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INDEX

आशुतोष टण्डन 'गोपाल जी'
मंत्री
प्राविधिक शिक्षा एवं
चिकित्सा शिक्षा विभाग

कार्यालय : 2236603
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कक्षा संख्या 59–59ए, मुख्य भवन
विधान भवन, लखनऊ

दिनांक ....

संदेश

मुझे यह जानकर प्रसन्नता हुई है कि उत्तर प्रदेश वस्त्र प्रौद्योगिकी संस्थान के 'जॉरनल ऑफ फाइवर टू फिनिश' का 56वाँ अंक प्रकाशित हो रहा है।

मुझे आशा है कि वस्त्र तकनीकी क्षेत्र के अग्रणी संस्थान के प्रतिष्ठित 'जॉरनल ऑफ फाइवर टू फिनिश' में प्रकाशित विभिन्न तकनीकी आलेखों के माध्यम से छात्र–छात्राओं के तकनीकी ज्ञान संवर्धन एवं उनके बहुमुखी विकास में सहायक सिद्ध होगा।

'जॉरनल ऑफ फाइवर टू फिनिश' के सफल प्रकाशन हेतु मेरी हार्दिक शुभकामनायँ।

आशुतोष टण्डन

प्रो0 विनय कुमार पाठक
कुलपति
Prof. Vinay Kumar Pathak
Vice-Chancellor

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Uttar Pradesh, Lucknow

दिनांक : जुलाई 07, 2017

सन्देश

मुझे यह जानकर अत्यन्त हर्ष हुआ है कि उत्तर प्रदेश वस्त्र प्रौद्योगिकी संस्थान, कानपुर अपने वार्षिक ''जॉरनल ऑफ फाइवर टू फिनिश'' का 56वॉ अंक मई, 2017 का प्रकाशन किया जा रहा है। इस प्रकार के प्रकाशनों से निश्चय ही विद्यार्थियों को अपनी क्षमताओं को प्रदर्शित करने का अवसर प्राप्त होता है।

आपकी यह स्मारिका ज्ञानवर्धक तथा दिशा निर्देशिका के रूप में सफलता प्राप्त करें। आप सभी को स्मारिका के सफल प्रकाशन हेतु शुभकामनाएं।

(प्रो0 विनय कुमार पाठक)
कुलपति

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From the Chief Editor's Desk.....

Dear readers

On behalf of the Editorial board, I would like to wish all authors, patrons and readers of "Journal of Fibre to Finish" (JFF) to receiving a good response from both academic and industry. The journal was publishing earlier with the name of Fibre to Finish since last six decades. Journal of Fibre to Finish is a Peer reviewed reformed journal, since this issue that aims that dissemination of knowledge about research in textile science. Journal of fibre to finish provides a platform to researchers, academicians, professional and students in all facets of textile from fibre forming polymer to finished garments to share research achievement, their prospective and day to day industrial manufacturing experiences. We have become more selective in accepting submitted papers. The acceptance rate of paper is between 70-80% of the total manuscript receipt for reviewable in our journal.

Our consistent efforts are aimed towards increasing the visibility, impact editorial cycle time citation and overall quality of our journal. JFF has been created to serve the professional needs of textile education and researchers worldwide in such a buoyant backdrop the role of Journal of Fibre to Finish as compiler of textile research experiences assumes paramount importance. Time frame and precise information base is an integral part of any development process and planning. The concept of theme "Make in India" has ushered a new era of development in our country.

The editorial board takes opportunity to express its deepest regard to our BOG, State of UP, Secretary Technical Education State of UP and Vice Chancellor AKTU, Lucknow for their humble contribution.

Prof. Mukesh Kumar Singh

Chief Editor

Silk Dyeing with Lichen (Evernia Mesomorpha)

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Abstract

The natural dyes are used since ancient time for colouring the wide varieties of products including textiles. After the invention of synthetic dyes, use of natural dyes decline to a large scale. With the growing awareness for the eco-friendly products in 1990's natural dyes again gaining its importance due to eco-friendly nature of the products. In this study among the different sources of Lichen, Evernia mesomorpha was used to standardise the dyeing recipe for silk. Aqueous medium was used for the extraction of the dye. The dye was used for dyeing of degummed silk cloth and treated with four chemical auxiliaries were: Citric acid, Sodium sulphate, Oxalic acid and Tartaric acid. Fastness tests of dyed clothes was also undertaken in this study. Large range of shades was obtained because of varying chemical auxiliares percent and combination. It was observed that treatment with chemical auxiliaries improved the colourfastness properties of the dyed samples.

Keyword: Natural dyes, Lichen, Evernia mesomorpha, Chemical auxiliaries, Colourfastness properties

1. Introduction:

Since the ancient time textiles plays a very important role in the development of any nation. India is known for its very rich and diverse range of textiles. The art of dyeing and printing of the textiles was first introduce in India for value addition with the use of natural dyes and mordant. With the invention and commercialization of the synthetic dyes in the 19th century the use of natural dyes decline to a very large scale. The synthetic dyes are easy to use, colour fast and cost effective but the manufacturing of these dyes required hazardous chemicals that poses threat towards the environment and living species. Many synthetic dyes are also responsible for causing cancer and other health hazards. With the growing awareness for the eco-friendly products the use of synthetic dyes are declining from the last few decades. The manufacturing of azo-dyes and its application was first ban in Germany and afterward many countries like Netherland, India etc. also ban these cancer causing dyes (Patel, 2011). Consumers nowadays are becoming more concerned about environmental issues and hence are demanding for natural product incorporating natural ingredient. Although natural colours cannot substitute use of synthetic dyes completely, there is definitely increasing market for such complete eco-friendly dyed or printed materials.

According to **Australian National Botanical Garden, (2014)** stated that a lichen is emerge from the combination algae or cyanobacteria (or both) living among filaments of a fungus in a mutually beneficial (symbiotic) relationship. Properties of the lichen is very different from properties of its constituent organisms. In all over the world there are about 20,000 lichen species described, and India represents 10% (2305) of the lichens known **(Singh and Sinha, 2010).**

In the present study an attempt has been made to optimize dyeing recipe for silk fabric using Evernia mesomorpha lichen. Four chemical auxiliaries were also used to study their effect on dye. These chemical auxillaries were: Citric acid, Sodium sulphate, Oxalic acid and Tartaric acid. After treating dye with the different chemical auxillaries its colour fasteness test was also performed along with control sample.

2. Methodology

(i) Selection of dye

Evernia mesomorpha was selected for the study. It was purchased from Ramnagar market, Nainital, Uttarakhand at the rate of Rs. 300/kg

(ii) Selection of fabric

Mulberry silk fabric was selected for the study and purchased from Central Silk Board, Dehradun, Uttrarakhand at a rate of Rs. 350/m.

(iii) Degumming of silk

Silk was degummed to remove natural impurities and to make it more absorbent. The recipe recommended by **Dantyagi (1983)** was used. A detergent solution containing 0.5 ml of genteel per 100 ml of water was prepared. It was heated by 50?C. Silk fabric was dipped into this solution and stirred gently for about 30 minutes. It was kneaded, squeezed in the soap solution and then raised under tap water till free from traces of detergent. After that the fabric was partially dried in shade and ironed when half wet.

(iv) Optimization of dyeing condition

For optimizing the dye condition series of experiments were conducted for *Evernia mesomorpha* such as medium of dye extraction, concentration of dye material, dye extraction time, dyeing time etc.

Selection of medium of dye extraction

For optimization of the dye extraction medium, three dye solutions were prepared by using 1.0 gm of dye per 100 ml of water in acidic, alkaline and aqueous media. Acidic solution was prepared by adding 1 ml of hydrochloric acid in 100 ml of water while the alkaline solution was prepared by adding 1 gm of sodium carbonate in 100 ml of water. Aqueous solutions were prepared by 100 ml of water without using any chemical. All these were boiled at 80?C for 60 minutes. After that, the solutions were filtered and pre-soaked silk samples (2g) was added to each beaker and dyed for 1 hour. Samples were then rinsed in cold water and dried in shade. Each samples were analysed visually and through percent absorption for the depth of the shade obtained and based on it extraction media was selected.

(v) Optimization of concentration of dye material

Four dye solutions were prepared by adding 2, 4, 6 and 8 gm of dye material in 100 ml of water and boiled at 80?C for 60 minutes. After that, the solutions were filtered and pre-soaked silk samples (2g) were then added to each beaker and dyeing was carried out for 1 hour. Samples were then rinsed in cold water and dried in shade. Each samples were analysed visually and through percent absorption for the depth of the shade obtained and based on it best concentration of dye material was selected.

(vi) Optimization of time of extraction of dye

Four dye solutions were prepared by extracting the optimum concentration of the dye material in 100ml of water. Solutions were boiled at 80?C for 30, 60, 90 and 120 minutes. After that, the solutions were filtered, pre-soaked silk samples of 2gm were then added to each beaker and dyeing was carried out for 1 hour. Samples were then rinsed in cold water and dried in shade. Each samples were analysed visually and through percent absorption for the depth of the shade obtained and based on it dye extraction time was selected.

(vii) Optimization of dyeing time

Four dye solutions were prepared by extracting the optimum concentration of the dyes material in 100ml of water at optimum extraction time. Two gm per soaked silk samples were added to each beaker and dyed for 30, 60, 90 and 120 minutes, respectively. Samples were then rinsed in cold water and dried in shade. Each samples were analysed visually and through percent absorption for the depth of the shade obtained and based on it dyeing time was selected.

(viii) Optimization of concentration of chemical auxiliaries

Chemical auxiliaries namely citric acid, sodium sulphate, oxalic acid and tartaric acid with four concentration of each were selected for the study. The concentration used for each chemical auxiliaries were 1, 2, 3 and 4 percent (o.w.f.). For this, solution of each chemical auxiliaries concentration were prepared separately using optimized dye concentration and extracted at optimized extraction time. Samples were then rinsed in cold water and dried in shade. Each samples were analysed visually for the depth of the shade obtained and based on it concentration of chemical auxiliaries were selected.

(ix) Colourfastness testing

The dyed samples were subjected to colourfastness testing against light, washing, rubbing and perspiration according to the standard test method, mentioned below.

Colour fastness to light: Test method AATCC-RR 92, 2013.

Colour fastness to washing: Test method IS: 3361-2003.

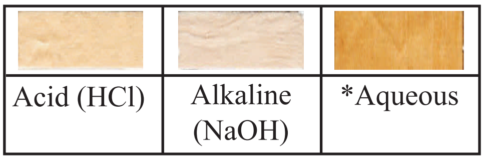
Colour fastness to rubbing: Test method AATCC-RA 38, 2005.

Colour fastness to perspiration: Test method AATCC-RA 52, 2006.

3. Results and discussion

Selection of medium of dye extraction: the samples were dyed in various media like acid, alkaline and aqeous and are shown in Plate 1. Aqueous medium was selected as extraction medium of dye.

Plate 1: Colour obtained from various medium



(i) Optimization of concentration of dye material

Dye material in a different concentration of 1g, 2g, 3g and 4g were tried for optimizing the concentration of Evernia mesomorpha for dye. The results are reported in Table 1 and the dyed samples are shown in **(Plate 2)**. From the plates it was cleared that 2g dye concentration per 100ml of water sample had given the darker shade than the rest of the samples dyed and also having the maximum absorption percent and maximum percentage rating. Hence 2g dye concentration per 100ml of water was selected.

Plate 2: Samples dyed with different concentration of dye material

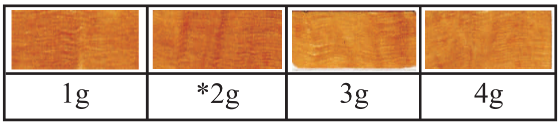


Table 1: Results for optimization of dye concentration

Dye material	Dye concentration (g)	Percent absorption	Percentage rating
Evernia mesomorpha	1	38.34	37
	**2	*59.44	*67
	3	55.55	40
	4	59.67	48

(ii) Optimization of dye extraction time: The dye was extracted for the different time period i.e. 60, 90, 120 and 150 minutes. The results are reported in **Table 2** and the samples dyed shown in **(Plate 3)**. From the plates it was clear that as the timing of dye extraction increases colour shades of the samples became lighter or less bright. Table shows that out of four dye extraction time tried, maximum absorption percent and percentage rating obtained with 60 minutes dye extraction time. So, 60 minutes dyeing time was selected.

Plate 3: Samples dyed with at different dye extraction time

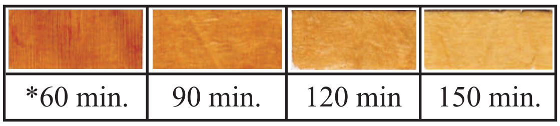


Table 2: Results for optimization of dye extraction time

Dye material	Dye concentration time (minutes)	Percent absorption	Percentage rating
Evernia mesomorpha	**60	*59.47	*62
	90	48.36	52
	120	38.34	41
	150	37.59	38

(iii) Optimization of dyeing time: Silk samples were dyed for 30, 60, 90 and 120 minutes with *Evernia mesomorpha.* The dyed samples are shown in **(Plate 4)**. From the plate it was clear that the sample dyed at 60minutes dyeing time gave the best shade. The result was reported in **Table 3**. It is clear from the figure that maximum percent absorption and percentage rating on silk was observed with 60 minutes dyeing time

Plate 4: Samples dyed at different dyeing time

			
30 min.	*60 min.	90 min.	120 min.

Table 3: Results for optimization of dyeing time

Dye material	Dye extraction time (minutes)	Percent absorption	Percentage rating
Evernia mesomorpha	30	57.64	60
	**60	*74.38	*84.5
	90	63.84	7.35
	120	61.46	65.5

(iv) Optimization of concentration of chemical auxiliaries: The optimized concentration of citric acid, sodium sulphate, tartaric acid and oxalic acid for *Evernia mesomorpha* were 2 percent, 2 percent, 3 percent and 4 percent respectively. Results reported in **Table 4** and samples shown in **Plate 5**.

Plate 5: Samples of Optimized concentration of chemical auxiliaries

	
Citric acid (2%)	Sodium sulphate (2%)
	
Oxalic acid (3%)	Tartaric acid (4%)

Table 4: Results for optimization of concentration of chemical auxiliaries

Dye material	Chem. Auxiliary	Conc.	Percentage rating
Evernia mesomorpha	Citric Acid	2%	71
	Sodium suplhate	2%	77
	Oxalic acid	3%	74
	Tartaric acid	4%	76

Colour fastness test: Final samples were subjected to colourfastness test. Colourfastness to light, washing, crocking and perspiration was evaluated.

Colourfastness to light for the dyed samples with tartaric acid showed excellent colour fastness because it change the colour into darker shade when exposed to light, blank sample and sample dyed with sodium sulphate showed very good colour fastness. Washing fastness of the blank samples showed considerably good washing fastness as compared to samples treated with chemical auxiliaries. Crocking fastness of dyed samples showed good colour fastness for colour change in both dye and wet conditioning. Fastness to perspiration, in case of alkali perspiration blank samples and sample treated with citric acid dyed using Evernia mesomorpha showed, negligible to slightly stain for silk samples and negligible stain for rest of the chemical auxiliary treated samples. Fabric dyed with Evernia mesomorpha and treated with chemical auxiliaries showed good colourfastness property. Results shown in table 5

Table 5 Colour fastness grades of samples dyed using optimum dyeing recipe

Dy	Chemical Auxiliary	Conc.	Colour fastness grades										
			Washing		Light	Rubbing				Perspiration			
			CC	CS		Dry		Wet		Acidic		Alkali	
						CC	CS	CC	CS	CC	CS	CC	CS
Evernia mesomorpha	Control Sample	-	4/5	5	6	5	5	4/5	4/5	5	5	4/5	4/5
	City acid	2%	3	5	4	4/5	4/5	4	4	5	5	4/5	4/5
	Sodium Suplphate	2%	4	4/5	6	4/5	4/5	4/5	4/5	5	5	5	5
	Oxalic Acid	3%	2	4/5	3	4/5	4/5	4/5	4/5	5	5	5	5
	Tartaric Acid	4%	4/5	4/5	8	5	5	4/5	4/5	5	5	5	5

CC= Colour Change; CS= Colour Staining

Conclusion:

Lichens are abundantly available in Western Ghats and Himalayan region of India that may be explored and used for dyeing of various textiles as these are natural and cheap and the processing does not involve any harmful chemicals thus making our environment safe. The study was conducted at the laboratory level, hence the optimized dyeing recipes can help the rural women to enhance their skills as well as motivate them to start their business enterprise at home level and cottage level that will generate employment opportunities and can give skill as well as economic empowerment. Further research can also be done on isolation of natural dyes to make easy packaging of these dyes for use in dyeing of various other textile materials.

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Effect of Spandex Count on Structural and Thermal Properties of Single JerseyKnitted Fabric

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Abstract

In the present study,the effect of spandex count on structural and thermal properties of single jersey knit fabric was investigated. Cover spun yarns of lyocell and spandex with different spandex denier were used to developed fabrics and were compared with pure lyocell fabric. The investigation showed that manifestation and change in denier of spandex effects the tested properties of the developed fabrics. Statistical analysis also showed that results were significant for fabric weight, fabric thickness, wales per inch, courses per inch, stitch density, air permeability and thermal insulation.

Keywords: Spandex, yarn linear density,air permeability, clo, thermal insulation, cover yarn.

1. Introduction

The generic name 'spandex' as defined by FTC is "A manufactured fiber in which fiber forming substance is a long chain synthetic polymer comprised of at least 85% of a segmented polyurethane" **(Spandex Fiber, 2015)**. Asia is a major production centre of spandex with 84% of the total, followed by America and Europe. So far as major consumers are concerned, North America consumes leads the tally with 53 percent of the total. In 2010, India consumed only 2 percent of global spandex but has been growing at the rate of 15% per annum in contrast to the world's average growth of 7-8 percent per year. This rapid increase is Indian context is due to its second highest GDP growth rateand a healthy growth in organized retail segment and branded clothing **Gupta (2011).**

The name "spandex" is the anagram of the word expands **(Kadolph, 2009)**. Chemically, spandex is synthetic linear macromolecule with a long chain containing alternating hard and soft segments linked by [- NH - CO - O -] urethane bonds. The soft structure is of polyurethane block copolymer which delivers elasticity to fibre, while hard chain segment contributes molecular interaction force to fibre which confirms fibre strength and long term stability **(Bardhan&Sule, 2004)**.

Spandex is known for its exceptional elasticity and replaces natural rubber as it can withstand body oils, sweat, soaps and detergents. Spandex has better mechanical and physical properties than rubber fibre in terms ofantiaging, linear density, dye ability and tenacity (Spandex is about 5 to 9.5cN/tex compared to 2.2 cN/tex for natural rubber). It possess very low moisture regain (1 to 13%). The breaking elongation of Spandexranges between 450%-700% depending upon denier and type of Spandex fibre. The thermal behaviour of Spandex at low temperature is governed by the soft segments while at high temperatureit depends on the molecular weight, the type of chain extension and orientation of the hard segment. At temperature above 170°C, a noticeable thermal degradation of the fibre is observed **(Goswami, 2005)**.Spandex was first developed at Dupont by Joseph Shivers in 1959 and first appeared in 1986 Olympics as swim wear and stretch ski suits. The singer Madona plays an important role in popularizing the use of spandex in high street fashion by wearing its outfit **(Teegarden, 2004)**.The bare spandex filaments are used in stretch fabrics, foundation garments, swimwears and hosiery. The stretchable yarns are produced by core sheath method using different spinning techniques like modified ring spinning, siro spinning, air jet spinning, hollow spindle spinning, friction spinning and rotor spinning. **(Das &Chakraborty, 2013)**. Yarns developed through these spinning techniques are used in knitting, weaving and nonwovens of fabrics (Goswamiet al., 2005).Spandex filaments are compatible with different fibers like cotton, bamboo, viscose, wool, silk, polyester, etc.

Different studies have been conducted to developed knit fabrics from yarns consistingnatural, regenerated or manufactured fibers as sheath,havingspandex ascore. **Mona (2013)** studied the physical and mechanical properties of cotton and spandex single jersey fabric and concluded that percentage of spandex in a fabric played an important role in determining the dimensional stability and air permeability.Bursting strength, crease recovery and pilling resistance were also affected by the same. **Duenser(2003)** explored an alternative way to plating techniques by the use of core spun yarn having spandex as core in the circular knitting machine. **Gokarneshan and Thangamani(2013)** investigated themechanical properties of core and plated cotton/spandex, polyester/spandex and viscose/spandex blended knits. It was concluded that core and plated knits shows different nature towards fabric geometry and mechanical properties. **Abdessalemet al.(2009)** studied the influence of elastane consumption on characteristics of plated plain knit fabrics and reported that the fabric width, weight and elasticity were affected by the presence of spandex.

In the present investigation,effect of linear mass density ofspandex on structural and thermal properties of knit fabrics were studied with the constant parameters viz. machine settings and yarn components.With this aim, plain knit/single jersey fabrics were prepared with cover spun yarns having spandex filament as core and lyocell yarn as sheath.

2. Materials and Methods

2.1 Preparation of fabric samples

Two fabricsamples were prepared with 20D/22dtex spandex lyocell cover yarn and 40D/44 dtex spandex lyocellcover yarn. Cover spun yarns were developed using hollow spindle spinning frame. For control sample,lyocell fabric was made using pure lyocell yarn. Properties of lyocell yarnand cover spun yarns are given in Table 1.Circular knitmachine specifications are provided in Table 2.

Table 1: Properties of yarns

S.No.	Yarn Properties	Lyocell yarn	Lyocell/22dtex Spandex	Lyocell/44dtex Spandex
1	Yarn count, Ne	40	38.51	31.63
2	Twist per inch	22.0	11.43	12.10
3	Tenacity, g/den	2.05	1.55	1.54
4	Breaking force, g	272	214	260
5	Elongation, %	5.90	7.07	8.02
6	% of spandex	-	4.8	7.9

Table 2: Knitting Machine Parameters

S.No.	Parameters	Knitting Machine
1.	Type	Single Jersey circular knitting machine
2.	Make	Indian
3.	Feeders	2
4.	Gauze	6 needle per inch
5.	Diameter	4 inch
6.	Total needle count	120
7.	Knitting speed	80rpm

2.2 Testing of the prepared samples

2.2.1 Fabric weight: The weight of single jersey knit fabric samples were tested according to the IS: 1964 (2001). Samples (10cm X 10cm) were cut and their corresponding weight were noted down. Following formula were used to calculate the weight of the sample:

Mass per unit area, $(g/m^2) = M \times 10^4 / A \times B$

Where:

M = weight of measured fabric

A = 10cm (length)

B = 10cm (width)

2.2.2 Fabric thickness: Fabric thickness was measured using fabric thickness tester of Paramount Instrument Pvt. Ltd., according to the specifications of IS: 7702 (2012).Average value from 10 readings was calculated.

2.2.3Wales and Coursesper inch: Wales/inch (WPI) and courses/inch (CPI) of the prepared sample were determined using ASTM D-3887. A square inch was marked on fabric sample and with the help of pick glass, wales and courses were counted. Average value from 10 readings was calculated.

2.2.4 Determination of stitch density: Stitch Density (SD) refers to the total no. of loops in a measured area of fabric. According to **Khalil (2014),** stitch density was determined by multiplying the number of courses by the number of wales i.e.

2.2.5 Loop length/Stitch length: Loop length was derived by counting no. of wales in a measured area followed by revealing 10 course yarns. Average length of the stretched courseyarns was calculated divided by no. of wales.

SL = X/Y

Where:

X = avg. length of the yarn

Y= no. of wales

2.2.6 Air permeability of fabric: Air permeability is an important aspect in determining the thermal property of a fabric. It helps to maintain the body temperature by allowing the air to reach and pick moisture from the surface of the body. Fabric porosity facilitates the ease of air flow across the fabric. Fabric use in apparels are suggested to have adequate air permeability i.e. 30cc/cm2/sec **(Shekaret al., 1999)**.The measurement of air permeability is based on the rate of flow of air through a given area of fabric by giving a pressure drop across the fabric and measured in cc/sec/cm2(IS:11056-1984). Exposed area of the knitted fabric was 10cm2 under the pressure drop of 20mm of water column. The data was obtained from average of five readings.

2.2.7 Thermal insulationof fabric: Thermal insulation is the reduction of heat flow (the transfer of thermal energy between objects of differing temperature) between two objects when they are in contact with each other. Thermal insulation is an essential parameter to determine the comfort level of the wearer. It is an inherent property of a material which designs its capacity to conduct heat. The insulating properties of clothing are expressed in "clo" derived from the word clothes. The clo defines the insulation value of clothing that would allow a heat flow of 1 kg cal m-2 with a temperature gradient across the fabric of 0.16 degrees C **(Mather, 1974)**. One "clo" is equal to a man dressed in a three-piece business suit (shirt, trousers, suit jacket) and light underclothes(Decker, 2011). Some basic insulation values of clo are: naked body: 0 ;summer clothing: 0.6 ;ski outfit: 2 ;light polar equipment: 3 ;heavy polar equipment: 4 and polar down duvet: 8 clo. **(Hedge, 2011)**. The thermal characteristics of the fabrics primarily depends on the entrapped air.

Thermal insulation of the prepared fabrics was tested using the apparatus developed by SASMIRA. The apparatus confirms to the standard of Niven's hot plate. Samples were placed between the hot plates and time taken by hot plate to cool down from 51ºC to 50ºC was noted by the help of stop watch. Ten readings were taken and their mean value was calculated. Clovalue was determined by using the given formula

Thermal insulation (clo) = Average time (sec) /2 x 240, where 1 clo=0.155m2KW-1

2.2.8 Statistical analysis: SPSS software was used to analyse significant difference betweendeveloped fabrics.

3. Results and Discussions

Abbreviation: S1= 100% Lyocell knitted fabric, S2= 22dtexLyocellspandex knitted fabric, S3= 44dtex Lyocellspandex knitted fabric.

3.1 Fabric weight and thickness

4. It can be seen from Fig.1that fabric weight and the count of spandex are directly related to each other. The control

sample S1 had least fabric weight due to the absence of spandex whereas S3 showedhighest weight. The significant difference was due to increase in denseness of fabric as the count and percentage of spandex was increased. The same result was obtained with thickness i.e. as the spandex content increased fabric thickness was also increased (Fig. 1). The results were supported by the findings of **Mona (2013)**, i.e. increased in spandex percentage increased the fabric weight, because greater the amount of spandexmore dense the fabric.

