

FUNCTIONAL TEXTILES AND APPARELS

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Among the diverse field of application of Technical Textiles, which is poised for tremendous growth in fast developing economies like that of India and China, non implantable healthcare and hygiene products are gaining significant importance because of specificity of their end uses. Protective textiles offer protection from hazardous chemicals, heat, extreme cold, radiation and have special application potential in today's technologically advanced world. In addition to this, advent of nano-technology has opened innumerable avenues giving rise to high performance textiles and apparels. This paper discusses overall status of this field and its scope for growth in near future.

Key words: Apparels, Medical textile, Nano-technology, Surgical textile, Technical Textile.

INTRODUCTION

The demography of India has been totally shifted towards young population and the purchasing potential of this young population has been increasing. For this reason most of the developing countries are looking at India as a global market. India and China constitute over 40% population of the globe and application of technical textiles in this region will increase with a very high rate. The developed countries are much ahead of India with respect to manufacture and consumption of Technical Textile. They are now finding a great potential to exploit the Asian market and hence, as per the industrial analysis, the field of technical textile is considered to be quite promising for the growth. Hence, those involved in textile business dealing with apparels and also thinking of diversification or adding new line to their business should look at this segment of Technical Textile with a great promise. The experience and the background of production as well as supply of conventional textiles as a whole will enable them to triumph in the segment of Technical Textile. It does not however mean

that the new comers in this business cannot succeed. Technical Textile field incorporates a number of segments as shown in Table - 1.

The market size of the technical textile reported in the year 2003-04 was Rs. 201286 million which is expected to be increasing almost by 100% making it to Rs. 420060 million. Among the various segments, the present conference

is focusing on Functional Textiles and Apparels having added values and specific end uses. From that point of view, Medtech and Protech, the two main branches of the Technical Textile segments are being covered in this paper. In addition to this, the field of Functional Textiles based on application of nano-technology has been also included in this paper. As far as developed countries such as US and Japan are concerned,

Table - 1: Market Size of Technical Textiles in India in Value Terms¹

Sr. No.	Technical Textile Sector	Market Size and Potential (Rs. Mn.)		
		2003-04	2007-08	Rank
1.	Clothtech	68332	84158	1
2.	Packtech	46020	73593	2
3.	Indutech	22120	29939	5
4.	Sporttech	15342	20495	7
5.	Medtech	15250	23390	6
6.	Mobiltech	13230	20463	8
7.	Hometech	10297	18977	9
8.	Agrotech	3036	4647	12
9.	Protech	2845	6385	10
10.	Buildtech	2816	4783	11
11.	Oekotech	2000	67320	3
12.	Geotech	-	65910	4
	Total	201286	420060	

more than 35% of the textile industrial production is in terms of Technical Textile. For China it is over 19% and in India it is just 5% and thus there is a very high growth prospect in Asia creating entirely a new market².

Table - 2 gives the forecast of the World Technical Textile consumption upto 2010. Within each of these areas of Technical Textile, newer and newer varieties of products are being developed and innovations remain the key factor of growth in the field of technical textile. Considering the fast growing (8%) economy of India and the significant size of over 1 billion population, the presence of raw material, and well trained manpower, the technical textile field is surely going to develop at a significant rate and so also its various segments such as Medical and Health Care Textiles, Functional Textiles, Protective Textiles, etc.

MEDICAL TEXTILES

The application of textile in the medical field requires a number of properties for the fibre, depending upon where exactly this material is used. The important aspects include non toxic nature of the material, ability to sterilize and to conform to the requirements of the mechanical properties as well as the bio-compatibility^{3,4} etc. All these above mentioned properties are justifiable since the material is expected to be free from contamination with bacteria and it is not supposed to be causing temperature rise of the person or chronic tissue inflammation or allergic reactions. Hence, it should be non-toxic. The bio-compatibility is also equally important property. Depending upon the end use application, the proper selection of the fibre could be made and some of the fibres used for surgical textiles, extracorporeal devices and health care and hygiene products are given in Table - 3.

