packaging materials

➤ Polyethylene, polypropylene, glass fibers.....



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Protective Textiles ➤ Personal and property protection  
➤ Nomex, kevlar fibers...



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Transportation Textiles ➤ Automobiles, shipping, railways  
and aerospace  
➤ Polyester, nylon, glass, UHMWPE,  
aramids compsites, carbon fibers...





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**Sports Textiles (Sporttech):**

Sports technical textiles are specialized fabrics designed to enhance performance, comfort, and durability in sports and leisure activities. They are engineered for specific functional properties like moisture-wicking, breathability, and stretch, using synthetic fibers such as polyester, nylon, and spandex, and are used in everything from apparel like jerseys and shoes to equipment like helmets and mats.

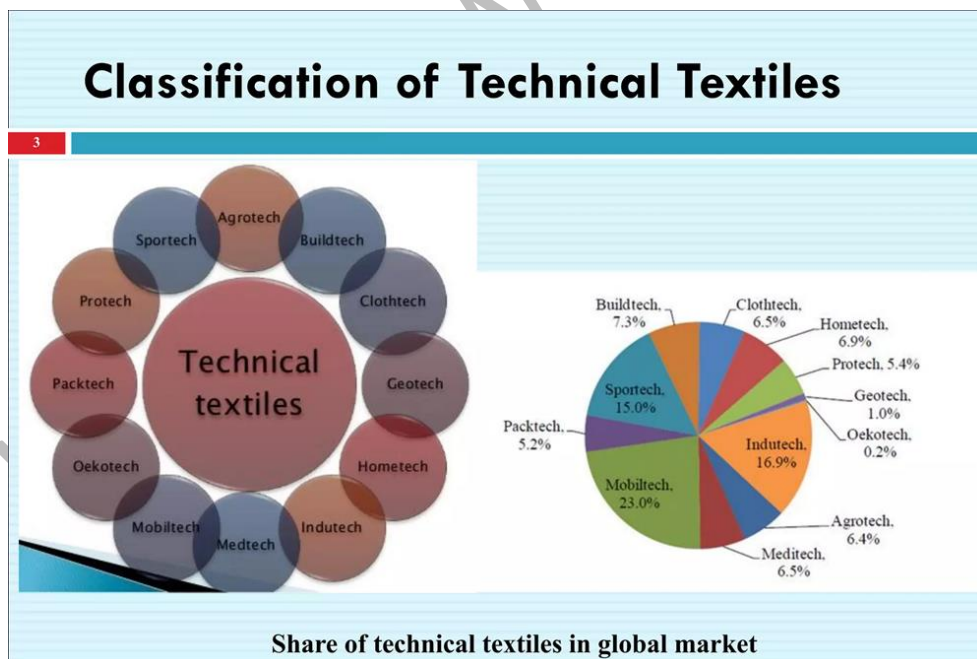
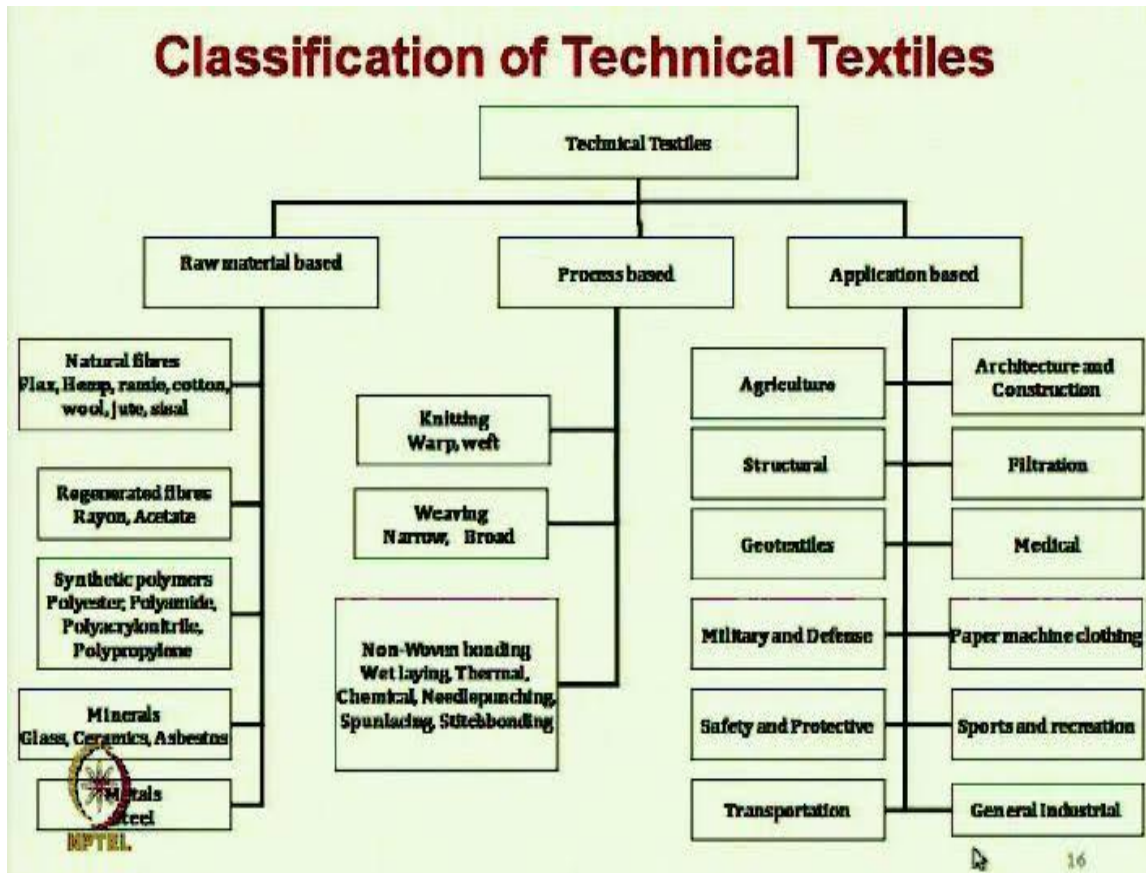
**Key properties**

- **Moisture-wicking:** Draws sweat away from the body to keep the athlete dry.
- **Breathability:** Allows air to circulate, preventing overheating.
- **Stretch and flexibility:** Provides a comfortable, non-restrictive fit.
- **Durability and strength:** Resists wear and tear from athletic activity.
- **UV protection:** Offers a layer of protection against the sun's rays.
- **Thermal regulation:** Helps maintain a consistent body temperature in both hot and cold conditions.

**Sport Textiles**

- Sport and leisure  
E.g Yatcht, Hot air balloons...
- Polyester, nylon, spandex, glass fibers.....



















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	<b>Agrotech</b> Horticulture + landscape gardening, agriculture + forestry, animal keeping		<b>Meditech</b> Hygiene, medicine
	<b>Buildtech</b> Membrane, lightweight + massive construction, engineering + industrial building.		<b>Mobiltech</b> Cars, ships, aircraft, trains, space travel
	<b>Clothtech</b> Garments, shoes		<b>Oekotech</b> Environmental protection, recycling, waste disposal
	<b>Geotech</b> Road infrastructure, Railways, Irrigation and Hydraulic structures, Waste Landfills, Dams etc.		<b>Packtech</b> Packaging, protective-cover systems, sacks, big bags, container systems
	<b>Hometech</b> Furniture, upholstery + interior furnishing, rugs, floor coverings		<b>Protech</b> Person and property protection
	<b>Indutech</b> Filtration, cleaning, mechanical engineering, chemical industry		<b>Sporttech</b> Sport and leisure, active wear, outdoor, sport articles.

**Scope of Technical Textile:**

One of India's oldest industries is the Textile industry. Known for its hand spun fabrics, intricate embroideries and traditional textiles, the textile industry is also amongst the largest employers in the country. One of India's biggest advantages and strength lies in it being the largest producer of cotton and jute and second largest producer of man-made fibres and silk across the globe.

Emerging India has seen exponential growth in the textile industry and amongst many other segments in the textile industry, Technical Textiles has received special attention in recent times. The term technical textile was coined in the year 1985 when industrial growth across the globe was racing towards new heights. The definition of technical textiles adopted by the authoritative Textile Terms and Definitions, published by the Textile Institute, is 'textile materials and products manufactured primarily for their technical and performance properties rather than their aesthetic or decorative characteristics. With industrialization the need for specialised textiles for industrial use was introduced. These were basically research based textiles which substantially supported industrial processes. Technical textiles are knowledge-based research products and hence the name. Technical textiles are manufactured using both natural as well as man-made fibres such as Nomex, Kevlar, Spandex, Twaron which have superior functional properties such as higher tensile strength, insulation, weather resistance etc. Various industries like automobile,



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healthcare, aerospace, defence etc extensively use technical textiles. The list is dynamic and has ever since its inception kept increasing considering the versatility of technical textiles.

### **Advanced Textile Materials: Applications**

#### **Fibers in Technical Textiles:**

Numerous applications widely embrace cutting-edge textiles made from natural fibres:

#### **Industrial Sector**

- In the automotive and aircraft sectors, natural fibres like flax, hemp, sisal, and wool have applications as interior components and are already being utilised in car interiors.
- Thermal insulation materials and sound-proofing solutions benefit from using modified natural fibres.
- In architectural applications, the use of synthetic fibres in architectural applications is likely to be substituted with natural fibre-reinforced textiles. In addition, we may soon see advanced textiles as a material for sunscreens, cladding, and more.
- The mirror casing, paperweights, voltage stabiliser cover, projector cover, helmet, and roof all utilise composites reinforced with coir and polyester.
- Rice husk fibres, cotton, ramie, and jute fibre are used in various applications like building materials, the furniture industry, clothing, ropes, sewing thread, fishing nets, packing materials, and paper manufacturing.

#### **Consumer or Non-Industrial Use**

Innovative eco-friendly textiles are rising, offering great potential in various applications like clothing and household fabrics.

Cotton, a highly absorbent and soft fabric found in nature, is widely employed worldwide in producing apparel and various consumer fabric goods. Nevertheless, cotton processing is laborious, encompassing activities like cleaning, bleaching the fibres, and transforming them into yarns. The cotton sector faces challenges associated with manpower-intensive cultivation but also grapples with outdated machinery at mills, subpar efficiency, and various operational concerns, including periodic scarcity of raw materials.

#### **Pineapple Fabric**

Pineapple leaves yield fibres which, after undergoing an industrial transformation, become a leather-like, natural, non-woven textile. This pineapple fibre is pliable, smooth, and readily adapted for cutting, stitching, or printing. The resulting fabric is also durable and breathable, making it a popular choice for fashion collections across various nations. Moreover, it finds utility in car seats and interiors.



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### **Coffee Ground Fibre**

The coffee ground, which remains after extracting the liquid coffee, possesses potential as a raw material for converting into a natural fibre. Using coffee ground fibre, the fabric offers remarkable anti-odour properties, protects against UV rays, and dries rapidly. This has sparked the interest of the fashion industry and various global apparel brands, who are keen on exploring the development of a clothing line incorporating this unique fibre.

### **Lotus Fibre**

For centuries, lotus stem fabric has been utilised in Myanmar and Thailand, which are located in the far eastern regions. Yet, the task is to update its production methods, ensuring commercial feasibility and appealing to present-day needs and preferences.

### **Fibres From Citrus Fruit By-Products**

Another source of technical textiles from plant fibre is the by-products of citrus fruits.

### **Technical Natural Textiles**

In addition to creating different types of eco-friendly fabrics, the industry focuses on enhancing traditional materials like cotton by addressing their limitations and introducing more convenient properties to meet diverse needs.