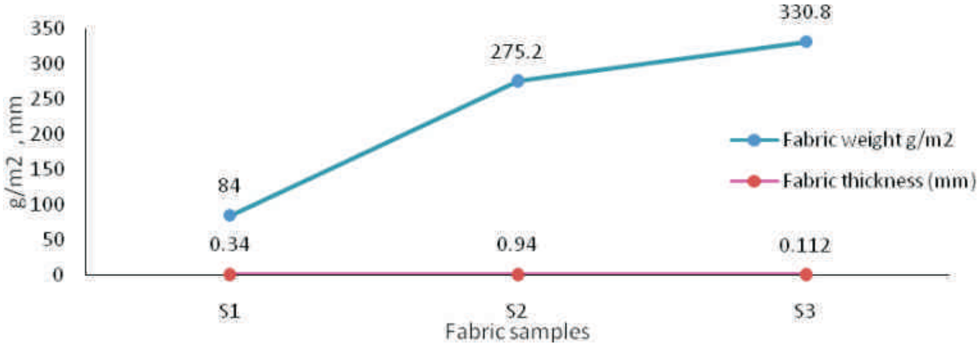

Fig. Effect of spandex count on Fabric weight and thickness

As fabric thickness and fabric weight are positively correlated (r = 0.99), the effect on fabric weight affects the fabric thickness.

3.2 Wales, courses and stitch density

It can be observed from the Fig. 2 and Fig. 3 that wales density, courses density and stitch density showed increasing trend with increased in the count of spandex from 22dtex to 44dtex. It may be ascribed to the fact that spandex made fabric dense and with an increased count, compactness of the fabric is increased. The upsurge in wales density and courses density effected the stitch density of the fabric as it is the product of these two. Change in linear density of spandex enhanced wales density to 65% and courses density to 45%.Result of ANOVA also confirmed that there was significant effect of spandex count on wales density, courses density and stitch density as indicated in Table 3.

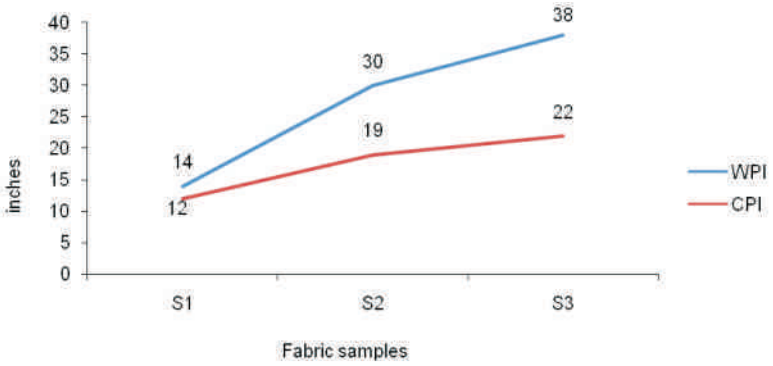

Fig. 2 Effect of Spandex Count on Wales and Courses

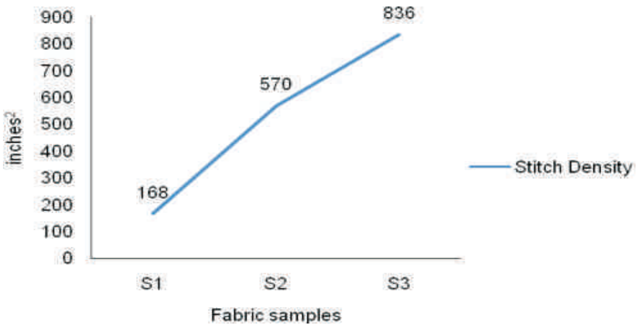

Fig. 3 Effect of Spandex Count on Stitch Density

The same results were reported by **Senthilkumaret al. (2012)**, the linear density of spandex

The same results were reported by **Senthilkumaret al. (2012)**, the linear density of spandex

effected the geometrical properties of the fabric. It was concluded that when spandex denier increases the wales and courses density also increases.

3.3 Loop length

It is evident from the Fig. 4 that loop length of pure lyocell fabric is longer as compared to

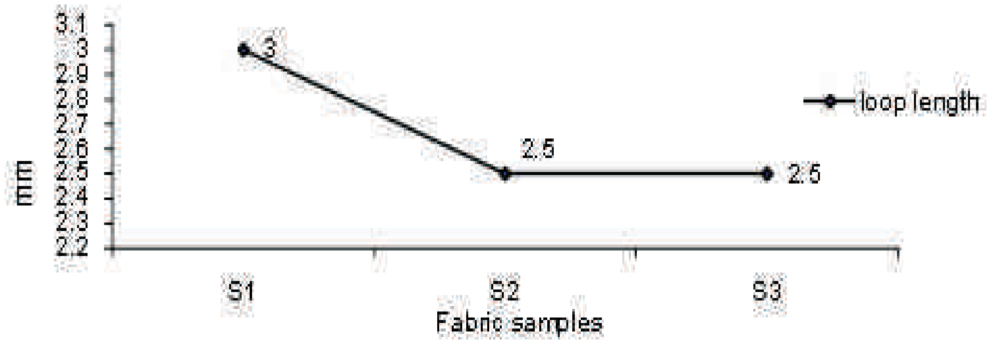

Fig. 4 Effect of Spandex on Loop Length

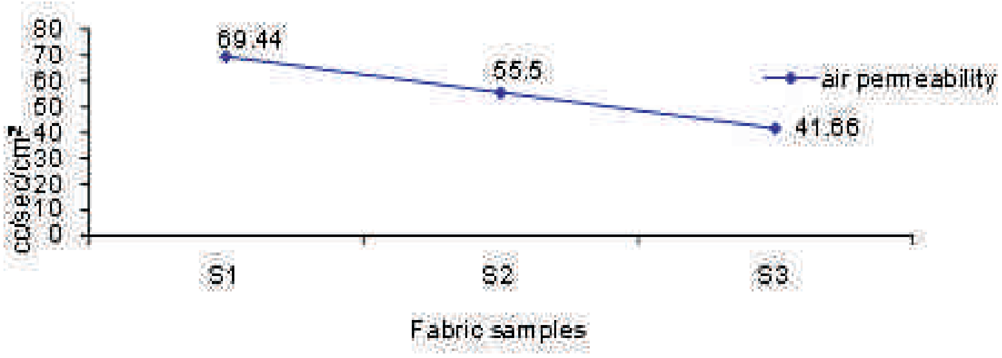

Fig. 5 Effect of spandex count on air permeability (cc/sec/cm2)

spun yarns was found to be significant at 5 per cent level of significance (Table 3).

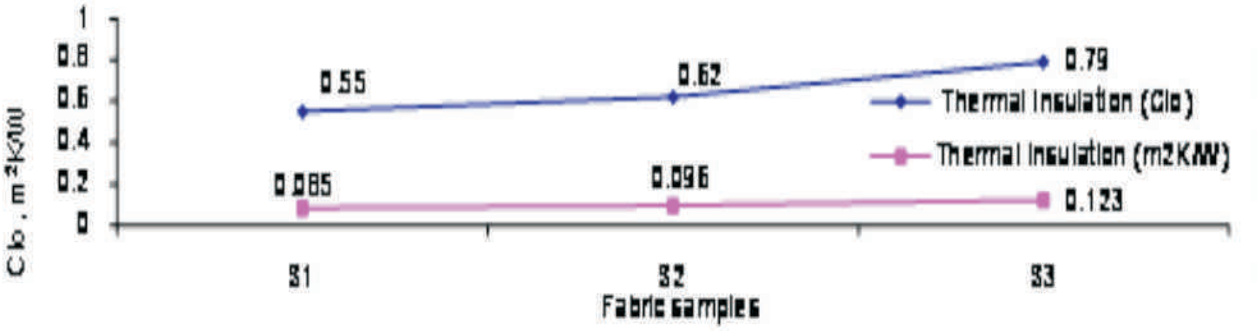

Fig 6 Effect of Spandex Count on Thermal Insulation

3.5 Thermal insulation

It can be concluded from Fig. 6 that minimum insulation value was of pure lyocell fabric whereas maximum was of S3 fabric. It is also evident from the Fig. 6 that increased in the count of spandex increased thermal insulation of fabrics. This may be because spandex compressed wales and courses in fabrics resulted in increased thickness and decreased inter yarn spaces which entrapped more air and hence high thermal insulation was reported. In this study, thermal insulation was measured in clo and converted to m2k/W. **Milenkovicet al. (1999)** concluded similar results that heat transfer through a fabric was majorly affected by fabric thickness, external air movement and entrapped air. Increased in fabric thickness resulted in increased thermal insulation, as there was less loss of heat from the fabric **(Chidambaram, 2012)**.ANOVA results concluded that pure lyocell knit fabric and developed fabrics from lyocell spandex coverspun yarnshad significant difference between thermal insulation at 5 percent level of significance (Table 3).

Table 3 Significance Values

Process variable	Fabric Wt. (gm^2)		Fabric Thickness (mm)		WPI		CPI		SD		Air Permeability (cm^3//s/cm^2)		Thermal Insulation (clo)	
	F Value	P Value	F Value	P Value	F Value	P Value	F Value	P Value	F Value	P Value	F Value	P Value	F Value	P Value
Spandex count	29771	.000*	1823	000*	3761	.000*	658	.000*	4810	.000*	224	.000*	1478	.000*

***significant for $\alpha = 0.05$**

5. Conclusion

The structural and thermal properties of single jersey knit fabrics developed from pure lyocell yarn and cover spun yarns of lyocell and spandex with 20D/22dtex and 40D/44dtex were investigated. It was observed that all three samples showed difference in the values of WPI, CPI and SD as they were significantly affected by the presence and denier of spandex. An increased in denier of spandex increasedthe weight and thickness of fabrics. The loop length of knit fabrics were found to be decreased when spandex yarns were used but no difference was noted with the change in denier of spandex. Thermal insulation of fabrics increased with the increased in linear density of spandex.

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Effect of Number of Web Layers on Properties of Needle Punched Polyester Nonwoven Fabric

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Abstract

This investigation is intended to develop anunderstandingof the effect of number of web layers on characteristics of needle punched polyester nonwoven fabric. Three different needle-punched nonwoven fabric samples were manufactured by varying number of layers viz. 6, 8 and 10 such that the resultant areal density of fabric remains constant. Needle punched nonwoven fabric was manufactured from polyester staple fibre of length 80 mm. Other machine parameters like punch density (180 punches/cm2) and depth of penetration (8mm) were kept constant. Experimental results show that with anincrease in number of layers there is gradually increase in fabric thickness but the porosity and air permeability decreases. However, fibre orientation becomes more random which is essential for effective filtration performance of thefabric. There is no influence of achange in number of layers on the mechanical properties of fabric. A sample having 10 layers has a better filtration characteristic that shows optimum thickness with desired porosity and permeability with same areal density as that of other samples.

Keywords: Filtration, Orientation, Pore size, Mechanical properties, Web layers

1. Introduction

Nonwovens are the products made by parallel laid, cross-laid or haphazardly laid webs reinforced by mechanical means or with the utilization of adhesives or thermoplastic filaments under use of heat and pressure. The popularity of these fabrics is developing colossally in view of its variable yet one of kind properties.Nonwoven fabrics are call as tailor-made fabrics as we can manufacture the fabric with fancied properties. Fabrics properties of nonwovens range crisp to that soft-to-the-touch to harsh, difficult to-tear to greatly feeble. This prompts an extensive variety of the items, for example, nappies, channels, teabags, geo-materials; and so on, some of which are strong and others are expendable. Alternate properties are compressibility, versatility. By applying different completions, the properties of nonwoven can be updated. They can be fire resistant, hydrophobic, hydrophilic, wash and corrosive resistance and hostile to microbial.

There are diverse process parameters that are required to be set while manufacturing nonwoven fabric with any technology. All these process parameters can affect the properties of produced fabric. By changing the process parameter, we can easily adjust the properties of the nonwoven fabric. To get desired properties in the last item it is critical to optimize the process parameters. Many studies were carried out on the effect of depth of penetration and punch density on properties of needle punched nonwoven fabric and the effect of number of layers is not much explored hence it is worth to study the effect of numbers of layers on the properties of the needle punched nonwoven fabric by keeping GSM Constant.

This study will focus on properties of needle-punched nonwoven by varying the number of layers keeping fabric areal density constant. This parameter has animpact on the properties of manufactured nonwoven fabric that is determined by characterizing the manufactured fabric samples.

2. Materials and Methods

In this study, recycled polyester fibres were used to manufacture nonwoven with needle punching technology. Nonwoven fabric samples were manufactured using web having three different number of layers viz. 6, 8 and 10 such that areal density of fabric remains unchanged. Other machine parameters like punch density (180 punches/cm2) and depth of penetration (8mm) were kept constant. Sample runs are shown in table 1.

Table 1 Sample runs

Sample	Number of Layers	Punch Density (Punches/cm^2)	Depth of Penetration (mm)
NL 6	6	180	8
NL 8	8		
NL 10	10		

All the manufactured fabric samples were characterized in standard atmospheric conditions for different properties such as areal density, thickness, fibre orientation, porosity, air permeability, bursting strength, tensile strength. After testing properties of nonwoven samples, the obtained results were analyzed by using one way ANOVA.

3. Result and Discussion

3.1 Areal density and fabric thickness

The areal density (GSM) describes the mass of material per unit area of the textile material determined according to ASTM D5261. It has been found that there is no significant effect of number of layers of GSM fabric as the study is carried by keeping the GSM of fabric constant.

The thickness of needle punched nonwoven fabric was tested according to ISO 9073-2 standard on SDL Atlas digital thickness tester. Fig. 1 shows the effect number of layers on thethickness of polyester needle punched nonwoven fabric.

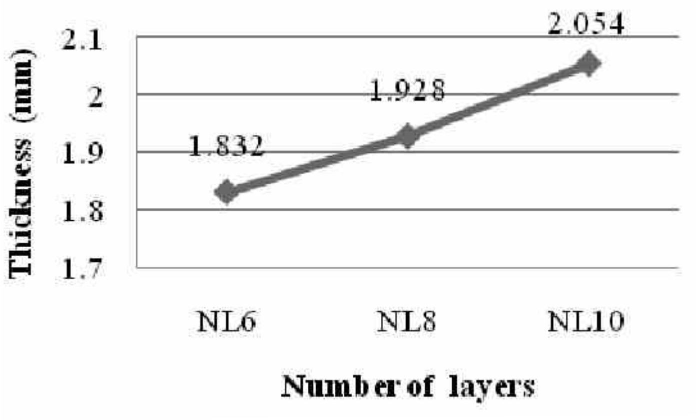

Figure 1: Fabric thickness

From fig. 1, it can be clearly seen that with anincrease in number layers from 6 to 10 there is 12.11% increase in fabric thickness. The effect number of alayeroffabric thickness is significant. This can be attributed to thefact that, as number of layers increases the consolidation is rather poor and perfect compactness is not achieved due to aconstant depth of needle penetration. This result in theformation of voids between the fabric layers which leads to increased loftiness of the fabric and intern the thickness of the fabric. Hence without altering any machine (punch density, depth of penetration, speed, etc.) as well as amaterial parameter (type, quantity, etc.)we can alter the fabric thickness just by increasing the number of web layers keeping resultant areal density constant.

3.2 Pore diameter

Porosity is the gross measure of open volume in the given nonwoven fabric. Pore size distribution is a pre-requisite to investigate any transport phenomena, especially in a porous include filtration, separation [6].

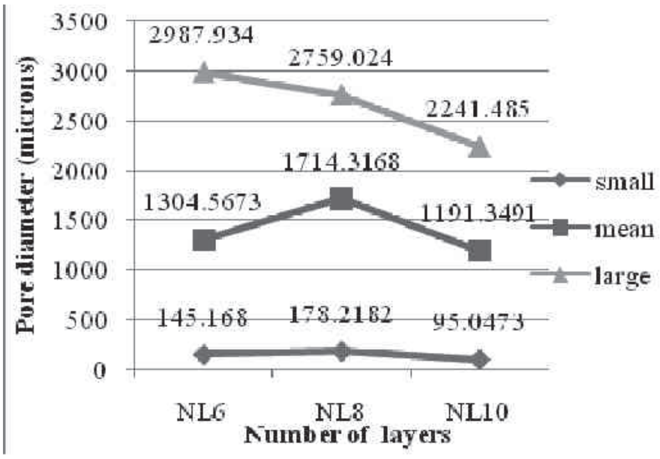

Figure 2: Pore diameter

Testing of pore size of needle punched nonwoven fabric was carried out according to ASTM F316-03. The pore diameter was obtained in terms of small, mean and large by porosity test method. Figure 2 exhibits the effect of number of layers on pore diameter of needle punched nonwoven fabric.

From fig. 2, it can be observed that as number of layers increases there is adecrease in small, mean as well as large pore diameter. However, this trend is not significant. One of the possible reasons behind this trend is overlapping of fibres. As the number of web layers increases, there is amore random arrangement of fibres that causes overlapping of fibres resulting enclosement of the pore. Because of enclosement of pores by subsequent layers, there is areduction in pore diameter.

3.3 Bubble point pressure

It is a pressure across the fabric required to form a bubble on the surface. It depends on the fibre arrangement and pore diameter. Figure 3 shows the effect of number of layers on bubble point pressure.

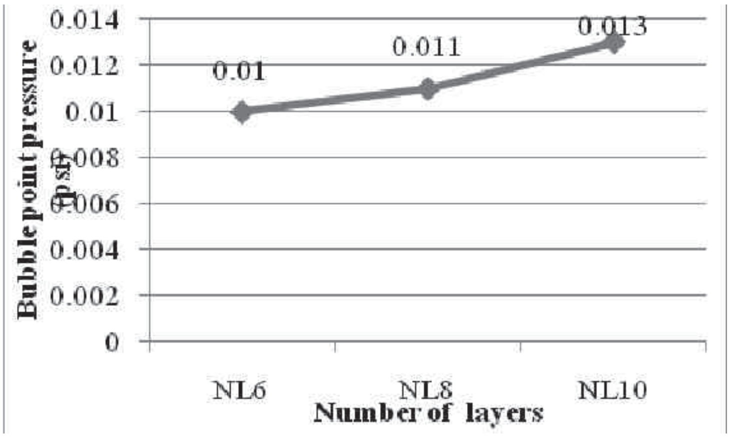

Figure 3: Bubble point pressure

From figure3, it is clearly inferred that the bubble point pressure significantly increases as the number of layers increases. As number of layers increases the randomization in the fibre arrangement increases which result in overlapping of fibres. This overlapping of fibres tends to reduce the pore diameter and makes it compact. For the compact structure of the fabric with small pore size, more pressure is required to force fluid of certain volume through it. Hence, more pressure drop is there across the fabric having 10 layers as it has smaller pore size.

Bubble point pressure increases by 30% from NL6 to NL10 fabric.

3.4 Sectional air permeability (SAP)

Sectional air permeability is used to compare the permeability of different fabric samples. Air permeability does not show any relationship with fabric thickness. This is due to reason that permeability of the fabric can be considered in terms of cross-sectional area of each whole, depth of each hole per unit area. It is conceivable that to thefabric may have same permeability. It is, therefore, desirable to have figure independent of thickness to represent air openness of fabric i.e. sectional air permeability defined as air permeability of fabric [7]. On TexTest-FX3300 machine, the testing of air permeability of nonwoven fabric is carried out by ASTM D737-96 standard. The effect of number of layers on air permeability of polyester needle punched nonwoven fabric is shown in fig.4.

Fig. 4 gives the clear idea that as number of layers increases sectional air permeability increases. The effect of number of layers on sectional air permeability is significant. Although air permeability does not seem to change with the thickness of fabric, the SAP changes almost proportionately with a thickness of fabric and the same trend was observed by Vinay Kumar Midha [7].

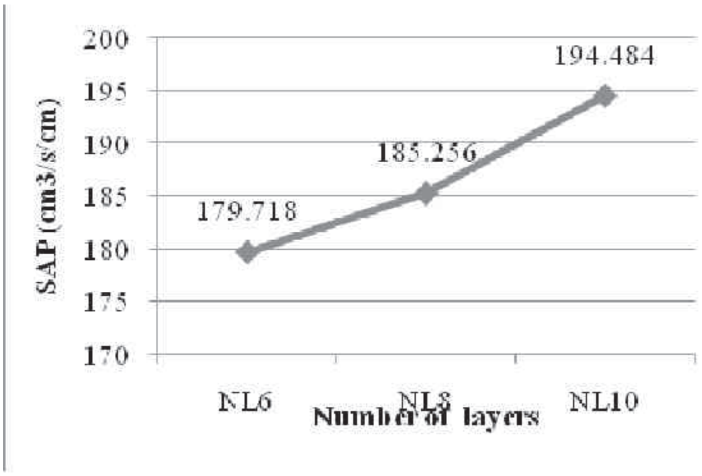

Figure 4: Sectional air permeability of fabric

SAP decreases with increase in fabric weight. While theincrease in number of layers, the fabric become thicker. Though the number of pores increases with increase in number of fibre, the pore size becomes smaller. Maximum pore size distribution and the diameter at maximum pore size distribution increases as number of layers increases. SAP and thickness are negatively correlated with significant correlation coefficient as shown in both the graphs.

3.5 Nonwoven orientation

The orientation of fibre that is in thenonwoven structure is a key element in the direction or degree of orientations that affects the property such as tensile strength and elongation. The arrangement of fibres in nonwoven is described not only by the fibre packing arrangement but also by fibre directional arrangement that is fibre orientation. The web structure plays significant role in helping to determine the physical characteristic of needle punched fabric. Needle punched fabric is focused on weight uniformity that is MD and CD [8].

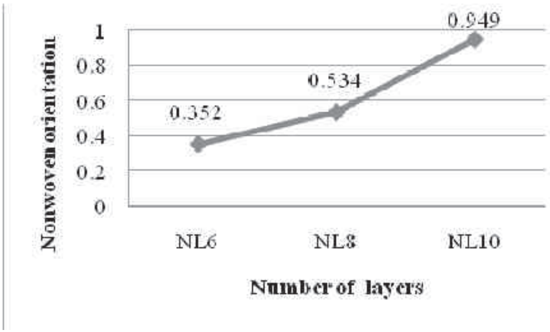

Figure 5: Nonwoven orientation of fabric

The testing of nonwoven orientation is carried on lazing instrument NOS 200 machine by in house method. The effect of number of layers on fibre orientation is shown if fig. 5.

There is asignificant effect of number of layers on fibre orientation. Fibre orientation increases as number of layers increases. There is169.60% increase in the orientation from number of layer 6 to number of layer 10. There is asignificant effect of number of layers on thenonwoven orientation of the fabric. As the number of layers increases the randomization of the of the fibres increase which is represented by MD/CD ratio. The randomization is due to more number of fibres are laid in adifferent direction for constant GSM of the fabric.

3.6 Tensile strength

Mechanical properties of the material are important where the material is subjected to loading during its implementation. The tensile strength of needle-punched nonwoven is tested by ISO 9073-3 standard on Instron 5967.

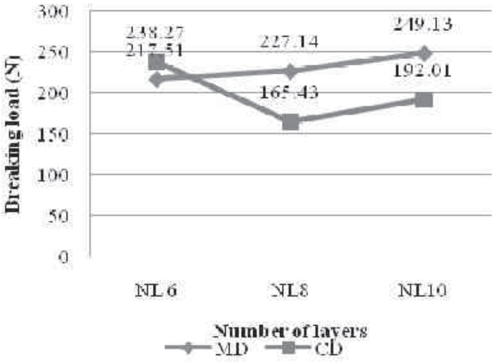

Figure 6: Breaking load of fabric (MD and CD)

From fig. 6, we can conclude that there is no significant effect of number of layers on the tensile strength of fabric both in the machine direction and cross direction. There is no significant effect of number of layers on breaking load of the fabric. This is because all the fabric samples were manufactured by keeping constant areal density. Because of which the load-bearing component per unit area of fabric remains same in unit area. Hence, tensile properties are unaffected.

3.7 Extension

Fig. 7 exhibits the effect of number of layers on the extensibility of samples.

From fig. 7, it can be observed that there is no significant effect of number of layers on the extension of the fabric i.e. trend is undefined. This trend is due to fact that more randomized orientation. This randomized orientation leads to uniform distribution of the load in all direction.

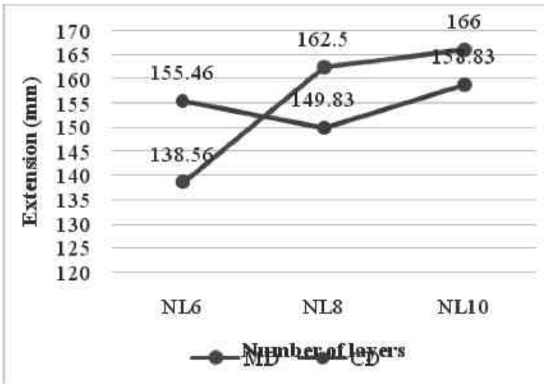

Figure7: Extension of fabric

3.8 MD/CD Ratio

MD/CD ratio is the indicator of ananisotropic characteristic of fabric. From MD/CD ratio, we come to know about directional effects. Fibre orientation affects this ratio. Fig. 8 shows the effect of number of layers on the MD/CD tenacity ratio of fabric.

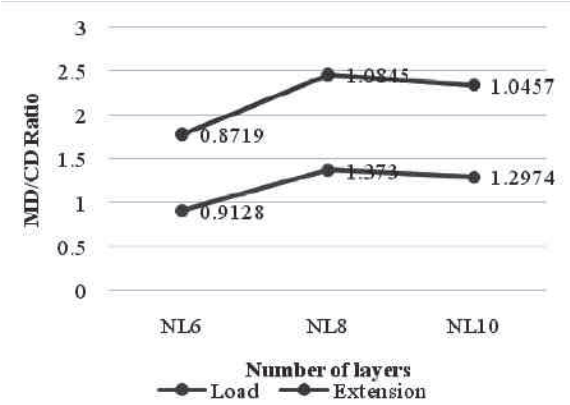

Figure8: MD/CD Ratio

There is no significant effect of number of layers on MD/CD ratio. Fabric shows similar properties in themachine as well as cross direction. This is because of increased fibre randomization.

3.9 Bursting strength

The bursting strength of needle punched nonwoven fabric was carried with ISO 9073-2 standard. Fig. 9 shows effect number of alayer on bursting strength of thefabric.

