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Innovative Plasma Applications in Textile: A Step towards Green Environment

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Abstract
Plasma treatments are gaining popularity in the textile industry due to their numerous advantages over chemical processing techniques. The plasma treatment does not alter the bulk property. Plasma surface treatments show distinct advantages, because they are able to modify the surface properties of inert materials, sometimes with environment friendly devices. Application of "Plasma Technology" in chemical processing of textiles is one of the revolutionary ways to enhance the textile chemical processing right from pre-treatments to finishing. This paper deals with application of plasma technology for cotton and polyester pre-treatment and finishing.

Keywords: Plasma technology, chemical processing, cotton, Polyester, pre-treatment.

Introduction

Plasma is a partially-ionized gas normally generated by an electrical discharge at near-ambient temperatures and reduced pressures. The components present will include ions, free electrons, photons, neutral atoms and molecules in ground and excited states, and there is a high likelihood of surface interaction with organic substrates. This interaction may be physical, for example in the cleaning of organic contaminants from the surface; other effect may be chemical, for example in the bonding of hydroxyl groups to the surface. In the treatment of textile substrates, the cleaning effect can modify Wettability and dye uptake, and the free radicals can incorporate atoms which also change the surface, for example making a hydrophilic material into a hydrophobic one. The main attraction of plasma in industrial processing is the avoidance of chemical effluents. Other advantages include: low cost, rapid reaction times, high cleaning efficiency, low consumption of gas due to physical effects, and the enclosed and dry nature of the process. Fluorocarbons have been used to reduce the wet ability of synthetic polymers such as polyethylene; this paper describes the plasma fluorination of cotton fabric with the objective of making this high-comfort, low-cost, cellulosic polymer water-repellent. Because of the complex nature of the plasma as a chemical and physical modifier, the effects of the plasma under varying conditions of the process were modelled by neutral networks, adaptive systems which are based on observed behaviour rather than recognized rules or explicit functions.

1.2 Literature Review

The hydrophilicity of cotton fabric was improved by treating it with RF air plasma. The process parameters such as electrode gap, time of exposure and RF power have been varied to study their effect in improving the hydrophilicity of the cotton fabric. The static immersion test has been carried out to assess the hydrophilicity of the air plasma treated samples and the process parameters were optimized based on those test results. [1] Plasma treatment of textiles was examined in the 1960's without much success; however in response to the electronics industrial need, significant developments have been made in plasma tools since then. For example, processes in the 1960's had l09 excited particles/cc Compared to 1012 excited particles /cc in the 1990's. [2] This means there is a great deal more energy available without developing excessively high temperatures. [3] Advances in plasma technology have lead to the development of coatings which increase surface hardness and lower the coefficient of friction of materials. We will assess the usefulness of these recent advances for wear surfaces of material used in textile processing. [4]. the modified polyester fabrics do attain good water repellence even after washing with water for ten cycles. Prior exposure of plasma before treatment of plasma solution modifies the fabric leading to deposition of more and more silane groups making it water repellent as compared to those treated directly with plasma. For plasma treatment, the optimized duration of plasma exposure for polyester fabric is 2 min and 30 s. If the cost factor of plasma device could be eliminated, this technology would be valid and useful for the textile finishing industry. [5]

2.1 Principle of Plasma Treatment

The plasma atmosphere consists of free electrons, radicals, ions, UV-radiation and a lot of different excited particles in dependence of the used gas. The figure bellow describes the principle of the plasma treatment. Different reactive species in the plasma chamber interact with the substrate surface. Cleaning, modification or coating occur dependent of the used parameter.

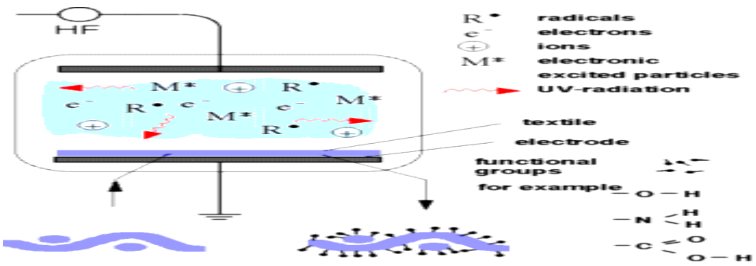

Fig 2 Principle of treatment

Material and information collected

Most of the material was available in local market, but plasma is not available in local market so it has been treated in IPR (institute of plasma research), Ahmadabad and Devi AhilyaVishwavidhyalaya, Indore. Cotton is the most consumed natural fiber in the world for wide range of application. The application includes apparel, automotive purposes, medical and personnel hygiene uses, environmental protection such as oil absorption purpose and home textile etc. Cotton is highly used in woven as well as nonwoven because of its characteristics like high absorption capacity, softness, comfort, chemical resistance and biodegradability. Plasma is based on a simple physical principle. By supplying energy the states of matter change: from solid to liquid and from liquid to gas. Through contact with the surfaces of materials utilizing Plasma treat's technology the added energy of the plasma state can be transferred to the material surface and made available for subsequent reactions on those surfaces.