### **Wrinkle-Free Cotton**

A fabric's proneness to wrinkling relies on its weight, weave intricacy, composition, and treatment. Generally, when the weight is higher, and the weave structure is more intricate, the material exhibits enhanced wrinkle resistance. Consequently, customers favour cotton apparel treated as wrinkle-resistant due to its comfort and convenience.

In India, numerous manufacturers specialise in the production of wrinkle-free cotton. They aim to enhance the fabric by treating it with formaldehyde and heat, increasing the fibre diameter and resulting in a straighter appearance.

### **Polyamide Fibers**

Development in polyamide (nylon) fibers for technical textiles focuses on enhancing properties like fire resistance, bio-compatibility, and high-performance characteristics through advancements in polymer blends and finishing processes.

### **Polyester Fibers:**

Polyester fibers are strong, durable synthetic fibers made from polymers, most commonly polyethylene terephthalate (PET), which is derived from petroleum-based chemicals. These fibers are known for being lightweight, moisture-resistant, quick-drying, and resistant to wrinkles, stretching, and shrinking. They are used in a wide range of products, including clothing, home



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furnishings, and industrial textiles, and are often blended with natural fibers like cotton to combine their beneficial properties.

### Key characteristics

- **Material:** A class of polymers that contain ester linkages, with the most common being polyethylene terephthalate (PET).
- **Origin:** A synthetic fiber made from petroleum-based chemicals like ethylene glycol and terephthalic acid.
- **Properties:** High strength, good elasticity, wrinkle resistance, and quick-drying.
- **Durability:** Resists stretching, shrinking, mildew, and abrasion, making it suitable for various applications.
- **Maintenance:** Easy to wash, quick to dry, and holds its shape well.
- **Common uses Clothing:** Used in apparel for its durability and wrinkle resistance, often blended with other fibers.

### Polyolefin Fiber:

Polyolefin fibres, such as polypropylene and polyethylene, are manmade artificial textile fibres valued for their durability, lightweight properties, and resistance to chemicals. Used in applications like carpets, geotextiles, and apparel, these fibres offer cost-effective solutions while posing environmental challenges due to their non-biodegradable nature.

Polyolefin fibres, including polypropylene and polyethylene, are versatile manmade artificial textile fibres known for their strength, lightweight nature, and chemical resistance. This article explores their production, properties, applications in textiles, and environmental considerations, emphasizing their role in durable and cost-effective textile manufacturing.

### High Speciality Fibers:

High specialty fibers are engineered materials designed for specific, high-performance applications, excelling in properties like exceptional strength, heat resistance, chemical resistance, and electrical conductivity. Unlike commodity fibers, they are not produced for general use but for demanding tasks in industries such as aerospace, defense, and medicine. Examples include aramid fibers like Kevlar, carbon fibers, and specialized polymers like PTFE.

### Key characteristics:

- **Exceptional strength:** Many specialty fibers, such as aramid and carbon fiber, offer superior tensile strength and stiffness compared to conventional materials.
- **High thermal and chemical resistance:** They are designed to withstand extreme temperatures and harsh chemical environments.



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- **Electrical conductivity:** Some specialty fibers are engineered to conduct electricity, making them valuable for smart textiles and other electronic applications.
- **Specific functional properties:** They are chosen for specialized functions, such as moisture absorbency, flame retardancy, and the ability to respond to external stimuli like heat or light.

**Examples of high specialty fibers:**

- **Aramid fibers:** Known for high tensile strength and heat resistance, used in bulletproof vests and protective gear (e.g., Kevlar, Nomex).
- **Carbon fibers:** Lightweight and very strong, used in aerospace, aircraft, and sporting goods.
- **PTFE fibers:** Exhibit excellent chemical resistance and low friction, used in applications requiring non-stick or chemical-resistant properties.
- **UHMWPE (Ultra-high-molecular-weight polyethylene) fibers:** Possess high strength, cut resistance, and chemical resistance, used in cut-proof gloves and marine ropes.
- **Specialty glass and ceramic fibers:** Used in applications requiring high-temperature stability or specific optical properties.

**Glass Fibers:**

Glass fiber (or glass fibre) is a material consisting of numerous extremely fine fibers of glass.

Glassmakers throughout history have experimented with glass fibers, but mass manufacture of glass fiber was only made possible with the invention of finer machine tooling. In 1893, Edward Drummond Libbey exhibited a dress at the World's Columbian Exposition incorporating glass fibers with the diameter and texture of silk fibers. Glass fibers can also occur naturally, as Pele's hair.

Glass wool, which is one product called "fiberglass" today, was invented some time between 1932 and 1933 by Games Slayter of Owens-Illinois, as a material to be used as thermal building insulation.[1] It is marketed under the trade name Fiberglas, which has become a genericized trademark. Glass fiber, when used as a thermal insulating material, is specially manufactured with a bonding agent to trap many small air cells, resulting in the characteristically air-filled low-density "glass wool" family of products.

Glass fiber has roughly comparable mechanical properties to other fibers such as polymers and carbon fiber. Although not as rigid as carbon fiber, it is much cheaper and significantly less brittle when used in composites. Glass fiber reinforced composites are used in marine industry and piping industries because of good environmental resistance, better damage tolerance for impact loading, high specific strength and stiffness.



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**Ceramic Fibers:**

Ceramic fibers are man-made, high-temperature resistant fibers used for insulation and reinforcement. They are produced from oxide materials like alumina and silica or non-oxide materials such as silicon carbide. Common applications include high-temperature insulation in furnaces and kilns, fire protection, and as reinforcement in composites for aerospace and automotive industries.

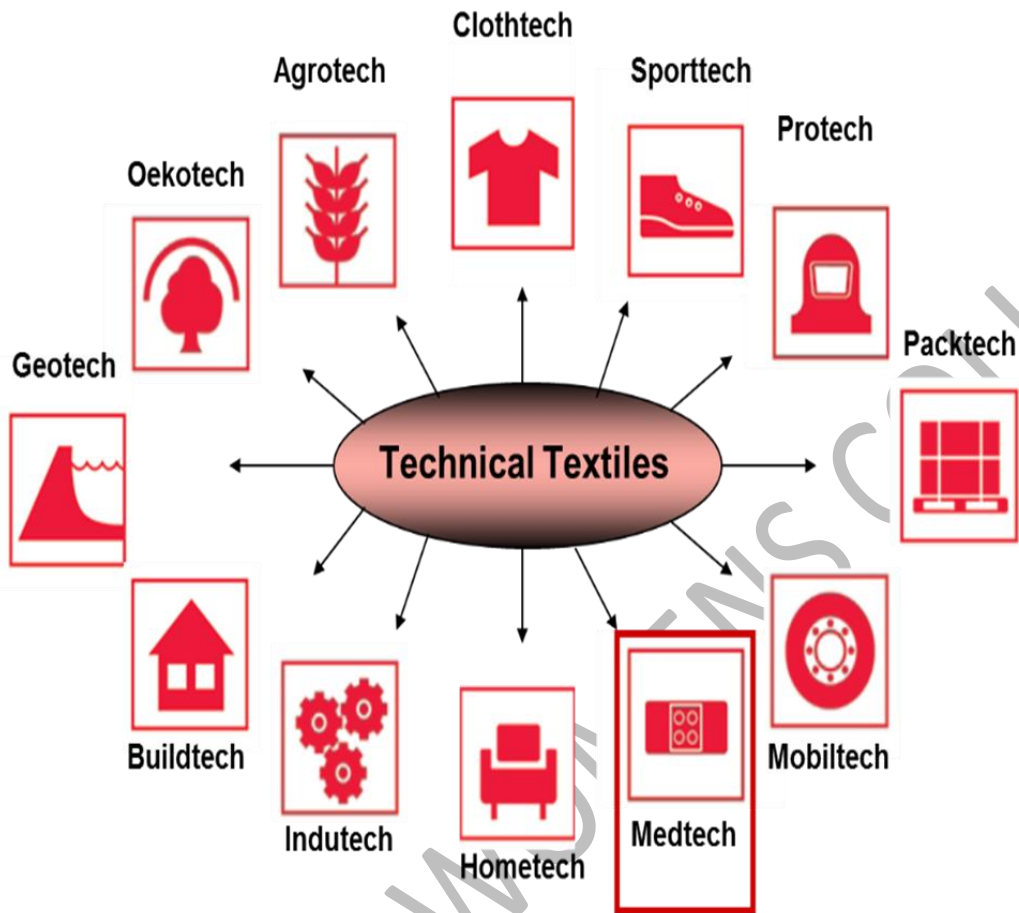
**Properties**

- **High-temperature resistance:** They can withstand very high temperatures, often between 2000–3000 °F. 2000 – 3000 space raised to the composed with power cap F  
2000–3000 °F  
1100–1650 °C. space 1100 – 1650 space raised to the composed with power cap C  
1100–1650 °C.
- **Low thermal conductivity:** This makes them excellent for insulation, as they dissipate very little heat.
- **Low density and thermal inertia:** This allows for rapid temperature control within furnaces.
- **High strength:** They provide excellent thermal and mechanical performance, especially when used as reinforcement in composites.
- **Chemical resistance:** Many types offer excellent chemical inertness.

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Classification of Technical Textiles





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<b>Meditech</b>	<b>Mobiltech</b>	<b>Oekotech</b>	<b>Packtech</b>	<b>Protech</b>	<b>Sportech</b>
<ul style="list-style-type: none"> <li>• Diapers, Sanitary Napkins, Disposables, Contact Lens, Artificial Implants</li> </ul>	<ul style="list-style-type: none"> <li>• Airbags, Helmets, Nylon Tyre Cords, Airline Disposables</li> </ul>	<ul style="list-style-type: none"> <li>• Recycling, Waste Disposal, Environmental Protection</li> </ul>	<ul style="list-style-type: none"> <li>• Wrapping Fabrics, Polyolefin Women Sacks, Leno Bags, Jute Sacks</li> </ul>	<ul style="list-style-type: none"> <li>• Bullet Proof Jackets, Fire Retardant Apparels, High Visibility Clothing</li> </ul>	<ul style="list-style-type: none"> <li>• Sports Net, Artificial Turf, Parachute Fabrics, Tents, Swimwear</li> </ul>
<b>Agrotech</b>	<b>Buildtech</b>	<b>Clothtech</b>	<b>Geotech</b>	<b>Hometech</b>	<b>Indutech</b>
<ul style="list-style-type: none"> <li>• Shadenets, Fishing Nets, Mulch Mats, Ant – hail Nets</li> </ul>	<ul style="list-style-type: none"> <li>• Cotton Canvas Tarpaulins, Floor and Wall Coverings, Canopies</li> </ul>	<ul style="list-style-type: none"> <li>• Zip Fasteners, Garments, Umbrella Cloth, Shoe Laces</li> </ul>	<ul style="list-style-type: none"> <li>• Geogrids, Geonets, Geocomposites</li> </ul>	<ul style="list-style-type: none"> <li>• Mattress and Pillow Fillings, Stuffed Toys, Blinds, Carpets</li> </ul>	<ul style="list-style-type: none"> <li>• Conveyer Belts, Vehicle Seat Belts, Bolting Cloth</li> </ul>

#	Type	Industry	Application
(a)	Indutech	Electronics, Filtration, and other industrial materials	Textile-reinforced rubber products, filtration, lifting, composites, cleaning, electronic components, pulling, others
(b)	Hometech	Furnishing, floor coverings, and habitat	Carpet and furniture components, filtration, cleaning, tarpaulins, coverings, etc
(c)	Clothtech	Shoes and clothing	Shoe components, sewn products, structure, and insulation
(d)	Buildtech	Building and construction	Construction materials and building components, protection, screen, reinforcement
(e)	Packtech	Packaging	Block and disposable packaging, ties, and others
(f)	Oekotech	Environmental protection or shield	Transverse field, products obtained from previous sectors



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**UNIT – II**

**Functional Apparels and Medical Textiles**

**Functional Apparels:**

Functional clothing is apparel designed with a specific purpose beyond appearance, prioritizing practicality, durability, and comfort for activities like sports, work, or military use, but now also for everyday lifestyles. It incorporates special features such as moisture-wicking fabrics, temperature regulation, ample storage, and protection from elements like fire, chemicals, or weather.

