RESEARCH ARTICLE OPEN ACCESS

Application of Plasma finishing on Cotton Fabric

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Abstract
"Plasma" word is derived from the Greek and referring to the "something molded or fabricated". **Plasma treatments** are gaining popularity in the textile industry. Plasma treatment has to be controlled carefully to avoid detrimental action of the plasma onto the substrate. Plasma surface treatments show distinct advantages, because they are able to modify the surface properties of inert materials, sometimes with environment friendly devices. For fabrics, cold plasma treatments require the development of reliable and large systems. Application of "Plasma Technology" in chemical processing of textiles is one of the revolutionary ways to boost the textile wet processing right from pre-treatments to finishing.

I. Introduction

Definition of Plasma:

Partially ionized gas composed of electrons, ions, photons, atoms and molecules, with negative global electric charge. It is called as Plasma Technology. Irving Langmuir first used the term plasma in 1926. Describe the inner region of an electrical discharge. Plasma, as a very reactive material, can be used to modify the surface of a certain substrate typically known as plasma activation or plasma modification. The Recent development in the plasma treatment of textile materials has revealed that it has an enormous potential as an alternate technology for the textile processing in terms of cost saving, water saving and eco friendliness..

Aims and Objectives of Plasma:

- It is a simple process which could be easily automated and perfect parameter control.
- It is applicable to most of textile materials for surface treatment.
- It is dry textile treatment processing without any expenses on **effluent treatment**.
- It is applied for different kinds of textile treatment to generate more novel products to satisfy customer's need and requirement.

Different forms of Plasma:

Artificially produced plasma	Terrestrial plasmas	Space & astrophysical plasmas
• Those found in plasma display. • Inside fluorescent lamps, neon signs etc. • Rocket exhaust. • The area in front of space craft's heat shield during reentry into the atmosphere. • Fusion energy research. • The electric arc in an arc lamp, an arc welder or plasma torch. • Plasma used for surface modification of textiles etc.	• Lighting. • Ball lighting. • St. Elmo's fire. • Sprites, elves, jets. • The ionosphere. • The polar aurora.	• The sun and other stars • (Which are plasmas heated by nuclear fusion). • The solar wind. • The interplanetary med (Space between the planet) • The Io-Jupiter flux-tube. • Accretion discs. • Interstellar nebulae.

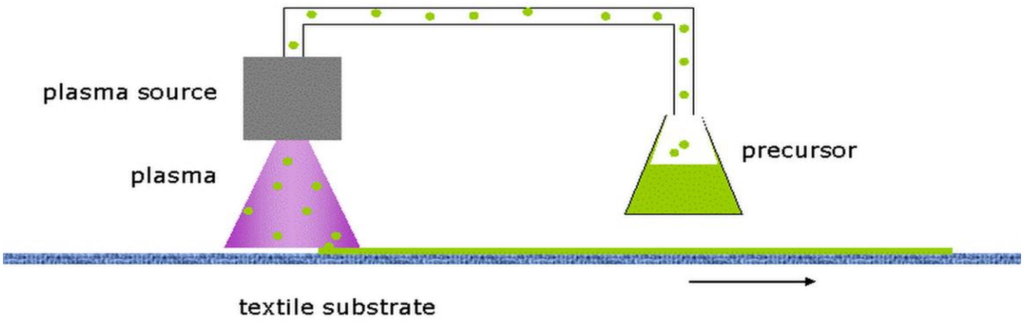
Generation of plasma can be created by applying an electric field to a low-pressure gas, as in neon or fluorescent tubes. Plasma can also be created by heating a neutral gas to very high temperatures. The degree of ionisation, a is defined as $a = n_i / (n_i + n_a)$ (Eq $_1$) Where, ni is the number density of ions and na is the number density of neutral atoms. The amount, or degree, of ionisation is called the "Plasma density". Generally, high plasma densities are desirable, because electrons impact gas molecules and create the excited-state species used for textile treatment. Having more electrons generally equates to faster treatment time. However, very high plasma densities (greater than 10^{13} electrons cm^{-3}) can only exist with the very high gas temperature. This extremely high level of plasma density is unsuitable for textile treatment, because of the plasma's energy will burn almost any material. Plasma properties are dependent on the plasma parameters like degree of ionization, the plasma temperature, the density and the magnetic field in the plasma region.