Table - 2: Forecast World Technical Textiles Consumption, 1995-2010, Vol. (000 tons)²

Application Area	Years				Compound Annual Growth Rate %		
	1995	2000	2005	2010	95-00	00-05	05-10
Agrotech	1,173	1,381	1,615	1,958	3.3%	3.2%	3.9%
Buildtech	1,261	1,648	2,033	2,591	5.5%	4.3%	5.0%
Clothtech	1,072	1,238	1,413	1,656	2.9%	2.7%	3.2%
Geotech	196	255	319	413	5.4%	4.6%	5.3%
Hometech	1,864	2,186	2,499	2,853	3.2%	2.7%	2.7%
Indutech	1,846	2,205	2,624	3,257	3.6%	3.5%	4.4%
Medtech	1,228	1,543	1,928	2,380	4.7%	4.6%	4.3%
Mobiltech	2,117	2,479	2,828	3,338	3.2%	2.7%	3.4%
Pactech	2,189	2,552	2,990	3,606	3.1%	3.2%	3.8%
Protech	184	238	279	340	5.3%	3.3%	4.0%
Sporttech	841	989	1,153	1,382	3.3%	3.1%	3.7%
Total	13,971	16,714	19,683	23,774	3.7%	3.3%	3.8%
Of which Oekotech	161	214	287	400	5.9%	6.0%	6.9%

Table - 3: Surgical Textiles, Extracorporeal Devices, Healthcare & Hygiene Products⁵

Product Application	Fibre Type	Manufacture System
(Implantable)		
Sutures		
● Biodegradable	Collagen, Polyactide	Monofilament, Braided
● Non-biodegradable	Polyamide, PP, PET, Teflon	Monofilament, Braided
Cardiovascular Implants		
● Vascular Grafts	PET, Teflon	Knitted, Woven
● Heart Valves	Polyester	Woven, Knitted
(Non-implantable)		
Wound Care		
● Absorbent Pad	Cotton, Viscose	Nonwoven
● Wound Contact Layer	Silk, PET, Viscose	Knit, Woven, Nonwoven
● Base Material	Viscose, Plastic film	Nonwoven, Woven
(Extracorporeal Devices)		
● Artificial Kidney	Hollow Viscose	Membrane
(Health Care & Hygiene)		
● Clothes/Wipes	Viscose	Nonwoven

As far as Medical Textile is concerned, it is beyond ambit of this presentation, to cover the various segments of Medical Textile, neither it is also the focus

of this conference and hence, suffice to discuss the products relating to health care and hygiene.

In case of Protective health care textiles and apparels, the main

purpose is to protect the health care professionals from getting contaminated by blood and other infectious material while dealing with the patients. Many a times the surgeons, nurses as well as the attendants in the operation theatre or emergency rooms are expected to wear the health care textiles and apparels so that, they will get required protection. The products under this include operating and emergency room textiles, breathable membranes, caps for surgeon and nurses, masks, footwear's, coats etc. The need for protecting the medical personnel is ever growing and thus increasingly effective health care garments and various barrier products are required to be manufactured.

The biological protective garments are defined by **occupational safety and health administrative (OSHA)** as follows:

"Personnel protective equipment will be considered appropriate only if it does not permit blood or other potentially infectious materials to pass through to or reach the employees work clothes, street clothes, undergarments, skin, eyes, mouth or other mucous membranes under the normal conditions of use and for the duration of time which the protective equipment will be used."

Table - 4 indicates those different types of fibres as well as the geometry of the material to be used in defining the products for health care and hygiene.

There are a number of tests recommended, depending upon the functionality of these products, the manufacturer is accordingly expected to conform to these established standards so that purpose for which such garments or the products are used, is well served. The protective apparel in the medical field also needs to be breathable, comfortable, reliable, effective and above all

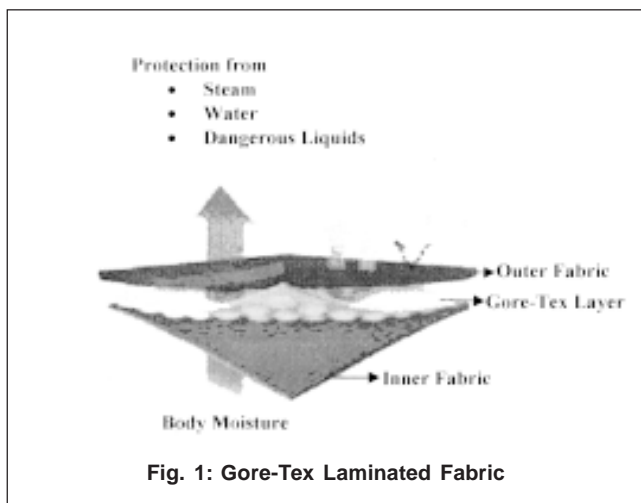
Table - 4: Healthcare and Hygiene Textile Materials⁵

