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Recent Developments in Space Suits Textiles Using Smart Materials

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Abstract

This paper aims to provide an introduction to smart materials, with an emphasis on the different types of smart materials including Piezoelectric Materials, Shape memory alloys, Electrostrictive Materials, Magnetostrictive Materials, Chromic Materials, Shape-changing materials and Magnetorheological Flu-ids and Electrorheological Fluids. applications of smart materials according to the different application areas. after that this paper considers the use of smart materials to produce smart textile and its applica-tions. In Technical Textiles, the space suit is considered one of the most important applications of smart textile. The purpose of a space suit is to keep a person alive and comfortable in the harsh environment of space. It is a complicated system of clothing, equipment, and environmental systems. the definition of space suit and focusing on their types and properties was mentioned in addition of the use of advanced fabrics in the manufacture of the space suit and the developments that occurred to it using modern and advanced technology.

Keyword: - smart materials, Smart textiles, space suit

Introduction

Numerous studies have been conducted over the last two hundred years to synthesize novel functional materials, which have been categorized into several families and groups. there are primarily four categories of materials: metals, polymers, ceramics, and newly developed materials [1]. Advanced materials are the most appealing because of all the ways they can be used in technology. [2-20]

Nature has offered a plethora of examples of smart materials, including the leaflets of the codariocalyx motorius, which rotate in response to sunlight, chameleons, which change color, sunflowers, which face the sun, and the leaves of the mimosa pudia, which suddenly decompose when touched. as a result of which academics' curiosity in smart materials has grown. [1]

The capacity of smart materials to alter their characteristics in response to environmental stimuli makes their use imperative in a variety of contexts. In addition to being characterized by their adaptability, healing capabilities, and environmental sensing capabilities, their reversibility makes them distinctive materials. Scent, size, wetness, flow viscosity, and color may all be affected by mechanical stress, pH, hydrostatic pressure, chemical action, temperature, electric current, magnetic field, or strain. therefore, the aforementioned parameters can be used to satisfy the application of smart materials like actuators, drug delivery, and sensors [21].

Materials with intelligence

Key concepts in smart materials

The term "smart material" has been used to describe a kind of technological material that can support any kind of novel product with exceptional properties. Clear definitions of "smart materials" are elusive. These materials are able to carry out a predetermined function in response to a single or several external chemical or physical stimuli. According to McCabe Zrinyi, "Materi-als that are able to be altered by stimuli and trans-form back into the original state after removing the stimuli" is the definition smart materials use. Factors such as humidi-

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ty, temperature, magnetic fields, stress, biomedical or chemical agents, electricity, and pH may all serve as stimuli. [22, 23]

Smart materials stand apart from the rest of the materials because of their unique properties, such as: [21]

- They are capable of existing in several states and responding to various inputs.
- They don't waste any time responding to the outside world.
- The materials may self-activate in response to environmental cues
- Accumulated in the same location are both acts and reactions.
- Their size, shape, and physical and mechanical qualities are all up for grabs.
- You can anticipate their reaction.

Smart material categorization

Based on how they behave, smart materials fall into one of two main categories: passive or active. [24, 25]

Passive smart materials

Unlike active smart materials, passive smart materials can only detect external stimuli or changes in their surroundings. they are able to transmit some kind of energy. One kind of material that may passively transmit electromagnetic waves is optical fiber.

Smart materials that are active

They fall into one of three categories:

a. substances whose properties are susceptible to alteration upon exposure to environmental influences. As far as active materials go, they are the pioneers. They are perceptive and reactive.

b. Superior smart materials: - Superior smart materials not only possess the same capacities as smart materials, but they can also adapt to their surroundings via learning and adjusting. When exposed to external stimuli, they are able to perceive, react, and adjust. in addition to the capability of transforming energy between many forms, including chemical, thermal, mechanical, electrical, optical, and nuclear.

c. Materials and structures that are capable of responding to stimuli or being triggered to carry out a task in a predetermined or manually controlled way constitute an advanced degree of intelligent smart materials.

The term "transducer" is often used to describe any kind of active substance. hence, they are capable of transforming energy into another form.

intelligent materials for a bunch of uses.

The fact that SMART materials react differently to various stimuli in the environment allows them to be classified into many classes. Different kinds of smart materials include piezoelectric materials, shape memory alloys, electrostrictive materials, magnetostrictive materials, chromic materials, shape altering materials, magnetorheological fluids, and electrorheological fluids.

Piezoelectric Materials

During the years 1880 to 1881, the Curie brothers—the first researchers to discover this intriguing phenomenon—discovered piezoelectricity. Piezoelectric materials are those that can undergo a two-way conversion, from mechanical to electrical energy. When subjected to mechanical stress, piezoelectric materials directly generate an electric charge that is directly proportionate to the stress. In contrast, piezoelectric materials undergo strain in response to an applied electric field; nevertheless, this strain is directly proportional to the field strength, as shown in Figure 1. Deliberate use of piezoelectric materials permits the execution of several technological operations. [1, 26]

In Figure 1, we can see the piezo-electric effect in action, with mechanical stress producing a charge (the direct effect on the left) and an electric field producing strain (the reverse effect on the right).

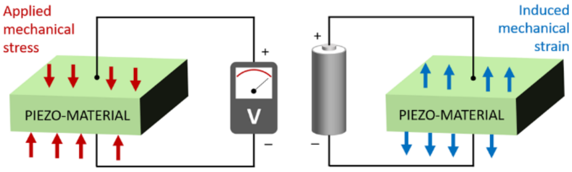

Figure 1: The piezo-electric effect: generation of charge due to mechanical stress (direct effect, left), and strain caused by the application of an electric field (converse effect, right)

Shape memory alloys

The capacity to deform and then return to their original shape in response to changes in temperature or stress is a property of shape memory alloys. Changing the temperature or applying stress may change the shape memory alloy from one of its two fundamental phases to the other. As seen in figure 2, two distinct phases, austenite and martensite, are theoretically possible. While austenite only occurs in one form, martensitic phase may take on several shapes. Their ability to remember their previous shape during the austenite phase allows them to regain that shape even after deformation. [27, 28]

Austenite and martensite on one-way and two-way memory effects are shown in Figure 2. *[29]*