**Key characteristics**

- **Purpose-driven:**

Each feature serves a specific function, from keeping you cool to protecting you from injury.

- **Specialized fabrics:**

Uses materials with properties like moisture-wicking, antimicrobial, or temperature-regulating capabilities.

- **Enhanced performance:**

Aims to improve comfort and performance, whether for athletes, workers, or everyday use.

- **Practical design:**

Includes features like strategic pockets, ergonomic fit, and durability.

- **Safety and protection:**

Can provide protection from hazards like fire, chemicals, or extreme weather conditions.

**Examples of functional clothing**

- **Athletic wear:** Compression shirts, moisture-wicking base layers, and weather-resistant jackets.
- **Workwear:** Garments designed for specific professions, such as fire-resistant clothing or clothing with built-in safety features.
- **Medical apparel:** Pressure garments or clothing with antimicrobial properties.
- **Outdoor gear:** Waterproof and windproof jackets or insulated thermal layers.
- **Military and tactical clothing:** Durable and versatile clothing designed for extreme conditions.



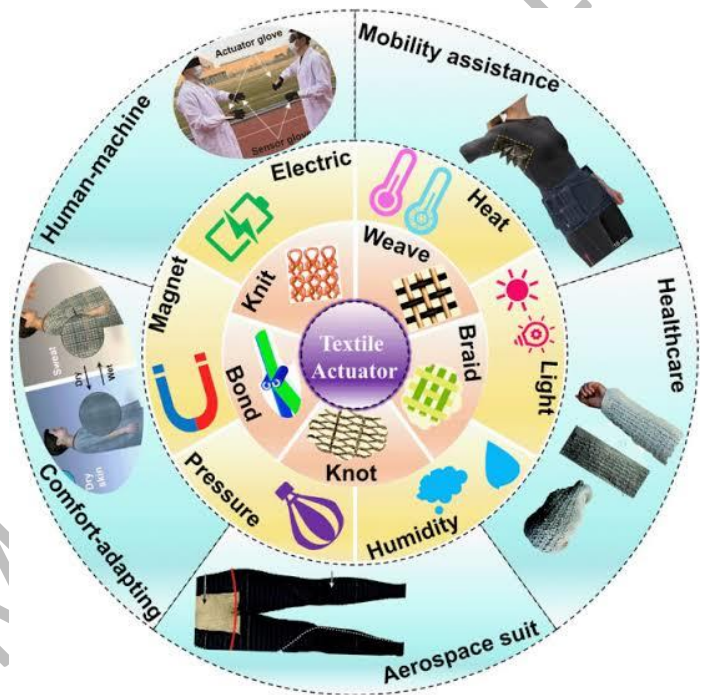
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- "Smart" clothing: Wearables with integrated sensors that can track health data.

Design and Engineering of Functional Clothing:

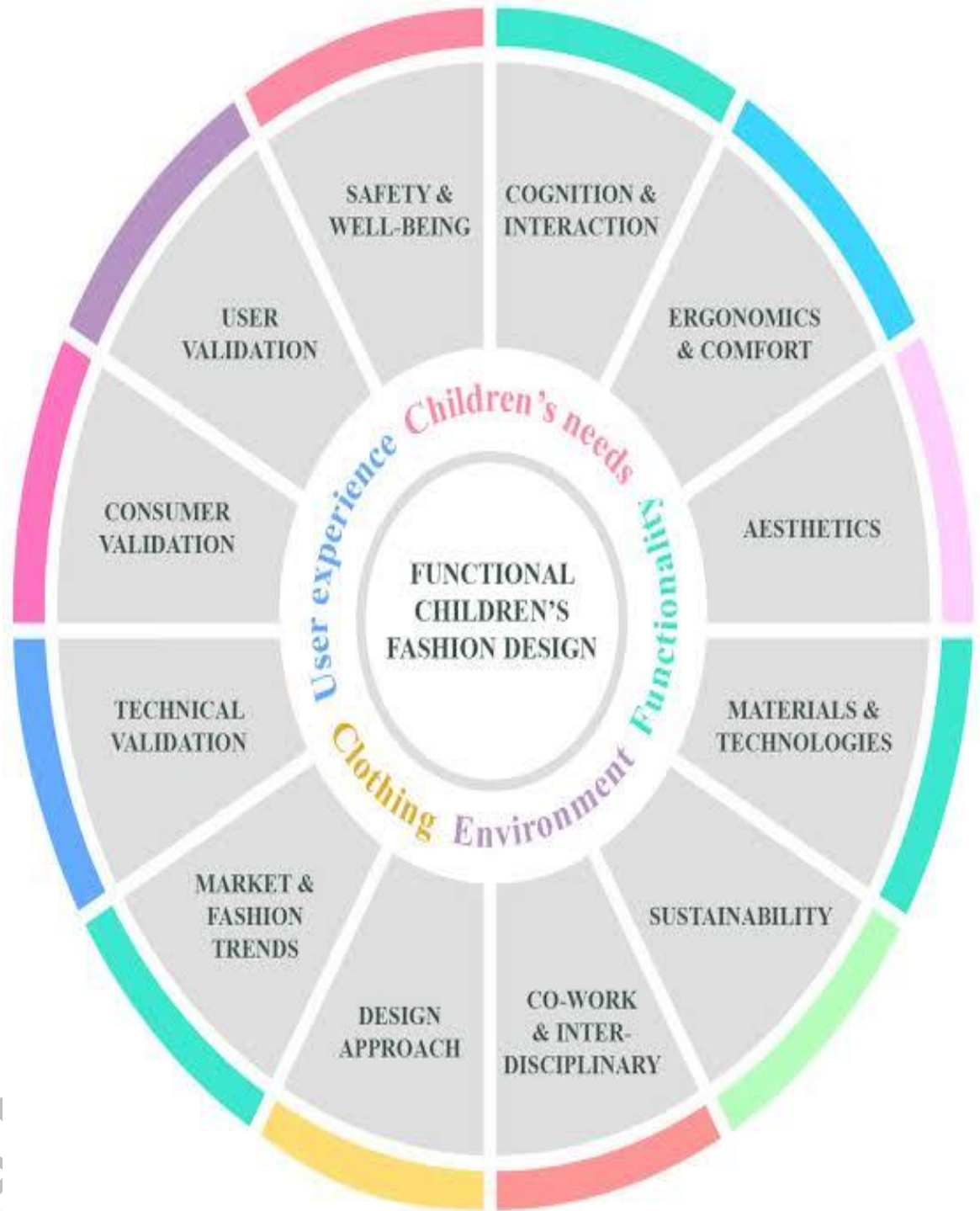
Functional Apparels Requirements



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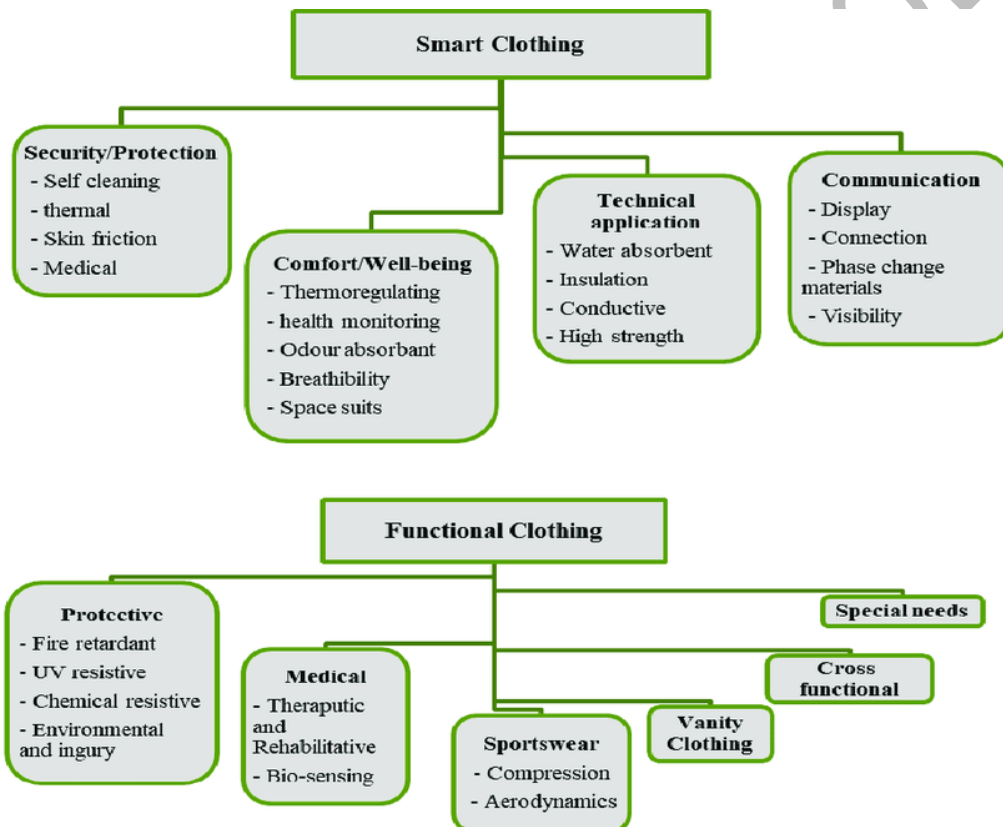


**Smart Characteristics Structural, Aesthetics and Comfort and Fitting of Clothing**

**Medical Textiles**

Medical textiles are numerous fiber-based materials intended for medical purposes. Medical textile is a sector of technical textiles that emphasizes fiber-based products used in health care applications such as prevention, care, and hygiene.

The spectrum of applications of medical textiles ranges from simple cotton bandages to advanced tissue engineering. Common examples of products made from medical textiles include dressings, implants, surgical sutures, certain medical devices, healthcare textiles, diapers, menstrual pads, wipes, and barrier fabrics.



Medical textiles include many fiber types, yarns, fabrics, non-woven materials, woven, braided, as well as knitted fabrics. Physical and chemical alterations of fiber architectures, the use of functional finishes, and the production of stimuli-sensitive materials are major approaches for developing innovative medical textiles.

**Types of fibers, fabrics and materials in different medical textile product**

Category	Medical textile products
Extracorporeal devices	Artificial organs



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	such as lung, liver, and kidney, etc.
Implantable materials	Vascular grafts, sutures, artificial joints, and ligaments.
Non-implantable materials	Dressing, bandages, and plaster, etc.
Hygiene and healthcare products	Clothing, surgical gowns, bedding, and wipes, etc.

Different types of fibers and manufacturing systems are utilized for the production of the various medical textile products.