Product Application	Fibre Type	Manufacture System
(Implantable)		
Surgical Clothing		
● Gowns	Cotton, PET, PP	Nonwoven, Woven
● Caps	Viscose	Nonwoven
● Masks	PET, Glass, Viscose	Nonwoven
Surgical Covers		
● Drapes	Polyester, Polyethylene	Nonwoven, Woven
● Clothes	Polyester, Polyethylene	Nonwoven, Woven
Bedding		
● Blankets	Cotton, PET	Woven, Knitted
● Sheets	Cotton	Woven
● Pillowcases	Cotton	Woven
Clothing		
● Uniforms	Cotton, PET	Woven
● Protective Clothing	PET, PP	Nonwoven
Incontinence diaper/stock		
● Coverstock	PET, PP	Nonwoven
● Absorbent Layer	Wood fluff, Superabsorbents	Nonwoven
● Outer Layer	Polyethylene	Nonwoven

economically affordable. The fluid resistance clothing needs to be used, if there is a possibility of splashing or spreading the blood on the fabric^{6,7}. The impact of AIDS and other contagious diseases create need of such clothing. In US, the fabric based products used by medical personnel are considered as medical device and thus fall under FDA (Federal and Drug Association). The protective material also needs to be water proof, but breathable and it makes use of two types of materials based on polyurethane or other co-polymers. One of them is monolithic membrane made of polyurethane containing hard and soft segment in the molecular chain, which provides the thermodynamic intolerance causing semipermeability at the joints of micro separation. The second one is microporous membrane which allows the body to transmit the perspiration through the fabric. The

dimension of the pore is 0.1 to 0.2 micron. Although it does not allow liquid water to pass through it, but it permits water vapour of size 0.0004 micron⁸. Needle sticks and sharp objects are the main causes of infection (HIV) and hence the proper sealing of the seam areas of these garments is very essential. This can be offered in knitted or non woven and in polyester cotton blended woven fabric.

Gore-Tex has two layers laminated fabric produced by W.L. Gore & Associates as a barrier material and it is shown in Fig. 1; while it keeps water and bacteria out, it also has vapour transmission, light weight and softness. There is a special coating used to make the fabric breathable but liquid proof. The surgical drapes are used in the operation theatre to cover patients or cover clothes. Many times, a nonwoven type is used having the backing material on one



or both the sides of the film. While the film is permeable to bacteria, non woven backing is highly absorbent to both body perspiration and secretions from the wound.

Surgical masks are made of 3 layers. Middle layer of extra glass fibre or synthetic micro fibre is covered on both sides by acrylic. The performance requirement for surgical face mask is high bacteria filtration capacity, high air permeability, light weight and non allergic nature. The surgical caps are made of non woven cellulosic fibres using spunlaid process or parallel process and now-a-days hydroentanglement is gaining popularity in producing disposable products and garments to be used in operation room. The properties for the surgical drapes include stiffness barrier performance for gowns as stiffness may affect the perspiration and movement. There should not be any linting which otherwise may carry particles to the wounds. Flame resistance is needed during laser applications and oxygen administration. There are specific norms by CPSC and also National Fibre Production Association with respect to flame retardancy required for this product⁹. The other Medical Textiles or Hygiene Textiles include bedding, shoe covers, mattress

cover and wipes. Cotton leno woven blankets replace woolen blankets to reduce the risk of cross infection due to the water washability of the former. In isolation wards and Intensive Care Unit (ICU), composite fibres are used for protective clothing, incontinential textiles, diapers or bedding. The disposable

diapers have 3 layers: Inner covering layer, an absorbent layer and an outer layer. The inner covered hydrophilic finish treated polyester web or spun-laid polypropylene non woven bonded fabric as well as tissue papers are used in clothes and wipes having antiseptic finish. These clothes and wipes are used to clean the wounds. Surgical hosiery or knitted material have a lot of compressibility and are used to support the knees and also in the treatment of disorder and during physical injury.