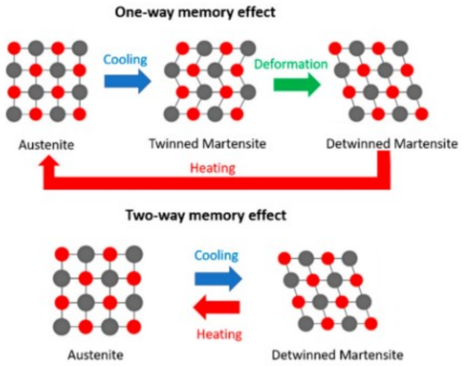

Figure 2: austenite and martensite on One-way and two-way memory effects *[29]*

Electrically Conductive Substances

Materials that change their size in reaction to an electric field are known as electrostrictive materials. The ions are drawn out of their original positions and the size is enlarged when an electric field is applied to electrostrictive materials. Any mechanical shift will be proportional to the square of the applied electric field. There are several similarities and differences between piezoelectric and electrostrictive materials. three, five. [21, 23]

Hypermagnetism in Materials

Magnetostriction is the process by which the size of ferromagnetic materials changes every time a magnetic structure expands or contracts in the direction of magnetization in response to an applied magnetic field. There are two types of magnetostrictive materials: negative and positive. The reaction of magnetostrictive materials to an applied magnetic field may be either a contraction or a stretching of the material. [30].

The positive MS material is shown schematically in Figure 3 within a magnetic field with different levels, where H4> H3> H2> H1. (a) There is no influence on the sample when H1=0. (b) Given an H2 magnetic field, the sample is somewhat extended. (c) Similarly, it is with a growing magnetic field, H3, that the growth is continuing. (d) As a last point, the sample length reaches its maximum value due to the fact that all magnetic domains take the same path. *[21]*

Chromic Materials

The term "smart material" refers to a category of materials that may respond to environmental stimuli by changing their color. The environmental circumstances cause them to be distinct. Color changeable materials are those that may undergo a reversible change in color when exposed to certain stimuli. They can go back to their original state after the stimulus has passed, which might be anything from changes in temperature or mechanical stress to changes in light, electricity, chemicals, etc. Certain physical conditions determine the reversibility of color change. Some kinds of chromic materials are included in the following table. [31].

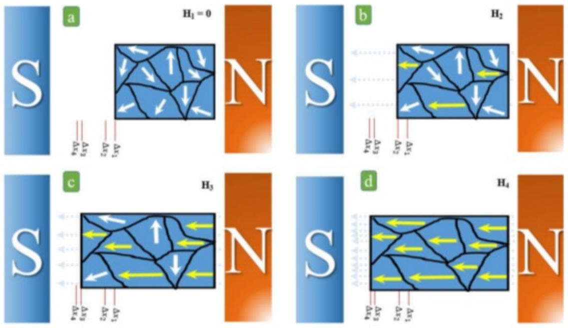

Figure 3: Schematic representation of a positive MS material that is put inside a magnetic field with different values, where H4> H3> H2> H1. (a) When H1=0, the sample get no effected. (b) For magnetic field of H2, the sample is elongated a little bit. (c) Likewise, the expansion continues with quantitatively increasing in magnetic field, H3. (d) Lastly the sample length gets to a maximum value, because all magnetic domains getting the same direction *[21]*

Table 1: types of chromic materials

Chromic group	**Stimuli type**
Thermochromic	Changing of temperature
Magnetochromic	Appling magnetic field
Electrochromic	Appling electric Field
Photochromic	Absorbing Electromagnetic light
Carsolchromic	Bombarding with electron beam
Solvatechromic	Contact with some liquid
Piezochromic	Mechanical Loading

Shape-changing materials

Smart materials are those that may alter their form in reaction to external stimuli, such as electric fields, heat, attractive fields, weight, or light, or even several external stimuli. A few things and materials may change form while retaining their dimensions exactly as they are. several other objects and substances that may have their dimensions altered without undergoing any changes to their physical form. [23, 32]

Fluids Utilizing Magnetorheology and Electrorheology

Smart materials include magnetorheological and electrorheological fluids. These fluids do not adhere to the Newtonian model. Iron particles in suspension may alter their thickness and viscosity when subjected to an external magnetic field in a magnetorheological fluid. The microparticles in these fluids are larger than the nanoparticles in ferrofluids, making Brownian motion less effective. Their sizes vary from 0.1 to 10 micrometers. The shear, valve, and squeeze-flow models are all applicable to magnetorheological fluids. Similarly, particles in electrorheological fluid are disorganized and suspended. When an electric field is applied, these suspended particles cling to one another, forming chains that run in the same direction as the field. In the same smart application systems, magnetorheological fluids and electrorheological fluids may be used. [33, 34]

Implementation of intelligent materials

Currently, smart materials are seen in most technological fields and play a significant role in modern society. The diverse responses of smart materials to environmental stimuli allow them to find usage in many different contexts. In our daily lives, we encounter smart materials in a variety of contexts, including civil engineering, robotic equipment, temperature-sensitive gadgets, the aerospace industry, medicine, the military, the arts, and textiles, among many others. [23]

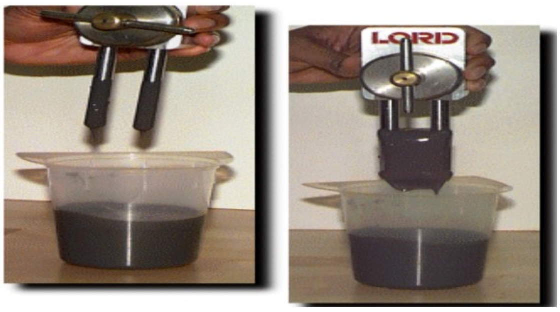

Figure 4: Magnetorheological Fluids

Smart textiles made from smart materials

Throughout human history, textiles have played a significant role. The usage of textiles has expanded throughout time. Originally, people only wore textiles for protection, but now, we encounter textiles of various types in almost every aspect of our lives, not to mention the garments we wear. The functional properties of textiles allow them to perform certain jobs. One promising new frontier for development and integration studies is the use of smart materials. Cutting-edge methods and innovative smart materials are revolutionizing the textile design industry, ushering in a new era of control and creativity with the introduction of ever-more-functional goods. thus, putting smart materials to use in the textile industry for the benefit of the future. referenced in [35, 36]

Textiles that have technology integrated into them may sense their surroundings, react to them, and even change to suit them, making them more helpful to the user. Any number of energies—thermal, mechanical, chemical, electrical, magnetic, or a mix of these—could be at work in response to the stimuli or circumstances. [37, 38]

Classification of SMART textiles

The following are examples of the three main types of SMART textiles: passive, active, and super smart [36, 39, 40]: -

Passive smart textiles

They are thought regarded as the pioneers of smart fabrics. Their particular functionality makes them perform better than standard fabrics. They can't react to their surroundings mechanically; instead, they rely on their structure. A really insulating coat, for example, would keep its insulating properties year-round.