Refers to a variety of materials used to maintain the hygiene, safety, and care of medical professionals and patients. Surgical drapes, gowns, uniforms, clothing, caps, wipes, masks, and hospital bed linens are all included in this category

Fiber types	Manufacturing system employed	Hygiene and healthcare products
Polyester, Polypropylene	Nonwoven	Protective clothes
Cotton, Polyester	Weaving	Uniforms
Polyester, Polypropylene, Cotton	Weaving, Nonwoven	Medical gowns
Polyester, Viscose, Glass	Nonwoven	Masks
Cotton	Weaving	Sheets and Pillow covers
Polyester, Cotton	Weaving, Knitting	Blankets
Polyester, Superabsorbent polymer	Nonwoven	Diapers

**Human textiles:**

Human textiles refer to textiles that utilize human materials, including bioengineered yarns made from human cells, for tissue regeneration. Textiles manufactured from human tissue-based 'yarn' can be intricately woven, knitted, or braided and have the potential to contribute to various applications, ranging from simple biocompatible sutures to complex woven tissues for surgical repairs, thereby aiding in the healing process of injuries. Human textiles offer a potential solution to mitigate the drawbacks associated with foreign agents that may induce adverse side effects.

**Properties for Medical Textiles:**

Products made from medical textiles are specially engineered textile-based products used in medical applications. These products are used for prevention, care, and hygiene purposes. A combination of properties are considered while selecting the materials, which largely depends



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upon the particular use. The materials used in medical textile products must have the following properties: strength, softness, biocompatibility, elasticity, flexibility, nontoxicity, noncarcinogenic, non-allergenic, and air and water permeability.

**Applications:**

Medical textiles cover a vast area of application that includes wound care, disease management, preventive clothing, bandages, hygiene (hospital linen), etc. Medical textiles are useful in first aid, treating a wound or keeping a wound or illness in the right condition during medical treatment, they also helps in protecting the healthcare workers from Infection and infectious diseases.

**Wound care**

Knitting, weaving, braiding, crocheting, composite materials, and non-woven technologies are all different fabric manufacturing systems used in contemporary wound care.

New medical textiles are an emerging field with significant growth in wound treatment products. These are all important characteristics of wound care fibers and dressings. They are non-toxic, non-allergic, absorbent, hemostatic, biocompatible, breathable, and non-toxic. They also have good mechanical properties. Chitosan, Alginate, Collagen, brananferulate, and carbon fiber-based goods offer numerous advantages over conventional materials.

**Antimicrobial dressing**

Chitosan may function as an inhibitor of bacterial and fungal development. In 2003, the United States Food and Drug Administration approved chitosan-based wound dressings for medical use. Combat medics use Hemcon dressings, which is a dressing with Chitosan, to treat wounds because it stops the blood flow with its hemostasis properties. Chitosan hemostatic agents are salts formed when chitosan is combined with an organic acid (lactic acid, or Succinic acid).

**Surgical suture thread**

Materials in surgical sutures are textile based products. Suture material is frequently subdivided into absorbable thread and non-absorbable thread, and then into synthetic fibers and natural fibers. Whether a suture material is monofilament or polyfilament is an additional critical distinction.

**Bandages**

A bandage is a piece of fabric used to cover, dress, and bind wounds. Bandages are typically manufactured from various textile materials. The dressing or splint is held in place using a bandage. Bandages are also used for medical purposes (strengthening and compressing) to support and restrict specific body parts.

**Compression Bandages**



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Compression bandages are used to apply pressure while directed pressure is used to treat lymphatic disease or venous disease, such as in the treatment of deep vein thrombosis. The most common classifications for compression bandages are inelastic and elastic.

### **Antimicrobial Textiles**

Antimicrobial textiles are the textile materials (fibers, yarns and fabrics) treated with antimicrobial agents, they are used in hygiene care. Antimicrobial treated textiles either kill the bacteria or inhibit the growth of microorganisms. The exemplary products are wipes, gowns, Odorless clothes, etc.

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**UNIT – III**

**PRODUCTIVE WEAR**

**Selection of Materials in Productive Wear**

The selection of materials for protective wear is based on the specific hazards present, which determines the required properties like chemical resistance, fire retardancy, puncture resistance, and static control. Common materials include natural fibers like cotton and leather for breathability and protection, synthetic fibers like polyester and spandex for durability and elasticity, and specialized non-woven fabrics like Tyvek® or aramids for high-level protection against chemicals, heat, and punctures.

**Material selection based on hazard**

- **Chemical resistance:** Nitrile, neoprene, latex, PVC-coated fabrics, and non-woven materials like Spunbond Meltblown Spunbond (SMS) are used to protect against chemical splashes and vapors.
- **Fire resistance:** Leather, treated cotton, and high-performance materials like aramids and carbon fiber are used for flame retardant clothing.
- **Puncture resistance:** Materials such as leather, chainmail, and spandex are reinforced or combined with polymers and aramids to provide protection against punctures.
- **Static control:** Nitrile, nylon, carbon fiber, and rubber are used in anti-static attire to prevent electrical discharge.
- **General protection:** Cotton and polyester-cotton blends offer basic protection and breathability, suitable for tasks where there is no risk of fire or chemical exposure.

**Key factors to consider**

- **Hazard assessment:** A detailed assessment of the workplace environment is the first step to identify the specific hazards and potential exposure levels.
- **Material properties:** The material's ability to provide the necessary protection (e.g., chemical resistance, flame retardancy) is critical.
- **Comfort and mobility:** Heavier fabrics can provide longer breakthrough times but may cause heat stress. Choosing the right fabric weight is important for comfort, especially in active or hot environments.
- **Garment design:** Features like sealed seams, double storm facings over zippers, and compatibility with other PPE, like gloves and respirators, are crucial for comprehensive protection.

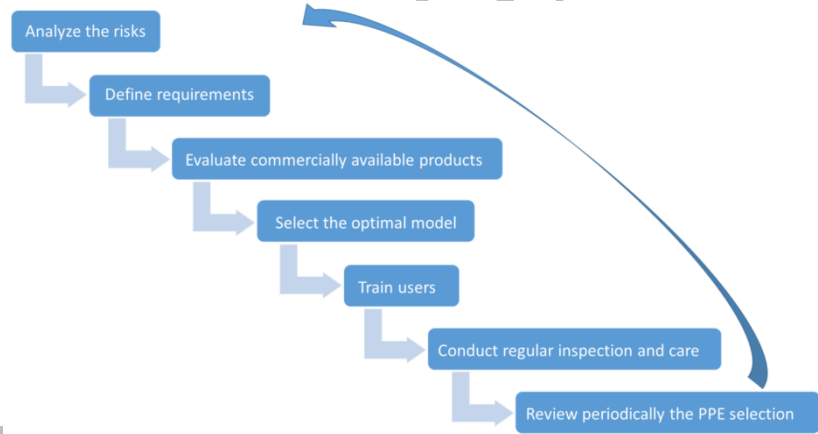
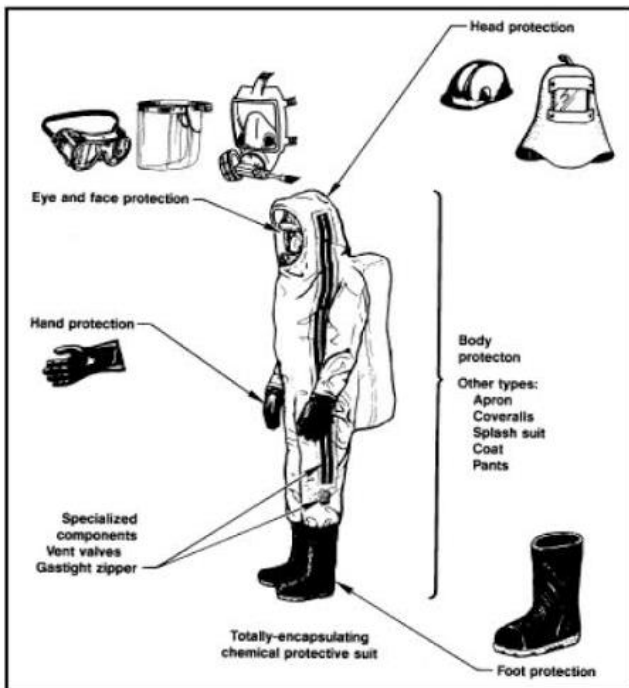


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- Degree of exposure:** The level of protection needed will vary based on the degree of exposure. For instance, a basic coverall might be sufficient for nuisance contamination (Level D), while a gastight suit is required for high-level chemical protection

Material	Key Properties	Primary Applications
Aramid fibers	High strength-to-weight ratio, heat resistance, and flame resistance	Ballistic protection (bulletproof vests), heat-resistant gloves, fire-retardant suits
Ultra-high-molecular-weight polyethylene (UHMWPE)	Extremely high tensile strength, low weight, and cut resistance	Cut-resistant gloves, helmets, and ropes
Flame-resistant fabrics (e.g., Nomex)	Excellent resistance to high heat and flames	Firefighting gear, welding apparel
Chemical-resistant fabrics (e.g., PTFE)	Protection against a wide range of chemicals	Chemical plant and laboratory protective suits
Carbon fibers	High strength, stiffness, and thermal stability	High-performance applications such as aircraft parts and specialized protective gear
Novoloid fibers	High heat and flame resistance	Protective clothing for specific industrial environments
Polyphenylenesulphide (PPS)	Good chemical resistance and thermal stability	Protective clothing and equipment for chemical and high-temperature environments
Polyetherketone (PEEK)	High strength and thermal stability	Specialized protective applications
Natural and synthetic blends (e.g., cotton, polyester)	Varying levels of comfort, durability, and light protection	Light-duty protective clothing, blends for specific applications like moisture-wicking



### Fire-Resistant Textiles and Their Applications

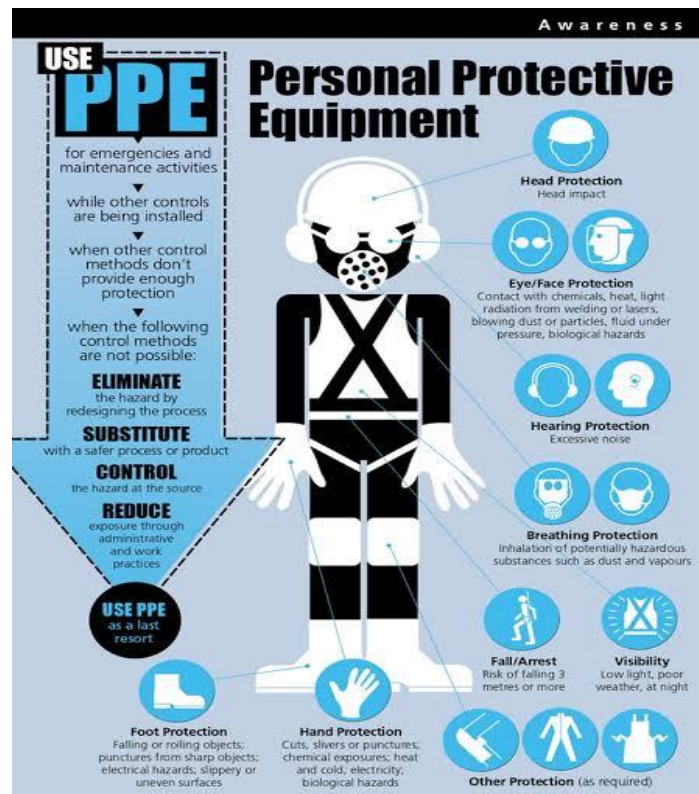
Fire-resistant textiles have emerged as a critical component in ensuring safety and protection against fire hazards in various industries. These specialized textiles are designed to resist ignition, slow down the spread of flames, and provide a barrier between individuals and intense heat. With their remarkable properties, fire-resistant textiles find applications in numerous fields where fire safety is paramount. Let's explore the significance and diverse applications of fire-resistant textiles.