PROTECTIVE TEXTILES

In case of protective textiles, the industrial need is to offer the protection either from extreme heat and fire on one hand or from extreme cold on the other. Also

protection from harmful chemicals, gases, bacterial environment, radiation etc. and ballistic protection which is also the form of mechanical protection is required. Low visibility textiles are used in military and defense purposes. These kind of textiles not only become the present need for accident free operations, but also it is by the legislations which are presently existing in the developed countries and which will soon be the part of human rights protection in our country. It has now become a law that the employer has to conduct the hazard assessment at the work place and provide the employee the proper safe surrounding and see that they wear safely designed and constructed protective clothing. Of course, these products also had to adhere to certain international quality standards. As to the protection from high temperature, in the standard clothing asbestos and mineral fibres were used in the past. However, because of its carcinogenic nature, it has been withdrawn. By definition a material which can be used at a temperature more than 200°C without decomposition and losing its physical property, is considered to be high temperature textile^{10,11}.

Table - 5 gives the thermal properties of some of the fibres which can be used for high temperature application and protection from such environment.

Table - 5: Thermal Properties of Selected High Temperature Fibres

Properties	Fibre					
	Aramid ³ M = meta P = para	PAN/ Carbon	Glass	Poly- acrylate	PTFE	Poly- amide
LOI	30 M 29 P	55	>100	43	>100	40
Thermal Conductivity (BTU-in/hr ² per °F)	0.26 M 0.30 P	<0.03	7.2	0.31	0.2	N/A
Usable temp. °C ● Short term: ● Continuous:	315-370 230	VH 220	VH 315	2 160	Decomp >430 288	<485 <260

VH : Very High

The factors which are required to be taken into consideration in high temperature clothing are as follows¹²:

- The nature of application (i.e., whether protection needs for a person or a machinery, fire curtains, filtration etc.).
- Temperature range and heat generation.
- Environment condition – whether dry, wet or chemical environment.

It is important that due to the continuous exposure to heat, the strength of the fabric should not be decreased to a level lower than what is required as optimum. By using higher GSM of the fabric, its weight strength loss can be delayed¹³. The flame retardant

clothes are designed to prevent ignition and even if they are ignited it is with a great difficulty. They have ability to get extinguished thus preventing the spread of flame. Flame resistant fabrics are obtained by using inherently flame retardant textile materials or treating the fibres or the fabrics with special flame retardant chemicals. Some of the commercially available flame retardant fibres for work apparels are given in Table - 6.

The requirement of flame retardant clothing includes ability to offer the protection from the flame, without compromising the comfort property and durability of such flame retardancy. Light weight garment with a flame retardant property is the present need and for a fire fighter, the moisture transferability

along with flame retardant property becomes special requirement¹³.

According to the degree of flame retardancy, various tests standards are maintained. As far as textile garment offering protection from flame is concerned, sewing thread should also be made of flame retardant material. The protective clothing should also have thermal comfort properties and thus under the higher outside temperature and humidity the vapours of sweat have to smoothly escape. It is also important to note that depending upon the construction parameters of the fabric and using this fabric in single, double layer or in a composite form, the extent of protection from flame offered generally differs as depicted in Tables - 7 and 8.

Table - 6: Commercially Available Flame Retardant Fibres for Work Apparel Fabrics¹⁴

Generic Name	Fibre	Manufacturer	MR(%)	Tenacity] (g/den)	Comments
Aramid (Meta)	Nomex	DuPont	6.5%	4.0-5.3	Fibre forming is a long chain synthetic polyamide. Excellent durability and chemical resistance. Relatively poor colourfastness to laundering and light exposure.
Aramid (Para)	Kermel Kevlar Twaron	Rhone-Poulence DuPont Akzo (Holland)	3.4 4.3 4.0	4.0-4.5 21-27 22.6	Blended with Nomex for strength. Difficult to dye. Excellent strength and abrasion resistance, sensitive to bleach, light and strong mineral acids.
Modacrylic	SEF Kanecaron	Monsanto (Italy) Kaneka (Japan)	2.5	1.7-2.6	Fibre forming substance is a long chain synthetic polymer containing acrylonitrile units. Excellent chemical and abrasion resistance. High thermal shrinkage.
Polyamide	P84	Lenzing (Austria)	3.0	3.7	Fibre forming substance is a long chain synthetic polyamide. High thermal shrinkage. Thermal properties inferior to Nomex.
Vinal	Vinex FR9B	Westex	3.0	3.0	Fibre composed of vinyl alcohol units with acetal cross links. Sheds aluminum slash, but very sensitive to shrinkage from wet and dry heat.