Active smart textiles

As far as smart fabrics go, they represent the second iteration. Passive smart fabrics are outperformed by them. Because it has both a sensor and an actuator, it is able to detect and react to environmental stimuli. The smart fabric is able to perceive a variety of environmental stimuli, interpret and process these inputs in line with its surroundings, thanks to its actuators and sensors. The phrase "active smart textiles" describes clothing that can detect and respond to changes in their surrounding environment.

Ultra (very) smart textiles

They are thought of as smart fabrics from the third generation. Active smart tex-tiles are outperformed by them. Adapting their qualities to ambient circumstances, ultra-smart fabrics can perceive their surroundings and react accordingly. For instance, they may be able to detect the ambient temperature and, in response, either cool down or warm up. In addition to having shape-changing capabilities, ultra-smart fabrics may also store and control energy.

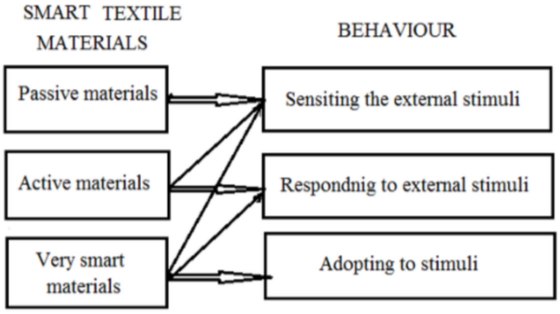

Figure 5: Classification of SMART textiles [41]

Smart textile applications

Many areas of study are finding more and more uses for smart textiles, such as miniaturized electronics, conductive materials, and wearable technologies that use wireless communication to enable humans and devices to communicate with one another. [42]

The world has had access to smart textile applications since their introduction in the late 80s. Smart fibers and smart textiles are becoming more popular among consumers. Smart fibers and textiles are finding use in a variety of industries at the moment, including those dealing with health care, biomedical textiles, protective apparel, the armed forces, athletics, and aerospace (including spacesuits and aircraft fabrics). Sensors embedded in these garments may measure a wide range of physiological parameters, including perspiration, temperature, heart rate, muscle tension, breathing rate, position, and more. While some smart fabrics only record data, others may sense their environment and adapt their properties to provide a more comfortable or bearable degree of functional performance for the user. paragraphs [43-46]

Spacesuit Utilizing SMART Textile Technology

The most well-known example of a smart textiles application is the space suit that astronauts wear. A space suit, of course, incorporates all the cutting-edge technology that smart textiles can muster. [45]

The spacesuit used by astronauts on spacewalks is much more than a simple set of clothes. In reality, a fully outfitted spacesuit is a spacecraft that can carry only one person. The official designation for the spacesuit used on the International Space Station and Space Shuttle is the Extravehicular Mobility Unit, or EMU. To be "extravehicular" is to be located outside of a spacecraft or vehicle. capability To be "mobile" is to have the freedom to move around while wearing the outfit. The astronaut is shielded from space's hazards by use of the spacesuit. The number

One of the most important pieces of clothing for an astronaut on a space shuttle mission is a space suit, which is specifically designed to keep the wearer alive in the very cold and hostile environment of space. Chemical, thermal, micrometeoric, pressure, and cold hazards are all mitigated by these. As an illustration of how the textile technology industry might be enhanced, consider the spacesuit [47]

Space suits' fabric components

Almost all materials used in space suits' protective garments are synthetic fabrics, such [46-50]

- **Spandex** is a fabric that can return to its original form and has special elastic qualities. This is a polymer with a lengthy chain. A long, amorphous strand with a random molecular structure and a short, rigid strand make up its two halves. Softness is imparted to the fibers by means of this combination of strands. When applied force causes the amorphous strand to expand, it breaks the rigid connections and returns to its relaxed form unaffected by the force.
- **Polyurethane-coated nylon**:This kind of nylon is composed of a nylon fabric that has been covered with a coating of polyurethane to make it water resistant. Furthermore, it reinforces the fabric and, most importantly, seals it to prevent gas leakage.
- **Mylar:** The polyester film fabric known as Mylar is made from molten poly-ethylene terephthalate (PET). The suit is able to retain body heat because to its high insulating properties and great tensile strength.
- **Kevlar fibers:** In terms of strength per unit weight, Kevlar fibers outperform steel by a factor of five. They have excellent resistance to abrasion and heat, are malleable, and provide good fabric safety even at high temperatures. Because of the benzene rings that build it up, it has excellent thermal stability and is very flame resistant. Bulletproof vests employ the same materials as the finished product.
- **Teflon:** Polytetrafluoroethylene (PTFE) is a coating or impregnated substance that may be applied to fiberglass fibers, resulting in Teflon. It is a fluoropolymer with excellent performance. It is very resistant to water because of its large molecular weight. The mechanical properties of chemical resistance in a fluoropolymer/woven fabric combination were best shown by Teflon/fiberglass materials.
- **Nomex** is a long-chain polyamide that shares flame resistance with Kevlar but is softer and more textile-like in texture. A fire-resistance feature is provided by it.
- **Dacron:** The pressure-restraining layer is made of Dacron, a kind of polyester.
- **Gortex**: owns the fabric membrane Gortex, which is both waterproof and breathable. Gore & Associates, L. C. Designed in 1969, Gore-Tex is a lightweight waterproof fabric that can be worn in any weather. It is impermeable to liquid water yet permeable to water vapor.

theoretical methods, space suit designs

Theoretically, there are four primary ways to construct spacesuits [49, 50]

Flowy garments

Soft suits are usually made from fabrics. Some soft suits even include hard joint bearings, and all of them have hard components. When it came to moving about inside vehicles and even doing some early EVM, soft suits were the way to go.