Principle of Plasma Processing:

Plasma technology is a surface-sensitive method that allows selective modification in the nm-range. By introducing energy into a gas, quasi-neutral plasma can be generated consisting of neutral particles, electrically charged particles and highly reactive radicals. If a textile to be functionalised is placed in a reaction chamber with any gas and the plasma is then ignited, the generated particles interact with the surface of the textile. In this way the surface is specifically structured, chemically functionalised or even coated with nm-thin film depending on the type of gas and control of the process.

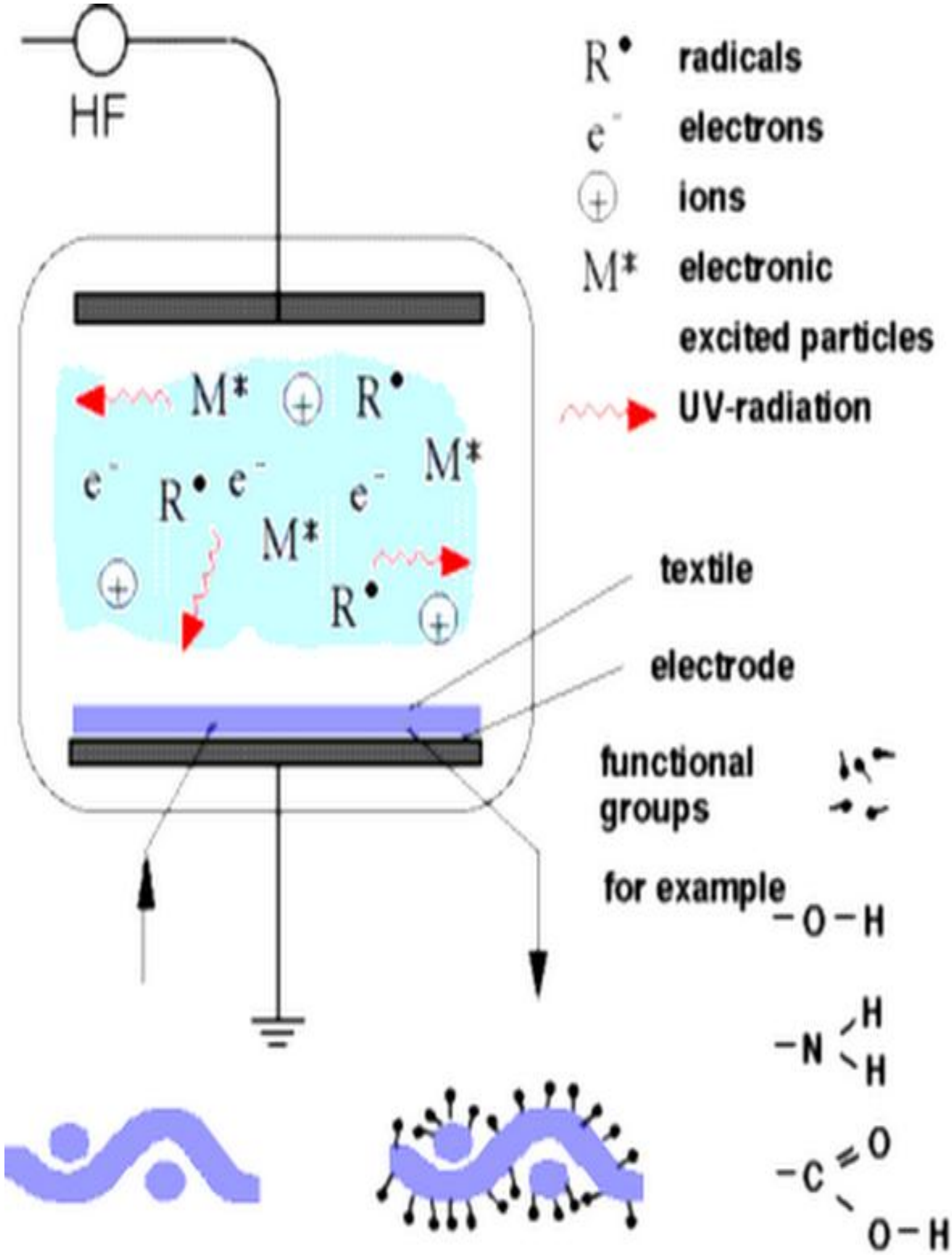
Principle of plasma processing can be shown as below:

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



Plasma treatments have been used to induce both surface modifications and bulk property enhancements of textile materials, resulting in improvements to textile products ranging from conventional fabrics to advanced composites. These treatments have been shown to enhance dyeing rates of polymers, to improve colourfastness and wash resistance of fabrics, to increase adhesion of coatings, and to modify the wet-ability of fibres and fabrics. Research has shown that improvements in toughness, tenacity, and shrink resistance can be achieved by subjecting various thermoplastic fibres to a plasma atmosphere. Recently, plasma treatments have produced increased moisture absorption in fibres, altered degradation rates of biomedical materials (such as sutures), and deposition of low friction coatings.

Unlike wet processes, which penetrate deep into the fibres, plasma produces no more than a surface reaction, the properties it gives the material being limited to a surface layer of around 100 angstroms. These properties are very varied and can be applied to both natural fibres and polymers, as well as to non-woven fabrics, without having any effect on their internal structures. For example, plasma processing makes it possible to impart hydrophilic or hydrophobic properties to the surface of a textile, or reduce its in flammability. And while it is difficult to dye synthetic fabrics, the use of reactive polar functions results in improved pigment fixation. Also, with plasma containing fluorine, which is used mainly to treat textiles for medical use, it is possible to optimise biocompatibility and haemo compatibility - essential for medical implants containing textiles.



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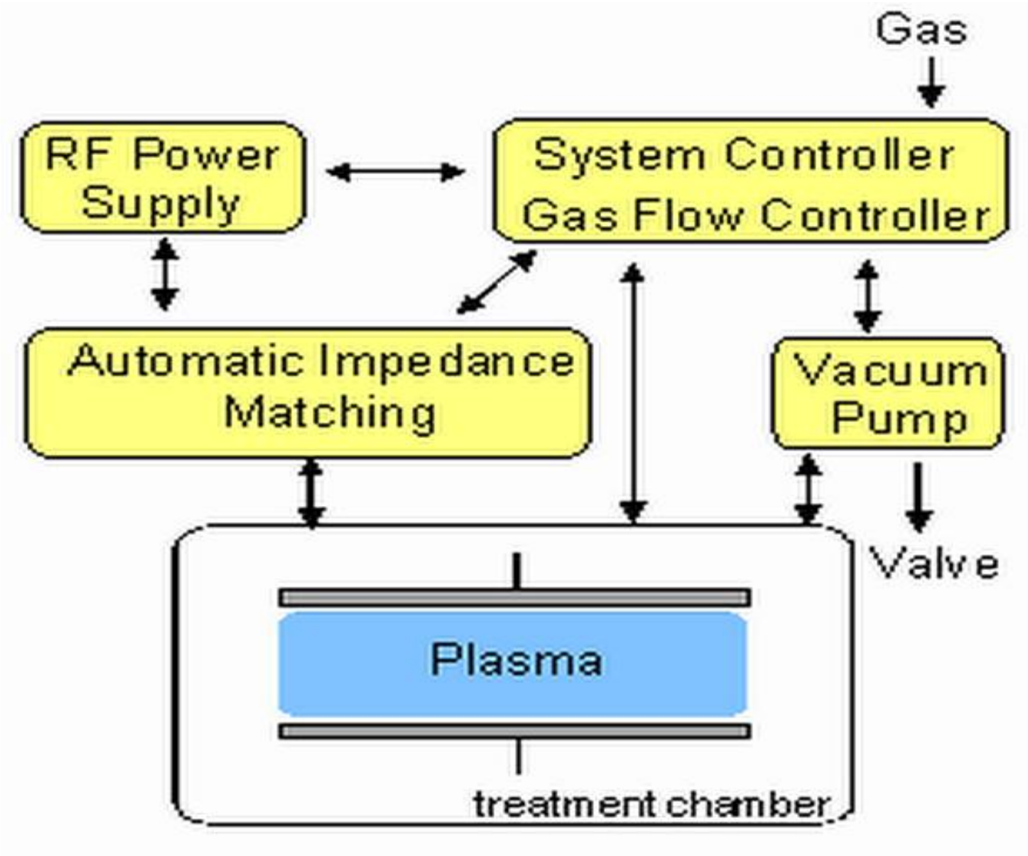
Furthermore, the plasma process can be carried out in different manners.