Table - 7 : Insulation of FR Fabrics in Surface Contact¹⁵

Fabric Composition	Tolerance Time, * S, at Surface Temperature, °C				
	100	150	200	300	375
Nomex III (6 oz)	23.0	6.6	13.9	1.8	1.2
Nomex III (10 oz)	>30.0	12.3	5.8	2.8	2.2
Kevlar (8 oz)	23.3	7.8	4.4	2.4	1.8
Aramid/Glass (18 oz)	>30.0	>30.0	19.9	10.0	7.4
PAN (17 oz)	>30	16.3	8.1	4.2	2.7
FR Cotton (13 oz)	20.2	5.8	3.4	1.8	1.6
FR Wool (18 oz)	>30.0	>30.0	15.9	5.3	3.0

Table - 8 : Properties of Selected Sewing Threads for FR Clothing¹⁶

Fibre	Yarn Type	Sewability
Nomex	Spun filament	Generally good
Kevlar	Spun filament	Spun: excellent, filament, can pull a part
Fibreglass	Filament	Breaks easily
PTFE	Filament	Slick, machine adjustment necessary
Carbon	Spun filament	Slower speed and machine adjustments needed
Quartz	Filament	Fibres may fracture

Flame retardant textiles find applications in fire fighters dresses, manufacture of furniture, airline suits, children sleepwear, etc. The fire fighters protective clothing system includes coat, pant, underwear, helmet, boots, gloves and breathing devices. While core property of resistance to flame has to be expected by such clothing, resistance to cut and punctures and mobility, water proofness, durability are other essential characteristics. In general fire fighting clothes of 3 layered material are made, the outer layer, the moisture barrier and the thermal barrier. The outer layer must be heat and flame resistance. The two most common materials used for outer layer are Kevlar and PBI 60:40 and Nomex. The main purpose of moisture barrier is to keep the fire fighter dry and the material is expected to prevent water penetration. Woven and spun bonded substrates coated or laminated with neoprene or PTFE are commonly used as moisture barrier. Although the first two layers are flame resistant, the 3rd inner layer of thermal barrier offers proper protection against heat. Different fibres can be used after planning to form a composite. It has to be light and airy. While it is a multi layer garment, it has to also offer least resistance to movement of the body parts¹⁷.

Chemical Protective Clothing

In this case the body parts are isolated from hazardous chemicals coming in direct contact with them e.g. protection of the farmers from insecticides or truck drivers from chemicals toxic during loading or unloading and fire fighters from chemical substances. Environmental protection agency has defined 4 levels of protection¹⁸.

- Level A which offers high, protection from skin and respiratory exposure to chemical hazards.
- Level B protects the wearer from getting in contact with liquid but not from toxic gases or vapours.

- Level C is similar as Level B but with air purity respirator.
- Level D is the normal work clothing to keep off dirt, grease and limited spill protection, etc.

These CPC may be of encapsulating i.e. covering the whole body including the respiratory protection or non-encapsulation which is assembled from supported components and the respiratory apparatus may be worn outside the suit. The materials used for chemical protection clothing are given in Table - 9.

A number of products are manufactured and supplied by various manufacturers to offer protection from hazardous particulates as well as liquid and gaseous substances. The chemical protective clothing includes gloves, boots, face mask, aprons and also highly sophisticated system enable encapsulated suit.

Clean Room Textiles (CRT)

In case of CRT where the environment is protected from the wearer for clothing carrier a good amount of dust, ions, hair, tobacco smoke and it is said that the human body sheds 1 billion skin cells every

Table - 9. Materials for Chemical Protective Clothing¹⁹

Fibre	Yarn Type	Sewability
Material	Material Type	Applications
Butyl/Nylon	Supported elastomer	Splash, encapsulating suits
Butyl rubber	Elastomer	Gloves
Natural rubber	Elastomer	Gloves, suit gaskets
Neoprene	Elastomer	Gloves, suit gaskets
Polycarbonate	Plastic film	Visors
PVC	Plastic film	Gloves, visors
Responder	Plastic laminate	Gloves
Viton/Nylon/Neoprene	Elastomeric laminate	Encapsulating suits
PVC/Nylon	Supported Plastic	Splash suits
Silvershield	Plastic laminate	Gloves
Polymethacrylate	Plastic film	Visors
Nitrile rubber	Elastomer	Gloves

day. The clean room textiles should be lint free, antistatic and should retard human contamination of textiles. Institute of environmental services recommends different types of garments for clean room²⁰. Woven, non woven and laminate fabrics used for clean room. The main properties of the fabrics require optimum filtration efficiency, moisture vapour transmission rate, static decay property and Flame retardance. The typical air permeability range is 1 to 45 cfm and typical filtration efficiency varies from 50-60% for particles measuring 0.3 to 0.5 microns. Conductive yarn such as carbon, nickel or aluminum can be woven in the clean room fabrics. The chemical protection ability and the flame retardency are added requirements during fabrication of clean room garment²¹.