Protective clothing

Metal or composite materials are common components of hard-shell suits. Fabric is not used for their joints.

Combo outfits

Hybrid suits combine hard-shell and textile materials. When it comes to flexibility, the experimental AX-5 Hybrid shell space suit produced by NASA Ames Research Center earned a whopping 95%. The extra-vehicular mobility unit uses a fibre glass hard upper torso and fabric limbs, in contrast to the early space suits that were made entirely of soft fabrics. To provide support, comfort, and mobility, new extravehicular mobility systems integrate hard and soft components.

Slinky outfits

Skintight suits, sometimes called mechanical counter pressure suits or space activity suits, are suggested garments that bind the body with thick elastic stockings.

Spacesuit Components.

Multiple components make up the Space Suit. [47, 51]

- **The Hard Upper Torso** is constructed from the lightweight yet durable material fibreglass. The other components of the space suit, including as the control module, arms, helmet, and life-support bag, may be securely attached to this. The astronaut wears this section of the spacesuit over their torso, even though it lacks sleeves.
- **Arms:** The upper arm and elbow joints are supported by the arm unit, which is attached to the hard upper torso. The astronaut is able to move his arms freely in all directions because to the arm unit's bearings in the shoulder, upper arm, and elbow joints. Since the arm modules are available in a range of sizes, they may be customized to accommodate various astronauts. Covering the arms, the arm assembly is fastened to the gloves.
- **Gloves**: they facilitate the movement of the wrist bearings. Attaching them to the arms is a breeze with the included quick-connect rings. Gloves provide a secure hold with their rubberized fingertips. As an added layer of comfort, astronauts wear fine-fabric gloves inside their regular gloves.
- **Helmet:** The helmet is crafted from transparent, impact-resistant polycarbonate. The Hard Upper Torso is fastened to it using a quick-connect ring. For your comfort, the helmet has padding on the rear. Oxygen is supplied to the astronaut's head, neck, and face via a system that runs through the astronaut's helmet. To remove carbon dioxide, a purge valve is provided. An anti-fog substance is applied to the helmet prior to the space walk. The Extravehicular Visor Assembly and helmet provide the astronaut with enough protection for their head while also maximizing their field of view. The shape of the spheroidal dome allows for a wide field of view, pressure control, and a lightweight construction.
- **The Lower Torso**: This assembly safeguards the legs and feet of the astronaut. A person's lower torso, including their lower waist, knees, ankles, boots, and pants, is one cohesive unit. The suit's multi-layered, flexible components are designed to perform several functions. A metal connect ring makes it easy to fit. The Hard Upper Torso is linked to it. To keep the tools from floating aimlessly, the Lower Torso features loops that attach them.
- **Life support system:** A backpack attached to the Hard Upper Torso serves as a life support system. In order to maximize mobility on space walks and provide each astronaut control over their own internal environment, the life support system is connected to each individual astronaut. The equipment consists of a regulator that keeps the pressure within the suit at a constant level, a fan that distributes the oxygen, and oxygen regulators that remove any carbon dioxide that the astronaut may have breathed in. It also prevents the astronaut's respiration from making the helmet fog up. The backpack comes with everything you need to cool down, including water, a water chiller, and a pump to move the water.

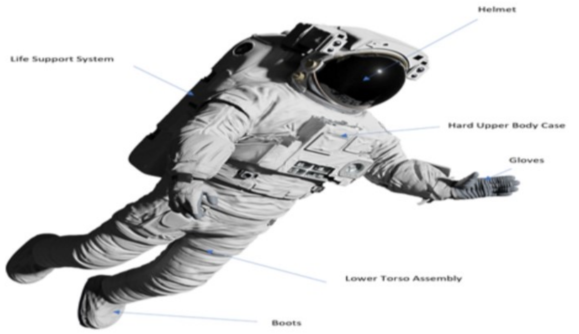

Figure 6: Spacesuit Components

Basic Requirements of space suit

Space suits must meet a number of criteria in order to be considered suitable for use in space. These include the following: the ability to provide oxygen while simultaneously eliminating carbon dioxide; the ability to keep the wearer's temperature comfortable regardless of their level of physical exertion or movement; the presence of a pressurized atmosphere to provide a stable internal pressure; the ability to shield the wearer from solar radiation; the ability to see clearly; the suit's low flammability; the suit's mobility for task execution; the suit's ability to offer protection from micrometeoroids; and finally, the suit's resistance to harmful radiations and micrometeoroids. [46]

A spacesuit might have anything from three to fourteen separate pieces and layers. Ensuring the astronauts' survival in space is the responsibility of each stratum. Built from specialized synthetic materials, each one has a unique purpose in creating an oxygen-rich atmosphere that is both comfortable and functional. Astronauts must survive outside of Earth's protective atmosphere, which requires a great deal of chemistry. References. [50]

As an alternative to having each astronaut's suit tailored to their unique measurements, today's spacesuits are modular and assembled as a kit. [50]

Before donning their spacesuit, astronauts put on a Liquid Cooling and Ventilation Garment, which consists of two layers. This is a pair of "long underwear" constructed from Spandex and Nylon Tricot. The astronaut's core temperature, excess body heat, and moisture levels may be managed with the use of this snug garment's interwoven tubes. [47]

The space suit is the next item on an astronaut's gear list, after a liquid cooling and ventilation garment. Every one of its many levels serves a distinct function. for example, the Max-imum Absorption Garment, which aids in the collection and storage of bodily wastes during spacewalks; the pressure garment, which is a part of the space suit and helps to keep fluids in the body; and the inside bladder, which is filled with gas and made of polyurethane-coated nylon, which allows the astronaut to breathe.

In order to eliminate carbon dioxide, space suits make use of lithium hydroxide canisters. Another layer, the constraint layer, keeps the bladder layer in place and molds it to the perfect form of the astronaut's body. The material utilized to make this layer is polyester. To avoid thermal micrometeoroid garment temperature variations, most space suits contain many layers of well insulated fabric.