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One of the primary areas where fire-resistant textiles play a crucial role is in personal protective equipment (PPE) for firefighters. Firefighters face extreme heat and flames while combating fires, and their safety heavily relies on the performance of their protective gear. Fire-resistant textiles used in firefighter turnout gear are engineered to withstand high temperatures and provide insulation from heat. These textiles offer a critical layer of defense, allowing firefighters to operate in hazardous environments while minimizing the risk of burns and injuries.



Fire-resistant textiles play a vital role in ensuring safety and protection against fire hazards in various industries. From firefighter gear to industrial PPE, transportation interiors, and building materials, fire-resistant textiles provide essential protection against flames, heat, and potential burn injuries. Advancements in fiber technologies and material innovations continue to enhance the performance and comfort of fire-resistant textiles, ensuring the safety and well-being of individuals working or residing in fire-prone environments.

**Chemical Resistance Protective Wear:**

**Chemical Protective Clothing (CPC)** is specialized equipment designed to prevent hazardous chemicals from coming into direct contact with the wearer. Used in chemical, physical, and biological operations as a last line of defense if safety controls fail. They are made of a variety of materials that are selected for their ability to prevent chemical penetration, permeation, and degradation.



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Chemical-resistant protective wear includes a range of gear, such as fully encapsulated suits, coveralls, gloves, boots, aprons, and eye protection, made from specialized materials like butyl rubber, neoprene, and PVC to protect workers from hazardous substances. The appropriate choice depends on the specific chemical and level of exposure risk.

**Mechanical Resistance Productive Wear:**

"Mechanical resistance" and "wear" are related but distinct concepts, with "mechanical resistance" often referring to a material's ability to withstand stress without permanent deformation, while "wear" is the progressive loss of material from a surface due to friction. "Productive wear" is not a standard term; it may be a misunderstanding of "productive" applications of wear or wear resistance. Wear resistance is a crucial characteristic of a material that can be improved by increasing its hardness, using coatings, and controlling its microstructure to resist wear mechanisms like abrasion or fatigue.

**Mechanical resistance and wear**

- **Mechanical Resistance:** This is the ability of a material to withstand mechanical forces without breaking, deforming, or fracturing. It includes properties like strength, hardness, and toughness.
- **Wear:** This is the physical damage or removal of material from a surface due to friction from another object or particles. It is a system response, not a material property in itself.
- **Wear Resistance:** This is the ability of a material to resist wear. It is a key factor in determining how long parts will last in mechanical systems, and it is often correlated with the material's hardness and microstructure.

**How to improve wear resistance**

- **Surface treatments:** Applying coatings like hard anodizing, electroless nickel, or thermal spray can protect the surface and improve wear resistance, as can surface treatments like shot peening, which modifies the material's microstructure.
- **Material composition:** Alloying elements can be added to improve a material's wear resistance. For example, adding aluminum and copper to zinc alloys can enhance their mechanical properties and wear resistance.
- **Microstructure:** A finer and more homogeneous grain size in the microstructure can reduce the susceptibility to wear mechanisms like microcrack propagation.
- **Composite materials:** Using composite materials with fillers like graphite or reinforcing particles can significantly enhance wear resistance by improving other properties like hardness and tensile strength.



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### Applications where wear resistance is crucial

- **Harvester machines:** The wear resistance of knives is critical for agricultural equipment to maintain performance over time.
- **Industrial equipment:** Wear-resistant coatings and treatments extend the life of machinery and parts, improving efficiency and productivity.
- **Smart clothing:** For smart textiles, wear can affect their electrical properties. Research focuses on improving wear resistance through better design and maintenance practices to ensure longevity.

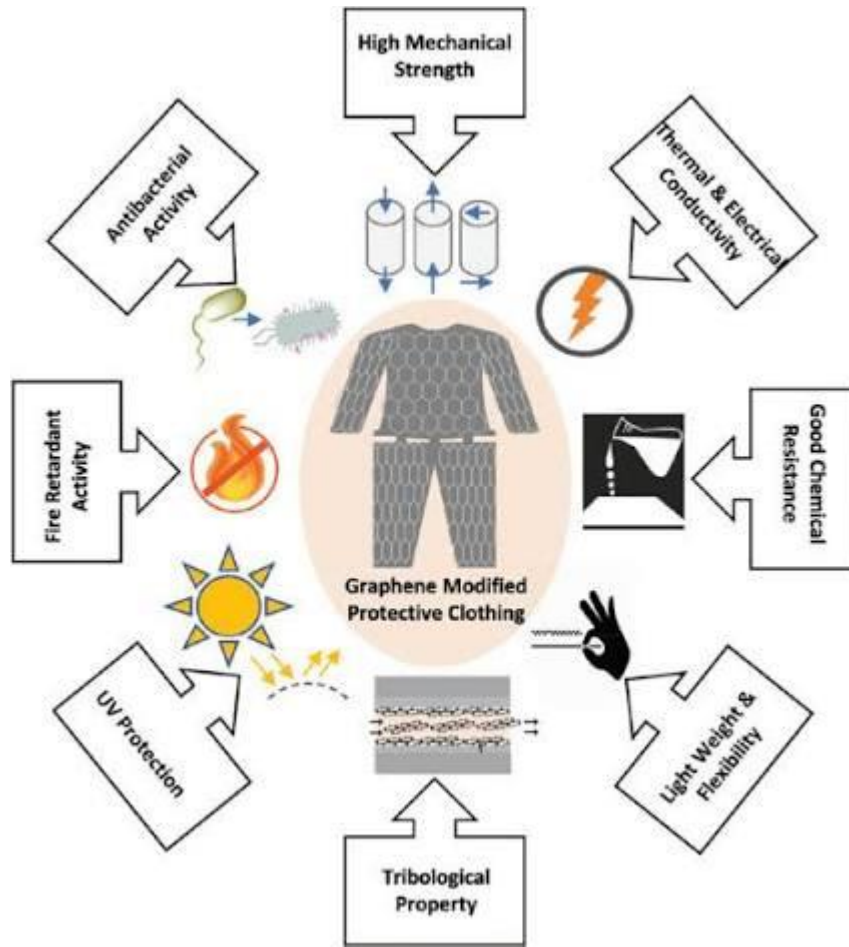
### Electrical Resistance Productive Wear:

"Electrical resistance productive wear" refers to protective clothing and footwear designed to prevent static discharge and electric shock by controlling electrical resistance.

This includes items like anti-static shoes that ground charges, insulating gloves rated for specific voltages, and specialized workwear that protects against arc flash and high-voltage hazards. The "productive" aspect comes from ensuring worker safety, which in turn allows for productivity by preventing accidents and downtime.

### Types of productive wear

- **Insulating gloves:** Protect against high voltage and must be rated for the specific voltage level a worker might encounter.
- **Protective workwear:**
  - Designed to prevent sparks, flames, and molten metal splashes.
  - Made from materials with specific anti-static properties, often compliant with standards like the EN ISO 1149 standard.
  - Includes hard hats for protection from electrical conductors.



**Radiation Protective Clothing:**

Radiation protective clothing is a type of personal protective equipment designed to shield individuals from various forms of radiation by either blocking the rays themselves or preventing contact with contaminated particles.

**Types of Protection and Materials**

Radiation protective clothing addresses two main types of hazards:

Hazard Type	Protection Mechanism	Common Materials	Products
Radioactive Contamination (Alpha & Beta particles, liquids)	Prevents contact and internal exposure (inhalation/ingestion). Garments are disposable or decontaminated to avoid	DuPont Tyvek® and Tychem® fabrics, multi-layer suits.	DuPont Tyvek® 500 Xpert coveralls; Ansell AlphaTec 6500 Multi-Layer Chemical Barrier Suit.



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	spreading contamination.		
Ionizing Radiation Exposure (X-rays, Gamma rays)	Uses dense materials to attenuate or absorb high-energy radiation. Effectiveness varies by material, thickness, and radiation energy.	Lead, or lead-free alternatives like tungsten, bismuth, barium sulfate, and tin, often embedded in polymer composites or woven fabrics.	Lead aprons/vests (standard in medical settings), lead-lined gloves, leaded eyewear, and thyroid collars. Lead-free options include the RST Demron™ suits and vests.

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**UNIT – IV**

**SPORTS WEAR**

**Sports Wear Requirements**

Sportswear requirements focus on performance and comfort, including moisture-wicking, quick-drying, and breathable fabrics that regulate body temperature and move with the body. Key features also include durability, flexibility, lightweight construction, and protection from elements like the sun and wind.

**Performance and comfort**

- **Moisture management:** Materials should effectively move sweat away from the skin to keep the athlete dry and reduce dampness.
- **Breathability:** The fabric needs to allow air circulation to prevent overheating.
- **Thermal regulation:** Wear should help maintain an optimal body temperature in varying conditions.
- **Flexibility and fit:** Clothing should be flexible, lightweight, and not restrictive, allowing for a full range of motion.
- **Lightweight:** Fabrics should be lightweight to avoid adding unnecessary weight.

**Durability and protection**

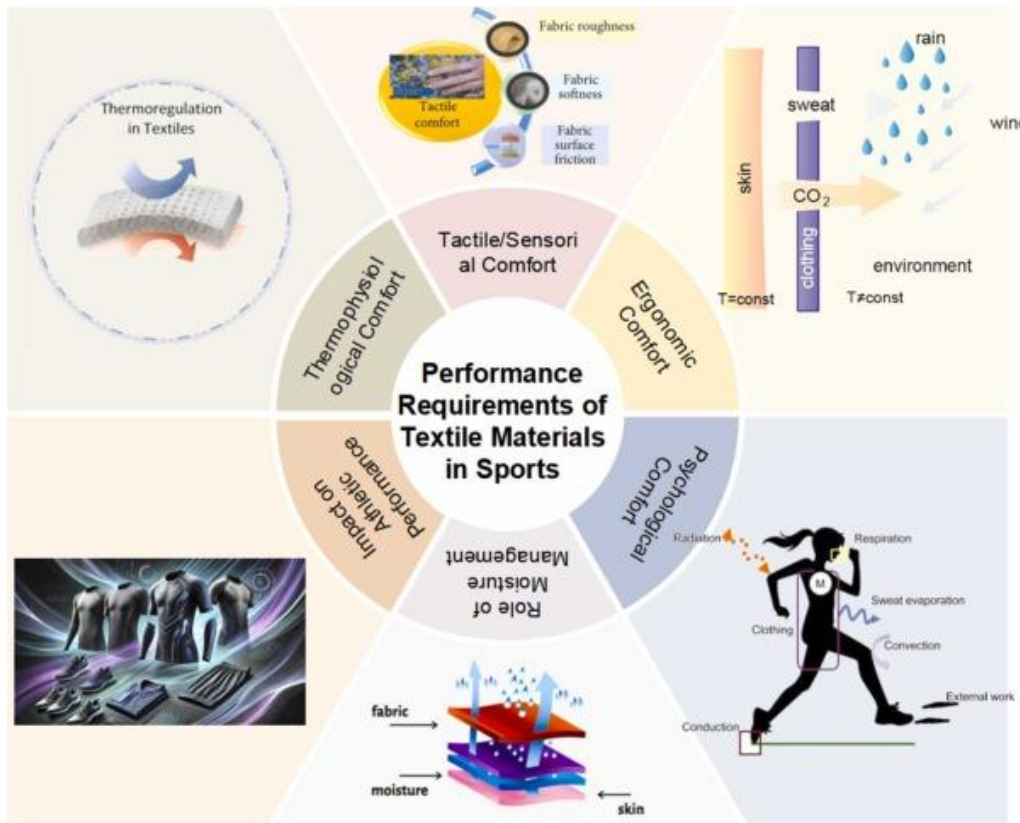
- **Durability:** Sportswear must withstand frequent use and washing.
- **Sun protection:** Some garments require UV protection to shield skin from harmful sun rays.
- **Element protection:** Certain types of sportswear need to provide protection against elements like wind and rain.