Protection from Radiation

People working in radioactive environment require such kind of outfits so that the transfer of radioactive material to the human skin is prevented. Radiation protection is necessary for employees of nuclear plant, x-ray professionals and the workers working in cancer treatment centers. Nuclear protection fabrics are made of cotton, polyester cotton, nylon polyester. One of the techniques for use of protection from gamma, beta emissions from an artificial material is by shielding the same using lead (Pb) metal barrier between the radioactive dirt. Protective clothing from radiation include head cover, gloves, shoe covers, etc²².

Protection from Extreme Cold

Some of the insulating materials available in today's market offering protection from cold are describing in Table - 10.

Most of these materials offer protection, while playing the wonderful games under the extreme cold condition. Albany

Table - 10: Some Commercially Available Insulation Materials²³

Products	Manufacturer	Characteristics	End Use
Gore-Tex	W.L. Gore	The original waterproof/ breathable laminated fabric with pores large enough for water to escape, small enough to block rain	Gloves, Hat, Footwear, Outwear, Running and Cycling apparel
Drylete	Hind	Combines hydrofoil nylon and hydrophobic polyester to push moisture from the body and then pull it through fabric for quick drying	Skiwear, Running apparel
Hydrofil	Allied	A new super-absorbent hydrophilic nylon that sucks moisture away from skin	Linings, Long underwear, Cycling apparel
Supplex	DuPont	A strong, quick drying nylon fabric, in smooth or textured weaves, that feels like cotton	Outwear, Skiwear, Running and Cycling apparel
Synera	Amoco	A strong, light weight PP fabric that transports moisture away from skin	Long underwear, Jacket linings
Thinsulate	3M	Thin insulation made of polyester and polypropylene fibres	Skiwear, Gloves, Footwear

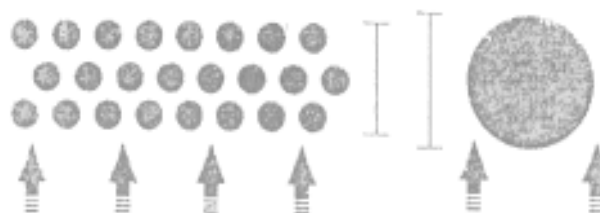


Fig. 2: Toothpick Theory (Albany International).

International has shown through the toothpick theory, that there can be a perfect balance between the density of the insulating material and the compressibility. As shown in Fig. 2.

The material with fine denier yarn offers better insulation as compared to that of the coarser denier.

High Visibility Materials

HVM have become very essential for the protection of pedestrians. Accidents in US alone in the night due to the vehicles, result in the death of more than 4,000 pedestrians and injury of more than 30,000 annually²⁴. In the dark, HVM

clothes increase the detectability and application of such high visibility material (HVM) has resulted in 40% decline was observed in such accidents. The 3 major types of HVM are as follows:

- Reflection materials which shine when struck by light,
- Photo luminescent material which give yellow light in dark
- Fluorescent material which is visible during the day.

Textile substrates of these kinds are used in personnel safety products. Fabrics covered with reflective micro prison sheeting offer high visibility for personnel safety. They are used by pedestrians, cyclists,

joggers, police etc. Personnels working in airlines, law enforcement and medical field also make use of reflective materials. Photoluminescent materials absorb the daylight or artificial light and emit green-yellow light in the darkness. Zinc sulphide crystals which are not radioactive and non toxic pigments provide the visibility in the dark²⁵.

NANO-TECHNOLOGICAL APPLICATIONS

The application of nano-technology in the field of textiles and apparels is gaining increasing importance. Nano-technology is defined as the utilization of structures with at least 1 dimension of nano size for the construction of material with improved properties owing to such a small size. Commonly, the products in the range of 1-100 nano meters are considered to be nano particles. It has been proved beyond doubts that permanent effect with improved performance properties even after repeated laundering are possible in case of textile goods manufacturer using nano technology. Nano particles have high surface area to volume ratio and thus present increased affinity for fabric which leads to improved durability. Some of the finishes based on nano particles are found to maintain the breathability and soft hand. A US based Berlinton industry first reported the nano technology application under the trade name Nano-text. The nano materials can be applied to textile by coating using various other ingredients and by varying the technology of coating. Out of the many possible applications in textile, some of the most successful one are water repellence, soil resistance, UV protection, anti bacterial and anti static finishes and as well as wrinkle resistance which are described below.