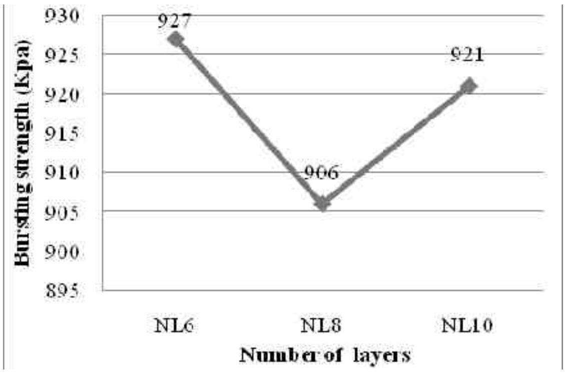

Figure9: Bursting strength of fabric

As we see in the fig.9, there is no significant effect of number of layers on bursting strength of thefabric. It is well known fact that with anincrease in weight, there is anincrease in bursting strength but in this, the GSM of fabric is constant hence there is no significant effect on bursting strength. The other reason can be given as the percentage difference is theminimum from number of layer 6 to number of layer 10 i.e. 0.64%. That there is no significant effect of number of layers on bursting strength of the fabric.

4. Conclusion

With theincrease in number of web layers fibreorientation become more random and increases fibre overlapping.Increased fibre overlapping at ahigher number of web layers encloses pores resulting reduced pore diameter.Bubble point pressure increases with increase in number of layers.Due to constant weight per unit, anarea the load-bearing component remains constant so tensile properties remain unchanged.By increasing number of web layers, there is asignificant change in structural characteristics of polyester needle punched nonwoven fabric.However,mechanical characteristics remain unchanged.Hence, we can design a fabric of desired filtration characteristics without altering other properties. A sample having 10 layers has a better filtration characteristic that shows optimum thickness with desired porosity and permeability with same areal density.

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Thermal Properties of ABS/PA6 Blends Compatibilized with Fixed Weight Ratio SAGMA Copolymer

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Abstract

SAGMA Copolymer has been demonstrated to be an efficient reactive compatibilizer for the incompatible polymer blends of ABS and PA6. Thermal properties; TGA, HDT and Vicat softening temperature of Blends of acrylonitrile-butadiene-styrene (ABS) and Nylon 6 (PA6) incorporating styrene-acrylonitrile-glycidyl methacrylate (SAGMA) copolymer as compatibilizer have been studied across five different compositions by varying the PA6 ratio from 15 wt% to 55 wt%. The change of morphology from discrete dispersed PA6 particles to phase inversion to co-continuous phases effected due to the compatibilizeris responsible for evolution of thermal properties.

Introduction:

The utilization of polymer blends is an increasingly important segment of the plastic industry. The demands for many applications need a set of properties that no polymers can fulfil. One method to satisfy these demands is by missing two more polymers. Mixing two more polymers to produce blends is a wellstabilished route to achieve desirable properties, without the need to synthesise specialised polymer systems. Blends of polyamides with ABS materials are of commercial interest and are a useful model system for exploring this concept owing to the inherent reactivity of the polyamide and the abundant options for designing functional polymers that would be miscible with the sytrene/acrylonitrile copolymer (SAN) matrix of ABS [1-7].

The problem of immiscibility of polymer blends can be overcome to a great extent by the introduction of a third component which acts as an interfacial agent to reduce the interfacial tension and promote adhesion at the interfaces. This third component, generally known as compatibilizer [8-10]; may be a block or graft copolymer capable of reacting with the amine end groups of the polyamide and is miscible with the SAN phase of ABS. The incorporation of compatibilizers like MAH, IA, SMA, SANMA and SAGMAimproves the mechanical properties of the polymer blends [11] as they effectively "stitch" themselves across the polymer/polymer interfaces thusreducing the possibility of interfacial failure [12-15].

In the present study, wereport on the changes in thermal properties associated with ABS/PA6 blends in which PA6 is incrementally incorporated into an ABS matrix at a fixed compatibilizer (SAGMA) weight ratio.

2. Experimental

General purpose molding grades of ABS Cycolac EX 10 U by UMG ABS Limited; Japan and PA6 Grade M-40 RC by GSFC; India were used to prepare the different blends of study. SAGMA copolymer (styrene acrylonitrile glycidyl methacrylate] having GMA 2 wt% was synthesized in the lab according to an adapted procedure [16]. This SAGMA copolymer was used as compatibilizer at a fixed 10 wt % in the blends. The compositions of the blends prepared are given in Table 1.

Melt blending for the preparation of the blends was performed by a conical intermeshing co-rotating twin-screw extruder, L/D =24 and 120 rpm, attached to a HaakeRheocord RC - 90 Torque Rheometer equipped with cooling bath and strand cutter using an extruder temperature profile :Feed zone: 2150C; Compression zone : 2250C; Metering zone: 2350C; Die ring: 2500C; Die: 2400C employing the following sequential steps:

- PA6 pellets were size reduced by grinding to increase their surface area to enable intimate melt mixing with SAGMA copolymer followed by vacuum drying overnight at 800 C. PA6 and SAGMA copolymer were extruded using the above processing profile and palletized.
- ABS and SAGMA modified PA6 along with antioxidant Irgafos 168 in accordance to the blends of study were dry blended in a tumbler mixer for approximately 30 minutes to enable good distribution and dispersion of the compositions. The dry blends were then vacuum dried at 800 C overnight prior to extrusion compounding.

- The extruded and pelletized blends formulations were vacuum dried at 800 C prior to injection moldingby a 120 ton Klockner Windsor Injection Molding Machine at 2400C. The injection-molded specimens for testing of various properties in accordance to ASTM were conditioned for at least 40 hours at 23 ± 20C and 50% RH prior to testing.

Scanning electron microscopy (SEM) was used to investigate the morphology changes using fractured surfaces from izod impact tests. The fractured surfaces were etched in formic acid for 24 hours to remove PA6, dried under vacuum and coated with a thin uniform gold film by an Ion Sputter JFC-1100.Micrographs were taken by a JSM-840, Jeol Scanning Microscope at 5000 X magnification tostudy the morphological changes.

Thermal degradation of the blends was analyzed by a TA Instruments Simultaneous TGA-DTA, Model 2960 in the dynamic mode at 10 0C/min from room temperature to 860 0C.

The vicat softening temperatures were determined by a Toyo Seiki Seisaku-shoVicat Softening / HDT Apparatus under one kilogram load and heating rate of 50o C / hour till 1 mm probe penetration was obtained. Two readings for each blend were taken and averaged.

The blends samples having dimensions of 20 mm ? 20 mm ? 3.0 mm were tested in accordance to ASTM D-1525.

Heat distortion temperatures were measured in accordance to ASTM D-648 by a Toyo Seiki Seisaku-ShoVicat softening / HDT Apparatus. Specimens having dimensions of 127 mm ? 13 mm ? 3.2 mm and 127 mm ? 13 mm ? 6.4 mm under 264 psi and 66 psi load and temperature ramp of 1200C were tested till a deformation of one-fourth millimeter was obtained. Tests were carried out on annealed and unannealed specimens. Annealing of specimens was carried out at 800C in an air-circulating oven for 4 hours. Two readings for each blend were recorded and averages presented.

3. Results and Discussion

3.1Vicat Softening Temperature

Vicat softening temperature of the blend sample and control ABS are given in Fig. 1. The vicat softening temperature of neat ABS is 105.50C. As 15% and 25% weight ratio of nylon 6 incorporated in the blend, no significant change is seen in the vicat softening temperatures, which are essentially comparable 103.50C and 104.5 0C, respectively. Beyond 25% weight ratio of nylon 6, an increase in the trend of values are observed, a slight increase by 50C is observed at 35% of nylon 6 weight ratio.

Further increase in the nylon content shows a steep rise in the vicat softening temperature (VST). Vicat softening temperature is recorded 143.5 0C and 180 0C for the blend in which nylon 6 is incorporated 45% 55% by weight ratio respectively.

Incorporation of greater quantity of nylon 6 (i.e. 45 and 55%) blend accounts for the steep rise in the value of vicat softening temperature, as the vicat softening temperature of nylon 6 is as high as 2150C and this starts influencing the blend material. It is interpreted from the obtained data that when nylon 6 is included in the blend up to 45% by weight and 55% by weight, the vicat softening temperature became 1.4 times and 1.7 times respectively than that of neat ABS, which is 105.5 0C.

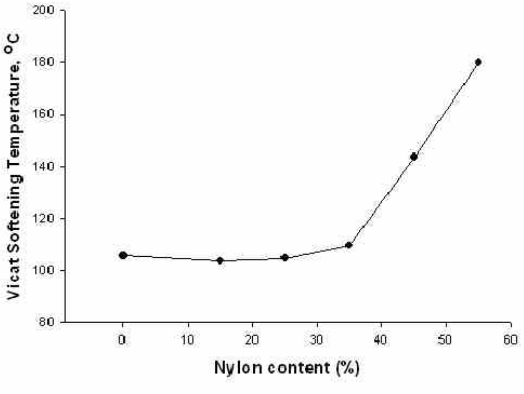

Fig: 1. Vicat softening temperature of ABS/Nylon 6 blends at varying composition

3.2 Heat Distortion Temperature:

It indicates the temperature limit above which polymer cannot be used for structural application.

In case of an amorphous polymer (ABS) heat distortion temperature is slightly (10 to 200C) lower than Tg, while in the case of semicrystalline polymer heat distortion temperature is more closely identified with Tm. Blends of one polymer with another having greater or lower Tg can be used to modify the Tg or heat distortion temperature of another polymer.

Heat distortion temperature (HDT) of unannealed and annealed control ABS and its blend sample with nylon 6 are given in figures (2 and 3).

3.2.1 Heat distortion temperature (HDT) of Unannealed Samples

Heat distortion temperature (HDT) at 264 psi load at ¼" of unannealed sample of neat ABS is 870C. Incorporation of varying amount of nylon 6 in the blend by 15%, 25%, 35%, 45%, and 55% by weigh ratio, the HDT obtained are 83.50C, 82.50C, 830C, 800C and 750C respectively. Different values of HDT of sample blends show a gradual decreasing trend with respect to HDT of neat ABS as the nylon content increases in the blend.

Heat distortion temperature (HDT) at 264 psi load when recorded at 1/8" its value for neat ABS comes to be 78.50C. When different ratio of nylon 6 is added to the blend in ratio of 15%, 25%, 35%, 45%, and 55% by weight the values of HDT obtained are 73.50C, 72.50C, 700C, 68.50C, and 63.50C respectively. Similar declining trend of HDT is observed as it was in the case of ¼" with the increase in the content of nylon 6. This decline in HDT is of narrow margin in both the cases.

The HDT at 66 psi load at ¼" of unannealed sample of neat ABS is 94.50C. The incorporation of nylon 6 15% weight ratio leads to decrease HDT to 920C. Any further incorporation of nylon 6 up to 55% weight ratio does not lead to any further decrease in HDT.

The HDT of at 66 psi load at 1/8" of unannealed sample of neat ABS is 890C. The incorporation of nylon 6, by 15% weight ratio, results in a decrease of HDT, which comes to be 840C. But further increase in nylon 6 contents by 25% and 35% by weight ratio shows a lower but identical HDT value, which is 830C. Beyond 35 % weight ratio of nylon 6 again a down face in HDT is observed for 45% and 55% weight ratio of nylon 6, which comes to be 820Cand 77.50C respectively.

Comparison of HDT of unannealed blend samples at ¼" at 264 psi load and 66 psi reveals that at higher load (264 psi) a regular declination in the HDT of blends samples is seen but at the lower load (66 psi) no significant decrease in the HDT is observed.

From the above data an inference is drawn that at 264 psi load, blend containing higher content of nylon 6 bends at lower temperature as compared to neat ABS. Nylon being soft component (ductile) and possessing low glass transition temperature (Tg) accounts for this behavior of the blend material. Also the value of rigidity looses as the nylon content increases in the blend.

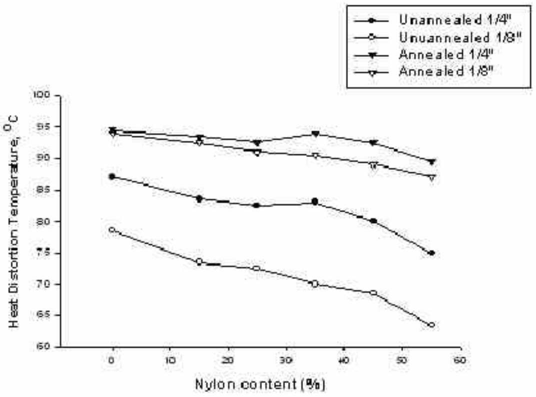

Fig: 2. Heat distortion temperature at 264 psi load of unannealed and annealed samples of ABS/Nylon 6 blends at varying compositions

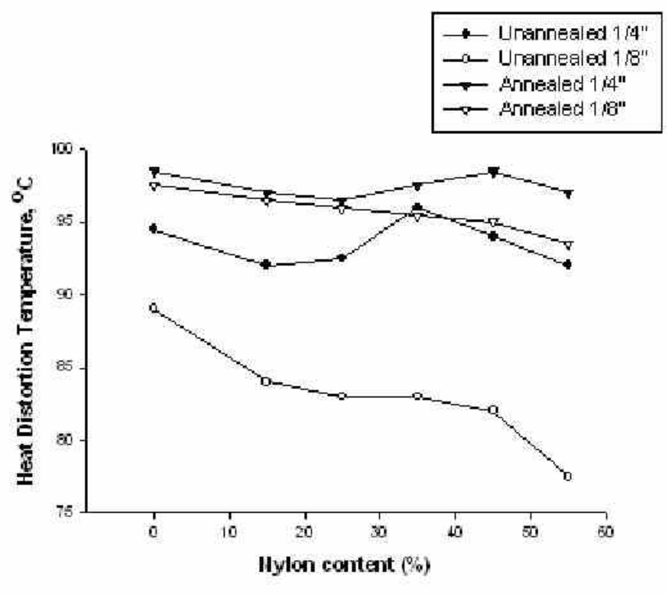

Fig: 3. Heat distortion temperature at 66 psi load of unannealed and annealed samples of ABS/Nylon 6 blends at varying compositions

On the other hand, at 66 psi load, the blend with higher content of nylon 6 bends at comparable temperature to that of neat ABS. The lower Tg of nylon 6 is compensated by high HDT of value (165 ±5 0C) of nylon 6 and this effect is accountable for no significant decrease in the HDT of blend in comparison to neat ABS and as such rigidity of the blend material is not reduced to a greater extent.

3.2.2 Heat Distortion temperature (HDT) of Annealed Samples

The HDT at 264 psi load at ¼" of neat ABS is 94.50C. The incorporation of nylon 6 in the range of 15% to 55% weight ratio leads to gradual decrease in a narrow margin from 93.50C for the blend incorporating 15% nylon 6 weight ratios to 89.50C for the blend incorporating 55% nylon weight ratio.

The HDT at 264 psi load at 1/8" of annealed sample of neat ABS is 940C. The incorporation of nylon 6 in increasing order of weight ratios by 15%, 25%, 35%, 45% and 55% leads to HDT values to be 92.50C, 91.00C, 90.50C, 89.00C, and 87.00C respectively showing a regular decline in HDT of blend material in comparison to that of neat ABS. HDT of annealed neat ABS at ¼" at 66psi load is 98.50C. As nylon 6 content is enhanced by 15% up to 55% weight ratio, no significant declination in the value of HDT is observed.

The HDT at 1/8" at 66 psi load of neat ABS is 97.50C. Incorporation of nylon 6 in increasing order of weight ratio 15%, 25%, 35%, 45% and 55% revealed a decrease in HDT as 96.50C, 96.00C, 95.50C, 95.00C, and 93.50C respectively. From above data it is evident that a regular downfall in the values of HDT is observable for the blend material. From the data obtained so far HDT of annealed blend samples at ¼" and 264 psi load states that there is a decrease in value of HDT of sample blends with respect to neat ABS. HDT at 66 psi at ¼" of annealed blend samples follow the similar trend as it was in the case of unannealed HDT of 66 psi at ¼".

This decrease in the HDT of blend with the increase of nylon 6 ratio by weight is in accordance with the fact that annealing renders the blend less brittle and more workable. In addition, annealing increases the ductility and lessens the possibility of failure by relieving internal strains, which in turn is the result of three dimensional network structure formed during compatibilization.

Corresponding values of HDT of annealed blends are higher than unannealed blend samples, which depend upon the combine effect of rigidity and glass transition temperature (Tg). The higher value of HDT of annealed blends can be explained in terms of crystallinity and rigidity. High HDT of annealed blends are in accordance with the fact that annealing render the blend less brittle and more workable. In addition annealing increases the ductility and lessens the possibility of failure by relieving internal strains. Annealing imparts dimensional stability and refines the grain size, which is responsible for high HDT.

3.3 Thermal stability

TGA results depicted in Table 2 show that there is no observable weight loss upto 395 0C for control ABS and 420 0C for control PA6. The onset temperatures of degradation for the blends essentially lay between that of both individual components. The onset temperatures were nearer that for ABS and increased with PA6 wt%. This showed good thermal stability of the blends despite two extrusion compounding steps during preparation.

Table 1 Composition of blends

S.No.	Sample Notation	ABS wt%	PA6 wt%	SAGMA copolymer wt%
1	Controal ABS	100	0	0
2	S_A	75	15	10
3	S_B	65	25	10
4	S_C	55	35	10
5	S_D	45	45	10
6	S_E	35	55	10

Table 2Thermal degradation data for ABS/PA6/SAGMA blends SA to SE at 100C/min

S.No.	Sample Notation	PA6 wt%	Degradation Onset Temperature ºC
1	Control ABS	0	396
2	Control PA6	100	422.5
3	SA	15	392
4	SB	25	396
5	SC	35	399
6	SD	45	401
7	SE	55	406

4. Conclusion

Blends of ABS and PA6 in varying ratios from PA6 15 wt% to 55 wt% and incorporating SAGMA copolymer as compatibilizer were prepared by a two-step extrusion compounding procedure to overcome incompatibility of the blend components. In previous paper we have discussed morphological changes from discrete PA6 particle dispersion at PA6 15 wt% and 25 wt% has been evidenced with phase inversion at PA6 35 wt% to co-continuous phases at PA6 45 wt% and 55 wt% resulting from partial dissolution of blend components effected by PA6-g-SAGMA at the interface [6-7]*. DMTA analyses also support partial dissolution by the observed shifts in Tgs of the blends components towards each other accompanied by broadening of the Tg peak of PB of ABS [6].

Incorporation of greater quantity of nylon 6 (i.e. 45 and 55%) blend accounts for the steep rise in the value of vicat softening temperature as a result of compatibilization, as the vicat softening temperature of nylon 6 is as high as 2150C and this starts influencing the blend material. It is interpreted from the obtained data that when nylon 6 is included in the blend up to 45% by weight and 55% by weight, the vicat softening temperature became 1.4 times and 1.7 times respectively than that of control ABS, which is 105.5 0C.

The decrease value of HDT of annealed and unannealed blend samples with the increase of nylon 6 ratio by weight is observed. The sharp change is observed on incorporation of PA6 at 45 wt% and 55wt% as a result of better compatibilization.

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Hybrid Woven Fabric for EMI Shielding

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The problem of Radio-Frequency Interference (RFI) or Electro-Magnetic Interference (EMI) in the form of leakage of information, cross talks and generation of noise has arisen due to growth of rapid electronic industry and the widespread use of digital electronic equipment in telecommunications & radars and detection systems, computations, automations, biomedicine, space, scientific field and other applications. This has created serious EMI problems to the systems operating in close vicinity/surrounding. This, in turn, has led to high demand of EMI shielding materials. Microwave frequency for which the wavelengths are of the same order of magnitude as the dimensions of the human body produce close coupling between the body and the microwave field and large amount of heat may be generated to cause severe damage in the body. It may also have a direct effect on human tissue which creates serious health problem viz. Leukemia, Brain tumours, Alzheimer's disease, Allergies, stress, disturbed sleep and depressions etc.

Phenomenon of interaction of EM wave and electromagnetic shielding:

Electromagnetic shielding is a mechanism to prevent the propagation of electromagnetic fields into a space by blocking them with a barrier made of conductive material. The materials or equipments which protect a body, environment or a circuit from harmful electro-magnetic radiation is called shield. The electromagnetic wave interacts with the material in the form of absorption, reflection and successive internal reflections which results into cumulative attenuation. When electromagnetic wave impinges on the surface of the object, it forces charge particles of object to oscillate at the same frequency. This forced oscillating charge behaves as an antenna and reflection takes place. The incident wave re-radiates in many directions in a pattern associated with a signal and hence the field is scattered. The charge is forced to vibrate in the medium, which causes to loss the wave energy in the form of heat. This is known as attenuation due to absorption. Total shielding effectiveness is given by sum of reflection, absorption and multiple internal losses; $SET\ (dB) = SE_R + SE_A + SE_M$

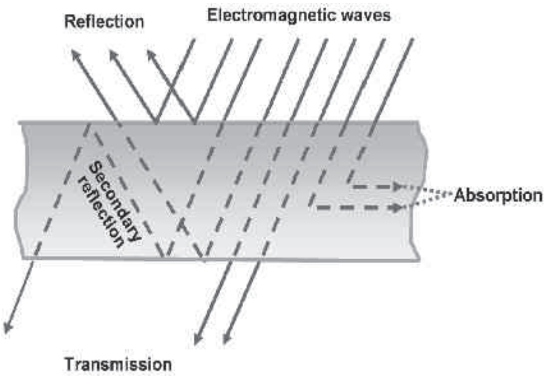


Fig. 1: Schematic representation of shielding phenomena

EMI Shielding Fabric based on conducting metallic wire/fibre composite yarn:

Metal fibre is a highly electrical conductive material. It is reported that the fabrics can be made using 100% stainless steel fibre in the weight range of 1000 g/m2 and thickness of 0.5 mm adopting knitting and weaving process. This high electrical conductivity leads to good EMI shielding characteristic. EMI shielding of woven and knitted fabric are also prepared with conducting yarn of copper/ stainless steel wire sheathed by polyester/polypropylene/ cotton/polyamide fibre. Woven and knit fabrics prepared by complex sheath core spun yarn, copper wire (0.05 mm diameter) in core and polyester staple fibre (38 mm staple length) in sheath for anti -

electrostatic dissipation and electromagnetic shielding. PP filament fibre as a matrix material and copper & stainless steel wires as conductive phase are used for EMI shielding composite materials. Copper wire of 0.08 mm diameter, stainless steel wires of 0.08 mm diameter and PP filament of 300d/96f are taken. Woven fabric forming a grid-like geometric pattern using PP filaments and rotor twisted conducting yarn (RTCY) into a 2/2 twill structure in both warp and weft directions with thread density of 80 ends/in. × 40 picks/in. have shown 30-40 dB EMSE in 30MHz- 1.5GHz.

Fabrics for EMI shielding effectiveness has also been prepared by sheath-core conducting yarn (328 tex) using 261 tex copper filament of 38 gauge in core and 4.22 g/m carded cotton sliver as sheath in the ratio of 67/33. Copper core conductive fabric exhibited the highest shielding effect in specifically lower frequency range of 760-860 MHz and can be used to shield television, computers, gadgets like cellular phones etc. EMI shielding of fabric prepared with copper / PET composite yarn of 500 denier by co- spinning of 40 µm diameter copper wire and 240 denier polyester filament together in plain, twill & satin weaves in weight range of 188-200 gsm, offered high SE of 40-50 dB in 2.25 - 2.65 GHz. Plain weave fabric showed improved shielding effectiveness due to minimum contact resistance, more interlacement of warp and weft with smaller aperture.

Woven fabrics prepared with hybrid yarns made of stainless steel wire (diameter 0.035 mm, density 8.0 kg/dm3, linear resistance 785 ?/m) covered with 100d/36f PES filament in different weave geometry have shown EMSE 25-65 dB in frequency range 30 MHz - 9.93 GHz for both the horizontal and vertical polarization. Density and arrangement of conductive hybrid yarn in fabric structure played an important role in effective electromagnetic shielding characteristics of woven fabrics. The woven fabrics containing hybrid yarns/ metal wire may be used to strengthen the walls and windows, in order to prevent the emission of electromagnetic energy. These fabrics may also be used in our house and office buildings for protection against electromagnetic radiation from the base stations of cellular phones, TV and radio broadcasting antennas, wireless network etc.

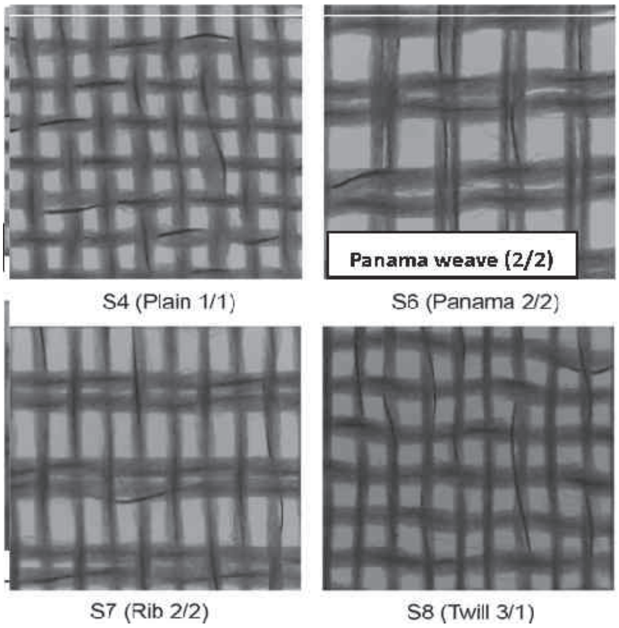


Fig. 2: Woven fabrics containing metallic wire in different weave geometry

Woven fabrics containing sheath core yarn, core stainless steel wire (dia 50 µm, density 7.9 kg/dm3, resistance 735 ?/m) and covering component cotton fibers in plain, sateen & twill weaves with weft density of 13 &15 Picks/ cm and warp density 15 ends/ cm have shown adequate electromagnetic wave absorbing properties in frequency range from 15 MHz to 3000 MHz. At high frequency range from 1200-3000MHz, the EMI shielding decreases.

EMI Shielding woven fabric prepared with metallic blended fibres:

When electromagnetic wave propagates through the metal fibre blended fabric, it gets attenuated due to absorption loss, surface reflection loss, fabric internal multiple reflection loss and loss due to difference in impedance. This energy attenuation of electromagnetic wave achieves shielding effectiveness. Metal fibre content and its distribution in fabric, fabric tightness plays a great role on the fabric shielding effectiveness. Stainless steel fibre blended fabrics have shown effective electromagnetic wave shielding. The best shielding effect was observed in the fabrics with conductive yarn in both warp and weft.