Fig.3 Plasma

Cotton

A cotton fabric made of 100% cotton fibers purchase from local market and its specifications are.

GSM	110
EPI	110
PPI	80
Weave	plain

Table.1 Sample Specification

Polyester

A Polyester fabric made of 100% Polyester fibers purchase from local market and its specifications are.

GSM	100
EPI	76
PPI	64
Weave	plain

Table.2 Sample Specification

3.2 Pre-Testing (RH-64%, 280C)

We did pretesting of prepared sample in our college. We tested 4 properties of prepared sample (cotton and polyester) details are given below.

For cotton:-

3.2.1Tensile strength:

Gauge Lengt - 8 inch
Tr. Speed - 200 m/min
Sample size - 2 × 12 inch
No of sample -6

Avg. Strength	30.72 kg
Avg. Elongation	29.8 mm

3.2.2 Wettability:

Sample Size - 6 inch dia.
Water - 250 ml
Angle - 450

Grade	ISO2

3.2.3 Crease recovery:

Sample Size - 1 × 2 inch.
Weight - 500 gm
Time - L-2min, R-5min

	Instant	**Total**
Recovery	35.60	46.30

3.2.4 Stiffness:

Bending angle - 450
Sample Size -1 × 6
Thickness -0.20 mm
GSM - 110

Bending length(c)	1.63 cm
Flexural rigidity(G)	47.72 mg/cm
Bending modulus(q)	71.58 kg/cm2

For polyester:-

3.2.5 Tensile strength:

Gauge Length - 8 inch
Tr. Speed - 200 m/min
Sample size - 2 × 12 inch
No of sample -4

Avg. Strength	50.15 kg
Avg. Elongation	48.90 mm

3.2.6 Wettability:

Sample Size - 6 inch dia.
Water - 250 ml
Angle - 450

Grade	ISO2

3.2.7 Crease recovery:

Sample Size - 1 × 2 inch.
Weight - 500 gm
Time - L-2min, R-5min

	Instant	**Total**
Recovery	No crease	No crease

3.2.8 Stiffness:

Bending angle - 450
Sample Size - 1 × 6
Thickness -0.22 mm
GSM - 100

Bending length(c)	1.41 cm
Flexural rigidity(G)	31.76mg/cm
Bending modulus(q)	kg/cm2

3.3 Plasma Treatment Methodology:

We used two types of plasma first for cotton and second for polyester i.e. air (oxygen) plasma and nitrogen plasma. Faraday proposed to classify the matter in four states: solid, liquid, gas and radiant. Researches on the last form of matter started with the studies of Heinrich Geissler (1814-1879): the new discovered Phenomena, different from anything previously observed, persuaded the scientists that they were facing with matter in a different state. Crookes took again the term "radiant matter" coined by Faraday to connect the radiant matter with residual molecules of gas in a low-pressure tube. Sufficient additional energy, supplied to gases by an electric field, creates plasma. For the treatment of fabrics, cold plasma is used, where the ambient treatment atmosphere is near room temperature. It can be produced in the glow discharge in a vacuum process or in more recent atmospheric pressure plasma devices.

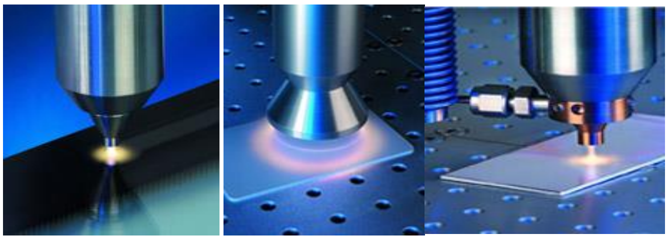

Fig.4 Plasma instrument

Almost any fiber or polymeric surface may be modified to provide chemical functionality to specific adhesives or coatings, significantly enhancing the adhesion characteristics and permanency. For instance, polymers activated in such a manner provide greatly enhanced adhesive strength and permanency, and this is a great improvement in the production of technical fabrics.