**Other important features**

- **Odor resistance:** Antimicrobial properties can help prevent the growth of odor-causing bacteria.
- **Easy care:** The clothing should be easy to wash and maintain.
- **Stretch and shape retention:** The garment should stretch and retain its shape during and after activity.



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**Fabric Requirement**

**Sports wear main requirements**

1. Fit
2. Quality
3. protection

**Parameters:**

1. Strength
2. Durability
3. Tailorability
4. Formability
5. Resilience
6. Absorptiveness
7. Air permeability
8. Lightweight
9. Stress and strain
10. Easy care

**Fibre available**

- 100% of cotton
- Poly cotton blend
- Cotton lycra blend
- Polyester
- Acrylic
- Wool
- Spandex

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### Functional Fibers

Sportswear functional fibers are engineered fabrics designed for performance, with common examples including polyester, nylon, and spandex for properties like moisture-wicking and stretch. Other functional fibers include natural options like bamboo and merino wool for breathability and moisture management, as well as innovative materials like microfiber and blends with special properties like UV resistance or antimicrobial qualities.

### Synthetic fibers

- **Polyester:** Widely used due to its lightweight, durable, wrinkle-resistant, and moisture-wicking properties.
- **Nylon:** Known for its strength, stretch, quick-drying, and mildew-resistant qualities, making it suitable for various sportswear items.
- **Spandex (Elastane/Lycra):** Often blended with other fibers to provide high elasticity and freedom of movement.
- **Polypropylene:** Used for activewear and provides moisture-wicking and thermal properties.
- **Microfiber:** A very fine synthetic fiber that can be used to create soft, lightweight, and durable fabrics.

### Natural and modified natural fibers

- **Bamboo:** Offers softness, breathability, moisture-wicking, and natural UV protection.
- **Merino Wool:** A natural, breathable option that is excellent for both insulation and wicking moisture away from the skin.
- **Modal:** A type of rayon made from beech trees that is very soft and breathable with good moisture regain, often used for sportswear.

### Other functional fibers

- **Gore-Tex:** A waterproof and breathable membrane that is often used in outerwear.
- **Dryarn:** A fine polypropylene fiber that is lightweight and has excellent moisture management properties.
- **Recycled Wool:** Eco-friendly option that can be used to create warm and durable sportswear.



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### **Yarns and Fabric Suitable for Sports Wear**

Suitable yarns for sportswear include polyester, nylon, and spandex, often blended together for durability, stretch, and moisture-wicking properties. Popular fabrics are synthetic knits like polyester, nylon, and spandex blends, which offer excellent breathability, quick-drying, and stretch for high-intensity activities. Natural fibers like merino wool and bamboo are also good for their moisture-wicking, odor-resistant, and temperature-regulating qualities.

#### **Common yarns for sportswear**

- **Polyester yarn:** A primary choice for its breathability, durability, and moisture-wicking capabilities.
- **Nylon yarn:** Provides a lightweight, quick-drying, and stretchy option that is also mildew resistant.
- **Spandex yarn (also known as Lycra or elastane):** Added to blends to provide significant stretch and flexibility.
- **Core-spun yarns:** Yarns with a core of one fiber (like spandex) wrapped in another (like polyester or cotton).

#### **Suitable fabrics for sportswear**

- **Polyester:** Known for being durable, wrinkle-resistant, and an excellent moisture-wicking fabric.
- **Nylon:** Lightweight, quick-drying, and breathable, making it ideal for high-intensity sports.
- **Polyester-spandex blends:** A very popular choice because it combines the durability of polyester with the stretch of spandex.
- **Bamboo:** A more eco-friendly option with natural moisture-wicking and antibacterial properties.
- **Merino wool:** A natural fiber that is excellent at temperature regulation and resists odors.
- **Knitted fabrics:** Often used for sportswear because they provide breathability, flexibility, and moisture-wicking properties.
- **Cotton elastane blends:** Good for activewear that requires a high degree of stretch and elasticity, such as swimwear and windbreakers.

#### **Key characteristics to look for**

- **Moisture-wicking:** Draws sweat away from the body to keep you dry.
- **Breathability:** Allows air to circulate to keep you cool.
- **Stretchability:** Provides a full range of motion.



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- **Lightweight:** Prevents the garment from feeling heavy.
- **Durability:** Can withstand strenuous activity and frequent washing.

### **Sweat Management for Sports Wear Application**

Sweat management for sportswear involves a combination of fabric properties and design to keep the athlete dry and comfortable through a five-stage process: absorption, transport, spreading, storage, and evaporation. This is achieved through synthetic, non-absorbent fibers that wick moisture away from the skin via capillary action, and sometimes using a blend of absorbent fibers for a multi-layer approach. The goal is to improve performance by preventing discomfort from wet, sticky clothing.

### **Key principles of sweat management**

- **Absorption:** The fabric takes up moisture from the skin surface.
- **Transport:** The moisture is moved away from the skin and through the fabric via wicking and capillary action.
- **Spreading:** The moisture spreads out within the fabric structure.
- **Storage:** Absorbent fibers can "store" sweat away from the skin, especially in a multi-layer system.
- **Evaporation:** The moisture eventually evaporates from the fabric's surface to the environment.

### **Common techniques and materials**

- **Synthetic fibers:** Polyester, elastane, and other synthetics are preferred over natural fibers like cotton because they do not absorb much moisture, keeping the garment dry and light even when wet.
- **Moisture-wicking fabrics:** Fabrics are engineered to pull sweat away from the body efficiently. Examples include Coolmax® and Dri-FIT.
- **Blended fabrics:** Some designs use multiple layers, such as an inner layer of synthetic fibers to wick sweat and an outer layer with more absorbent fibers to help spread and evaporate the moisture.
- **Merino wool:** This type of wool is a good choice, particularly for cold-weather workouts, as its fibers are thin, making the fabric lighter than traditional wool and providing good warming and moisture management properties.
- **Engineered structures:** Advanced designs use specific fiber structures and fabric constructions to enhance moisture vapor permeability and thermo physiological comfort.



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### Why it matters

- **Improved performance:** Keeping athletes dry and comfortable can improve performance, especially during high-intensity activities.
- **Comfort and skin health:** Managing moisture prevents the discomfort of wet, clingy clothing and can reduce the risk of skin irritation and infection.
- **Temperature regulation:** By moving moisture away from the body, sportswear helps regulate temperature, whether it's for cooling in hot weather or preventing a "chill" in cold weather.

### Foot Wear Clothing

Footwear refers to items worn on the feet like shoes and boots, while apparel refers to clothing worn on the body such as shirts, pants, and dresses. Both categories are available from a wide range of brands and retailers to suit various styles and occasions.

### Footwear

Footwear provides protection, stability, and can also be a fashion statement.

- **Athletic Shoes/Sneakers:** Popular for sports, training, and casual wear. Key products include the Nike Air Force 1 (an enduring icon since 1982), Adidas Samba (originally for indoor soccer, now a fashion favorite), and performance runners like the ASICS GEL-KAYANO 32.
  - **Boots:** Available in many styles for different needs, from rugged Woodland Trekking Boots for outdoor enthusiasts to fashion-oriented options like thigh-high or combat boots.
  - **Formal Shoes:** Brands like Louis Philippe and Hush Puppies offer a range of formal shoes and loafers known for comfort and style, suitable for office or dressy occasions.
  - **Sandals and Flip-flops:** Casual options ideal for home or beachwear, with brands like Relaxo and Paragon offering durable and affordable choices.

### Clothing/Apparel

Apparel includes a vast array of items for men, women, and children, from everyday essentials to performance wear.

- **Casual Wear:** Includes items like jeans (Ben Martin offers baggy and loose fits), T-shirts, and hoodies.
- **Activewear:** Features apparel designed for sports and physical activity such as sports bras, tights, jerseys, and running gear.



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- **Formal Wear:** Encompasses items like formal shirts, blazers, and dresses from various brands.
- **Outerwear:** Essential for colder weather, this category includes jackets, sweaters, and coats.

### **Fabric Requirements for Footwear**

Fabric requirements for footwear include being breathable, durable, moisture-wicking, and flexible. Common materials used are synthetics like polyester and nylon for sports shoes, which provide a balance of these properties, while cotton is often used for casual or canvas shoes. Tactical footwear requires high-tensile strength and abrasion resistance, with water-repellent fabrics being important for wet conditions.

### **Key fabric properties**

- **Breathability:** Allows air to flow through to keep feet cool and dry.
- **Moisture-wicking:** Draws sweat away from the foot to prevent discomfort and odor.
- **Durability:** Resists wear and tear, and can withstand intense use and abrasion.
- **Flexibility:** Allows for comfortable movement without being too stiff.
- **Lightweight:** Reduces fatigue and enhances overall comfort.
- **Water resistance:** Keeps feet dry in wet conditions, especially for outdoor or tactical footwear.

### **Common fabrics and their uses**

- **Polyester:** A common choice for sports shoes due to its durability and moisture-wicking properties.
- **Nylon:** Often used in premium sports shoes for its strength and durability.
- **Cotton:** Used in casual and canvas shoes, as well as for its ability to be printed on easily.
- **Mesh:** Typically made of polyester or nylon, this open-structured fabric is excellent for breathability in running shoe uppers.
- **Non-woven fabrics:** Frequently used for liners and sockliners to manage moisture and keep feet dry.

### **"Finishing Adaptability" in Footwear**

"Finishing adaptability" in footwear refers to the final processes that make a shoe look good and perform well, but the term can also be interpreted in different ways. One interpretation is the aesthetic finishing process, which includes polishing and coloring to give the shoe its final look. Another interpretation is the functional finishing of the sole and heel, which ensures durability



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and a smooth, comfortable surface. Finally, it could be about material adaptability, where the finishing process modifies the properties of the upper materials to enhance comfort, water resistance, or other features.

### **Aesthetic and functional finishing**

- **Upper finishing:** This involves processes like cleaning, buffing, and applying creams or polishes to the shoe's upper to restore and enhance its appearance.
- **Sole and edge finishing:** This critical step includes actions like smoothing, inking, and polishing the edges of the sole and heel to improve both durability and appearance. Techniques include burnishing (friction polishing) and edge painting.

### **Material and comfort finishing**

- **Modifying material properties:** The finishing process can alter a shoe's physical properties. For example, different finishing techniques on leathers can affect water vapor permeability, air permeability, and thermal resistance.
- **Enhancing comfort:** Applying a proper finish can seal the leather to protect it from water and improve its feel.
- **Ensuring durability:** Finishing processes, like edge treatments and the application of certain sealants, are crucial for the longevity of the shoe.

### **What adaptability means in this context**

- **Adaptable to customer preference:** The range of finishing options allows for the creation of different aesthetics to meet diverse customer tastes.
- **Adaptable to different environments:** Materials and finishes can be chosen or created to make footwear suitable for various conditions, such as water resistance for outdoor use or breathability for athletic activities.
- **Adaptable to the wear and tear of use:** Finishing the sole and edges provides a protective layer that can withstand wear and tear over time.



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**UNIT – V**

**SMART AND INTELLIGENT TEXTILES**

Our textile industry is distinctly moving towards an new era, an era of “smart and intelligent textiles”.