EMI shielding of woven fabric depends on denier of yarn, its conductivity level and thread density in the fabric. Higher is the conductivity, fabric surface will be more reflective. Generally, hybrid yarn (SS/PET) of conductivity level 150-700 ?/m in the denier range of 400-600 is preferred. The surface reflectivity depends on surface resistivity of woven fabric. Less resistive surface is the more conductive which offers higher reflection; this in turn depends on conductivity of yarn itself and closeness of yarn in warp and weft direction. Fabric with yarn density 24 x 24 to 32 x 32 in the weight range approx 100 gsm, surface resistivity lies in the range of 8 to 20 ?/? which offers reflection more than 50%.

Fabric weave geometry also plays a significant role in EMSE. Woven fabric in different weave design i.e. Plain, Twill, Satin, Bedford weave (Weft rib + Plain), Weft rib, Hopsack, Compound twill, Reinforced sateen, Stripe weave (Twill +Twill), Crepe weave etc. using hybrid yarn made of stainless steel metal fibers and cotton fibers in three groups (A: 20% SS metal fibre, B: 15% SS metal fibre and C: 10% SS metal fibre) are prepared. Fabrics with different weave geometry have different yarn float length which causes the change of inter-space of yarn and aperture size for propagation of wave. This changes the micro arrangement of metal fibre and response towards electromagnetic wave. Smaller float length samples, Plain weave (sample 1) and Broken twill weave fabric (sample 7) have shown highest SE whereas long float weave samples, sateen weave (sample 4) and Hopsack weave (sample 6) have shown less SE at 1.5, 2.0 and 2.5 GHz frequencies. Also, 'A' group fabric with higher metal content has shown highest SE at each frequency range.

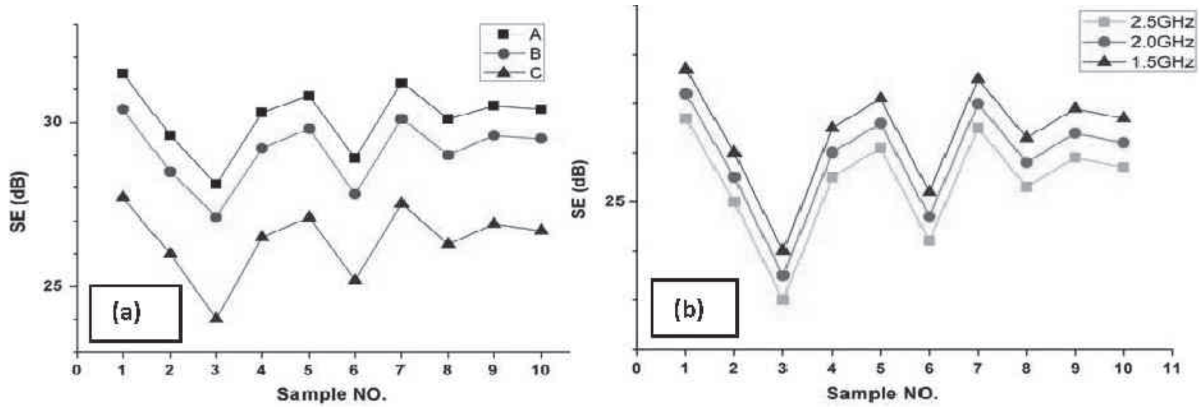


Fig. 3: EMSE of woven fabric (a) in different weave design, (b) at different frequency

Hybrid electromagnetic shielding fabrics are also prepared in twill weave using polypropylene / SS blended yarn containing stainless steel metal staple fiber in 1, 3, 5, 10, 15, 20 % (SS fibre configuration: dia 8 ?m, fiber length 50 mm).

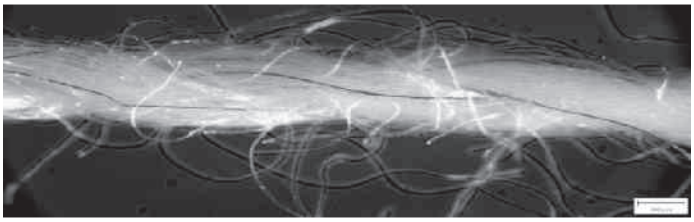
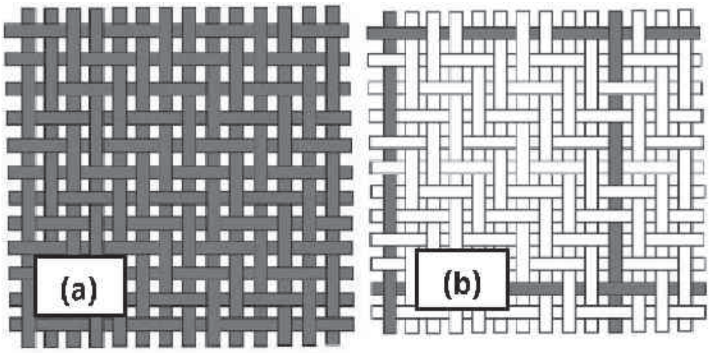


Fig. 4: Microscopic images of hybrid yarn containing 5% of stainless steel fibre

The first six samples were made of 100% hybrid yarn containing different portion of conductive phase, second six samples were made of polypropylene twill with mesh (5x5 mm) composed of the hybrid yarn.



For first group of samples made with POP/SS hybrid yarn (SS fibre composition 1-20%), EMI SE varies from 19.26 - 36.02 dB, and second group of samples with 5 mm x 5 mm mesh (SS fibre composition 1-20%), EMI SE varies from 4.2- 16.72 dB at 2.4 GHz.

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An overview of Electromagnetic Interactive Textile

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Abstract-

This technical paper deals with the electromagnetic interactive textile for defence applications. In today's scenario textile based fabrics has immense applications in defence and civilian industry. The presented paper deals with the overview of electromagnetic interactive fabrics in camouflage and in other strategic applications. For the development of camouflage textiles, various conducting dielectric and magnetic materials, smart materials along with base fabrics are required. Based on sequential approach, various camouflage/stealth products e.g. mobile camouflage system, multi-spectral camouflage nets, textile decoys, military textiles are developed for various applications.

Index Terms - Camouflage materials, textile fabrics

I. INTRODUCTION

The word Camouflage is meant for deceiving or disguising or to conceal in order to reduce the possibility of detection. In a military sense it is used for a system that disguises forces and equipment against detection by adversaries.

The history and inspiration of camouflage is taken primarily from nature, as some natural materials e.g. lizards, frogs etc, which quite often used for protection and survivability. Camouflage materials have long been employed to conceal objects, personnel, and equipment in various terrains from visual detection. Generally, such camouflage materials are drapable sheets or net structures of varying size and shape possessing colored, dyed or printed in multiple color patterns. In general various combination of colors, patterns and textures are used for disrupting or match the contour as well as merging with the background. The application of camouflage material in various forms e.g, sheets, fabrics, nets, and decoys are used for various deployment. Broadly camouflage materials or products works differently in various region of electromagnetic spectrum. On the other hand various sensors are employed for detecting the camouflage products in UV, near infra-red (NIR), far infra-red (FIR), radar in the millimetric or centimetric band, and acoustic ranges.

Briefly camouflage is more than just blending into foliage. It means blending into background in the infrared and ultraviolet spectrum as well. Handheld IR sensor is widely found, even in commercial form and UV sensor is often employed as airborne sensors. In totality camouflage includes all the countermeasure technologies which is used for electromagnetic region.

2. CAMOUFLAGE MATERIALS

Camouflage materials can be broadly classified into three categories based on their applications which are as follows

a. Built-in Camouflage

Add-on Camouflage is an aspect of built-in camouflage which applies to retro-fit situations, Built-in camouflage include exhaust cooling, shielding, dissipation, structural arrangements to reduce highly reflective geometries, and flash suppressors. Many built-in features can only be used successfully when an item/system is in its concept formulation, engineering development, or early prototype stages.

b. Operational camouflage:

In field situations, the material responds to the local tactical situation and the degree of camouflage applied by the field commander. Included are such matters as sound and light discipline and proper use of terrain and shadow in position and movement of troop training and that cause successful operational camouflage

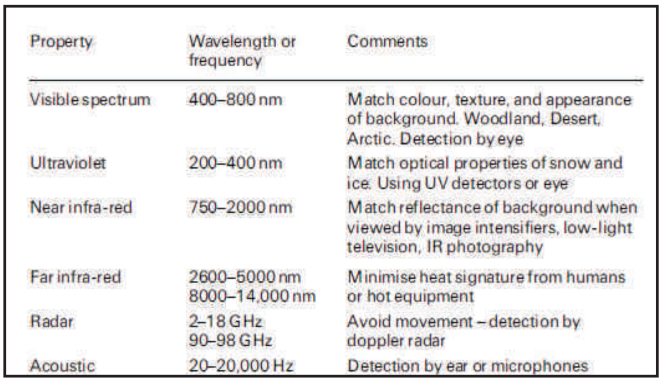
c. Field Applied Camouflage:

Troops in the field apply camouflage to themselves or to their equipment by using either locally available material such as mud, brush or grass, or materials issued from inventory, such as camouflage screens, multiband width camouflage material.

3. CAMOUFLAGING IN ELECTROMAGNETIC REGION

The concept of camouflage works in various spectrum of electromagnetic region starting from visible to acoustic region, a broad summary has been given in table I.

Table :I Electromagnetic Spectrum



Property	Wavelength or frequency	Comments
Visible spectrum	400–800 nm	Match colour, texture, and appearance of background. Woodland, Desert, Arctic. Detection by eye
Ultraviolet	200–400 nm	Match optical properties of snow and ice. Using UV detectors or eye
Near infra-red	750–2000 nm	Match reflectance of background when viewed by image intensifiers, low-light television, IR photography
Far infra-red	2600–5000 nm 8000–14,000 nm	Minimise heat signature from humans or hot equipment
Radar	2–18 GHz 90–98 GHz	Avoid movement – detection by doppler radar
Acoustic	20–20,000 Hz	Detection by ear or microphones

4. DESIGN OF CAMOUFLAGE TEXTILES

There are various parameters that affects the camouflage efficacy of the materials which are as follows:

a. Ph factor

The chromospheres and the auxochromes tend to change the parental color, when it is placed in contact with acid/alkali material. It is quite important to consider the Ph factor of the constituent materials for development of camouflaged products.

b. Bond breaking/making

There are a number of systems that undergo reversible bond-breaking, bond-forming processes that result in dramatic color changes. Most commonly, these are light-initiated processes.

c. Photo chromic material

The change in color effect is due to incident light. Till date, photochromism is most important for optical switching data and imaging systems. They emit the color when activated by visible light and those emit different color when activated by ultraviolet radiation.

d. Thermoochromic materials

As the name suggest, it is a chromic material that changes color based on heat effect. But this thermochromism is difficult to attain because changes in the fabric can be found when the temperature difference is high typically 100-200°C, and so are not of much use for producing thermo chromic effects on textiles. An alternative method of inducing thermo chromism is by means of a rearrangement of the molecular structure of the dye, as a result of a change in temperature.

5. DEVELOPMENT OF CAMOUFLAGE TEXTILES

a. Camouflage fabrics

Fundamentally textile fabric broadly consists of synthetic polymer multifilament yarns which can be classified in three types: i. Multifilaments comprising carbon black in an amount of from about 10 parts per million to about 300 parts per million, ii.Multifilament comprising pigments which modify a NIR reflectance characteristic, iii. Multifilament substantially free of additives capable of modifying the NIR reflectance. Characteristics of third type of multifilament exhibited a single substantially uniform color appearance in the VIS spectrum of 400-680nm and further exhibited a patterned appearance in the NIR spectrum of 700-900 nm due to different NIR reflectivity of the component multifilament yarns.

b. Camouflage wools

Photo chromic wool fabric is prepared by applying a photo chromic- dye hybrid silica sol-gel onto the surface of fabric. The photo chromic fabric have a very quick optical response. The silica sol is prepared by mixing silane, TAS, water, and ethanol with the ratio of silane: TAS: ethanol: water at 1:1:10:7 (mol), and stirring intensively at room temperature for 24 hours. Further 0.5% of photo chromic dye-ethanol solution was then added into the as-prepared silica sol solution (15 ml) and stirred for 20 minutes to give a homogeneous solution. A piece of wool fabric padded with this dye-silica sol solution and dried at room temperature and cured. UV-VIS spectrometer is carried out in the wavelength range of 450-800 nm.

c. Camouflage Pigment Coating

The optical properties of paint films and dyed or printed fabric surfaces can be largely attributed to the type of pigment present. Thus, application of surface coating techniques to the field of camouflage has resulted in a need for information on the optical properties of pigments in the infrared region.

d. Camouflage dyed fabrics

The fabric is dyed to a substantially single color appearance in the visible spectrum. In general, the fabric has a NIR spectrum comprising two reflectance curves having about 10% to about 85% reflectance separated by about 5% reflectance in a range of wavelengths from about 700 to about 860 nanometers (nm).

Requirement for camouflage pigments/color

Camouflage prints have to meet extremely high standards of color fastness, infrared reflectance properties and consistency of shade:

1. Color matching of shade variation in visible region.
2. Ability to meet defined fastness requirement.
3. Ability to produce required infrared reflectance values.

6. Application of camouflage textiles

i. Visual decoys

Textile materials are widely used to fabricate and simulate the outline of high value military targets such as aircraft, tanks, missile launchers, and other vehicles. These decoys vary in their complexity depending on the source of the potential attack. If surveillance and target acquisition is at short range, and with sufficient time to study detail, then the decoy has to be a realistic three-dimensional copy of the genuine item. Inflatable decoys made from neoprene or hypalon-coated nylon fabrics have been used to mimic armored fighting vehicles. The tactical advantages of decoys are obvious: they confuse the enemy into believing that opposing forces are larger than in reality.

Fig.1. Multispectral camouflage net

ii. Multispectral camouflage nets and mats

A multispectral three-dimensional camouflage mat has a base or substrate layer into which are woven strands of yarn of varying length and color to simulate terrain or landscape, or alternatively to serve as a decoy by simulating a target. Desired reflection and absorption of visible light as well as infrared, ultraviolet, and microwave frequencies is provided by materials integrally contained within the yarn strands, and by supplemental materials on the base layer.The backing layer is polypropylene; the tufted yarn strands have different coloration and are arranged at different height levels above the backing layer, the colorations and levels being selected to provide visual simulation of a natural terrain.

Different lengths whereby at least some shorter strands are concealed from visual observation by longer overhanging strands, the shorter and longer strands having different signatures to interrogating wavelengths, the strands being colored and arranged to provide an accurate and detailed simulation of a desired scene. The strands are formed as loop pile rather than cut pile to provide a self-supporting springy quality to the mat upper surface. Each strand has at least a single base fiber or filament which is preferably a plastic material such as bulk-continuous-filament (BCF) polypropylene or nylon. Preferably The plastic material incorporates additives, and other fibers may be interwoven with the base fiber to impart desired reflecting or absorbing properties Tuft density which may range from about 5000 (for a bulky yarn) to over 200,000 loops per square yard. Multilevel tuft construction which provides a three-dimensional effect and accurate terrain simulation over a range of potential viewing angles.

Dye or other colouring agent are added to impart the desired color (typically black, brown or tan, and various shades of green, as discussed below) to the strand and to provide controlled absorption or reflection of infrared radiation. Radar-absorbing material such as finely powdered carbon or graphite, a radar-reflecting metallic material such as silver, copper, and the like (including compounds of such metals), or mixtures of absorbers and reflectors.

iii. Camouflage coverings

A camouflage covering for covering military equipment comprising several layers as counted from a bottom side to an outer surface; a strength layer, an aluminized plastic film, a layer comprising fibers of a super-absorbent matter, and a surface layer, layers are needled together and surface layer has a pile configuration, a mat-like structure having the desired properties is obtained by needling together several webs of different materials, one of which comprises a so-called super-absorbent material. There exist several such materials, some of which have a very poor structure when wet, e.g. metoxycellulose. It is therefore preferred to use some such material which has better structural properties when wet, e.g. an acrylic-based fiber-like Lanseal, mixed with some fibers which further improve the structure, like rayon or polypropylene. It is advantageous to include in the structure some fibers which are hydrophilic, as this will improve evaporation from the layer comprising super-absorbent material. It is also advantageous to comprise in all the webs, or at least some, electrically conducting fibers, as this will give a good radar absorption property. The fact that the radar absorbency is distributed in a three-dimensional structure that improves substantially the radar camouflage effect. For obtaining a good visual camouflage effect, its particularly advantageous feature that the outermost pile of the camouflage covering is a Dilo-made pile, which substantially diminishes light reflexion properties.

Fig 2: Invisible cloak (hyper stealth biotechnology)

IV. Invisible camouflage fabric (hyper stealth biotechnology)

Quantum Stealth' camouflage material is said to render its wearers completely invisible by bending light waves around them:

V. Mobile Camouflage Systems

MobileCamouflage System(MCS), intended primarily for protection during movement and in combat. The MCS can be applied in a number of configurations and provides stealth capability in the visual, near-infrared, thermal infrared and broadband radar wavebands. It consists of interlocked panels, attached using a variety of techniques, none of which require modification to the vehicles.

Fig.3. Mobile camouflage system

7. CONCLUSION

Camouflaged targets are harder to identify than uncamouflaged targets when similar background objects are present. The specific details of the camouflage patterns have little impact on this effect. If one has to move, camouflage cannot impede detection; but if one is surrounded by similar targets (e.g. other animals in a herd, or moving background distracters), then camouflage can slow identification. Despite previous assumptions, motion does not entirely break camouflage.

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Antimicrobial Finishing of Cotton Based Textiles

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ABSTRACT

Antimicrobial finish is most desirable treatment for textiles. Synthetic antimicrobial agents have been developed during last few years. Although, the synthetic antimicrobial agents are very effective against a range of microbes and give a durable effect on textiles, but they are responsible for associated side effects. Hence there is a great demand for antimicrobial textile based on eco-friendly agents which help to reduce the ill effects associated due to microbial growth on textile material. Recently, an interest has also been developed to identify and develop eco-friendly process using natural dyes for antimicrobial treatment on textiles. Keeping in view, a critical review has been made on eco-friendly process of antimicrobial treatment for cotton products.

Introduction

Textile materials and garments are very much susceptible to microbial attack as these provide large surface area and absorb moisture required for microbial growth. Cellulosic as well as protein (keratin) fibres also provide all essential basic requirements such as moisture, oxygen, nutrients and temperature for bacterial growth and multiplication. This bacterial growth generally leads to objectionable odour, dermal infection, product deterioration, allergic responses and other related diseases (1). The development of antimicrobial textile finish is highly indispensable and relevant since garments are in direct contact with human body. Antimicrobial textile with improved functionality find a variety of applications such as health and hygiene products, specially the garments worn close to the skin and several medical applications such as infection control and barrier material.

In the last few years to meet the above mentioned demand a range of textile product based on synthetic antimicrobial agents such as triclosan, metal and their salt, organometallics, phenols and quaternary ammonium compounds have been developed and quit a few are also available commercially. Although, the synthetic antimicrobial agents are very effective against a range of microbes and give a durable effect on textiles, but they are responsible for associated side effects, action on non-target microorganism and water pollution. Hence there is a great demand for antimicrobial textile based on eco-friendly agents which not only help to reduce effectively the ill effects associated due to microbial growth on textile material but also comply with the statutory requirements imposed by regulating agencies.

The use of natural products such as chitosan and natural dyes for antimicrobial finishing has been widely reported (2, 3). Other natural herbal product such as Aloe vera, Neem extract, Tulsi leaf extract, tea tree oil, eucalyptus oil can also be used for this purpose. Although there are many natural product and vast source of medicinal plants with active antimicrobial properties but the study on their use in textile is very limited and not well documented. Recent developments on plant based bioactive agents have opened up new avenues in this area of research (4-7). In this paper, antimicrobial finishes based on natural products and nano silver have been critically reviewed and reported in detail.

Antimicrobial agents for textiles

Man has adopted antimicrobial substances since ancient times. The need to protect and preserve is still fundamental in many textile applications today. Antimicrobials are protective agents that, being bacteriostatic, bactericidal, fungistatic and fungicidal, also offer special protection against the various forms of textile rotting. ***Quaternary ammonium compounds*** seem attractive because their target is primarily the microbial membrane and they accumulate in the cell driven by the membrane potential. These compounds, particularly those containing chains of 12-18 carbon atoms, have been widely used as disinfectants. They carry a positive charge at the N atom in solution and inflict a variety of detrimental effects on microbes, including damage to cell membranes, denaturation of proteins and disruption of the cell structure (8). Shao et al. (9) showed that, a novel quaternary ammonium salt, which contains both perfluoroalkyl group and diallyl groups, should be suitable a finishing agent for providing the fabrics with barriers against microorganisms, water, oil, soil and blood. Moreover, the introduction of diallyl groups into the quaternary ammonium salt not only can enhance the antimicrobial activity, but also extend its application fields (Shao et al, 2003) (9).

PHMB is a hetro-disperse mixture of polyhexamethylenebiguanides with an average molecular weight of approximately 2500 Da. These are known as powerful biocides active against wide variety of bacteria, fungi, allege and viruses. Being a potent and broad spectrum bactericidal with low toxicity (MIC=0.5-10 ppm), it has been used as a disinfectant in the food industry and in the sanitisation of swimming pools and is being used as a biocide in mouthwashes and wound dressing8. Due to good absorption onto cellulosic fibre, PHMB is used as germicides wound dressing and hygienic wipes and as an antimicrobial agent for textile as well. Poly hexamide treated cotton fabrics have been reported to maintained bactericidal properties for 10-15 laundry cycles. **Regenerable N-halamine** compounds (10-12) are broad spectrum disinfectants that have been used in water treatment and their antimicrobial activity is attributed to the oxidative properties of the halamine bond (N-Cl). In deactivating a microorganism, the N-halamine bond is reversibly reacted to N-H. However inactive substances can be recharged with chlorine in a bleaching solution during laundering. **Regenerable peroxides** are alternate methods for textiles functional finishing employ renewable antimicrobial agents. Another approach is using peroxydic moieties, such as peroxide and peroxyacids, which have been widely used disinfectants in the food and beverage industries as well as bleaching agents for textiles and paper. As for their mode of action, peroxydic compounds attack the microbe cell membrane, get into the cytoplasm and affect the microorganism enzymes (13).

Bioactive Plant based antimicrobial agents

Coating of antimicrobial plant natural dyes and bioactive plant extract onto cotton fabrics is an emerging technology in the production of medical cloths. As many of the identified compounds from plants are colored, they are used as natural antimicrobial dyes and pigments for dyeing natural and synthetic fibers [14-16]. Ecologically friendly pigments have also been produced by the fermentation of microorganisms such as fungi and bacteria [17, 18].

Natural dyes as antimicrobial agents

Many natural dyes obtained from various plants are known to have an antimicrobial property. The plants contain large amount of tannins viz. pomegranate (Punica granatum) and several other plants rich in napthoquinones such as henna, walnut etc. are reported to exhibit antibacterial and antifungal activities (19). Dutta et. al. (1) reported that many natural dyes which obtained from plant materials are found some medicinal values. The dyeing materials were prepared from pomegranate (Punicagranatum), wild maangosteen (Diospryos peregrine), myrabalan (Terminalia chebula), arjun (Terminalia arjuna), betel nut (Areca catech), onion (Allium cepa), tea (camellia sinensis), eucalyptus (Eucalyptus cenerea) and dye flower (Coreopsis basalis). Cotton fabrics were dyed with the extracted coloring materials and evaluated antimicrobial property against Bacillus subtilis (gram positive) and Escherichia coli (gram negative). The cotton fabrics dyed with extracts of arjun, betel nut, pomegranate, tea and onion were found to have antimicrobial activity against both the test bacteria at varying efficiency. The dyed fabrics also showed reasonably good wash fastness; hence have good potential for adding antibacterial properties along with vibrant colors to textiles of medical and other delicate uses.

The dye extracted from bark of Araucaria columnarisis, known as Christmas tree, using two solvents-methanol and ethyl acetate and its antimicrobial activity was tested against major clinical pathogens. The methanol extract showed the maximum antibacterial activity with the inhibition zones ranging from 15 to 20 mm against both gram positive and gram negative bacteria. The extracts were treated with cotton fabrics which showed dark brown color (methanolic) and light brown color (ethyl acetate) on cotton fabric. A dyed fabric shows interrupted growth underneath the fabrics (20). Ramasamy (21) used natural dyeing solutions obtained from rind of P.granatum for dyeing cotton fabrics. He also confirmed that fabric dyed with the natural colorant from P.granatum extracts displayed excellent antibacterial activity against test organisms S. aureus and E. colli. Mohammad et. al. (22) reported that natural dye extract obtained from walnut; applied on polymide fabric; showed antibacterial activity against pathogenic strains of gram positive (Staphylococcus aureus) and gram negative (Escherichia coli) bacteria. Curcumin a common dye used for fabric and food coloration, a dye isolated from Quercusinfectoria and the colorant Berberine which contains the quaternary ammonium group all exhibit durable antimicrobial efficacy when attached to textiles (8). Other dyes like kerrialacca, rubiacardiofolia and acacia catachu have also indicated antibacterial activity upto some extent (6).

Gupta et. al. (14) reported the antimicrobial properties of eleven natural dyes against three types of Gram-negative bacteria. Seven of the dyes showed activity against one or more of the bacteria. The minimum inhibitory concentration for three selected dyes was determined. The results demonstrate that certain dyes are able to reduce microbial growth almost completely in the case of Escherichia coli and Proteus vulgaris. Selected dyes would therefore be valuable for the dyeing of sheets and gowns for hospital use, and on articles which are less suitable for laundering such as mattresses and upholstery. The dyes examined exhibited good wash fastness and the antibacterial effect is therefore likely to be durable (16).

Raja and Thilagavathi (24) reported that wool fabrics treated with four natural dyes viz. Silver oak, flame of forest, tanner's senna and wattle bark; having in vitro antimicrobial efficacy to both gram positive and gram negative bacteria with and without the use of enzyme and mordants. The test results showed that the antimicrobial efficacy of dyed wool samples was significantly influenced by enzyme and mordants treatments. The control dyed fabrics showed antimicrobial efficacy only against gram positive S. aureus bacteria whereas the enzyme treated fabrics had antimicrobial efficacy against both S. aureus and gram negative E.coli bacteria. This may be due to 17% higher dye uptake in the enzyme treated materials. The mordant treated wool fabrics generally showed less antimicrobial efficacy against S. aureus compared to control dyed fabrics (24).

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Thermal and Acoustic Behavior of Non-woven Material

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1. Introduction

Non-Woven's are produced by high speed and low cost of processes as compared to traditional woven and knitted technology. A large volume of materials can be produced at lower cost by using non woven technology. Textile industry play a major role in national growth because these industries produced different kind of products but Indian government made some measures to save the environment. The non woven is a kind of fabric which doesn't harm the nature in anyway. This kind of material is manufacturing the bags as the government has banned plastic bags. These bags are made more decorative by using embroidery lace. That's why manufacturing of non woven fabric gain potential growth in the eco friendly fabrics.