Integrated Thermal Micrometeoroid Garments, which are meant to withstand micrometeoroids. Insulation is provided by many layers of a substance called Mylar. Its primary function is to shield the astronaut from harmful solar radiation while also insulating the suit's occupant and preventing heat loss. The space suit also has a ripstop layer. This layer prevents micrometeoroids from crashing into the astronaut. The ripstop layer safeguards the suit and ensures its structural integrity with its exceptional tear resistance. Ripstop is made of Dacron or Kevlar or other strong textiles layered many times. White outer layers manufactured utilizing three separate threads, each with its own purpose, cover the suit and reflect sunlight. Astronaut gloves have a similar design since they, too, must protect hands from cold, but provide movement of the joints and the ability to grip in order to operate and lift objects. The space suit comes with an in-suit beverage bag as well. A 32-ounce (1.9-liter) water bladder may be accommodated by inserting a short tube close to the astronaut's mouth into a plastic bag that is housed within the Hard Upper Torso. [47, 49]

The typical soft-good architecture of a space suit includes a pressure enclosure, a liquid cooling and ventilation garment, and a thermal meteoroid garment.

An ortho-fabric (rip stop woven fabric) constructed of 14 oz Nomex/Teflon/Kevlar used as the Thermal Micrometeoroid Garment for the ISSEMU's outer shell layer. In addition to providing the thermally controlled space suit with the essential optical properties, this was done to provide adequate protection against rips, micrometeoroid damage, and abrasion. For thermal insulation, underlay the Ortho fabric with many layers of aluminized polyester film or Mylar, connected polyester scrim.

The Thermal Micrometeoroid Garment was further protected from micrometeoroids by a layer of rip-stop nylon covered with neoprene. A Dacron restraint fabric and a nylon bladder covered with polyurethane currently make up the Ex-travehicular Mobility Unit's pressure enclosure. The LCVG makes use of ethyl vinyl acetate cooling tubes, a nylon tricot comfort layer, and stretch nylon knit fabric. [50]

An astronaut may communicate without using their hands thanks to the communication carrier assembly (CCA), a cap equipped with microphones and headphones. This skull hat is crafted from materials such as nylon/lycra and Teflon. Modern space suit helmet coverings have lights added so astronauts can see in the dark. The suits go to such lengths as to incorporate visors, which protect the astronauts' eyes from the sun's glare. [47, 49]

Attached to the rear of the garment is a SAFER device, which stands for Simplified Aid for Ex-travehicular Activity Rescue. Several small thruster jets are housed in the SAFER. In the event of disconnection, an astronaut may use SAFER to make it back to the space station.

Superior SMART material properties

A space suit's primary framework looks like this. However, as material science and sophisticated textile technologies continue to evolve, the need to discover innovative alternatives to existing composites that outperform them has grown. Some of the characteristics of these alternatives to metals include being easy to work with, gentle on the touch, lighter, more malleable in terms of size and form, and as strong as metals. In particular, smart fabric technologies are fascinating for potential use in NASA's human spaceflight missions to low Earth orbit and beyond. Numerous prospective uses have the possibility to lessen the power, weight, volume, and safety requirements of current support gear while simultaneously increasing staff productivity, efficiency, and dependability. [52]

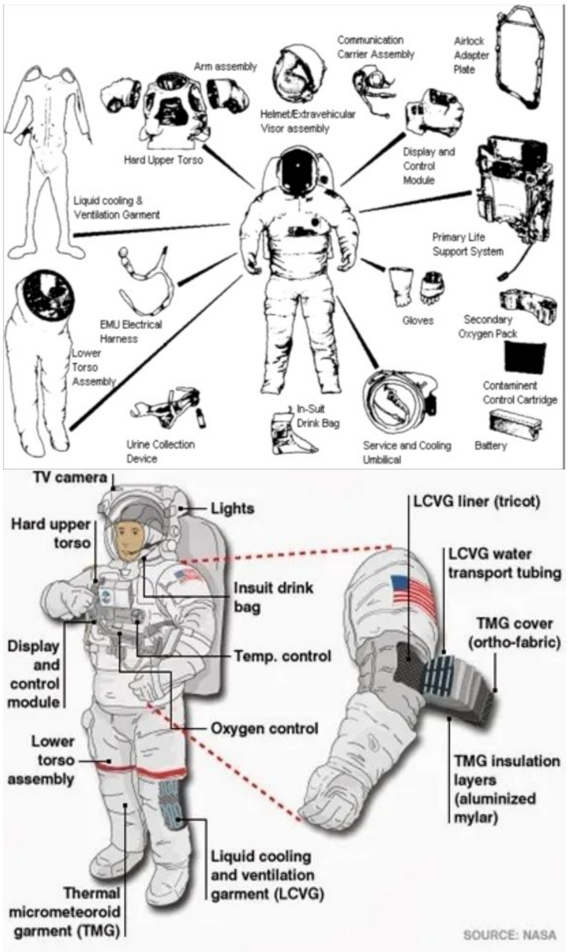

Figure 7: space suite composition [54]

New research out of MIT is targeting the creation of warning systems that might be sewn into spacesuit fibers or integrated into the outside of spacecraft. By inserting sensor fibers into conventional spacesuit materials, these devices might detect hits from space debris and provide an early warning. Piezoelectric fibers, developed by a group at MIT, may be sewn into common textiles to act as sensors. These fibers provide an electrical signal in response to mechanical stress, including bending or orbital debris collisions. Beta cloth, a fabric made of fibreglass and Teflon, was used to construct the first spacesuits and inflatable homes. The group intends to incorporate its piezoelectric fibers into this fabric. The piezoelectric fibers developed by the MIT researchers may one day allow for the early detection of debris impacts on spacecraft and satellite structures, as well as crew members. Spacesuits or structural spacecraft and satellites might have networks of these fiber sensors embedded into them to provide hazard alarms based on the frequency and count of debris hits. [53]

Current EVA suit cooling and pressure controls are located on the astronaut's chest. The mechanical sliders and pushbuttons need to be sufficiently large to accommodate an astronaut's gloved hand. Traditional wiring might be replaced by conductive tiles, and smart textiles could make it easy to insert controls into any part of the EVA outer garment. This may reduce the EMU's weight and make the controls easier to reach[41]. In 2005, the Extravehicular Mobility Unit conducted research with the help of NASA, the University of Maryland, and ILC Dover on several innovative robotic interfaces for use by astronauts. The crew pressure suits used by the International Space Station and the Space Shuttle are made by ILC Dover. Among the technologies being evaluated was a pressure-sensitive fabric control pad that was first attached to the suit's lower arm and then moved to the wrist. [55]

Covering the surface of the EMU or EVA suit with flexible solar cells would create additional power, which might assist reduce the size of the batteries, umbilical hookups, and fuel cells now needed to run the suit. If the piezoelectric devices were strategically placed in the suit fabric, more power may be harvested from the EVAer's motions. [52]

Integrating biosensors into the cooling undergarment of the Extravehicular activity suit would allow for more extensive physiological monitoring of crew members during rigorous EVAs. Researchers in the field of smart textiles have put in a lot of time and effort into initiatives like the Long-Term Medical Survey and Intelligent Sock to develop continuous, accurate, and comfortable ways to integrate physiological sensors into garments.