Smart textiles are fabrics with integrated electronic components, sensors, or other technology that allow them to sense, react to, or adapt to their environment or the wearer's body. These "e-textiles" can be used for a wide range of applications, from performance-enhancing sports apparel and medical devices that monitor vital signs to clothing that heats, cools, or changes color.

**Characteristics**

- **Sensing:**

Smart textiles can monitor things like body temperature, heart rate, moisture, and movement.

- **Reacting:**

They can respond to stimuli, such as warming up when it gets cold or changing color.

- **Adapting:**

They can adapt to the wearer's needs or the environment, for example, by regulating temperature or wicking away sweat.

- **Communicating:**

Some smart textiles can transmit data to external devices or systems, such as a smartphone.

**Common applications**

- **Sports and Fitness:**

Apparel that tracks performance, monitors health metrics, or regulates temperature.

- **Healthcare:**

Garments that monitor the vital signs of a patient or a fetus, or advanced wound care dressings.

- **Military and Defense:**

Uniforms that provide protection, monitor soldier health, or help with navigation.

- **Fashion and Entertainment:**

Clothing that changes color or illuminates for aesthetic purposes.



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- **Automotive:**

Fabrics integrated into vehicle seats or interiors that can heat, cool, or monitor occupants.

**Examples**

- A running shirt that tracks your heart rate and transmits the data to an app.
- A jacket with integrated heating elements that can be adjusted by the wearer.
- Medical pads that monitor a pregnant woman's and fetus's vital signs during pregnancy.
- A self-healing fabric that can repair minor tears on its own.

**TYPES OF SMART TEXTILES:**

According to the manner of reaction, they can be divided into passive smart, active smart and very smart materials:

**1. Passive smart textiles**

- **Function:** Sense and react to environmental stimuli, but do not alter their own behavior in response.
- **Examples:**
  - Fabrics that are UV-protective, sensing and blocking harmful rays.
  - Moisture-wicking athletic wear that pulls sweat away from the body to keep the wearer dry.
  - Thermo chromic pigments that change color in response to temperature without any active control.

**2. Active smart textiles**

- **Function:** Contain both sensors to detect changes and actuators to respond to them.
- **Examples:**
  - Clothing with phase-change materials that absorb and release heat to regulate the wearer's body temperature.
  - Thermochromic fabrics that actively change color in real-time as temperatures shift.
  - Water-resistant fabrics that can adjust their water repellency.

**3. Ultra-smart textiles**

- **Function:** Combine sensors, actuators, and a central processing unit to sense, react, and adapt to their environment, similar to a "brain".

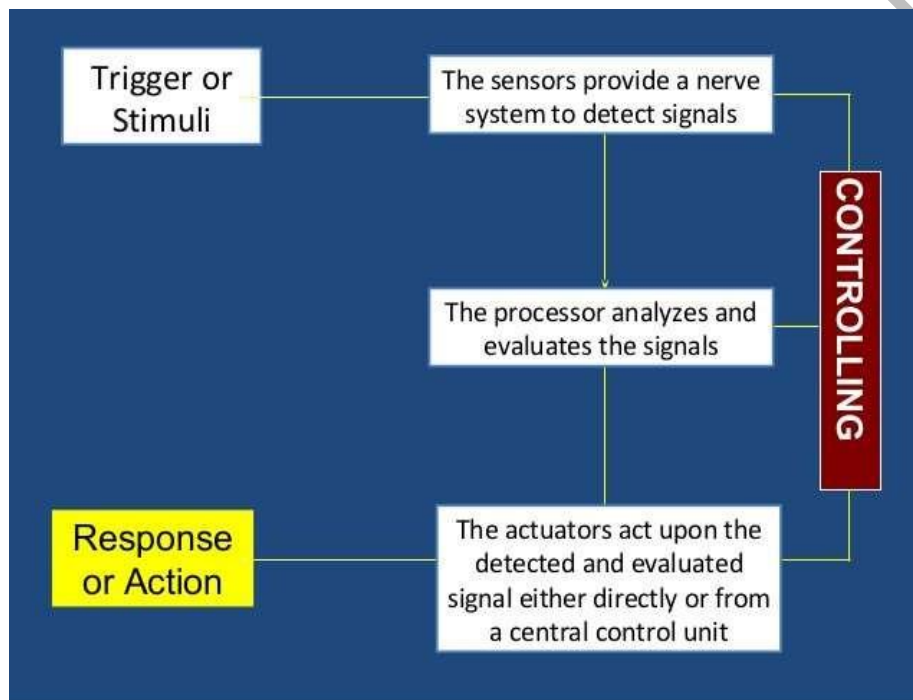


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• **Examples:**

- Smart bandages that monitor a wound and alert a doctor if an infection occurs.
- Health-monitoring shirts that track heart rate or oxygen levels and sync the data to a smartphone.
- Garments with embedded microprocessors that can learn and adapt to the user's needs.



Smart fibers are advanced fibers that can sense, respond to, and process environmental or internal stimuli, unlike traditional fibers. They are made from materials that enable functions like sensing light, heat, or stress, converting mechanical energy to electrical power, and even self-repairing or self-adjusting. These properties make them ideal for applications in wearable electronics, self-powered electronic skins, and textiles that can monitor health or adjust to environmental changes.

**Key characteristics of smart fibers**

- **Sensing and responding:** They can detect and react to external stimuli like light, heat, stress, and radiation. Some can also recognize internal states, such as changes in a person's health through motion or touch.
- **Energy conversion:** Piezoelectric and triboelectric smart fibers can convert mechanical energy from movement or pressure into electrical energy, enabling self-powered devices.



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- **Self-functionality:** Some smart fibers have capabilities like self-diagnosis, self-repairing, and self-adjusting to maintain optimal performance.
- **Integration:** They can be woven into traditional textiles to create smart fabrics that are flexible, lightweight, and capable of complex functions without bulky electronics.
- **Advanced fabrication:** Techniques like electrospinning are used to create smart nanofibers from a wide range of materials, including organic, inorganic, and composite materials.

### Applications

- **Wearable electronics:** Creating electronic skins that can provide tactile feedback or monitor motion.
- **Health monitoring:** Developing self-powered devices for continuous health tracking by converting body motion into electrical signals.
- **Environmentally responsive textiles:** Creating fabrics that can change their properties (e.g., thermal insulation) based on the environment.
- **Smart clothing:** Enabling clothing that can perform complex tasks, from environmental control to advanced health management.
- **Sensing networks:** Weaving fibers into a network that performs in-situ computing and logic-switch functions, reducing reliance on cloud computing.

### Nano Fibers

Nanofibers are ultra-fine fibers with diameters typically ranging from 1 to 1,000 nanometers. They have a very high surface area-to-volume ratio, which gives them unique properties valuable for applications such as drug delivery, filtration, tissue engineering, and energy storage. They can be made from natural or synthetic polymers and are often produced using electrospinning.

### Properties and characteristics

- **High surface area-to-volume ratio:** This is a key property that makes them highly efficient for applications like filtration and catalysis.
- **Unique pore structures:** Nanofiber mats can have very small pores, allowing them to be used for filtration of viruses and other tiny particles.
- **Functionality:** Their surfaces can be modified to have specific properties, such as electrical conductivity, to enhance their performance in different applications.

### Common fabrication methods

- **Electrospinning:** A process where a strong electric field is used to draw fibers from a polymer solution or melt.



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- **Phase separation:** A technique involving separating a polymer into distinct phases, followed by removal of one phase.
- **Meltblowing:** A process that uses high-velocity air to draw a polymer melt into fine fibers.

### Photo Adaptive Fiber

Photo-adaptive fibers are a type of smart or responsive material engineered to undergo reversible changes in their optical properties (such as color, transparency, and heat reflectivity) upon exposure to light, particularly UV-visible light. These changes are dynamic and typically reverse once the light stimulus is removed or altered.

### How They Work

The primary mechanism involves incorporating light-sensitive compounds, such as metal complexes or photochromic dyes, into a polymer matrix that forms the fiber.

- **Mechanism Example:** In one research approach, colorless polymer fibers containing gold or silver complexes are exposed to high-intensity UV-visible light. This light triggers a photoreduction process, forming nanometer-sized metal particles within the fiber matrix, which causes the fiber to turn a distinct color (e.g., brown for silver, red for gold).
- **Reversibility:** The "adaptive" or "responsive" aspect comes from the ability of these metal particles to oxidize back into their original colorless ionic form when the light intensity decreases (e.g., under ambient light), often aided by oxidizing agents within the fiber material. This process is similar to how photochromic eyeglasses work.
- **Alternative Mechanism:** Another method uses Photonic Band Gap (PBG) fibers, whose color is determined by their internal micro-structure rather than chemical additives. The color can be changed dynamically by controlling the intensity of guided light within the fiber versus ambient light reflection, or by physically stretching the fiber to alter the structure.

### Chameleon Fiber

- Chameleon fiber, also known as chromic material or smart textile fiber, is a type of material designed to change its color or appearance in response to external stimuli such as light, heat, electricity, or pressure.
- These "smart" materials are created by incorporating chromic dyes, pigments, or other color-changing compounds into the fiber matrix or as a coating.

### Types of Chameleon Fiber

- **Photochromic Textiles:** These change color when exposed to light, particularly UV radiation. They are used in products like light-adjusting eyeglasses and are being researched for military camouflage applications.



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- **Thermochromic Textiles:** These materials change their color in response to changes in temperature (heat). The color change is often reversible and can be integrated into athletic wear or medical patient monitoring tools to indicate temperature fluctuations.
- **Electrochromic Textiles:** Color changes in these fibers are triggered by the application of a weak electric current. This technology is being investigated for dynamic, patterned clothing designs where the color can be controlled on demand, as well as for use in biosensor applications.

### **Conductive Fibers- Properties and Applications**

Conductive fibers have properties like flexibility, durability, and conductivity, and are used in applications such as wearable electronics, smart textiles, electromagnetic shielding, and biomedical engineering. They are made by infusing or coating traditional fibers with conductive materials like metals, carbon, or conductive polymers. Their ability to carry electrical signals while retaining textile-like properties makes them revolutionary for integrating technology directly into fabrics.

#### **Properties**

- **Conductivity:** They can conduct electrical signals or power, and can also be designed to exhibit higher or lower conductivity depending on the application.
- **Flexibility and durability:** They are designed to be flexible, stretchable, and durable, withstanding repeated use and wash cycles.
- **Lightweight:** They are lightweight, which is crucial for wearable and portable applications.
- **EM interference protection:** They can effectively shield and absorb electromagnetic waves.
- **Thermal conductivity:** Some conductive fibers also possess good thermal conductivity.

#### **Applications**

- **Wearable and smart textiles:**
  - **Sensors:** Used in smart clothing to monitor biosignals like ECG, EEG, and EMG.
  - **Heating:** Integrated into textiles for heating applications, such as heated gloves or seats.
  - **Data transfer:** Serve as conductive pathways for data management in clothing.
  - **Energy harvesting:** Used to convert kinetic energy into usable power for electronics.



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- **Industrial and safety:**
  - **Anti-static clothing:** Worn in environments like the petrochemical or electronics industries to prevent static buildup.
  - **Protective equipment:** Used in the military for high-precision processing, radiation protection, and in self-healing gear.
- **Aerospace and automotive:**
  - Used for thermal management, as dashboards, and for heated steering wheels.
- **Biomedical:**
  - **Tissue engineering:** Serve as scaffolds for cardiac, nerve, and bone tissue engineering to guide cell growth and electrical signals.
  - **Sensing:** Integrated into "electronic skin" for monitoring various biological parameters.