The development of materials which can provide both thermal and sound insulation will become a sustainable alternative. Patnaik et al reported that use of recycled polyester fibre combined with wool fibre gave better result by enhancing the physical and thermal properties of composites up to some extent. The excellent warmth provided by the wool fibre is primarily because of its structural features and low conductivity, although the amount of air entrapped plays a vital role in providing warmth. As the density of composites are increases with decreasing in the thermal conductivity. (Patnaik A,Mvubu M , Muniyaswamy S , Botha A. et. al. ,2015). Sakthivel et al used the waste materials obtained from industries effectively. The use of recycled fibres has the advantage of (i) Consuming less resource usage (ii) Consuming less energy (iii) recycling textile materials which would otherwise waste (iv) Providing economical benefits and recycling of material from solid waste help the community environmentally, economically, socially and ecologically (Sakthivel .S , Rama Chandran .T et. al. , 2012).

2. Present status of non woven material

Among various manufacturing techniques of non woven , needle punching is the second most popular technique after the spun bounding and widely used in various engineering application. The world produced 1.1 million tones of needle felt in year 2000, of which 800,000 tones (Approx. 35%) needle felt used new fibres and the rest used reclaimed and recycled fibres. (Midha V.K., Mukhopadyay A et. al. ,2005). The recent year to year growth in the manufacturing sector has been approx. 15% and more importantly, there has been growth in the non durable goods and sector. Most of the non durable goods are non woven product and it is extremely important that this sector grows quickly in India. According to the resent statistics from the USA based association of the non woven fabric industry, due to the explosion in the number of disposable income group in India the non woven industry in India expected to register the growth of over 12.4% with the increase in disposable incomes, the need of life enhancing products, automobile etc. increases. These products are perfectly fit for non woven. The auto mobile industry is expected to growth over 20% and with this, the use of non woven. Global nonwoven fabric market is estimated be valued at US$ 35.4 Bn by 2016 end, and is projected to expand at a high single-digit CAGR in terms of value during the forecast period, 2016-2024 (Seshadri Ramkumar et.al. , 2010).

The government and the industry are looking for diversification opportunities to enlarge the overall market size of the Indian textiles industry. India textiles industry wants to reach the size of US $ 115 billion by 2012. The expectation is that the technical textiles sector will contribute at least 10% to the overall market size, which will be US $ 11.5 billion. The current value of the Indian technical textiles sector is around US $8 billion. This means, India's technical textiles sector has to nearly double in size in years ahead. All stake holders, i.e., industry and trade associations, Government, industry related trade associations and textile academia and working seriously to build a viable technical textiles sector in India. In this connection, Government of India is playing a significant role in creating awareness and developing a knowledge base for the NWTT sector. Since mid 2000s, the government has supported many technical awareness programs. Both INDA and EDANA have offered sector wise training programs in major textile hub such as Surat, Coimbatore, New Delhi, etc.

3. Types of non woven materials

Various high-tech processes such as spunlaid, wetlaid and drylaid technologies are used to manufacture nonwoven fabrics in order to achieve desired characteristics in the finished products. Spunbond and meltblown are the most preferred spunlaid techniques. Spunlace and needlepunch are the other prominent types of nonwoven fabric manufacturing techniques. Basic features of different technologies are highlighted below:

Spun laced non- woven : Spun laced process is high pressure micro flow injection into a layer or layers of fibrous web, so that the fibre are twisted together, so that the web can be strengthened and have a certain strength.

Thermal bonded non-woven: Thermal bonded non woven's is defined in the web of fibrous or powder adding hot melt adhesive reinforcement material, web after heating melt cooling reinforcement into cloth.

Pulp air laid non woven: Air laid non woven can be called clean paper, paper non woven fabrics. It is the use of air laid fibre plate technology will be opening a single fibre state, and then use the air flow method of making fibre agglutination in a certain net, web reinforcement into cloth.

Wet non woven: Wet non woven fabric is placed in water medium fibre opening into single fibres, while the different fibre raw material mixing, into the fibre suspension slurry, suspension slurry to web forming mechanism, fibre in wet state into the net reinforcement into cloth.

Spun bounded nonwoven: Spun bounded nonwoven is into the polymer has been extruded, stretched and form a continuous filament, filament laying into the net the web through the self bonding, thermal bonding, chemical bonding or mechanical reinforcement method, make the web into a non woven fabric.

Melt blown nonwoven: Melt blown non woven process: polymer blend melt extrusion formation - Fibre-fibre cooling - Net - Reinforcement into nonwoven.

Acupuncture nonwovens: This is the dry non woven by the use of needle puncture, the fluffy web reinforcement into composites.

Stitch bonded nonwoven: It is also a dry nonwoven, stitch bonded is the use of warp coil structure on the web, a yarn layer, a non woven material (Such as plastic sheet, plastic such as thin foil) and their combination for reinforcement, with made of non woven.

4. Basic Properties of Non woven

Nonwoven fabrics are technical textiles that are manufactured using sheets or web structures bonded by means of various thermal, chemical or mechanical processes. Such fabrics can be manufactured or modified to exhibit superior properties as per requirement of certain applications. Some of the desired properties include absorbency, elasticity, and filterability and flame retardancy.

Factors Affecting Acoustic Properties of Non woven

Various parameters that influence the sound absorption properties of fibrous materials or nonwoven fabrics are summarized below:

Fiber Parameters

i. ***Fiber Size:*** An increase in sound absorption coefficient is reported with a decrease in fiber diameter. Fine denier fibers ranging from 1.5 - 6 dpf perform better acoustically than coarse denier fibers. Moreover it has been reported that, micro denier fibers (< 1 dpf) provide an increase in acoustical performance.

ii. ***Fiber Type:*** The effect of fiber type on sound absorption is hard to detect as it is often accompanied by differences in fiber size and shape. Nonwovens made of acrylic and cotton fibers perform better as compared to those made of polyester fibers in the medium and high frequency range, i.e. above 1000Hz. Surface properties of fibers also play an important role. Untreated Kenaf had a negative effect on the noise reduction performance compared to polyester and reclaimed polyester fibers however, this effect is less pronounced in high frequencies.

iii. ***Fibre Cross-section:*** There is a direct correlation between sound absorption and fiber surface area. A study explained the fact that friction between fibers and air increases with fiber surface area resulting in a higher sound absorption. Moreover it has been said that, in the frequency range 1125Hz - 5000Hz, fibers with serrated cross-sections (e.g. Kenaf) absorb more sound compared to ones with round cross-sections

iv. Fiber Blend: Comparing the sound absorption coefficient of nonwovens made up of cotton- polypropylene, flax-polypropylene and hemp-polypropylene blends for automotive applications, it was found that cotton-polypropylene blend showed higher sound absorption compared to other blends, probably due to the higher fineness of cotton fibers as compared to flax and hemp.

5. Process Parameters

i. Web Formation: Higher value of airflow resistance was recorded due to random orientation of fibres as compared to aligned fibres of carded web. A random web of fibre creates more tortuous channels which increases sound absorption. Random arrangement of fibres produce samples with small pores and a higher number of fibre to fibre contact points which leads to better sound absorption.

ii. Web Bonding: Needled and needled with thermally bonded samples did not show much variation in sound absorption properties.

6. Physical Parameters

i. Thickness: Low frequency sound absorption has direct relationship with thickness. The effective sound absorption of a porous absorber is achieved when the material thickness is about one tenth of the wavelength of the incident sound. Peak absorption occurs at a resonant frequency of one quarter wavelength of the incident sound (ignoring compliance effect). A study showed the increase of sound absorption only at low frequencies, as the material gets thicker. However, at higher frequencies thickness has insignificant effect on sound absorption. When there is air space inside and behind the material, the maximum value of the sound absorption coefficient moves from the high to the low frequency range.

ii. Density: Density of a material is often considered to be the important factor that governs the sound absorption behavior of the material. At the same time, cost of an acoustical material is directly related to its density. A study showed the increase of sound absorption value in the middle and higher frequency as the density of the sample increased. The number of fibers increases per unit area when the apparent density is large. Energy loss increases as the surface friction increases, thus the sound absorption coefficient increases. Less dense and more open structure absorbs sound of low frequencies (500Hz). Denser structure performs better for frequencies above than 2000Hz.

iii. Airflow Resistance: One of the most important qualities that influence the sound absorbing characteristics of a nonwoven material is the specific flow resistance per unit thickness of the material. The characteristic impedance and propagation constant, which describes the acoustical properties of porous materials, are governed to a great extent by flow resistance of the material. Fibers interlocking in nonwovens are the frictional elements that provide resistance to acoustic wave motion. In general, when sound enters these materials, its amplitude is decreased by friction as the waves try to move through the tortuous passages. Thus the acoustic energy is converted into heat.

iv. Porosity: Number, size and type of pores are the important factors that one should consider while studying sound absorption mechanism in porous materials. To allow sound dissipation by friction, the sound wave has to enter the porous material. This means, there should be enough pores on the surface of the material for the sound to pass through and get dampened. The porosity of a porous material is defined as the ratio of the volume of the voids in the material to its total volume. In designing a nonwoven web to have a high sound absorption coefficient, porosity should increase along the propagation of the sound wave.

v. Tortuosity: Tortuosity is a measure of the elongation of the passage way through the pores, compared to the thickness of the sample. Tortuosity describes the influence of the internal structure of a material on its acoustical properties. Tortuosity is measure of how far the pores deviate from the normal. It was mainly affects the location of the quarter wavelength peaks, whereas porosity and flow resistivity affect the height and width of the peaks. It has also been said by the value of tortuosity determines the high frequency behavior of sound absorbing porous materials.

vi. ***Compression:*** Compression of fibrous mats decreases the sound absorption properties. Under compression the various fibers in the mat are brought nearer to each other without any deformation. This compression results in a decrease of thickness. More interestingly, other physical variation occurs during compression. Compression resulted in an increase in tortuosity and airflow resistivity and a decrease of porosity and thermal characteristic length. Despite these physical parameter variations in the compressed material, it stated that the reason for a drop in sound absorption value is mainly due to a decrease in sample thickness.

vii. ***Air Gap:*** One of the research stated that, for the same amount of material, it is much better to have an air gap behind the layer. The creation of air gap increases sound absorption in mid and higher frequencies. Moreover, maxima peak for different air gap is different. This indicates that there is an optimum value for an air gap beyond which there is not much influence seen in sound absorption properties. (Parthraj R. Puranik, Rajnikant R. P. Pritesh P. Rana et. al., 2014).

7. Factors affecting thermal Properties of non woven

Weight and Thickness

A study showed the increase of thermal absorption only, as the material gets thicker. However, at higher thickness has insignificant effect on thermal insulation. When there is air space inside and behind the material, the maximum value of the thermal absorption coefficient moves from the low to the higher.

Thermal conductivity and Density

Heat transfer can take place by means of conduction, convection or radiation across the barrier from the hot side to the cooler side. In conduction, heat passes from a hotter to a cooler region along the static material (as in textile barriers). Convection is the transfer of heat by a flow of gases or liquids of different temperatures. In radiation, thermal energy is transmitted as electromagnetic waves (X. Tao, et. al ,2001). The density of non woven material is increase with the density of fibres in side the cross section. Thermal insulation materials are specifically designed to reduce the heat flow by limiting heat conduction, convection, radiation or all three while performing one or more of the following functions: conserving energy by reducing heat loss or gain Controlling surface temperatures for personnel protection and comfort Facilitating vapor flow and water condensation of a process Increasing operating efficiency of heating/ventilating/cooling, plumbing, steam, process and power system found in commercial and industrial installations (Jirsak, O, et. al, 2000).

Dead Air Space

The thermal insulation properties of textile fabrics depend on their thermal conductivity, density, thickness and weight. The efficiency of thermal insulating materials generally depends on the amount of dead air space present within. The insulative materials are bulky as air entrapped helps in increasing the insulation properties of the fabric (Z. S. Abdel-Rahim, M. M. Saad, and Others, et. al,2006). Batting and nonwovens are used widely for thermal insulation applications otherwise apparel. As nonwoven fabrics have the advantage of containing many dead air spaces (micro-spaces) present within the material that give the fabric its insulation abilities. Compound structures with more than one layer of different materials are also effective in certain applications (E. Payne, B. T. Perry, and Others, et. al.,1996) (S. Adanur, et. al ,1995).

Thermal insulation value

Thermal Insulation Value is represents the efficiency of the textile fabric as an insulator. It is defined as the percentage reduction in heat loss from a hot surface maintained at a given temperature. The TIV increases to 100% when a perfect insulator is obtained. It is expressed as a percentage which represents the reduction in the rate of heat loss due to the insulation, relative to the heat loss from the surface. TIV can be measured based on the insulation factor (R). (Rsi) can be described in the relation Rsi = d ? .

Whereas ? : It represents the heat flow in watts (W) through a 1 m2 surface and 1 m thick flat layer of a material when the temperature difference between the two surfaces in the direction of heat flow amounts to 1 kelvin (K). The unit of measurement for thermal conductivity (?) is W/(m.k).d: thickness of the samples (Y. L. Bozec, S. Kaang, and others, et. al. ,2000).

8. Conclusion

The types of materials (Fibre fineness, cross section, and length) and weight have great impacts on the thermal insulation and air permeability. More number of finer fibre in the given space inside the nonwoven absorbs more heat as compared to less number of coarse fibre. Similarly as the thickness of non woven increases thermal insulation value will also be increased. Using various fibres and their blends, one can enhance heat absorption properties. Random fibre orientation gives better heat absorbency due to small pores and higher number of fibre to fibre contact points. The dead air space inside the non woven will increase with its thermal insulation and simultaneously thermal conductivity will also be decrease.

There is inversely proportional relation between the sound absorption coefficient, air permeability and thickness. Which means, increasing of thickness, leads to decreasing of sound absorption coefficient and the surface area and fibre size have significant influence on sound absorption properties, higher surface area and lower fibre size increases sound absorption. Using various fibres and their blends, one can enhance sound absorption properties. Random fibre orientation gives better sound absorbency due to small pores and higher number of fibre to fibre contact points. Thicker, less dense and more open structure, absorbs sound of low frequencies (500Hz), denser structure performs better for frequencies above 2000Hz. Increase in air gap, porosity, air flow resistance and tortuosity value results in better sound absorption. On the other hand, material compression adversely affects sound absorption

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Fourier Transform Infrared Spectroscopy: Fast and Versatile Technique for Chemical Characterization of Textile Materials

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Introduction

Spectroscopy, refers to determination of a property of a material as a function of energy. Infrared spectroscopy is branch of spectroscopy which is based on the interaction of electromagnetic radiation with molecular vibrations. Invariably, all organic or inorganic compounds having covalent bonds absorbs electromagnetic radiation in infrared (IR) region at a particular wavelength.The molecules can undergo different kind of stretching and bending vibrational motion. Some of these vibrational motions are IR active, and gives rise to IR absorption. For chemical analysis the vibrational part of infrared region lying between 2.5 and 25 μm is important because radiation in this wavelength region encompasses the stretching and bending vibrational frequencies of the bonds in almost all covalent bonded molecules.Infrared spectrometer is used to determine absorption spectrum for a compound. An IR spectrum is basically a graph of IR light absorbance/transmittance on Y-axis versus frequency/wavelength/energy/wavenumber on X-axis. However, most spectroscopic techniques, do not use energy units directly for plotting the graph. The chemists prefer to use wavenumbers as units in IR spectroscopy as wavenumber is directly proportional to energy. The wavenumbers are expressed as reciprocal centimetres (cm-1). The most commonly used unit in spectroscopy is cm-1.

The IR spectrum is collected by passing infrared radiation through a sample. The interaction between radiation and molecule take place. At a particular frequency, of incident IR radiation that matches with the natural frequency of vibration of molecule, IR absorption takes place.However, all vibrational motion in molecule do not absorb IR energy. To understand IR absorption, let us take simple case of diatomic molecule. The diatomic molecule can be thought as a spring attached at both ends to vibrating masses (atoms). The bond distance continually changes due to vibrating nature of masses but we can define an average bond distance. The bonds that have time varying dipole moment, they only absorb IR energy. The molecules need not to have permanent dipole moment to absorb IR radiation, but only change in dipole moment is required. Every type of bond has a different natural frequency of vibration and these natural frequencies change in different local chemical environment inside the molecule. Therefore two different molecules will always have different IR spectrum. Therefore, the absorption of IR radiation at particular frequency is taken as fingerprint for particular molecular. The IR spectrum can also be employed to study structural information for a molecule. The IR absorption corresponding to same chemical bond having different local environment occurs in certain regime. For example, carbonyl group having C=O bond absorbs in the range of 1715±100 cm-1.The bond strength, modes of molecular vibration, and masses of bonded atoms etc. affects IR absorption frequency.

Mainly two types of spectrometer are in common use in laboratories. These are dispersive and Fourier Transform instruments. Both type of spectrometers provide spectra in the range of 4000-400cm-1and identical spectrum for same molecule. Dispersive instruments record spectrum in the frequency domain and therefore data acquisition is slow, but FTIR spectrometer provide IR spectrum quickly. The details of FTIR spectroscopy is discussed in next section.

FTIR Spectroscopy

The design of optical pathway for Fourier Transform spectrometer, produces a pattern called interferogram. The interferogram is wave like pattern composed of all frequencies that constitute the IR spectrum. The interferogram is plot of IR intensity with respect to time. The plot between intensity versus frequency can be obtained by performing a mathematical operation known as Fourier transform (FT). FT separates a function of time into the frequencies that make it up and generates intensity versus frequency spectrum, which is virtually identical to that obtained by employing dispersive spectrometer. This kind of spectrometer is known as Fourier Transform Infrared (FTIR) spectrometer. The main advantage of FTIR instrument is rapid spectrum acquisition with improved signal to noise ratio in comparison to that of dispersive spectrometer.

In order to acquire absorbance/transmittance IR spectrum of a sample, the sample needs to be put in sample holder/cell, which goes into FTIR spectrometer. The sample cell should be transparent to IR radiation in region of interest, so that signalsonly from sample can be obtained. The cells must be fabricated of substances, which are transparent to IR radiation e.g. NaCl and KBr.FTIR spectroscopy can be employed for wide range of samples: solid, liquid and gases.

A liquid sample is prepared for analysis by placing a drop of liquid between NaCl/KBr salt plates. On squeezing the salt plates a thin film of liquid forms between the salt plates. The salt plates along with thin film is put in FTIR spectrometerfor IR spectrum acquisition. Solid samples can also be analysed using FTIR spectrometer. Solid powder samples is mixed with KBr powder. The mixture is then pelletized by employing pellet making machine. The synthesised pellet is put in FTIR spectrometer for IR spectrum acquisition.FTIR spectrum is then analyzed and matched with known signatures of identified materials in the FTIR library.IR spectrum of samples can be deconvolutedto get quantitative structuralinformation. After deconvolution band centre and the area under peak can be used for further structural analysis.

Reflectance IR spectroscopy

In addition to conventional IR spectroscopy of measuring light transmitted from thesample, the light reflected from sample can also be employed for chemical analysis of the sample. This is known as reflection IR spectroscopy, which was developed by combining IR spectroscopywith reflection theories. In the reflection spectroscopy method, the absorption propertiesof a sample can be extracted from the reflected light.Reflectance IR spectroscopy can be employed for samples that are difficult to analyze by theconventional transmittance method.When IR radiation incidents on a sample surface, depending on the features of the sample surface, the light may undergo different kind of reflections. Depending on type of reflection different reflectance IR spectroscopytechniques have been developed. These are described very briefly in sections given below. The reflectance spectrum differ from those recorded in absorbance/transmission mode due to change in optical path. These spectra can be transformed into absorption spectrum by employing Kramers-Kronig transformation. This feature is available in most of the spectrometer with software package.

Internal reflectance spectroscopy (IRS)

Internal reflection spectroscopy is based on total internal reflection phenomenon of light.This type of spectroscopy is also known as attenuated total reflection (ATR) spectroscopy. ATR technique is frequently employed in the near - infrared for acquiring IR absorption spectrum for thin films and most importantly for opaque materials. ATR spectrum can be acquired by utilizing dispersive IRspectrometers, but rapid and more sensitive spectrum can be obtained by utilizing FTIR spectrometers. It is very versatile sampling techniques and requires little sample preparation.

Specular reflectance spectroscopy (SRS)

Specular reflectance spectroscopy is similar to mirror-like reflection from the sample surface. The incident IR radiation focused onto the sample gets reflected by the sample surface and give rise to specular reflection. The reflection occurs when angle of incidence equals the angle of reflection. It is employed for samples, having mirror like reflective and smooth surface. This kind of spectroscopictechnique can be used for evaluation of surfaces such as coating,thin films etc.

Diffuse Reflectance Spectroscopy (DRS)

When light incident on a solid sample, some fraction of it scattersdiffusely and some fraction penetrates into the sample. The fraction of light, which penetrates into the sample may be absorbed within the particles or get diffracted at grain boundaries and other inhomogeneities, which give rise to diffusely scattered light in all directions. Diffuse reflectance spectroscopy utilizes fraction of the reflected lights which are produced by diffuse scattering. Since regularreflection distorts the DRS spectrum therefore DRS instrument id designed to eliminate regular reflection component in diffuse reflectance measurement. DRS method is employed for solid samples having rough surfacesuch as paper, cloth etc.

We have discussed various techniques to acquire IR spectrum. Infrared microanalysis is useful tool in characterization of samples Depending on samples' absorption properties and morphology, suitable techniques can be chosen to acquire IR spectrum.

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Chemical, Biological, Radioactive and Nuclear (CBRN) Protective Clothing: Present Trends and Challenges

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Introduction

In present hostile environment across the globe the significant and pivotal role of an NBC suit under protective textile cannot be over- emphasized. An NBC suit (a type of military PPE) is designed to provide protection against direct contact and contamination by Nuclear, biological & chemical substances. The term NBC has been replaced by CBRN with addition of the new threat Radiological. CBRN suit also provide protection from the contamination with radioactive materials and some type of radiation depending on the design besides NBC threats. These suits are generally designed to be worn for the extended period to allow the wearer to fight while under threat of or under actual nuclear, biological and chemical attack.

Protective clothing used in World War-1 against chemical warfare agents were consisting of rubber clothing, which together with the gloves and boot to cover the entire body.; clothing of this type is usually characterized as Impermeable. This means that CW agents cannot pass through the material and the perspiration released from the skin is also prevented rendering it extremely uncomfortable for long duration especially in the hot climate. Later on permeable clothing was designed and developed, where a layer of active carbon particles were bound in polyurethane foam. Presently selective permeable membranes and flouro films are also being successfully utilized to mitigate the threat.

While on the subject, a number of variables to be considered including type of threat, exposure time, weight of clothing, comfort, level of protection, and the duration of protection required. In addition, the types of challenge to be encountered are of significant consideration. Due to the large number of variables involved several CBRN protective materials and clothing systems have been developed and these will be discussed through this article:-

To design effective CBRN clothing, it is necessary to have an understanding of the hazardous threats that must be prevented/mitigated from reaching the wearer:-

1. Types of Hazards

1.1 Chemical agents-chemical agents are toxic chemical substance that occur naturally or artificially synthesized. Chemical warfare agents possess different characteristic and belong to various classes of compounds with pronounced physiochemical, physiological and chemical properties. Based on their volatility, they are classified as persistent and non- persistent agents i.e. Examples of selected volatile CWAs are: hydrogen cyanide, sarin, soman, tabun, and tear gases; and persistent CWAs include VX, thickened soman, mustard agent, and thickened mustard agent. Based on their chemical structure they can be further classified as organophosphorous, organosulphur, organofluorine compound and arsenical. However due to physiological effect produced on human by CW agents, they are classified as follows:

- Nerve agents-sarin, soman, tabun
- Vesicants (blistering agents)-Mustard gas
- Choking agents(Pulmonary agents)
- Riots control agents-Tear gases

1.2 Biological agents: -These are microorganism, whether naturally occurring, genetically modified or synthetically engineered. These agents may cause infections, toxicity or allergy in humans, animals and plants. Toxins are also classified biological agents. A wide range of biological agents have been developed as weapons in military biological weapons programs. Bacterial agents include those causing Anthrax, Plague, Tularemia and Viral Encephalitis.

1.3 Radiological/Nuclear materials

Radiological materials are radioactive substances (i.e., substances that emit high-energy particles or gamma rays while undergoing radioactive decay). Nuclear materials are the key ingredientsin nuclear weapons and include Special nuclear materials (SNMs), which are fissionable radionuclides. A radiological dispersion device (RDD) is a weapon that combines radioactive material andconventional explosives. One example of such threat is Dirty bomb whichinvolves the packaging of explosives with radioactive materials. The intention is to disperse the radioactive material when the bomb detonates.

1.4 Emerging threats

Military across the globe is concerned about toxic industrial chemicals (TICs) which include chemicals such as common acids, alkalis, and organic solvents as they have encountered industrial chemicals during various deployments. Protection from TICs needs to be assured.

Type of hazards vis-a-vis level of personal protection required are the first parameters to be considered while designing the ensemble.

2. Levels of personal protection

There are four levels of personal protection for dealing with hazardous substances. As mentioned above. These are described as levels A, B, C and D for chemical protective clothing in combination with different types of respiratory protection.

Level A protection should be worn when the highest level of respiratory, skin, eye and mucous membrane protection is needed. This protection consists of a fully encapsulated, vapor-tight, chemical-resistant suit, boots and gloves together with a self-contained breathing apparatus (SCBA).

Level B protection should be selected when the highest level of respiratory protection is needed, but a lesser degree of skin and eye protection is required. This equipment consists of a chemical-resistant suit, chemical-resistant boots and gloves and SCBA.

Level C protection should be selected when the types of airborne substance are known, concentration is measured, criteria for using air-purifying respirators are met and skin or eye exposures are unlikely. This PPE consists of a chemical-resistant suit, full-face mask with air-purifying canister-equipped respirator and chemical-resistant boots and gloves.

Level D protection provides no respiratory protection and minimal skin protection and should not be worn on any site when respiratory or skin hazards exist.

Therefore design and selection of the materials for the protection against the hazards will be as per the level of threats.

3. Different types of protective materials:-

There are basically four different types of CBRN protective materials.

3.1 Impermeable materials: - Initially impermeable materials such as butyl rubber, halogenated butyl rubber, and neoprene were commonly used over the years to provide CB agent protection. These type of material while providing the excellent barrier to penetration of CB agents in liquid, vapour and aerosol forms, impede the transmission of moisture vapour from the body to the environment. Prolonged use of these clothing in the warm/hot climate of tropical areas, significantly increases the danger of heat areas.