3.3.1 Parameters for oxygen & Nitrogen Plasma:

Sr. No.	Condition	Parameter (Oxygen)	Parameter (Nitrogen)
1.	Max. width of plasma zone	18 cm	18 cm
2.	Temperature	35-450C	45-500C
3.	Frequency	13.56 MHz	13.56 MHz
4.	Plasma Power	800 W	800 W
5.	Base Pressure	10-3 mbar	10-3 mbar
6.	Gas pressure	0.5 mbar	mbar

Table.3 Parameter

3.4 Post-Testing (RH-64%, 280C)

We test both samples again after plasma treatment in IPR Ahmadabad and DAVV Indore, and the post testing done in our college laboratory with maintaining RH and temperature and the results are shown below:

For cotton:-

3.2.1Tensile strength:
Gauge Length - 8 inch
Tr. Speed - 200 m/min
Sample size - 2 × 12 inch
No of sample -6

Avg. Strength	27.43 kg
Avg. Elongation	25.30 mm

3.2.2 Wettability:
Sample Size - 6 inch dia.
Water - 250 ml
Angle - 450

Grade	ISO2

3.2.3 Crease recovery:

Sample Size - 1 × 2 inch.
Weight - 500 gm
Time - L-2min, R-5min

	Instant	**Total**
Recovery	51.0	59.60

3.2.4 Stiffness:
Bending angle - 450
Sample Size -1 × 6
Thickness -0.20 mm
GSM - 110

Bending length(c)	1.48 cm
Flexural rigidity(G)	35.65 mg/cm
Bending modulus(q)	35.16 kg/cm2

For polyester:-

3.2.5Tensile strength:
Gauge Length - 8 inch
Tr. Speed - 200 m/min
Sample size - 2 × 12 inch
No of sample -6

3.2.6 Wettability:
Sample Size - 6 inch dia.
Water - 250 ml
Angle - 450

Avg. Strength	46.87 kg
Avg. Elongation	41.47 mm

Grade	ISO2

3.2.7 Crease recovery:

Sample Size - 1 × 2 inch.
Weight - 500 gm
Time - L-2min, R-5min

	Instant	**Total**
Recovery	No crease	No crease

3.2.8 Stiffness:
Bending angle - 450
Sample Size - 1 × 6
Thickness - 0.24 mm
GSM - 100

Bending length(c)	1.27 cm
Flexural rigidity(G)	20.48mg/cm
Bending modulus(q)	17.78kg/cm2

Result

After doing this project, we saw some changes in fabric properties which are our result of this project due to plasma treatment. Some major changes shown below…

Wetability increase: By the plasma treatment fabric become pores, and absorb more water in less time, by this we can change the moisture regain of polyester. In the grading system it changes from 70 ISO2 to 80 ISO2 and in polyester 50 ISO2 to 70 ISO2. Stiffness decrease: Esthetic properties have more importance in the garment field, and plasma treatment give comfortness to the fabric. We have seen the change in the bending length from 1.63 cm to 1.48 cm in cotton and from 1.41 cm to1.27 cm in case of polyester.

Crease recovery increase: Cotton fabric is most poor in case of crease recovery, that's why it shows limited field in the garment industry. After the plasma treatment we can increase its value in the garment manufacturing. And for that we saw the changes in cotton crease recovery from 46.30 to 59.60.

Strength decrease:As we know strength is very important factor in every field, but in this treatment fabric passes through plasma rays of high temperature that's why loss some strength. As we seen the strength is slightly decrease from 30.72 kgs to 27.43 kgs in the case of cotton and from 50.15 kgs to 46.87 kgs in case of polyester.

Plasma does increase all the properties of textile except strength, by the effect of plasma rays some degradation takes place, that's why strength decreases slightly. But in the future by using other plasmas and optimizing parameters it can be minimized.

Conclusion

Let us conclude telling the extra advantages of plasma treatments. The finished textile shows better Performance and improved Wetability properties. All though the strength of the fabric is decrease but the addition of other value has more importance. Though currently not very relevant introduced amounts, this type of high-performance textile will certainly grow in economic importance. As a result of their high added value even small textile batches can be produced at high profit, although perfect process control is absolutely necessary. Typically, textiles for medical applications or uses in the sector of biotechnology are expected to increase in importance. Key future applications such as special selective filtrations, Biocompatibility, and growing of biological tissues, would be interesting fields for plasma physics.

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