Nano Text²⁶

Nano text contains non viscous

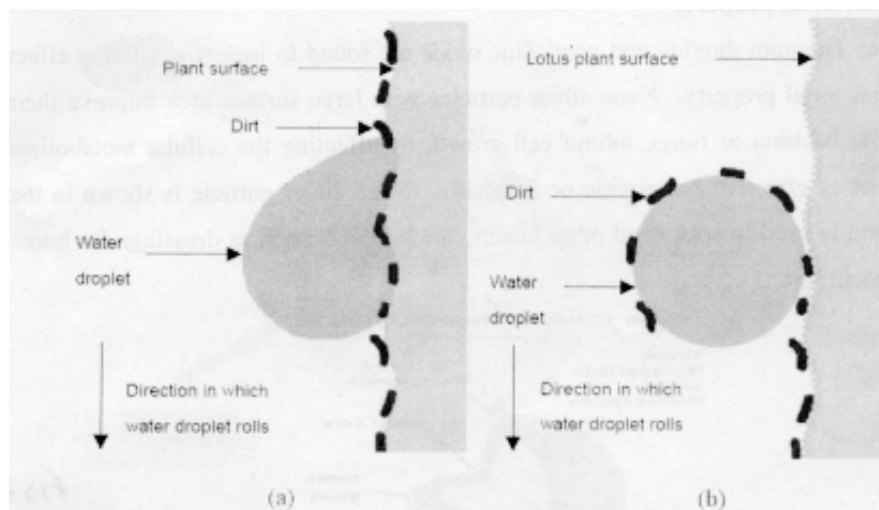


Fig. 3 : Mechanism of Nano Sphere on textiles applied by Nano Sphere technology; (a) water droplet rolls down a plant, (b) water droplet rolls down a lotus plant²⁶

finish material which has hydrocarbons of 1000th of the size of typical cotton fibre. Just like a peach skin having a fuzzy surface, this finish creates such a surface without lowering its strength. The spaces between viscous finish are smaller than a typical drop of water but still larger than molecular water and hence while the water drops can roll-off the fabric giving water repellence, liquid water can still pass through the fabric if pressed through paddlers. Scholler developed Nano-sphere to make water repellent fabric having the mechanism of the system similar to the lotus effect occurring in nature as demonstrated in the Fig. 3.

Once the water drops falls on the super hydrophobic surfaces developed by nano sphere technology, giving 3 dimensional surface structures, it rolls off keeping the surface dry even in heavy shower. These droplets pick up the dirt particles while rolling-off keeping the fabric clean. The third way is to impart hydrophobic property to cotton fabric by coating it with non particulating plasma film²⁶. Audio frequency plasma of some kind of fluorocarbon chemicals deposits nano

particulate hydrophilic film to improve the water repellency.

Wrinkle Resistance

In order to impart wrinkle resistance, normal procedure is to use resin precondensates. However, to overcome the limitations of resin, nano Titanium dioxide and nano silica are employed using polycarboxylic acid as a catalyst under UV radiation to catalyze the cross linking reaction between cellulose molecules and the acid. On the other hand, the application of nano-silica with maleic anhydride showed successful improvement in the wrinkle resistance of silk²⁶.

Anti Bacterial Property

Nano silver Titanium dioxide and nano Zinc oxide are found to impart sterilizing effect with anti bacterial property. Nano silver particles with large surface area improve their contact with bacteria or fungi, inhibit cell growth by affecting the cellular metabolism and thus act as effective bactericide or fungicide. Nano silver particle is shown in the Fig. 4 and is used in socks and other health care products such as dressings for burns and skin-donor, etc.