3.2 Permeable materials:- These usually consist of a woven shell fabric, a layer of sorptive material such as activated carbon impregnated foam or carbon loaded nonwoven felt and a liner fabric. Liquid can easily penetrate permeable materials at low hydrostatic pressures, therefore liquid repellent finishes such as Quarpel and other fluro-polymer coatings are usually applied to the outer shell fabric to provide liquid repellency. Additionally, liquid and/or an aerosol- proof over-garment such as non-perforated Tyvek protective clothing(A DuPont proprietary suit- made up of HDPE) must be used in addition to permeable clothing in a contaminated environment to provide liquid and aerosol protection.

3.3 Semipermeable materials:- There are two different types of semipermeable membranes: porous and solution-diffusion membranes. Porous membranes include macro-porous, micro-porous, and ultra-porous membrane structures. A macro-porous membrane allows a convective flow of air, aerosols, vapors etc., through their large pores. A micro-porous membrane follows diffusion through pores with diameters less than the mean free path of the gas molecules allowing lighter molecules to diffuse through its pores. A solution diffusion membrane has also been called a nonporous or a monolithic membrane, where gas dissolves into the membrane, diffuse across it and desorbs on the other side based on concentration gradient, time, and membrane thickness.Examples of some semipermeable materials include W.L. Gore & Associates-Gore-Tex®, Polytetrafluoroethylene (PTFE),and micro-porous membranes include Mitsubishi's Diaplex , polyurethane nonporous membrane, and Akzo's Sympatex- co-polyester ether

3.4 Selectively permeable materials (SPM's):- It is an extremely thin, lightweight, and flexible protective barrier material to CB agents and selected toxic industrial chemicals, but without the requirement for a thick, heavy and bulky sorptive material such as the activated carbon material layer being used in current protective systems. They allow selective permeation of moisture vapour from the body to escape through the protective clothing layers so that the body of a soldier is continuously evaporatively cooled during missions while being protected from the passage of common vesicant chemical agents in liquid, vapour and aerosol forms.SPM's have the combined properties of impermeable and semipermeable materials. SPM's consist of multi-layer composite polymer systems produced using various different base polymers such as cellulose, polytetrafluroethylene (PTFE), polyallylamine, polyvinyl alcohol, among other gas or liquid molecular separation membranes.

Recently DRDO while developing the latest version of CBRN Mark-VI suithas sought expression of interest with focus on Activated carbon fibre or Selective permeable membrane based technology as the conventional system with powder carbon as adsorbent imparts severe heat stress.

Besides heat stress problem in the overall ensemble some other critical and key features also need to be understood.

4. Key aspects of material design: -

Material design is critical in the development of a desirable CBRN protective garment. Users often seek material/clothing that is lightweight, comfortable, durable, low cost easy care requires little maintenance and is compatible with the existing individual equipment. In order to develop such material and clothing systems, several different aspects of the importance of proper material design must be considered. These aspect include

(i) Material performance, garment durability, design of the garments and their closure interfaces.

(ii) The intended use, environment, productivity and cost.

(iii) Duration of the protection as per the level defined above.

(iv) Decontamination factor and shelf life of the ensemble.

Therefore in the designing of CBRN protective clothing, following properties will be required in the different layers in consideration with the above mentioned aspects.

A CBRN protective ensemble includes three main components: a textile outer layer materials (nonwoven or woven fabric), and inner layer of CBRN protective material and a textile liner fabric.

Outer Layer: It should be water repellant/ oil repellant/ flame retardant material as per the environmental requirements.

Middle Layer: It should be activated carbon impregnated nonwoven material/SPMs providing the barrier against the chemical, biological and nuclear hazards.

Inner Layer: This layer should have the capability of breathability, so that thermal stress and discomfort can be reduced.

Apart from the above criteria for the selection of the material for CBRN protective ensemble, following properties in the clothing may also be considered for the better protection level along with the less physiological, psychological effect on the wearer.

(a) Ventilation facility in the clothing to reduce the thermal discomfort during the longer period use of the protective clothing. i.e use of Raglan sleeve.

(b) Ensemble designs whether it has front entry or rear entry.

(c) Seamless provision in the clothing. By using seam sealing effect, entry of the hazards may be restricted.

(d) Closure system, components and system:- Closure interfaces between hood and gas mask, jacket and gloves, jacket and trousers and trousers and boot are very important in a NBC protective garment. Closure systems are very important because protection is a function of fabric, closure/interfaces, activity level and the motions of the user.

Based on above criterion some prominent features of CBRN suits are reviewed as per following detail.

5. Recent Trend in CBRN

Recentlyvarious technological advances were done in this field and some of the advance versions with their features are enumerated below.

(1) Suit Hazmat was developed by USA as personnel protective equipment consisting of an impermeable whole body garment worn as protection against hazardous materials. Such suits are often combined with Self-contained breathing apparatus (SCBA) to ensure the supply of breathable air.

(2) Remploy UK based company has also developed CBRN protective suit to an ever changing CBRN threat. Outer material of the suit comprises of rip stop polyester cotton material for increased tear resistance and enhanced abrasion. The material is also water repellent and flame resistant. The inner layer is a lightweight knitted carbon. It has shelf life of 10 years and washable upto 10 times without degradation. Weight of the suit has been claimed to be 2.1 Kg.

(3) STEPO (Self Contained Toxic Environment Protective Outfit):- This suit has been developed by Saint-Gobain Performance Plastics, USA based company. Suit has been developed for level A threat. Its main features are here as under:-

  (a) Suit is composed of multi-laminate material consisting of layers of Fluoro-polymer film and nonwoven Kevlar/Nomex blend.

  (b) STEPO provides 4 h of respiratory protection against all CB agent.

  (c) Use/Reuse: STEPO is capable of being decontaminated for reuse after five vapor and liquid agent exposures anddecontamination cycles.

  (d) Operational Limitations: Approved for use from -29 °C to 52°C (-20 °F to 125 °F).

(4) Sharba:-This CBRN permeable suit developed by joint venture of DRDO and Private firm. This suit is claimed to offer outstanding protection against CWA with optimal operational freedom. This suit consisting of three layers of fabric stitched together giving optimal protection of more than 24 hrs. The main features of it are as follows:-

  (a) Outer shell:- Non-woven, inherent FR synthetic fabric (rip stop design) agent barrier provides protection against vapour, aerosols and liquids. Antistatic, fire retardant, water and oil repellent treatment protects it from flames, water, oil, radioactive dust particles and harmful biohazards.

  (b) Middle layer:- Consists of high quality activated carbon spheres laminated on 100% non-woven polyamide.

  (c) Inner layer:- Inner layer is soft 100% cotton knitted fabric treated for nontoxic, anti-bacterial and enhanced sweat absorption.

6. Conclusion:-

Decisive progress has been achieved in terms of improvement of CBRN, especially in the field of material science wherein Nano technologies and smart textiles have also found applications in the development. However major challenges still exist for intensified research in the field of textile, in particular: materials, design, manufacturing as well as in aging behaviorso that compliance to safety ensured during the whole service of life.

As such improvement in following area is required to make it effectively serviceable during nuclear warfare:-

1. Reduction in weight of garment: - Soldiers always carries lifesaving accessories with himself like sleeping bag, Ration, Armaments etc. NBC suit weigh 2.5 to 3.0 kg itself and while soldier wear NBC suit, additional weight of suit, reduces his efficiency in battle field. Hence technologist must do the research to reduce the weight of garment and increase the efficiency of soldier in battle field.
2. Increase in BTT - BTT stands for Break Through time. This test has been carried out to assess the with-stand time of NBC suit in nuclear environment. Inrecentlyindigenously developed NBC suit i.e.MK-IV HD break through time is 30-36 Hours. The use of Nano- materials may be explored to improve this property.

3. Thermal comfort: - Technologists are still looking for major breakthrough to increase the thermal comfort of garment with the help of increased water vapor transmission rate in inner layer.

Due to the complex nature of threat agents, a multidisciplinary approachinvolving different disciplines such as Fiber science, Clothing technology, Materials technology, Physics, Chemistry, Mathematics, and Bio-technology is needed to tackle the CBRN threats of the twenty-first century.

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Phase Change Materials

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Introduction -

Material that is capable of absorbing heat energy or releasing heat energy at large scale are called phase change materials(PCMs).

PCM are also known as latent heat storage units. By latent heat we mean amount of heat absorbed or released by a body without any change in temperature as a whole.

PCM control temperature swings in textile using passive control strategies.

PCM are known for their high enthalpy of fusion or heat of fusion .for understanding this point we have to understand the meaning of enthalpy and fusion.

- Enthalpy means the measure of total energy of a thermodynamic system or body
- Fusion also known as melting, is a physical process that result in the phase change of a substance from a solid to a liquid.

Latent heat storage is one of the efficient way of storing thermal energy .unlike the sensible heat storage method , the latent heat storage method provides much higher storage density, with a smaller temperature difference between storing and releasing heat.

Classification-

PCM latent heat storage can be achieved through solid-solid, solid-liquid, solid-gas & liquid-gas phase change.

But only phase change used for PCM is the solid - liquid change.

Major types of PCM -

- Organic PCM - paraffin ,fatty acids
- Inorganic PCM - salt hydrates
- Eutectics - organic- organic ,organic- inorganic ,inorganic-inorganic compounds.
- Hygroscopic materials - many natural building materials are hygroscopic.

Selection criteria of PCM

1). Thermodynamic properties-

- Melting temperature in the desired operating temperature range.
- High latent heat of fusion per unit volume.
- High specific heat , high density & high thermal conductivity.
- Small volume changes on phase transformation & small vapour pressure at operating temperatures.
- Congruent melting.

2). Kinetic properties-

- High nucleation rate to avoid super cooling of the liquid phase .
- High rate of crystal growth , so that the system can meet demands of heat recovery from the storage system.
- chemical properties
- chemical stability
- No degradation after a large number of freeze/melt cycle.
- Non -corrosiveness ,non-toxic, non flammable& non explosive materials.

3). Economic properties-

- Low cost.
- Availability.

Benefits of PCM in clothing-

- As PCM are latent heat storage units so the garments or apparel units made up of these are also heat storage units.
- If due to external or internal conditions if temperature of PCM garment rise then its solid phase encapsulations start absorbing heat energy under a constant temperature and change to liquid phase , thus providing cooling effect to the user.
- In case of freezing temperature or cold conditions, the liquid phase encapsulated apparel releases the stored energy under constant temperature , thus providing heat & soothing effect to the body.

Graphical Analysis :

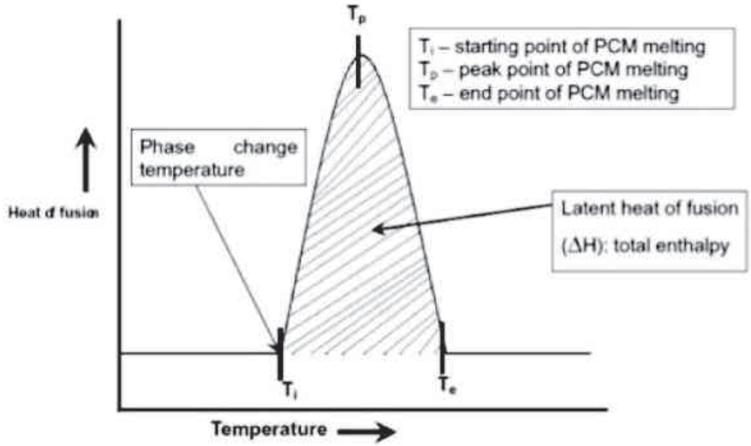

Fig. 1 Effect for Temp. on Head of Fusion

Working principle of phase change materials (PCMs)-

Thermal energy storage is an essential technique for thermal energy utilization . For thermal energy storage there are four alternatives viz. sensible heat utilization, latent heat utilization, utilization of reversible chemical heat, and utilization of heat of dilution. Material has four state viz. solid, liquid, gas and plasma. When a material converts from one state to another, this process is called phase change. PCM which can convert from solid to liquid or from liquid to solid state is the most frequently used latent heat storage material, and suitable for the manufacturing of heat-storage and thermo-regulated textiles and clothing.

Modes of heat transfer are strongly depends on the phase of the subs tances involve in the heat transfer processes. For substances that are solid, conduction is the predominate mode of heat transfer. For liquids, convection heat transfer predominates, and for vapors convection and radiation are the primary mode of heat transfer. For textile applications, we will only consider the phase change from solid to liquid and vice versa. There fore, the principle of solid to liquid phase change and vice versa would be discussed. When the melting temperature of a PCM is reached during heating process, the phase change from the solid to the liquid occurs. Typical differential scanning calorimetry(DSC) heating thermogram for PCM melting is schematically. During this phase change, the PCM absorbs large quantities of latent heat from the surrounding area. PCM may repeatedly converted between solid and liquid phases to utilize their latent heat of fusion to absorb, store and release heat or cold during such phase conversions as shown in Fig.1.

Phase change materials as such are not new .They already exist in various forms in nature. The most common example of a PCM is water at 0º C, which crystalizes as it changes from liquid to a solid (ice) . A phase change also occurs when water is heated to a temperature of 100ºC at which point it becomes steam. In order to compare the amount of heat absorbed by a PCM during the actual phase change with the amount of heat absorbed in an ordinary heating process; water can be used for by one degree celcius. ordinary heating process; water can be used for comparisons. When ice melts into water it absorbs approximately a latent heat of 335 kJ/kg. When water is further heated, a sensible heat of only 4 kJ/kg is absorbed while the temperature rises by one degree celcius.

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Achieving Functional Excellence with Silicone Coatings

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INTRODUCTION

In the textile industries, silicones are used in all stages of the process, on the fiber during production, on the fabric and/or directly on the finished goods. Silicones are applied from different delivery systems to provide various benefits like lubrication, softening, foam control or hydrophobic coatings.

Higher production rates oblige artificial fiber producers to continuously search for more efficient materials to lubricate fiber and spinneret and to avoid excessive overheating due to friction during high-speed manufacturing [1-2].

Because of properties such as heat stability and good lubrication, silicones can provide a reduction of the dynamic coefficient of friction, reducing the risk of fiber melting and breakage during production. Low viscosity polydimethylsiloxane (PDMS) is generally used in combination with solid particles (e.g., those made of magnesium stearate), as this also reduces the static coefficient of friction.

During the manufacturing of artificial fibers, PDMS can also be used as a lubricant to avoid adhesion of the thermoplastic fiber material to the spinneret, which would cause unstable production and cleaning issues.

Silicones can also be used to achieve low coefficients of friction between the fibers them-selves. Generally a silanol-functional silicone, a reactive cross-linker (e.g., a silane or an epoxy-functional silicone) and a condensation catalyst are formulated together into a coating to encapsulate the fiber. Such treated fibers will lead to high thermal insulating textiles and filling material for fiberfill systems as found in duvets or overalls.

Cleaning silicones used during fiber production can sometimes be an issue. To minimize this, lubricant silicone polyethers have been developed with higher hydrophilicity and easier to clean.

SILICONES IN FABRIC COATINGS

Silicones are not limited to fiber processing or finishing. Their use extends as coatings in diverse applications, from fashion wear such as women's stockings to technically demanding air bags. Applications here call for substantially thicker coatings, with typical coating weights up to 10 to 800 g/m2.

These applications are based on cross-linked silicone polymers or elastomers, which can be formulated into crystal-clear coatings that can be either soft and flexible or hard and rigid. All such coatings have very similar compositions and share common raw materials for up to 70% of their formulation. They perform well over a wide range of temperatures and with better thermal stability characteristics than organics.

Apart from one-part RTV (Room Temperature Vulcanisable) elastomer used in women's stockings, liquid silicone rubbers (LSRs) are today the preferred material for such fabric coatings because of their ease of use and rapid cure when exposed to elevated temperatures. Cross-linking in these elastomers is achieved by the addition of SiH functional polymers to SiVi functional polymers using a platinum catalyst.

These LSRs, as other silicone elastomers, contain fume silica, as such fillers dramatically improve mechanical properties. However, compared to other silicone elastomers with high mechanical properties such as high consistency rubbers, LSRs can be metered/mixed with pumps and easily dispensed as coatings on various fabrics .

Silicone coatings remain flexible even at very low temperatures, typically -100 ºC. Service life has been reported as 30,000 h at 150 ºC and 10,000 h at 200 ºC in air. When needed, additives such as cerium or iron oxides can used to further improve heat stability [3-4].

Compared to many organic elastomers, silicones do not contain organic plasticizers. They are therefore not prone to plasticizer migration problems or embrittlement due to plasticizer evaporation or degradation.

Other properties make LSRs desirable as coating materials (see Table 1):

- Solvent less compositions with long bath life at room temperature and low viscosity, (15,000 mPa.s) and therefore easy to process in coating operations using methods like "knife over roller" or "knife over air"
- Fast cure at elevated temperatures (e.g., 1 to 2 minutes at 160 ºC)
- Good adhesion to various coated substrates like glass, polyamide or polyester fabrics

o Good visual appearance.

o Adequate data to satisfy relevant regulatory requirements (e.g., food grade, skin contact).

SILICONE AS FABRIC SOFTENERS

Once produced, fibers can be treated with silicones to impart initial softness to the textiles made from these fibers. Softening is considered to come from the siloxane backbone flexibility and the freedom of rotation along the Si-O bonds. This allows exposure of the low interacting methyl groups, reducing fiber-to-fiber interactions.

To enhance durability through multiple wash cycles, some methyl groups can be replaced on the silicone polymer by other functional groups to increase the silicone softener attraction to, and interaction with, the fibers to be treated.

In this respect, amino-functional groups like -CH2-CH2-CH2-NH-CH2-CH2-NH2 are particularly popular for increasing physical adsorption and providing better softening properties.

SILICONES AS PROCESS AIDS

As in many other processing industries, silicones are widely used in the textile industries as antifoams. Silicone antifoams can operate in a wide range of temperature and pH conditions and can manage highly foaming media. Their compositions can be complex, but there are some formulation rules well known to the silicone industry for producing highly efficient antifoams for many different applications and in various foaming media. Conditions are so diverse that a "universal" antifoam has not yet been formulated.

In the textile industry, the main use of antifoams is during the scouring step, which is the cleaning of raw fibers before further processing or during the finishing step. Both of these are high foaming steps, as surfactants are extensively used to clean, or in the formulation of fabric softener emulsions. As the industry is also trying to minimize the amounts of water used in such process steps, this results in even higher surfactant concentrations.

The greater use of high-shear jet machines requires antifoam emulsions that are stable under very high shear to avoid undesired localized deposition of silicone polymers. Such deposition can result in staining problems.

Other process aids include:

- Needle lubricants or PDMS fluids to avoid needle overheating during sewing.
- Silicone polyethers to facilitate the wetting of difficult substrates that contain high levels of organic fats in their structures.

SILICONES AS HYDROPHOBIC AGENTS

Silicones provide very hydrophobic finishes on various fabrics. This treatment involves full fabric impregnation from silicone-in-water emulsions, usually via a padding process.

The silicone phase of such emulsions contains SiH-functional polymers because of their reactivity towards the fabric, but also because these polymers can cross-link with each other into a hydrophobic and durable fabric treatment, particularly if formulated with a suitable catalyst [5-7].

Table 1. Typical Properties of LSRs Used in Fabric-Coating Applications

Mixed viscosity, mPa.s	15,000 - 200,000
Tensile strength, MPa (psi)	3.5 - 9.0 (500 - 1300)
Elongation at break, %	100 - 800
Tear strength, kN/m (ppi)	5 - 40 (28 - 230)
Hardness, Durometer Shore A	15- 70

In many cases, the prime purpose of silicones in such fabric coatings is to provide some form of protection from exposure to high temperatures (as in conveyor belts), low temperatures (as with many outdoor goods) or exposure to stress over long periods of time (as in air bags or compensator bellows) (see Table 2). In such applications, silicones are more stable than other elastomers.

Table 2. Typical Applications and Key Properties of Silicone Elastomer Fabric Coatings

Coating type	Application area	Key properties
Soft coating	Hold-up stockings (RTV)	Ease to process Crystal clear Soft Non slip/high elongation
	Outdoor clothing and tents (LSR, RTV)	Adhesion Flexible Thermal stability Colorless Hydrophobicity
	Air bags (LSR)	Strength Adhesion Slip Stability at elevated temp.
Hard coating	Conveyor belt coating (LSR)	Adhesion Non slip/abrasion resistance Thermal stability Food grade
	Compensator bellow (LSR)	Adhesion Chemical/Thermal stability abrasion resistance
	Medical protective wear (LSR, RTV)	Hydrophobic Autoclavable Adhesion

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Collagen- Unique Biomaterial for Tissue Engineering

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Introduction

Collagen, found in the most abundant mammalian protein, is the basic structural biomaterial of vertebrates. Collagen is scattered in most of the animal parts but primarily accumulated in tissues and bones under the skin. The complex hierarchical structure of collagen enhances its versatility as a building material. Collagen exhibits attractive characteristics like excellent biocompatibility, weak antigenicity, remarkable biodegradability and unique fibril constituting potential. However, when collagen is used as base material for scaffolds, poor mechanical properties and low thermal stability of collagen based hydrogel, often restricts their biomedical applications. Hence, most of the collagen research has concentrated on enhancing its denaturation temperature (Td), and mechanical properties by crosslinking at intramolecular and intermolecular level.

In vertebrates, 28 different type of collagen are found which are made of at least 46 polypeptide chains. Collagen can form fibres with better strength and stability through its self aggregation and cross linking potential.

Easily available sources of collagen

Fish is a easily available source of collagen apart from mammalians. Silver carp is a fresh water fish found in subtropical climate is a good source of collagen from biomedical point of view. Collagen derived from silver carp has denaturation temperature (Td) 34°C which is lower than beef collagen. Gelatin is a form of hydrolysed beed collagen, which is essential part of broken -down collagen. In spite of sufficient potential to replace mammalian collagen, silver carp collagen has limitations in terms of poor thermal and mechanical properties with quick biodegradation. Hence crosslinking is essential to enhance its acceptability as useful biomaterial.

Crosslinking of collagen

The crosslinks in collagen enhances molecular stability but it limits the molecular mobility also. The crosslinks in collagen should be performed in such a way that tensile strength increases without restricting its extensibility. Unguided cross-links in collagen may produce undesirable structural features because the potential to conceive tissue should not suppress significantly.

The collagen stability can be improved by both chemical crosslinking and physical treatments like hydrothermal and radiation. Collagen has ample number of functional groupd to support crosslinking with glutaraldehyde, glyoxal, carbodiimide and genipin. Recently alginate, xanthan gum, polysaccharides, cellulose, schizophyllan, starch and dialdehyde has resistered remarkable applications as cross-linkers. Dialdehyde cellulose is a biodegradable and biocompatible crosslinker of cellulose.

Characterization of collagen as a biomaterial

Collagen is the primary structural material of vertebrates and is the most abundant mammalian proteinaccountingforabout20-30%oftotalbody proteins (Harkness, 1961). It is present in tissues of primarily mechanical function. About one half of thetotalbodycollagenisintheskinandabout70% of the material other than water present in dermis of skin and tendon is collagen. Collagen made its appearance at the early stage of evolution in such primitive animals as jelly?sh, coral and sea anemones (Bergeon, 1967). Collagen is synthesized by ?broblasts, which usually originate from pluripotential adventitial cells or reticulum cells. The molecular structure of collagen has been ?rmly established on the evidence from earlier studies, such as amino acid composition analysis, X-ray diffraction analysis, electron microscopy and physicochemical examination of solutions (Gross, 1963; Ramachandran and Sasisekharan, 1965;) Collagen has a unique structure, size and amino acid sequence (Miyata et al., 1992; Rao 1995). The collagen molecule consists of three polypeptide chains twined around one another as in a three-stranded rope. Each chain has an individual twist in the opposite directions. The principal feature that affects a helix formation is a high content of glycine and amino acid residues (Piez, 1984). The strands are held together primarily by hydrogen bonds between adjacent CO and NH groups, but also by covalent bonds

(Harkness, 1966). The basic collagen molecule is rod-shaped with a length and a width of about 3000 and 15 A°, respectively, and has an approximate molecular weight of 300 kDa (Traub and Piez, 1971; Nimni and Harkness, 1988). At least 19 types of collagen have been reported. Types I, II and III collagen as well as types V and XI are built up of three chains and all are composed of the continuous triple-helical structure. Types I, II, III, and V are called as ?bril forming collagens and have large sections of homologous sequences independent of species (Timpl, 1984). In type IV collagen (basement membrane), the regions with the triplehelical conformation are interrupted with large non-helical domains as well as with the short non-helical peptide interruption. Fibril associated collagens (Type IX, XI, XII and XIV) have small chains, which contain some non-helical domains. Type VI is micro?brilla collagen and type VII is anchoring ?bril collagens. An investigation on the native collagen has led to a better understanding of a structure function relationship between target drugs and collagen. A three-dimensional (3-D) model of ?bril-forming human type II collagen was proposed for the development of synthetic collagen tissues and the study of the structural and functional aspects of collagen (Chen et al., 1995). This system also allows the studies of the stereochemistry of all the side chain groups and speci?c atomic interactions, and further evaluation of its therapeutic effects on collagen related diseases. The orderly arrangement of triple helix tropocollagen molecules results in a formation of ?brils having a distinct periodicity. Nonhelical telopeptides are attached to both ends of the molecule and serve as the major source of antigenecity. Atelocollagen, which is produced by elimination of the telopeptide moieties using pepsin, has demonstrated its potential as a drug carrier, especially for gene delivery (Ochiya et al., 1999).