Multiple iterations of the Long Term Medical Survey have been developed and tested. While worn comfortably for up to 24 hours, this device can record respiration, blood pressure, electrocardiogram, core body temperature, pulse oximetry, activity/posture, and core body temperature.

A variety of training tools and astronaut workout routines may have their efficacy monitored by the Intelligent Sock Project System. Developed as part of the Smart Fabrics and Intelligent Textiles project by the European Commission, this sock will monitor the metabolic and electrical activity in the muscles of the astronauts' legs during exercise. [52]

A new spacesuit called the Exploration Extravehicular Mobility Unit (xEMU) has been developed by NASA. Protecting people from the dangerous space environment is the primary objective of the Exploration Extravehicular Mobility Unit. It makes more use of state-of-the-art technology than the current Extravehicular Mobility Unit. The xEMU is the name of the next-generation spacesuit that will be used by a number of space programs. In the xEMU, the Environmental Protection Garment serves as the exterior. An astronaut's Environmental Protection Garment is their primary safety measure while on a spacewalk. The xEMU's exterior layer dust protection system has to be in place and able to withstand abrasion, penetration, and dust adhesion. One possible solution is to use a very pliable fabric that has a durable covering. A metalized-film insulating fabric may be the best option, according to the development of the Explora-tion Extravehicular Mobility Unit PGS vehicle. Protecting the astronaut from potentially dangerous surface conditions and oxygen-rich environments is the main goal of the Environmental Protection Garment.

Considering that scientists are always looking for new materials to include into future space suits, it's possible that a redesign of the present space suit is imminent. Mechanical counter-pressure space suits may improve the movement of astro-nauts when they are exploring planets. Mechanical counter-pressure suits function differently from traditional gas-pressurized space suits. Instead of pressurized gas, the wearer is provided with surface pressure via snug-fitting textiles.

Mechanical counter-pressure suits are designed to be much more maneuverable and conformal, similar to a wetsuit, rather than an inflexible balloon. This not only reduces the overall bulk of the suit but also greatly reduces the likelihood of catastrophic failures caused by punctures or depressurization. Consequently, me-chanical counter-pressure suits could be a promising new technology for use in next exploratory missions.

Wearing and removing a mechanical counter-pressure suit remains a formidable challenge because to the non-existence of the foundational technologies required to produce uniform compression inside a garment at pressures appropriate for interplanetary flight. For each of these problems, active materials technology seems to be the best bet. Materials that are able to change their form in response to external stimuli include shape memory metals and shape memory polymers. Using active material technologies (up to 30 kPa), this study aims to develop a one-of-a-kind garment with compression capabilities that can be adjusted. By incorporating these technologies into garments, we may design smart fabrics with the ability to dynamically alter their compression characteristics. With these technologies, mechanical counter-pressure suits would have a much better chance of becoming operationally practical. [50, 56, 57]

A sensate skin concept prototype for the outside of an extravehicular exercise suit is developed using electrical fabric sensors that are easily accessible. Then, it is shown that this prototype can differentiate between crucial surfaces for space explorers, such as metal objects, rocky surfaces, and spacesuit gloves. This suggests that various surfaces may be translated into diverse sensory perceptions. More specifically, haptic actuators attached to the astronaut's biological skin may allow them to receive touch input directly via the pressurized suit, bypassing the need for external sensors. An external wristband was equipped with commercially available fabric sensors to fabricate a representational prototype of this skin. It is a depiction of suits used for exploratory and extravehicular activities. The suit's exterior skin layer incorporates sensors such as capacitive proximity detection, piezoresistive pressure detection, and piezoelectric vibration detection. [58]

Gloves made of Chrome-R, a metal fabric, were utilized in suits such as the Apollo A7L to prevent punctures as the frequency of extravehicular activities increased. The silicon finger tips of the gloves were engineered to provide the astronauts a heightened feeling of touch, enhancing their sense of touch while they were in space. Astronauts need gloves that are robust, comfortable, and lightweight for use in environments similar to space. There are a lot of good, old designs that are still in use today. Astronaut gloves may need to be more durable in the future. This glove can cure most problems, depending on the space environment's specifications and the astronaut's operating circumstances. A space glove must be strong and has attributes such as manipulation, tactility, and dexterity. Its primary function is to facilitate control, movement, and object handling by giving astro-nauts the best possible use of their fingers. [50, 59]

Summary

Academics are paying more attention to a handful of smart materials because to their usage in delicate sectors, but all of them are important. New smart applications for textiles have emerged with the advancement of smart textile technology in the last few years. As time goes on, wearable smart textiles becoming smarter and more practical, enhancing the functionality of geo-space textiles, everyday clothes, and professional attire alike. Putting together a space suit is no easy feat. When an astronaut is wearing a space suit, their normal range of motion is unrestricted. The space suit contains a focus on protection for space mis-sions. The space suit provides complete coverage for an astronaut's basic safety needs, including protection from sunlight, micrometeoroids, and solar radiation. besides the standard amenities like climate control, oxygen supply, CO2 removal, and pressurized housing. A complete overhaul of the present space suit could not be far off, as scientists are always seeking for new materials to construct the futuristic, high-tech suits of the future.

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References.