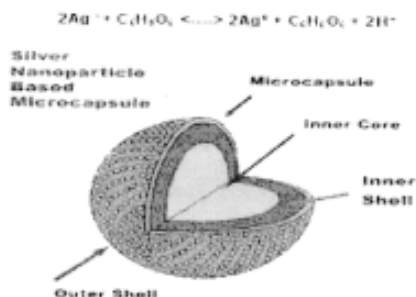


Fig. 4: Structural View of Silver Nanoparticle-Containing Functional Microcapsule²⁷

Titanium dioxide acts as a photocatalyst and on being illuminated by light, electrons of titanium dioxide jumps from the valence band to the conduction band, and the electron (e-) and the electric hole (h+) pairs formed on the surface of photocatalyst generate hydroxyl radicals. Since these are unstable chemical substances, when the organic compound falls on the surface of the photocatalyst, it combines with O₂ and OH- respectively, and results into carbondioxide (CO₂) and water (H₂O). This is called oxidation-reduction reaction and the mechanism is shown in the Fig. 5 and is used in controlling the bad odour or bacterial growth. Nano Zinc oxide can also be used as a good photocatalytic agent having anti bacterial property²⁶. Self cleaning suits make use of a film polymer of polyglycidylacry late mixed with nano silver which has

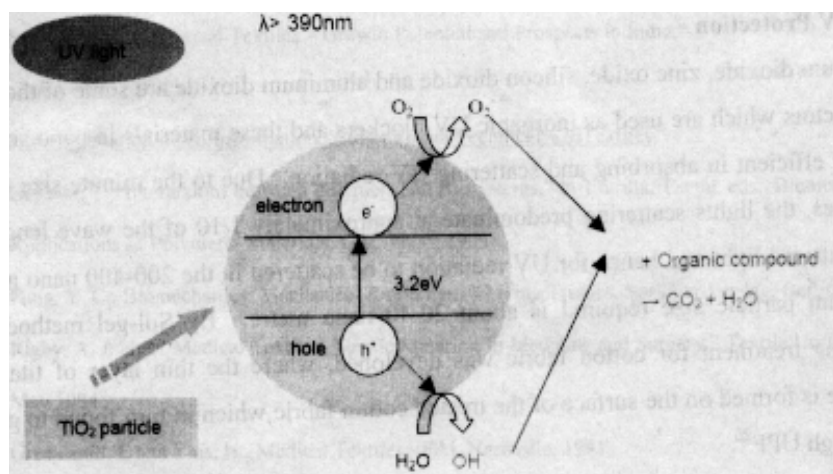


Fig. 5: Photocatalysis Mechanism of Titanium Dioxide²⁶

inherent property of imparting anti microbial or odor free effects²⁷.

Antistatic Properties

Synthetic fibres are notorious for development of static large and thus durable anti static finishes are required to be given to these fibres to enable processing of them free of problems. Nano size titanium dioxide, zinc oxide, viscous and nano antimony dioxide, tin dioxide have been found to provide anti static effect, as they are electrically conducting materials causing the effective decay of static charge. The garments based on electrically conductive nano particles, which durably anchored in the fibrils of the Gore-Tex membrane of Teflon, prevent the formation of isolated chargeable areas and voltage peaks commonly found in conventional anti-static materials²⁶ and Gore-Tex Antistatic Workwear is shown in the Fig. 6.

UV Protection

Titanium dioxide, zinc oxide, silicon dioxide and aluminum dioxide are some of the semi conductors which are used as inorganic UV blockers and these materials in nano size are highly efficient in absorbing and scattering UV radiation. Due to the minute size of the particles, the lights scattering predominate at approximately 1/10 of the wave length of the scattered light and



Fig. 6 : Gore-Tex Antistatic Workwear

hence for UV radiation to be scattered in the 200-400 nano metre, optimum particle size required is about 20-40 nano metre. By Sol-gel method UV blocking treatment for cotton fabric was developed, where the thin layer of titanium dioxide is formed on the surface of the treated cotton fabric which in turn found to give a very high UPF²⁶.

Nano Finished Garments

In general the nano finished garments offer protection due to a coating which is water and beverage repellent. The naked eye cannot detect the protective layer due to the near about 100 nano meter size of finish on the clothing which is water and dirt resistant. A lot of saving on laundry time and cost can be obtained with good feel and breathability as well as resistance to wrinkles. The finish is non toxic in nature and bright and fresh looking. These are value added effects with environment friendly technology²⁷.

CONCLUSION

Functional textiles have opened a new vista of applications in diverse field of human life. Many of these applications are highly crucial and thus these materials with high end performance properties are going to play paramount role in the life of modern man. Surely in the fast developing economy like ours, the growth of such Textile Materials will take place at galloping rate. Not only will it act as the driving force for R&D activities, tapping hitherto

untapped field of Functional Textiles and Apparels, it will also be a great booster to our economy and to the same extent it will slowly reduce India's dependence of imported Technologies in this field.

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