Collagen-based systems for tissue engineering

Collagen as skin replacement

Collagen based implants have been widely used as vehicles for transportation of cultured skin cells or drug carriers for skin replacement and burn wounds (Boyce, 1998). Since sponge implant was originally developed for recovery of skin and was very ef?cient in that purpose, various types of arti?cial skin were developed as a form of sponge. Cultured skin substitutes developed on collagen lattice were also used for skin replacement and skin wounds. Reconstituted type I collagen is suitable for skin replacement and burn wounds due to their mechanical strength and biocompatibility (Rao, 1995). Chronic wounds resulting from diabetes have been successfully cured with allogenic cultured skin substitutes prepared from cryopreserved skin cells (Boyce, 1998). In the cultured skin substitutes, the contracted collagen lattice was used as a support for epithelial growth and differentiation to replace pathological skin (Yannas et al., 1989). Allogenic cultured dermal substitute prepared by plating ?broblasts on to a collagen sponge matrix and subsequently freeze dried from a 1% aqueous solution of atelocollagen provided a good environment for epithelialization. The effectiveness of collagen sponges as a substrate for human corneal cells was demonstrated and corneal cells exhibited normal cell phenotype when cultured individually on an engineered collagen sponge matrix. Addition of selected antimicrobial drugs like amikacin to the bovine skin implantable collagen managed to control microbial contamination and increased healing of skin wounds (Boyce et al., 1993). The modi?ed sponge for arti?cial skin was developed by combining ?brillar collagen with gelatin. Dehydrothermal crosslinks were used to stabilize collagen-based sponge physically and metabolically. Sponges made of gelatin by itself in a resorbable gelfoam were also used as a carrier matrix for human mesenchymal stem cells in cartilage regeneration therapy. When this gelatin sponge was implanted in an osteochondral defect in the rabbit femoral condyle, gelfoam cylinders were observed to be very biocompatible, with no evidence of immune response or lymphatic in?ltration at the site. Some limitations inherent to cultured skin substitutes, such as de?cient barrier function in vitro and delayed keratinization after grafting in comparison to native skin autografts, were reported. To address those limitations, modi?cations of collagen-based systems by the combination of collagen with other proteins, such as glycosaminoglycan, ?brin, and biotin, were proposed. The role of glycosaminoglycan and difference in its concentrations between pathological and normal tissues were reported earlier. Dermal skin substitutes (membranes) made of collagen and glycosaminoglycan were found to be suitable substrates for the culture of human epidermal keratinocytes (Boyce et al., 1988). Cultured skin substitutes consisted of human keratocytes and ?broblasts attached to collagen-glycosaminoglycan substrates, which were subsequently crosslinked, decreased the rate of biodegradation and further reduced the engraftment of skin substitutes (Boyce et al., 1995). Restoration of functional epidermis by cultured skin substitutes developed from collagen was stimulated by incubation in reduced humidity in vitro. In the case of collagen and fibrin combination, cultured cells were best grafted directly onto the wound bed or in combination with either a thin layer of collagen or fibrin but not both (Lam et al., 1999). Biotinylation of bovine skin collagen by covalent addition of biotin has been used to attach peptide growth factors with avidin as a bridge. This technique retained the activity of peptide growth factors and demonstrated a potential to be used as a modulator of the response in wound treatment (Boyce et al., 1992). Sponges in a combination of silicone and collagen were also used to address the limitations inherent to cultured skin substitutes. Acellular bilayer artificial skin composed of outer silicone layer and inner collagen sponge was used for a thin split thickness skin graft and achieved good performance in the long term postoperative appearance of the split thickness skin graft site.

Collagen as bone substitute

Among the many tissues in the human body, bone has been considered as a powerful marker for regeneration and its formation serves as a prototype model for tissue engineering based on morphogenesis. Collagen has been used as implantable carriers for bone inducing proteins, such as bone morphogenetic protein 2 (rhBMP-2) (Reddi, 2000). Recently, collagen itself was used as bone substitutes due to its osteoinductive activity (Murata et al., 1999). The uses of collagen film as gene delivery carriers for osteoinduction and collagen sponge for bone related protein carriers were described earlier in Sections 3.1 and 3.4, respectively, and this section mainly focused on its uses as a bone substitute and a bone marker. Type I collagen crosslinked N-telopeptide was used as a marker of bone resorption and clinically used as a marker of bone metastasis of prostate cancer and breast cancer . The polymorphisms of collagen gen type Ialpha1 and vitamin D receptor as genetic markers for osteoporotic fracture in women was also reported. This result added to evidence that interlocus interaction is an important component of osteoporotic fracture risk. Collagen in combination with other polymers or chemicals was also used for orthopaedic defects. Demineralized bone collagen was used as a bone graft material for the treatment of acquired and congenital orthopaedic defects either by itself or in combination with hydroxyapatite. The result of this study showed that grafted demineralized bone collagen in combination with hydroxyapatite was an excellent osteoinductive material and could be used as a bone substitute. A recent study showed that addition of 500 IU of retinoic acid to collagen at a site of a bone defect enhanced regeneration of new bone, achieving union across the defect and leading to its complete repair.

Collagen as bioengineered tissue

Crosslinked collagen gel has used to replace human skin which proved its importance in tissue engineering and led to the development of bioengineered tissues, such as blood vessels, heart valves and ligaments (Auger et al., 1998). Miyata et al. 1992 has demonstrated that collagen has hemostatic potential that promote blood coagulation and play decisive role in tissue repairing. Collagen gel or sponge initiates adhesion and aggregation of platelets that guides thrombus formation. Polymeric collagen having regular arrangement of the molecules with a length of around 1 µm has platelet aggregation capability while monomeric does not has. Arginine side chains of collagen interact with platelets (Wang et al., 1978).

Arginine side chains of collagen seemed to be responsible for its interaction with platelets (Wang et al., 1978). A provisional extracellular support was developed using type I collagen lattice to organize the cells into a three-dimensional structure in vitro . A small-diameter (4 mm) graft constructed from type I bovine collagen was earlier used to integrate into the host tissue and provide a scaffold for remodeling into a functional blood vessel. Three-dimensional collagen scaffolds, that are biodegradable in vivo and have a large surface area for cell attachment, can support vascularization processes and can be used as artificial blood vessels, heart valves or cell transplant devices. The use of collagen as a coated material for permeation filters made of culture endothelial cell monolayers was also tested to evaluate in vitro vascular permeability of a drug to contrast media. A method for generating a cellular layer of intestinal collagen from the porcine submucosa without compromising the native collagen structure further facilitated the use of collagen in tissue engineering . Biological tissue grafts in the form of collagen-based matrix have been derived from bladder, ureter or small intestine (Clarke et al., 1996). These collagen constructs were designed to be similar to synthetic polymer prostheses in terms of their ability to persist. The structure-mechanical behavior relationship of biomaterials acquired from intestine submucosa demonstrated mechanical anisotropy and stiffer direction preferred in biomaterials. Using a phenomenological constitutive model, it was demonstrated that glycan increased the tensile stiffness and ultimate tensile strength of collagenbased matrix and further increased their resistance to collagen degradation. Natural collagenous materials were used for surgical repair and abdominal wall repair by taking advantage of their inherent low antigenecity and their ability to integrate with surrounding tissues. Moreover, new generations of collagen-based biological tissue are practical and remodelable due to its simple membranous con?guration, relative uniformity and abundant availability. These characteristics are employed in a new type of surgical adhesive made from porcine collagen and polyglutamic acid, developing for sealing air leaking from the lung, which takes a relatively long period for recovery (Sekine et al., 2001). The absorption rate of collagen-based adhesive can be controlled by collagen concentration in the system. Recent progress in tissue engineering may lead to well-characterized and reproducible biomaterials from natural collagenous materials.

Concluding remarks

Countless advantages of collagen as a biomaterial establish it as carrier systems for delivery of drug, protein and gene. Biomedical applications of collagen are compiled in this paper. Collagen has proved its utility to substitute human skin which guided scientific community to engineer tissues of blood vessel and ligaments. The research achievements of native collagen for drug delivery systems and tissue engineering can form a path to treat various diseases also. Very high molecular binding potential of collagen guides to apply it in targeting delivery of drugs. It can further provide a new guide for tissue growth and organization and leading to bioactive signals for tissue-speci?c gene expression. Collagen-based biomaterials are expected to become a useful matrix substance for various biomedical applications in the future.

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PBI (Polybenzimidazole): Properties, Applications and Recent Developments

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Abstract

Before the 1980s, the major applications of PBI were fire-blocking, thermal protective apparel, and reverse osmosis membranes. Now, its applications became diversified by the 1990s when molded PBI structures and micro porous membranes were developed. PBI fibre is the World's leading inherently flame resistant and thermally stable fibre today. This paper will provide an overview of PBI fibre manufacturing techniques, properties, and applications etc.

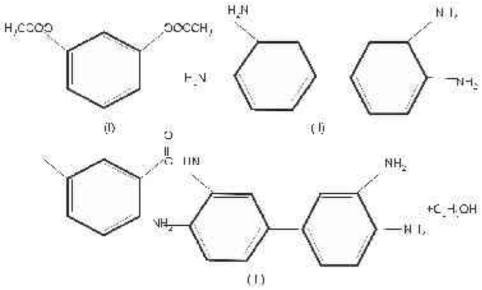
1. Introduction

Brinker and Robinson invented the first aliphatic polybenzimidazoles[1] in 1949. However the discovery of aromatic polybenzimidazole which show excellent physical and chemical properties was generally credited to Carl Shipp Marvel in the 1950s. (Leonard, Nelson Feb 2014) The materials Laboratory of Wright Patterson Air Force Base approached Marvel. They were looking for materials suitable for drogue parachutes which could tolerate short-time mechanical stress. The original search concentrated on aromatic condensation polymers but the amide linkage proved to be weak link for the aim of maximum thermal stability of the polymer, whereas Marvel's research focused on condensation polymers with aromatic and heteroaromatic repeating units. This progressively led to the discovery of polybenzimidazole.Polybenzimidazole (PBI) is abbreviation of poly [2, 2'-(m-phenylene)-5, 5'-bisbenzimidazole]) polymer with very high melting point. It has exceptional thermal and chemical stability and does not readily ignite, superior stability, retention of stiffness, and toughness at elevated temperature. Due to its high stability, polybenzimidazole is used to fabricate high-performance protective apparel such as firefighter's gear, astronaut space suits, high temperature protective gloves, welders' apparel and aircraft wall fabrics. In recent years, polybenzimidazole found its application as a membrane in fuel cells.

2. Synthesis

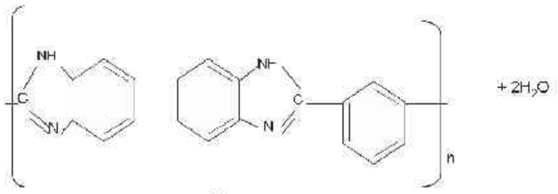
The preparation of PBI (IV) can be achieved by condensation reaction of diphenyl isophthalate (I) and 3,3',4,4'-tetraaminodiphenyl (II) (Figure 1). The spontaneous cyclization of the intermediately formed animo-amide (III) to PBI (IV) provided a much more stable amide linkage.

This synthesis strategy was first adopted and developed a two step process. In a typical condition, starting materials were heated at 270ºC degree for 1.5 h to form the PBI prepolymer and later the prepolymer was heated at 360 degree for another 1 hr to form the final commercial-grade product. The reason for the second step is due to the formation of the by-product phenol and water in the first step creating voluminous foam, **(Tai-Shung Chung, 1 May 1997)**which leads to the volume expansion of several times of the original. This was advised to commercial manufacturers to consider it during synthesis. This foam can be reduced by conducting the polycondensation at a temperature around 200 °C and under the pressure of 2.1-4.2 MPa **(Kricheldorf, H R. 1992)**. The foam can also be controlled by adding high boiling point liquids such as diphenylether during polycondensation. The boiling point can make the liquid stay in the first stage of polycondensation but evaporate in the second stage of solid condensation. The disadvantage of this method is that there are still some liquids which remain in PBI and it is hard to remove them completely **(Kricheldorf, 1992)**.



diphenyl isophthalate + 3,3',4,4'-tetraaminodiphenyl $\xrightarrow[\text{(270°c for 1.5}]{\text{Poly condentation}}$ amino amide +Phenol+water

(I) (II) (III)

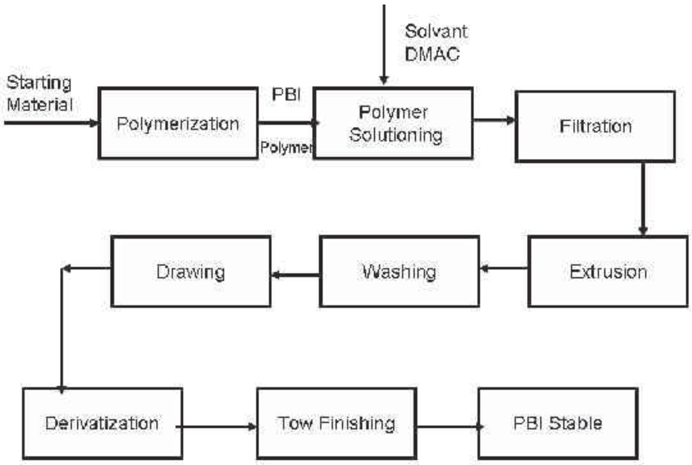


(IV

Polybenzimidazole (PBI)

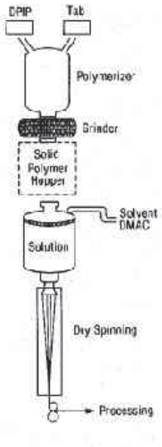
Manufacturing Process

The most common form of PBI used in industry is the fiber form. The fiber process following polymerization is shown in the figure. The polymer is made into solution using dimethylacetamide as solvent. The solution is filtered and converted into fiber using a high temperature dry-spinning process. The fiber is subsequently drawn at elevated temperature to get desired mechanical properties. It is then sulfonated and made into staple using conventional crimping and cutting techniques.



The PBI fiber is made in a serial of steps following polymerization to get PBI staple form for direct usage.

Spinning of PBI fibre:



PBI Process

Fibre forming involves the dry extrusion of the polymer solution through a fine holed spinneret into a heated inert atmosphere. As the dope solution exits the spinneret, the DMAc evaporates and the solution begins to form into a semi-solid fibre. The resulting bundle of fibres is drawn through a heated chamber to complete the fibre formation and remove most of the DMAc. The DMAc vapour is recovered through a vapor-recovery system. As individual fibre ends exit the heated chamber, they are combined with other ends to form a sub-tow. After the required number of sub-tow creels are produced, they are brought together to form a heavy denier tow band for final processing; known as tow finishing consist of Washing, Drawing, Sulphonating, Crimping, finishing and cutting.

Properties

1. General physical properties

PBI is usually yellow to brown solid infusible up to 400 °C or higher (Springer 1982).

The solubility of PBI is controversial For example, one type of PBI prepared in phosphoric acid was found by Iwakura et al. (Iwakura, Yoshio; Uno, Keikichi; Imai, Yoshio :June 1964). to be partially soluble in formic acid, but completely soluble in dimethyl sulfoxide and dimethylacetamide, whereas Varma and Veena (I. K.; Veena Varma, April 1976). reported the same polymer type to dissolve completely in formic acid, yet only partially in dimethyl sulfoxide or dimethylacetamide.

2. Thermal stability

Imidazole derivatives are known to be stable compounds. Many of them are resistant to the most drastic treatments with acids and bases and not easily oxidized. The high melting point and high stability at over 400 degree. Polybenzimidazole and its aromatic derivatives can withstand at temperature about 500 degrees without softening and degrading. The polymer loses only 30% of its weight after exposure to high temperature up to 900 degrees for several hours. **(Marvel, C. S. Vogel, Herward; April 1961)** This proves a high thermal stability for PBI.

3. Flame resistance

PBI are highly flame resistant material compared to common polymers. (Dirk W.van Krevelen 30 March 1972)

4. Moisture regain

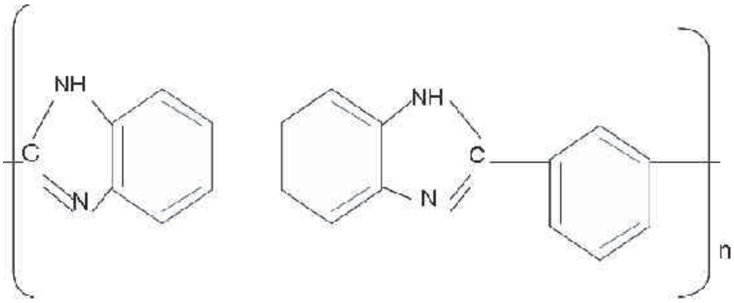
The moisture regain ability of PBI (13%) compares favorably with cotton (16%). (R. N. Demartino,1 August 1984).

5. Textile properties

Properties of PBI Stable Fibre		
Property	**English Unit**	**Metric Unit**
Denier Per Filament	1.5 Denier	1.7decitex
Tenacity	2.7g/D	2.7gN/tex
Elongation at break	27%	27%
Initial Modulus	45g/D	40gN/tex
Crimp Frequency	9.5/inch	3.7/cm
Finish	0.35%	0.35%
Specific Gravity	1.4	1.4
Moisture Regain at 65%RH,20'C	15%	15%
Limited Oxygen Index LOI	<41%	>41%

6. Applications in apparel

PBI filaments were fabricated into protective clothing like firefighters' gear and astronauts' suits due to its high thermal stability , flame resistance, moisture regain. (Raymond B. Seymour, Gerald S. 1987). Aluminized crash rescued gear, industrial worker's apparel, and suits for racing car drivers.(R.B.Sandor, 1990). Now the fibers used in the protective gear is poly (2, 2'-m-phenylene-5, 5'-bibenzimidazole) which use tetraaminobiphenyl as monomer for a better thermo resistance property.



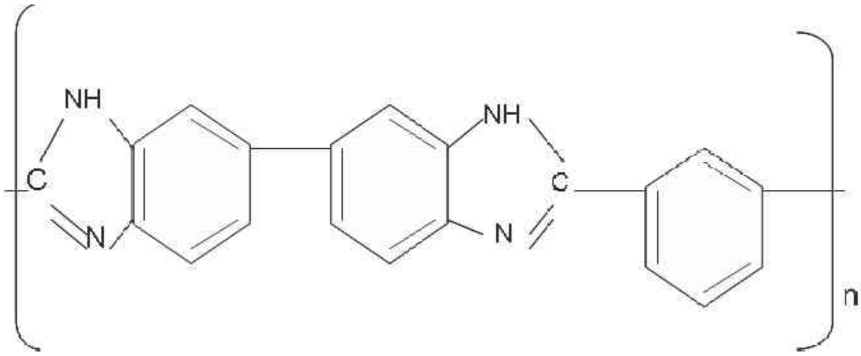
The problem of PBI protective apparel is that it keeps heat out but it also keeps the heat in, too. Thus, by the time the firefighters feel heat and pain, it is too late and they will get burnt or killed since it is hard for the heat to penetrate the suit and be released into the air.

6.1 PBI membranes

PBI has been used as the membranes for various separation purposes. Traditionally, PBI was used semi-permeable membranes for electro dialysis, reverse osmosis or ultra filtration. **(Mager, David Mar 2014)** Recently PBI is also used for gas separations. **(Kumbharkar,October 2012)**.due to its close chain packing since PBI has rigidity structure and strong hydrogen bonding.

6.2 Molded PBI resin

PBI resin is molded via a sintering process that was jointly developed by Hoechst Celanese (North Carolina, USA) and Alpha Precision Plastics, Inc. (Houston, Texas, USA).(Ward, B.C 1987). Molded PBI resin is an excellent candidate for high strength, low weight material. (Sandor, R.B. 1990) Moreover, its thermal and electrical properties also make it a well-known thermoplastic resin. The PBI resin comprises a recurring structural unit represented by the following figure.



The recurring structural unit for PBI resin

In the industrial sector, PBI resin's high dimensional stability as well as retention of electrical properties at high temperature make it used as a thermal and electrical insulator.

6.3 Fuel cell electrolyte

Wang et al. reported that PBI doped with phosphoric acid was utilized as a high temperature fuel cell electrolyte.**(Wainright,, J.S.; Wang, J.-T., Weng, D., Savinell, R.F., Litt, M July 1995)**, **(Samms,1996).**

PBI/H3PO4 is conductive even in low relative humidity and it allows less crossover of the methanol at the same time. **(T.S. Zhao 2009)**. This means that the thinner films can be used, thus reducing ohmic loss.

6.4 Asbestos replacement

Moreover, a safety garment manufacturer reported that gloves containing PBI outlasted asbestos two to nine times with an effective cost. Gloves containing PBI fibers are softer and suppler than those made of asbestos, offering, the worker greater mobility, and comfort even if the fabric becomes charred. Besides, PBI fiber avoids the chronic toxicity problems associated with asbestos because it processes on standard textile and glove fabricating equipment.**(Celanese Mar 2014)** PBI also can also be a good substitute for asbestos in several areas of glass manufacturing.

6.5 Flue gas filtration

PBI's chemical, thermal and physical properties demonstrate that it can be a promising material as a flue gas filter fabric for coal-fired boilers. Few fabrics can survive in the acidic and high temperature environment encountered in coal-fired boiler flue gas. **(Hearle, J.W.S. 2004)** The filter bags also must be able to bear the abrasion from the periodic cleaning to remove accumulated dust. PBI fabric has a good abrasion resistance property. The acid and abrasion resistance and thermal stability properties make PBI a competitor for this application.

7. Recent Development in PBI Fibre

7.1 Chemical and bonding effects of exposing uncured PBI-NBR insulation to ambient conditions

Uncured Polybenzimidazole-Nitrile Butadiene Rubber (PBI-NBR) insulation experiences altered chemical and bonding phenomena if exposed to ambient conditions while in a sheet-stock configuration. Multiple lots of a PBI-NBR formulation exposed to ambient and slightly elevated temperature (1008F) conditions experience bonding degradation when vulcanized to a metal substrate.[21]

7.2 Recent advances in polybenzimidazole/ phosphoric acid membranes for high-temperature fuel cells

Proton exchange membrane fuel cells are one of the most promising technologies for sustainable power generation in the future. In particular, high-temperature proton exchange membrane fuel cells (HT-PEMFCs) offer several advantages such as increased kinetics, reduced catalyst poisoning and better heat management, good proton conductivity as well as stability and durability at the required operating temperatures. [22]

7.3 Synthesis and Properties of Fluorine- and Siloxane -Containing Polybenzimidazoles for High Temperature Proton Exchange Membrane Fuel Cells

In this study, new fluorine-siloxane-containing polybenzimidazole (PBI) copolymers were synthesized by copolymerization of 3,3-diaminobenzidine, 2,2-bis(4- carboxyphenyl) -hexafluoropropane (HFA), and 1,3 bis (carboxypropyl) tetramethyldisiloxane (BTMDS) with different molar ratios. PBI copolymer membranes were prepared by solution-casting and then doped with phosphoric acid. The solubility of the PBI copolymers was significantly increased by the introduction of the bulky HFA group and the flexible BTMDS group into the polymer backbone. The PBI copolymers still maintained good thermal stability and mechanical properties. [23]

7.4 Polybenzimidazole (PBI) Nano filtration hollow fiber membranes applied in forward osmosis process

It has demonstrated that the asymmetric PBI Nano filtration hollow fiber membranes with a mean effective pore size around 0.32 nm in radius can be used effectively for forward osmosis .ThePBI Nano filtration hollow fiber membrane is of great potential to be utilized in the forward osmosis process for water recover and concentrating various feed solution.[24]

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Ultrasonic Technology in Textile Processing

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Introduction

Ultrasonics may be employed to reduce processing time and energy consumption, and to maintain or improve product quality. In addition to its well established applications in forming stable dispersions and cleaning materials and machine parts, several new areas are being investigated. The widespread availability of cheap and reliable ultrasound generators, mainly in the form of cleaning baths, has promoted increased interest in the effects of ultrasonics in textiles. Growing interest in sonochemical reactions is an example which does not require the use of specialized equipment.

Ultrasonics

Acoustic frequencies between 16 kHz and 1 GHz are referred to as ultrasound; in industrial settings we call it "ultrasonics". Ultrasonic vibrations are mechanical longitudinal waves that achieve deformation in plastic materials , cause friction between molecules The resulting friction heat generates a melt that bonds the joining partners within the molecules.

Friction occurs due to impedances in the material, absorption and reflection of the mechanical vibration:

- internal friction in the molecule bond = dissipative work
- external friction between joining partners = surface friction

Usage in desizing

In a study on the sizing and desizing of textiles with starch, size removal was effected by means of ultrasonically accelerated techniques. It was found that the use of degraded starch followed by ultrasonic desizing could lead to considerable energy savings as compared to conventional starch sizing and desizing.

Usage in scouring and bleaching

Reports stated that it was possible to scour wool in neutral or very slightly alkaline baths. Fiber damage was less when ultrasound was used as compared to conventionally scoured wool fibers. Another study on the scouring of wool also claims that fiber properties are improved and the rate of processing increased when ultrasonics are used.

Usage in dyeing

The influences of ultrasound on the dyeing of textile material are proposed to have possible three effects namely

1. Dispersion: breaking up of micelles and high molecular weight aggregates into uniform dispersions in the dye bath
2. Degassing: expulsion of dissolved or entrapped gas or air molecules from fiber capillaries and interstices at the crossover points of fabric into liquid and removal by cavitation, thus facilitating dye-fiber contact
3. Diffusion: Accelerating the rate of diffusion of dye inside the fiber by piercing the insulating layer covering the fiber and accelerating the interaction or chemical reaction, if any, between dye and fiber.

Usage in finishing

Finishing of textiles involving ultrasonics has been studied by several researches applied ultrasound at 8 and 18 kHz frequency to formaldehyde resin treatment of cotton fabric and measured the change in physical properties before and after 60 washing cycles. The crease recovery angle, even after 60 washings, was much higher than with ultrasound .

Usage in washing

Laboratory tests have shown that the washing time of wool can be reduced from 3 hours to 15 or 30 minutes for an equivalent whiteness.

The rapid cavitation is followed by powerful shocks which act on the fabric being washed. This weakens the molecular forces of adhesion between the particles of impurities and the fabric. Under these conditions, the foreign bodies which soil the fabric surface are detached and disperse into the washing solution.

Problems with ultrasound

- No significant commercial installations have been developed to date for the following reasons:
- Applying ultrasound to a bath is expensive, and environmental problems have not been a significant concern until recently;
- The ultrasound waves may be less predictable with production size equipment; and Intensity of the wave could vary with production size equipment.

Conclusion

It has been found that the benefits of ultrasonic waves in textile processes may include savings in energy, reduction in consumption of chemicals and/or dyes, and reduces in process time. Improvement in quality and easier process control of textiles and other criteria that merit consideration while determining the economical viability of the technique. Another important aspect of today's concern is the possibility of reducing the pollution load on effluent water. Increased mass transfer from liquid to textile substrate leads to two possibilities: (i) increase in add-on, or (ii) less dosage of dyes or chemicals to the bath to obtain equivalent add-on to the substrate.

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Camouflage Textile

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1. Introduction

The word camouflage has its origin in the French word camoufler. The purpose of camouflage is preventing the detection and identification of objects, in the broad sense of the word, by misinforming, pretence and hiding. The development of modern detection means which work in a wide range of electromagnetic radiation stimulates the development of camouflage agents, including paint, screens, and camouflage cover.

Camouflage helps an organism blend in with its surroundings. Camouflage can be colours or patterns or both. Camouflage textiles not only help protect armed forces from visual and IR detection but also-with regards to their heat and sweat management capabilities-ensure that the soldiers can perform to the best of their abilities even in extreme climatic conditions.