1. Ghareeb, N. and Farhat, M. Smart materials and structures: State of the art and applications, *Nano Res. Appl*, **4** 1-5 (2018).
2. Callister, W.D. Materials science and engineering an introduction, (2007).
3. Hassabo, A.G., Elmorsy, H., Gamal, N., Sediek, A., Saad, F., Hegazy, B.M. and Othman, H. Applications of nanotechnology in the creation of smart sportswear for enhanced sports performance: Efficiency and comfort, *J. Text. Color. Polym. Sci.*, **20**(1) 11-28 (2023).
4. Ali, M.A., Hassabo, A.G., Seddik, K.M., yahia, s. and Mohamed, N. Characterization of the thermal and physico-mechanical properties of cotton and polyester yarns treated with phase change materials composites, *Egy. J. Chem.*, - (2022).
5. Hassabo, A.G., Zayed, M., Bakr, M. and Othman, H.A. Chromic dyes for smart textile: A review, *Letters in Applied NanoBioScience*, **12**(4) LIANBS124.161 (2023).
6. Mohamed, A.L., Khattab, T.A. and Hassabo, A.G. Color-tunable encapsulated perylene-labeled silica fluorescent hybrid nanoparticles, *Results in Chemistry*, **5** 100769 (2023).
7. Zaied, M., Abd El-Aziz, E., Ghazal, H., Othman, H. and Hassabo, A.G. Construction of intelligent bio-pcm matrix for cotton fabrics to improve thermal comfortability and human protection, *Egy. J. Chem.*, **67**(13) 109-119 (2024).
8. Hassabo, A.G. and Mohamed, A.L. Enhancement of thermo-regulating textile materials using phase change material (pcm), *Evolution in Polymer Technology Journal*, **2**(1) 180009 (1-11) (2019).
9. Hassabo, A.G. and Mohamed, A.L. Enhancement the thermo-regulating property of cellulosic fabric using encapsulated paraffins in modified pectin, *Carbohydrate Polymers*, **165** 421-428 (2017).
10. Saada, M.A., Abdelkareem, S.T., Elemam, Y.A., Subaih, R.A., Elhefnawy, H.I. and Hassabo, A.G. Evolution and importance of materials in industrial design, *J. Text. Color. Polym. Sci.*, - (2024).
11. Hassabo, A.G., Eid, M.M., Mahmoud, E.R. and Asser, N.A.H., A. Innovation of smart knitted fabrics for functional performance of sportswear upon treatment using phase change material, *Egy. J. Chem.*, **66**(3) -133-156 (2023).
12. Hassabo, A.G., Hegazy, B.M., Elmorsy, H.M., Gamal, N., Sedik, A., Saad, F. and Othman, H.A. Intelligent smart textiles: Wearable textile devices for solar cells, *Journal of Art, Design and Music*, **3**(2) Article 10 (2024).
13. Hassabo, A.G., Saad, F., Hegazy, B.M., Elmorsy, H., Gamal, N., Sedik, A. and Othman, H. Intelligent wound dressing textile fabric using various smart materials, *Materials International*, **5**(1) 1-23 (2023).
14. Al-Minyawi, O.M.A., Mahmoud, M.N.I., Ragab, A.G., Al-Gizawy, A.S.H. and Hassabo, A.G. Smart technology and materials in the clothing industry, *J. Text. Color. Polym. Sci.*, - (2024).
15. Mohamed, M., Abd El-AAty, M., Moawaed, S., Hashad, A., Abdel-Aziz, E., Othman, H. and Hassabo, A.G. Smart textiles via photochromic and thermochromic colorant, *J. Text. Color. Polym. Sci.*, **19**(2) 235-243 (2022).
16. Hassabo, A.G., Gamal, N., Sediek, A., Saad, F., Hegazy, B.M., Elmorsy, H. and Othman, H. Smart wearable fabric using electronic textiles – a review, *J. Text. Color. Polym. Sci.*, **20**(1) 29-39 (2023).
17. Khaled, M., Ahmed, M., Maamoun, D., Abdelrahman, M.S., Gaffer, H., Hassabo, A.G. and Khattab, T.A. Sustainable cationization for dyeing cotton fabric using natural substrates, *J. Text. Color. Polym. Sci.*, **21**(1) 187-191 (2024).
18. Hassan, S.S., Elgohary, R.M., Eldesoky, A.R., Metwaly, H.A. and Hassabo, A.G. The effect of using smart materials to improve the efficiency of industrial products, *J. Text. Color. Polym. Sci.*, - (2024).
19. Ghoneim, E.H.s., Zein El dein, E.A., Ali, S.M. and Hassabo, A.G. The impact of technology on jewellery design and manufacturing: Exploring traditional and modern techniques, *J. Text. Color. Polym. Sci.*, - (2024).

20. Fiad, N.S., Muhammad, R.R., Muhammad, K., Farghaly, S.T., Alaswad, M.H. and Hassabo, A.G. Transforming fashion: The influence of technology, smart clothing, and historical costumes, *J. Text. Color. Polym. Sci.*, **21**(2) 467-476 (2024).

21. QADER, İ.N., Mediha, K., DAGDELEN, F. and AYDOĞDU, Y. A review of smart materials: Researches and applications, *El-Cezeri*, **6**(3) 755-788 (2019).

22. Bhatnagar, A., Wagh, S., Singh, B., Agarwal, R. and Khan, F. Smart materials–a review, *Annals of Dental Specialty*, **4**(1) 10 (2016).

23. Sharma, P.K. and Singh, T. Smart materials: A review of capabilities and applications, *Inter. J. Sci. Eng. Res.*, **10**(5) (2019).

24. Laws, J. and Parachuru, R. New and emerging smart materials and their applications: A review, *Journal of Material Sciences & Engineering*, **10:**(9) 2-6 (2021).

25. Kamila, S. Introduction, classification and applications of smart materials: An overview, *American Journal of Applied Sciences*, **10**(8) 876 (2013).

26. Holterman, J. and Groen, W.A. An introduction to piezoelectric materials and components, Stichting Apllied Piezo, (2012).

27. Savi, M.A., Paiva, A., Araujo, C.J.d. and Paula, A.S.d. Shape memory alloys, Dynamics of smart systems and structures, Springerpp. 155-188, (2016).

28. Naresh, C., Bose, P. and Rao, C. Shape memory alloys: A state of art review, IOP Conference Series: Materials Science and Engineering, IOP Publishing, p. 012054 (2016).