### Phase Change Materials

Phase change materials (PCMs) are substances that absorb and release large amounts of thermal energy at a relatively constant temperature as they change between solid and liquid states. This latent heat storage makes them useful for thermal energy storage applications, such as heating and cooling systems, temperature-controlled packaging, and building insulation. PCMs can buffer temperature changes, improve energy efficiency, and reduce energy consumption.

### How they work

- **Absorption:** When the temperature rises, a PCM absorbs heat and melts from a solid to a liquid. This process stores the heat energy without a significant temperature increase.
- **Release:** As the surrounding temperature falls, the PCM releases the stored energy by solidifying from a liquid back into a solid, providing heat or cooling.

### Applications

- **Buildings:** Integrated into building materials like drywall or insulation to store solar heat during the day and release it at night, improving energy efficiency and thermal comfort.
- **Thermal energy storage:** Used in systems to store thermal energy for later use, such as in solar energy systems.
- **Cold-chain logistics:** Employed in packaging for transporting temperature-sensitive goods like vaccines, blood, and food.
- **Consumer products:** Incorporated into apparel like jackets and boots to help regulate body temperature.



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- **Electronics:** Can be used to cool electronic devices.

### Key characteristics

- **Melting point:** A specific temperature at which the phase change occurs.
- **Latent heat of fusion:** The amount of energy absorbed or released during the phase change.
- **Thermal conductivity:** How efficiently heat moves through the material.
- **Energy storage capacity:** The total amount of energy the PCM can store.

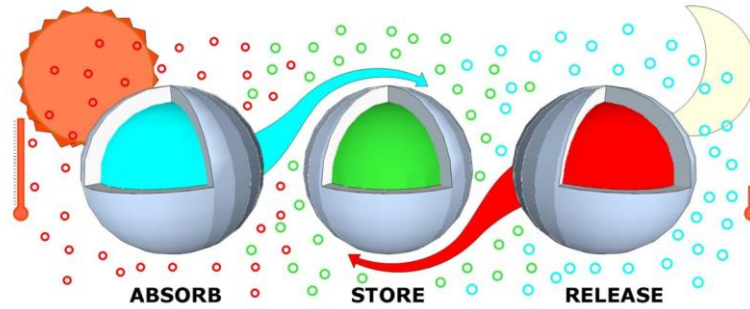
### Advantages

- **Energy efficiency:** Can significantly reduce the energy needed for heating and cooling systems by storing and releasing energy as needed.
- **Compactness:** Can store a large amount of thermal energy in a small volume, making thermal storage units more compact.
- **Cost-effectiveness:** Many PCMs are cost-effective and environmentally friendly.
- **Stable temperature:** Maintain a stable temperature during the phase change process, which is useful for many applications.

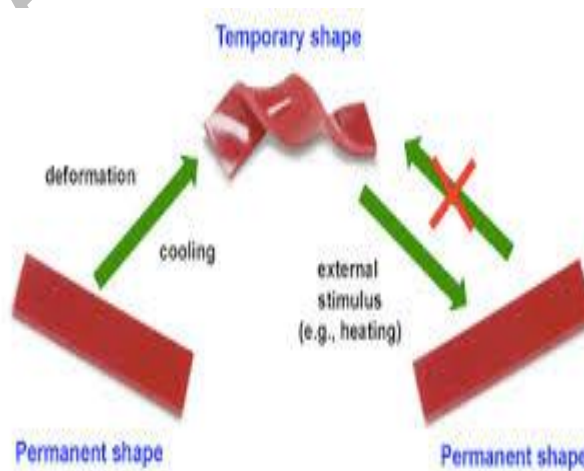




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Shape Memory Polymers and its Properties





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Shape Memory Polymers (SMPs) are smart materials that can be deformed into a temporary shape and then recover their original, permanent shape when exposed to an external stimulus like heat, light, or an electric field. Their properties include high recoverable strain, versatility in processing, lightweight characteristics, and biocompatibility, although their neat mechanical properties can be poor and may require reinforcement.

### Key properties

- **Shape recovery:** SMPs can recover their original shape from a deformed state when an external stimulus is applied.
- **High recoverable strain:** They can undergo large deformations, with strains greater than 200% in some cases.
- **Versatile stimuli response:** The shape recovery can be triggered by various stimuli, including heat, light, electricity, magnetic fields, humidity, and chemical changes (pH).
- **Biocompatibility:** Many SMPs are biocompatible and biodegradable, making them suitable for biomedical applications.
- **Lightweight:** SMPs are less dense than metal alternatives like shape memory alloys.
- **Tailorable:** They can be tailored for specific applications and can be combined with other materials to enhance their properties.
- **Processing flexibility:** They are easy to process and can be manufactured using conventional methods.

### Other considerations

- **Reinforcement:** The inherent mechanical and thermal properties of neat SMPs can be poor, which can limit their engineering applications. Reinforcing them with nanofillers can significantly improve properties like tensile strength, hardness, and thermal conductivity.
- **Limitations:** SMPs have limitations in conductivity compared to shape memory alloys and have lower mechanical strength and recovery stress than their metal counterparts unless reinforced.
- **Applications:** Due to their properties, SMPs are used in various fields, including aerospace for deployable structures, medicine for devices like stents and sutures, self-finishing textiles, and electronics.

### Stimuli Sensitive Intelligent Textiles

Stimuli-sensitive intelligent textiles are fabrics that can sense and react to environmental changes, such as temperature, light, moisture, or mechanical stress, by changing their properties. They use integrated electronic components and specially engineered materials to alter features like color,



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shape, or electrical conductivity, enabling applications in medicine, safety, and performance wear.

### How they work

- **Sensing:** These textiles use various methods to detect external stimuli.
- **Environmental:** Sensors can detect changes in temperature, light, chemical presence, moisture levels, or pH.
- **Interaction:** They can also respond to mechanical force or electromagnetic fields.
- **Responding:** After sensing a stimulus, the textile can automatically and reproducibly change its properties.
- **Aesthetic changes:** The fabric might change color, texture, or even shape.
- **Physical changes:** The material can alter its mechanical, electrical, or thermal characteristics, or control liquid absorption (wetting).
- **Examples:** These responses can include photochromic (light-sensitive) and electrochromic (voltage-sensitive) color changes, shape-memory effects, or controlled drug release.

### Applications

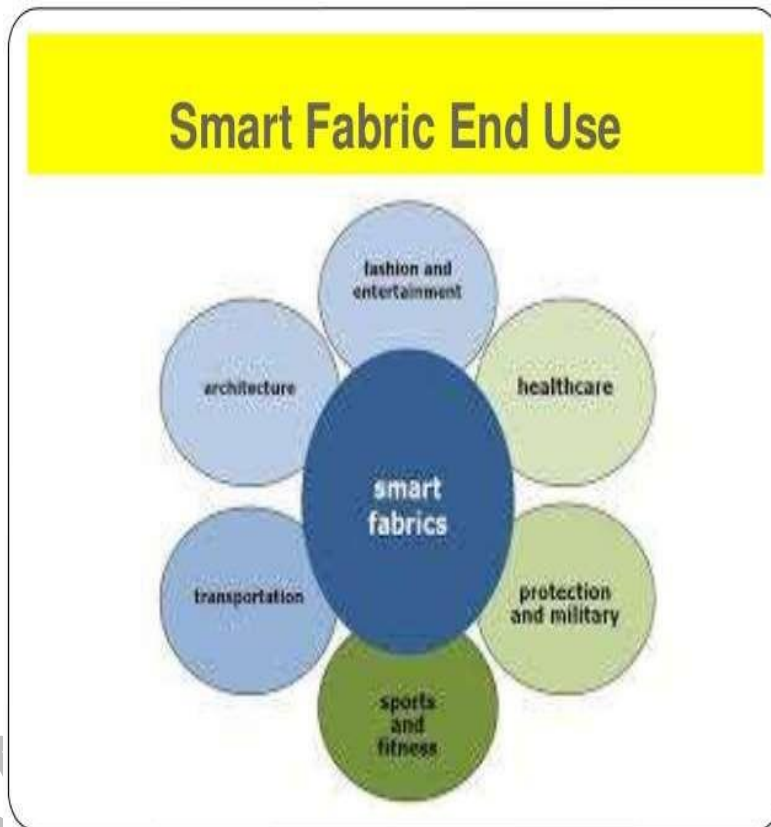
- **Medical:** Monitoring wounds or controlling drug delivery.
- **Safety:** Creating clothing that changes color to signal danger or provides protection from extreme conditions.
- **Performance wear:** Providing feedback on the wearer's physical activity or environmental exposure.
- **Fashion:** Enabling dynamic and responsive clothing designs.

### Key characteristics

- **Integration:** They integrate technology directly into the fabric, creating a seamless experience rather than using traditional external devices.
- **Versatility:** The properties of the textile can be customized for various functions.
- **Types:** They can be classified as active (reacting to stimuli) or passive (just monitoring).

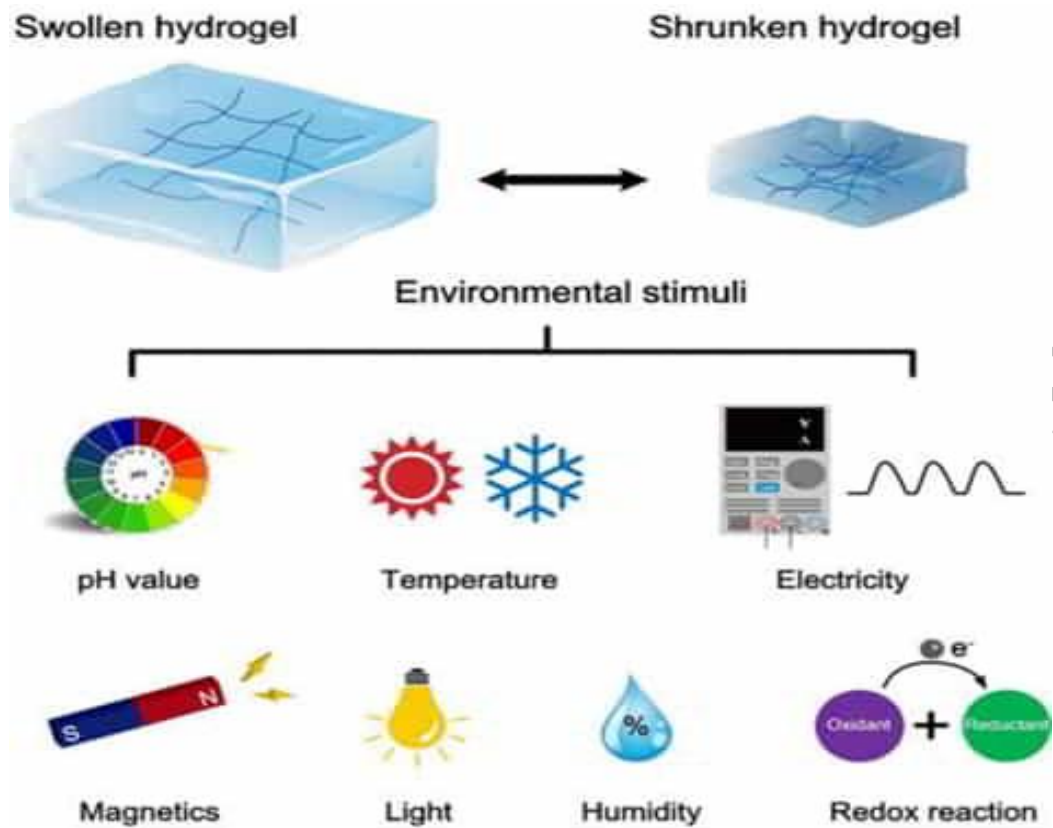


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