2. Salient features of camouflage textiles:

- Physical lightweight and durability " Non glaring/shining
- High tear and tensile strength
- Comfort wear and antistatic
- Shade stability
- wash and perspiration fastness
- Windproof, water repellent or even water proof and breathable
- Flame retardant
- Antimicrobial, insect, mosquito repellent

3. Types of camouflage

1. Natural and artificial camouflage
2. Thermal camouflage
3. Visual camouflage
4. IR camouflage
5. Camouflages for multiple spectra
6. Anti-radar camouflage

3.1 Natural Camouflage: There are mainly two types of camouflage under this category:

1. Mimetic camouflage 2. Disruptive camouflage

Mimetic Camouflage :- Mimicry Some animals and plants look like other things they mimic them. Mimicry is another type of deceptive coloration. It can protect the mimic from predators or hide the mimic from prey. If mimicry was a play, there would be three characters.

The Model - The species or object that is copied. Mimic - looks and act like another species or object.

Dupe- the tricked predator or prey. The poisonous coral. Snake and the harmless king snake look a lot alike. Predators will avoid the king snake because they think it is poisonous. This type of mimicry is called Batesian mimicry.

Disruptive camouflage: Counter shading, which defeats a predator's ability to identify prey by shape. In countershading, the upper parts of an animal are dark and its lower parts are light. This reverses the normal distribution of luminance on objects, which are usually lit from above. Boundary disruption, Each zebra's stripes blend with the stripes of the other zebras around it. This kind of camouflage is called Boundary disruption, and it confuses predators, which tend to see only a large, striped mass instead of many individual animals.

Digital Camouflage: Digital camouflage is a type of camouflage pattern combining micro- and macro patterns, often though not necessarily with a pixelated look created with computer assistance. The function is to provide military camouflage over a range of distances. The "digital" refers to the coordinates of the pattern, which are digitally defined. The term is also used of computer generated patterns like the non-pixelated Multi-cam and the Italian fractal Vegetato pattern. According to the patent for MARPAT, pixelation does not in itself contribute to the camouflaging effect. The pixelated style, however, simplifies design and eases printing on fabric, compared to traditional patterns. While digital patterns are becoming widespread, critics maintain that the pixelated look is a question of fashion rather than function

3.2 Thermal Camouflage: A thermal camouflage tarpaulin (heavy waterproof cloth for covering) for hiding heat sources against detection in a thermal image, comprising a base textile composed of a loop-forming knitted or woven glass fabric is provided on the side which is remote from the heat source with a compound whose reflectance values are in the region of a visual camouflage and/or in the infrared region. Said base textile is provided on that side which faces the heat source with a free-standing polyester film to which has been applied a vapor-deposited coating which reflects thermal radiation.

Material Used For Camouflage Textile: In manufacturing of the camouflage materials that secure protective features in visible and NIR spectral ranges these coloration technologies are dominant:

- use of special selected dyes and pigments
- incorporating strongly IR absorbing pigments into printing paste
- incorporating strongly IR absorbing pigments into the polymer at a fiber forming process
- use of special and minimizing IR reflectance coatings (layers)

It is relatively easy to print a wide range of textile fibre types in the correct visual shades with the colour fast dyes. However it is more difficult to achieve NIR cover on the same fabric. Artificial fibres such as polyamide, polyester, aramids and their blends with natural fibres cause these particular problems. The camouflage should stay efficient during all the wearing time, so the colour fastness to various influences and treatments becomes an extremely important parameter, ensuring the concealment of the target both in the visual and NIR radiation spectral ranges.

In short, stealth comprises various means employed in offence to avoid detection by the other party. One typical example where stealth plays a very important role is the fighter aircraft. The aircraft in the air is seen conspicuously against a uniform background if it is not made stealthy. Similarly, a ship on a uniform background of sea and/or sky can be easily detected unless made stealthy. Ofcourse, on land, there is a lot of heterogeneity for a military object such as a tank. Tanks of the future may also have to be made stealthy. Stealth technology or low observable technology deals with the design of weapon platforms from the beginning stage itself to include low observable features as a major design goal, rather than as a retrofit capability. The various signatures that are to be considered in a stealth warship are: Radar, Infrared, Acoustic, Magnetic, Electric, Hydrodynamic wake, Extra low frequency, Miscellaneous such as contaminants etc.

3.3 Visual Camouflage

Basic Principles Of Camouflage In The Visible Region:

1. Hiding: In hiding, the objects are physically hidden by the use of natural materials such as vegetation natural and cut and artificial materials such as nets, screens etc. Screens: A variety of screens, such as horizontal, vertical and overhead types, are used for concealing stationary military objects. These screens act as physical barriers between the target and the sensor. Besides, there are smoke screens which provide temporary concealment in situations such as movement of troops.

Blending: In camouflaging by blending, the object is made to blend with the background. The object becomes an integral part of the background and is hence rendered invisible, and thereby unrecognizable. Camouflaging by blending involves optical principles which produce illusory effects. Principles which nature has applied to camouflage various animals

2. Colour Matching: The first requirement for an object to blend with its general background is that the colour of the object should be the same as that of the background.

3. Disruptive Colouration: Colour matching and simultaneous countershading is not possible under all conditions. One of the most important principles of camouflage is that produced by dazzle. It is an American term which came into popular use during war in connection with camouflage painting of military objects. When an object is painted with irregular patches of colours of varying contrast and tones, the attention of the observer is diverted away from the actual shape of the object but drawn towards the dazzling patches. The patterns which attract attention do not bear any relationship with the shape of the object with which the observer is familiar.

3.4 Infrared Camouflage:

The term infrared camouflage denotes any device or equipment or technique employed to counter detection by an infrared system. Advances in infrared sensor technology have put great stress on infrared camouflage and demanded countermeasures.

Properties of Infrared Radiation :

Propagation Characteristics Infrared radiation travels with the speed of light, like any other type of electromagnetic radiation, and, in its transit from the source undergoes reflection, scattering, absorption, transmission, diffraction and polarization. In most of the cases, the intervening medium between the source and the detector is the atmosphere. As the radiation passes through the atmosphere, it gets attenuated by its interaction with the various constituents of the atmosphere. This process is known as extinction. Visual vulnerability The detection probability, aided or unaided, is dependent on shape, size, hue, colour contrast, mobility.

Microwave Camouflage

These were synthesized in the laboratory and characterized by IR spectroscopy and elemental analysis. Absorber samples of finite thickness were prepared and tested for radar absorption at X-band frequencies.

3.5 Multispectral Camouflage Materials

DMSRDE has initiated a programme for developing a multispectral camouflage system which should be able to cater for visible, NIR, thermal IR and centimeter and millimeter wave radar regions.

3.6 Anti-Radar Camouflage: Camouflage material incorporates means for specifying and providing predetermined degree of reflection of incident radar waves which is optimum for particular use environments. The overall pattern is the resultant of control of reflection of longer radar wavelengths by a layer of electrically conductive fibrils of controlled density and reflection of shorter radar wavelengths by thin mosaic layer of metal. Metafil Mat is the ultimate material to provide effective shielding from electromagnetic interference. Our Metafil Mat is used in radar blocking equipment for the military and in shielding for satellite antennae. Metafil consists of aluminium coated glass fibres thermally bonded into a nonwoven mat of uniform density. The fibres are oriented to provide superior electrical and shielding performance. The structure of the material allows for conformability to irregular surfaces and compatibility with other base substrates or resin systems.

Camouflage For Military Textiles: Through nanotechnology, new personnel camouflage systems can be developed that can change pattern and colors as environment changes. "Chameleonic" camouflage allows the soldier to become a mirror of his surroundings. Military camouflage is the use of camouflage by a military force to protect personnel and equipment from visual observation by enemy forces. In practice, this means applying colour and materials to military equipment of all kinds, including vehicles, ships, aircraft, gun positions and battledress, either to conceal it from visual observation , or to make it appear as something else. The aim is to make sure that the surface of the soldiers and not form a contrasting shape against the background. The principles involved in camouflage materials are shape, shine, shadow, silhouette, surface, spacing and movement. The hues used in the camouflage are green, olive, khaki, brown and black.

4. Principles

4.1 Compromise: No single camouflage pattern is effective in all terrains. The effectiveness of a pattern depends on contrast as well as colour tones. Strong contrasts which disrupt outlines are better suited for environments such as forests where the play of light and shade is prominent While civilian hunting clothing may have almost photo-realistic depictions of tree bark or leaves ,military camouflage is designed to work in a range of environments. With the cost of uniforms in particular being substantial, most armies operating globally have two separate full uniforms, one for woodland/jungle and one for desert.

4.2 Movement: While patterns can provide more effective crypsis than solid colour when the camouflaged object is stationary, any pattern, particularly one with high contrast, stands out when the object is moving. Jungle camouflage uniforms were issued during the Second World War, but both the British and American forces found that a simple green uniform provided better camouflage when soldiers were moving. After the war, most nations returned to a unicoloured uniform for their troops. Some nations, notably Austria and Israel continue to use solid colour combat uniforms today. . Similarly, while larger military aircraft traditionally had a disruptive pattern with a darker top over a lighter lower surface, modern fast fighter aircraft often wear gray overall.

4.3 Digital Camouflage: Digital camouflage provides a disruptive effect through the use of pixellated patterns at a range of scales, meaning that the camouflage helps to defeat observation at a range of distances.

4.4 Non-Visual Stealth technology by class corvette stealth. With the birth of radar and sonar and other means of detecting military hardware not depending on the human eye, came means of camouflaging against them. Collectively these are known as stealth technology. Aircraft and ships can be shaped to reflect radar impulses away from the sender, and covered with radar absorbing materials, to reduce their radar signature.

5. Applications Uniforms: The role of uniform is not only to hide each soldier, but also to identify friend from foe. Armies facing service in different theatres may need several different camouflage uniforms. Separate issues of temperate/jungle and desert camouflage uniforms are common. Patterns can to some extent be adapted to different terrains by adding means of fastening pieces of vegetation to the uniform. Helmets often have netting covers; some jackets have small loops for the same purpose

Land Vehicle: The purpose of vehicle and equipment camouflage differs from personal camouflage in that the primary threat is aerial reconnaissance.

Ships, Aircraft: Aircraft camouflage faces the challenge that an aircraft's background varies widely, according to whether the observer is above or below the aircraft, and with the background, e.g. farmland or desert. Aircraft camouflage schemes have often consisted of a light colour underneath and darker colours above.

In Fashion And Art: Fashion and the "Dazzle Ball" The scheme of decoration for the great fancy dress ball given by the Chelsea Arts Club at the Albert Hall, the other day, was based on the principles of 'Dazzle', the method of 'camouflage' used during the war in the painting of ships .The total effect was brilliant and fantastic.

Camouflage In Art Wear: Protesters and fashionist as through nanotechnology, new personnel camouflage systems can be developed that can change pattern and colors as environment changes. "Chameleonic" camouflage allows the soldier to become a mirror of his surroundings. Non-military use of camouflage includes making cell telephone towers less obtrusive and helping hunters to approach wary game animals. Patterns derived from military camouflage are frequently used in fashion clothing, exploiting their strong designs and sometimes their symbolism.

Application:

- Microwave antennas
- EMI/RFI shielding
- Lightning strike protection
- Electrostatic finishing
- Electrostatic dissipation
- Thermal dissipation
- Radar reflective composites
- Multi-resin compatibility
- Good drapeability, conforms to irregular surfaces 6.

Production Of Camouflage Textiles

The concept of producing textiles that readily vary in colour has long been an anathema to the textile colourist for whom achieving permanency of colour has been a primary goal stretching back into antiquity. Consequently, colourant manufacturers have striven for many years to develop fast coloured materials by hunting for dyes and pigments that are chemically inert and physically unresponsive once they have been applied to a substrate.

6.1 pH changes: Molecules can change colour dramatically in the presence of acids and bases, but these reagents and the solvents required to transport them make this method extremely difficult to implement in the applications.

6.2 Oxidation state changes: This method is also highly effective, but requires the migration of ions. The response time can be fast in solvents, but this complicates the device. Gel-type devices might also be possible, though physical robustness, oxygen stability and response times represent serious engineering chal- lenges. A device built on this principle would be similar to a polymer LED.

6.3 Bond breaking/making: There are a number of systems that undergo reversible bondbreaking, bond-forming processes that result in dramatic colour changes. Most commonly, these are light-initiated processes.

6.4 Mechanochromism: Certain compounds have been shown to undergo colour changes as a result of applied stress. A mechanochromic system is constructed by surface modification of conducting polymers.

6.5 Electric or magnetic field : effects Some highly polarizable systems have been observed to change colour in the presence of electric or magnetic fields.

7. Chromic materials

Chromic materials are also called camouflage fibres, because they can change their colour according to the external conditions. These materials have been used mostly in fashion, to create novel colour changing designs. Because of this, some people fear that the chromic materials will be a short boom, but the accuracy and endurance of the materials are being improved. Chromic materials refer to materials that radiate the colour, erase the colour or just change it because its induction is caused by the external stimuli (as 'chromic' is a suffix that means colour). So the chromic materials can be classified depending on the stimuli affecting them.

- Photochromic: external stimuli energy is light.
- Thermochromic: external stimuli energy is heat.
- Electrochromic: external stimuli energy is electricity.
- Piezorochromic: external stimuli energy is pressure.
- Solvatochromic: external stimuli energy is liquid.
- Carsolchromic: external stimuli energy is electron beam.

8. Conclusion:

The development of several surveillance technology has rendered obsolete textile production techniques that provide camouflage solely in the visible region of the electromagnetic spectrum. Modern military forces require counter surveillance materials that afford protection against several surveillance technology, camouflage textiles must satisfy for all threats. The ease of fulfilling such requirements varies with the substrate of the camouflage material. Conventional methods for the coloration of other fibers have been found to be inadequate. Novel dyes and pigments, as well as new techniques, have had to be developed in future.

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Plasma Technology

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Introduction

Plasma modification of textiles represents great opportunity for improvement of older, energetically demanding, and slow, sometimes not very eco-friendly treatment technologies. Application of plasma is ecological and friendly for production costs due to energy savings and reduction of processing times. [1] Compared with current standard finishing processes, plasmas have the crucial advantage of reducing the usage of chemicals, water and energy. Moreover, they offer the possibility to obtain typical textile finishes without changing the key textile properties. No wonder there is an increasing interest in plasma for textile materials processing but for now plasma treatment is commonly used for surface activation and modification of different materials including textiles. [3]

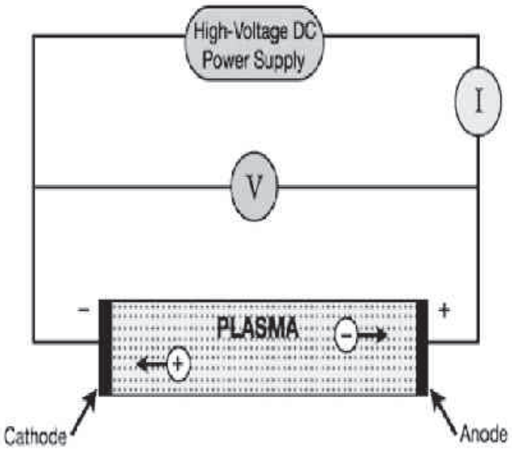
History of Plasma Technology

Plasma, the 4th state of matter is not so a strange thing, it had been first developed by M. Faraday in 1880s and plasma concept was first proposed by I. Langmuir in 1926. The plasma is an ionized gas with equal density of positive and negative charges which exist over an extremely wide range of temperature and pressure. [4] The plasma consists of free electrons, ions, radicals UV-radiation and other particles depending upon the gas used. Plasma is a gas of which a fraction of its constituents are no longer electrically neutral. Instead, the atoms/ molecules are ionised, i.e. they lost (or gained) one or more electrons. These free electrons are also present in the plasma. Practically, one generates the plasma by applying an electrical field over two electrodes with a gas in between. This can be carried out at atmospheric pressure or in a closed vessel under reduced pressure. [3]

Production of Plasma

Plasma is generated when an electrical current is applied across a dielectric gas or fluid.

Plasma Reactors



Different types of power supply to generate the plasma are:

1. Low-frequency (LF, 50-450 kHz)
2. Radio-frequency (RF, 13.56 or 27.12 MHz)
3. Microwave (MW, 915 MHz or 2.45 GHz)

The power required ranges from 10 to 5000 watts, depending on the size of the reactor and the desired treatment.

Classification of Plasma

As mentioned, one needs a gas to generate plasma. Then pressure of this gas will have a large influence on the plasma properties but also on the type of equipment needed to generate the plasma. Basically there are three pressure ranges in plasma: low pressure, sub-atmospheric and atmospheric.

1. Low Pressure Plasma

Low pressure plasmas are typically in the pressure range of 0.01 kPa. A vacuum chamber and the necessary vacuum pumps are required. A vacuum vessel is pumped down to a pressure in the range of 0.01 to 0.001 mbar with the use of high vacuum pumps. The gas which is then introduced in the vessel is ionised with the help of a high frequency generator. The advantage of the low-pressure plasma method is that it is a well controlled and reproducible technique. These plasmas are characterised by their good uniformity over a large volume 2,3.

2. Atmospheric Plasma

Atmospheric plasmas operate at standard atmospheric pressure (100 kPa). Open systems using the surrounding air exist. The range of processes is not as large as for low pressure plasmas. On the other hand, these systems are easily integrated in existing finishing lines, a major advantage from industrial view point. Different methodologies used to induce the ionisation of gases are Glow discharge, Corona discharge and Dielectric Barrier discharge.

Corona discharge is characterised by bright filaments extending from a sharp, high-voltage electrode towards the substrate. Corona treatment is the longest established and most widely used plasma process; it has the advantage of operating at atmospheric pressure, the reagent gas usually being the ambient air. In particular, corona systems have an effect only in loose fibres and cannot penetrate deeply into yarn or woven fabric so that their effects on textiles are limited and short-lived. Essentially, the corona plasma type is too weak. Corona systems also rely upon very small inter electrode spacing (1 mm) and accurate web positioning, which are incompatible with 'thick' materials and rapid, uniform treatment.

Glow discharge is characterised as a uniform, homogeneous and stable discharge usually generated in helium or argon (and some in nitrogen). This is done, for example, by applying radio frequency voltage across two parallel-plate electrodes. Atmospheric Pressure Glow Discharge (APGD) offers an alternative homogeneous cold-plasma source, which has many of the benefits of the vacuum, cold-plasma method, while operating at atmospheric pressure.

Dielectric Barrier discharge/Silent discharge is a broad class of plasma source that has an insulating (dielectric) cover over one or both of the electrodes and operates with high voltage power ranging from low frequency AC to 100 kHz. This results in non-thermal plasma and a multitude of random, numerous arcs form between the electrodes. However, these micro discharges are non uniform and have potential to cause uneven treatment.

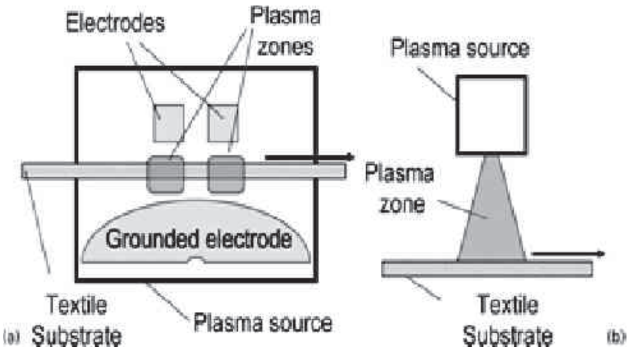
3. Sub Atmospheric Plasma [3]

In between, one has the sub atmospheric plasmas (typically around 1 kPa). The disadvantages of this pressure range are a mixture of the ones of the low and atmospheric pressure range. Sub atmospheric plasmas aim at providing the process flexibility of the low pressure without the more complex and expensive equipment. However, one does need a closed reactor which means that the process is not compatible with inline processing.

Application

Method of Application

Two methods have been devised for application of Plasma on textile substrate. The first one in which the substrate is made to pass in between the electrodes where Plasma is originally ionised, the second one in which the plasma state is first formulated completely and then treated on the substrate separately. The first one is generally used for low pressure plasma treatment while the other one is mostly adopted for atmospheric pressure plasma treatment [2-4.]



Various application of plasma in textile finishing

Application	Material	Treatment
Hydrophilic finish	PP, PET, PE	Oxygen plasma
Hydrophobic finish	Cotton, P-C blend	AiSiloxane plasma
Antistatic finish	Rayon, PET	Plasma consisting of dimethylsilane
Reduced felting	Wool	Oxygen plasma
Crease resistance	Wool, cotton	Nitrogen plasma
Improved capillarity	Wool, cotton	Oxygen plasma
UV protection	Cotton/PET	HMDSO plasma
Flame retardancy	PAN, Cotton, Rayon	Plasma containing phosphorus

Conclusion

Compared with current traditional finishing processes, plasmas have the crucial advantage of reduced usage of chemicals, water and energy. They also offer the possibility to obtain typical textile finishes (e.g. hydrophilic, oleo phobic, antibacterial) without changing the key textile properties (hand, softness, flexibility, etc.). This potential explains why plasma treatment has already been investigated extensively. Integrating plasma processes at different stages of the production process (sliver, yarn level, or on fabric) have been investigated, for a whole range of different materials and applications. Nevertheless, industrial application is still very limited because important hurdles exist at various levels (cleanliness of the substrates, investments, offline treatment, scale-up).

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Electronic Textiles

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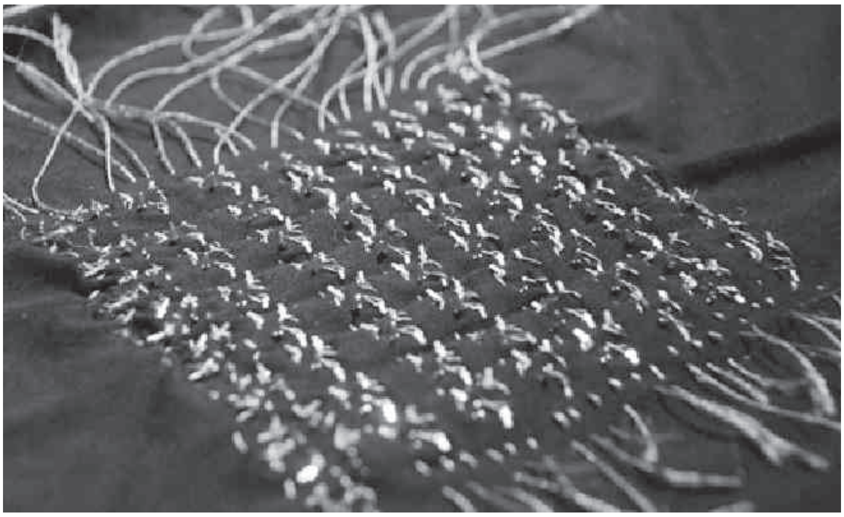
Introduction

Now that we've grown comfortable with carrying technology, we're starting to see new benefits in wearing it. Ever-shrinking electronic components have been a key enabler of the current generation of wearable technologies. Smarter and smaller microprocessors are also becoming more power-efficient with every release. The introduction of Bluetooth Low Energy (BLE) has been one of the most important breakthroughs, allowing wearable devices to connect to smart phones as "hub" devices and transmit/receive high volumes of data over higher ranges (up to 100 meters) with a much lower amount of power than any previous versions. BLE has another benefit which is helping to establish its position as the de facto wireless transmission technology in wearable. E-textiles i.e. electronic textiles, also known as smart textiles, or smart fabrics, are fabrics that enable digital components (including small computers), and electronics to be embedded in them. In the early 1990s, MIT students started research on smart clothing for military use. Pailes-Friedman of the Pratt Institute states that "what makes smart fabrics revolutionary is that they have the ability to do many things that traditional fabrics cannot, including communicate, transform, conduct energy and even grow". Fibretronics deals with the construction of electronic capabilities on textile fibers, requires the use of conducting and semi-conducting materials such as a conductive textiles.

Conductive fibers include:

- Nickel copper plated nylon fabric
- 30% Stainless steel 30% cotton 40% polyester fabric
- 100% silver fabric (woven, knitted)
- Silver cotton/ polyester fabric (woven, knitted)
- Conductive thread (silver fiber, stainless fiber)



Fibretronic is a provider of wearable electromechanical interfaces such as joysticks and pushbuttons used in outdoor wear (such as jackets and gloves). These devices provide users access to traditional electronic devices such as smart phones, GPS receivers, and portable music players. The Peregrine glove uses swatches of conductive fabric and strings of resistive elements (coiled steel wire) to provide up to 18 programmable "button" locations on the glove surface for user input into a computer. Nottingham Trent University (NTU) in the U.K. has done extensive research in e-yarns and e-textiles. It's expertise in advanced textiles includes textile fiber materials, digital textile manufacturing processes and garment making. To date, the main drivers of e-textile-based wearable have been health care, sportswear and the military.

1 In military, it helps to sense tank movements, chemical sensors etc. Production and design issues common across the industry, such as creating simple and reliable connectors for integrating electronic hardware or creating durable flexible-component technologies, have often been resolved with proprietary solutions developed by the individual.

2 Conductive yarns and fabrics continue to improve and the ranges expand, creating better, more durable and reliable building blocks for new products. Textile electrodes are now able to collect clinical grade physiological data comparable to gel electrodes, but can be integrated into clothing and worn comfortably all the time, adding critical core health data to monitoring in both sports and healthcare settings.

- ZOLL life vest is a wearable defibrillator. In this if heart palpitations or alarming rhythm is detected i.e. Sudden Cardiac Arrest, it gives a signal to the patient. If the signal is not stopped by the patient then the defibrillator gives off the conducting gel, then sending a shock to the patient.
- Many of the same materials can be used to sense other signals, too, and new uses are beginning to emerge. EMG (electromyography) sensors, for example, can detect muscle fatigue.
- EMG sensors can also create gesture controls in areas as diverse as prosthetics, security or mobile payment systems.

3 In the fashion and entertainment sectors, the focus has mostly been on connecting people through clothing-based wearable technology.

A key goal for wearable suppliers is making the technology "invisible" for the wearer. Integrating it comfortably into clothing can achieve part of this, but equally important is reducing the need for frequent charging. Integrating induction coils for wireless charging is an interesting option to encourage take-up of e-textile wearable, allowing clothing to be charged simply by hanging it in the wardrobe!

Although it has certain limitations like cost and lack of water proofing etc but as wearable and e-textile technologies continue to evolve, devices and smart garments will connect directly to the cloud and each other without the need for smart phones tethering. The integration of electronic components and power will become even less visible as they become part of the fabric building blocks (power-generating yarns and micro-component containing yarns are already in development), making future integration of technology truly invisible.

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