29. Stachiv, I., Alarcon, E. and Lamac, M. Shape memory alloys and polymers for mems/nems applications: Review on recent findings and challenges in design, preparation, and characterization, *Metals*, **11**(3) 415 (2021).

30. Hristoforou, E. and Ktena, A. Magnetostriction and magnetostrictive materials for sensing applications, *Journal of Magnetism Magnetic Materials*, **316**(2) 372-378 (2007).

31. Vik, M. and Periyasamy, A.P. Chromic materials: Fundamentals, measurements, and applications, CRC Press, (2018).

32. Bogue, R. Smart materials: A review of recent developments, *Assembly Automation*, (2012).

33. Madeja, J., Kesy, Z. and Kesy, A. Application of electrorheological fluid in a hydrodynamic clutch, *Smart materials and structures*, **20**(10) 105005 (2011).

34. Mazlan, B. and Amri, S. The behaviour of magnetorheological fluids in squeeze mode, Dublin City University, (2008).

35. Jul, L. Adding values–smart textile options for automotive applications, *The Nordic Textile Journal*, **1** (2008).

36. Chika, Y.-B. and Adekunle, S.A. Smart fabrics-wearable technology, *International Journal of Engineering Technologies and Management Research*, **4**(10) 78-98 (2017).

37. Vagott, J. and Parachuru, R. An overview of recent developments in the field of wearable smart textiles, *Journal of Textile Science & Engineering*, **8** 364 (2018).

38. Koncar, V. Smart textiles and their applications-visual perceptions, Proceedings of 9th International Symposium on Graphic Engineering and Design, (2018).

39. Ashour, A.F. and Rashdan, W. Design and smart textile materials, *WIT Transactions on Engineering Sciences*, **133** 145-151 (2021).

40. Syduzzaman, M., Patwary, S.U., Farhana, K. and Ahmed, S. Smart textiles and nano-technology: A general overview, *Textile Science & Engineering*, **5**(1) (2015).

41. Rotari, E. and Negara, C. Possibilities and applications of smart textiles, MATEC Web of Conferences, EDP Sciences, p. 04025 (2017).

42. Ferraro, V. Smart textiles and wearable technologies for sportswear: A design approach, *Sensors and Applications*, (2015).

43. Das, S.C. and Chowdhury, N. Smart textiles—new possibilities in textile engineering, *Journal of Polymer Textile Engineering*, **1**(1) 1-4 (2014).

44. Dang, T. and Zhao, M. The application of smart fibers and smart textiles, Journal of Physics: Conference Series, IOP Publishing, p. 012084 (2021).

45. Deng, H.-Y. and Cui, Y.-M. The application of smart textiles in the brand fashion design, MATEC Web of Conferences, EDP Sciences, p. 04022 (2016).

46. Kiron, M.I. Aerospace textiles: Raw materials and applications, (2021).

47. Kiron, M.I. Requirements, raw materials and components for space suit manufacturing, (2021).

48. Sinha, T.K. and Malik, T. Space suit - an ultimate protection *technical textile* 11 (2018).

49. Kiron, M.I. Protective clothing for space shuttle traveler, https://textilelearner.net/protective-clothing-for-space-shuttle/, (2014).

50. Tarafder, N. Materials, methods and techniques in textiles for the development of space suits, *Advancements in Material Engineering*, **4**(1) 12-21 (2019).

51. Uddin, F. Textiles in aerospace applications, PTJ, (2008).

52. Simon, C., Potter, E., McCabe, M. and Baggerman, C. Smart fabrics technology development, (2010).

53. O'Neill, P. Mit to use the iss to test smart, electronic textiles for use in spacesuits and spacecraft, (2020).

54. Dover, I.L.C. Space suit evolution: From custom tailored to off-the-rack, (1994).

55. Graziosi, D., Ferl, J., Splawn, K., Akin, D., Tie, E., Kosmo, J. and Ross, A. Human and robotic enabling performance system development and testing, *SAE transactions*, 392-402 (2005).

56. Holschuh, B., Obropta, E., Buechley, L. and Newman, D. Materials and textile architecture analyses for mechanical counter-pressure space suits using active materials, AIAA Space 2012 Conference & Exposition, p. 5206 (2012).

57. Anderson, A.P. Addressing design challenges in mechanical counterpressure spacesuit design and space-inspired informal education policy, (2011).

58. Payra, S., Wicaksono, I., Cherston, J., Honnet, C., Sumini, V. and Paradiso, J.A. Feeling through spacesuits: Application of space-resilient e-textiles to enable haptic feedback on pressurized extravehicular suits, IEEE, pp. 1-12 (2021).

59. Rawal, S., Madhubalan, A., Manikandan, P. and Kanna, J. Study on the design of space gloves and eva suits with future challenges, *Textile & Leather Review*, **5** 18-30 (2022).

التطورات الحديثة في ملابس الفضاء بالمنسوجات التي تستخدم مواد ذكية

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المستخلص .

تهدف ورقته البحثية إلى تقديم مقدمة للمواد الذكية، مع التركيز على الأنواع المختلفة من المواد الذكية بما في ذلك المواد الكهرضغطية، وسبائك ذاكرة الشكل، والمواد المقيدة كهربيًا، والمواد المقيدة مغناطيسيًا، والمواد الكرومية، والمواد المتغيرة الشكل، والسوائل المغنطيسية والسوائل الكهربية. . تطبيقات المواد الذكية حسب مجالات التطبيق المختلفة. بعد ذلك تتناول هذه الورقة استخدام المواد الذكية لإنتاج المنسوجات الذكية وتطبيقاتها. وفي المنسوجات التقنية، تعتبر بدلة الفضاء واحدة من أهم تطبيقات المنسوجات الذكية. الغرض من بدلة الفضاء هو إبقاء الشخص على قيد الحياة ومريحًا في بيئة الفضاء القاسية. إنه نظام معقد من الملابس والمعدات والأنظمة البيئية. وتم ذكر التعريف ببدلة الفضاء والتركيز على أنواعها وخصائصها بالإضافة إلى استخدام الأقمشة المتطورة في صناعة بدلة الفضاء والتطورات التي طرأت عليها باستخدام التكنولوجيا الحديثة والمتقدمة.

الكلمات المفتاحية: المواد الذكية، المنسوجات الذكية، بدلة الفضاء