1. The substrate can be treated directly in the plasma zone.
2. The substrates can be positioned outside the plasma; this process is called remote process.
3. The substrate can be activated in the plasma followed by a subsequent grafting.

4. The substrate can be treated with a polymer solution or gas which will be fixed or polymerised by a subsequent plasma treatment.

Plasma Equipment:
The figure below shows a block diagram of a typical plasma system. It consists of 5 modules or functions: vacuum system, power supply, matching network, reactor centre, and controller.



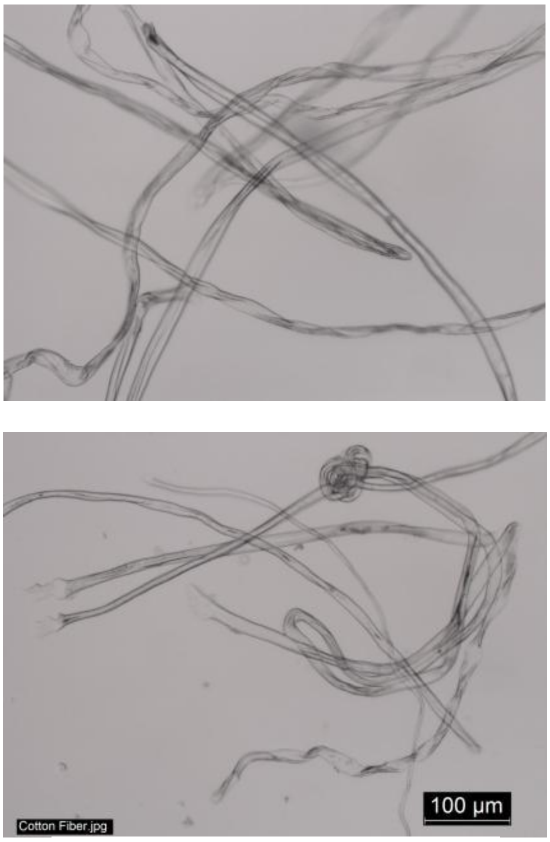
Vacuum system: Low pressure plasma systems operate at 0,1 mbar to 1 mbar with a continuous gas flow into the reactor. In some cases it is necessary to reduce the base pressure in front of the treatment below 0,1 mbar.
1. Power supply: This furnishes the electrical power necessary to generate the plasma. The power required ranges from 10 to 5000 watts, depending on the size of the reactor an the desired treatment.
2. Plasma reactors have been built utilising a wide range of frequencies, from DC to microwave.
3. Controller: It controls all the process variables: type of gas, pressure, gas flow rate, power level, and processing time.
4. Reactor centre: This is the "heart" of the plasma system. It can be adapted to the process. The material for processing can be treated as batch, semi continuous or air-to-air. The last is very expensive due to the necessity of vacuum transfer systems.

Physical Parameters:
Frequency: 13.56MHz
Plasma Power: 10-1000W
Base Pressure: 10-3 mbar
Working Pressure: 0.01-1 mbar
Speed: 0.2-20 m/min
Max. Width: 18cm

II. Description of Cotton(Structure and Properties)

Structure Characteristics:
Cotton is the most popular cellulosic fibre nowadays. It is a natural vegetable seed fibre obtained from mature capsule of the cotton plant.

Cotton has kidney-shaped cross-section with lumen and ribbon like convoluted longitudinal shape. The length is the most important attribute of the fibre. Cotton can be divided into two large categories: long fibre cottons (long staple), which measures more than 28 mms like United States and Egyptian cotton, and short fibre cotton (short staple), that do not reach the 18mms and that derive from the Asian regions mainly. The longer the fibre, the better the quality is the fibre as the long fibre can spun into a fine and smooth yarn that can be made into comfortable wear.



The cotton fibres are convoluted in shape.

Properties:

Cotton has comfortable soft hand since its surface is smooth. It also has good absorbency with about 7-8% moisture regain that not only enable comfort by absorption of sweat when wear next to skin, but also make it easy to absorb dyestuff. It can be dyed by different dye classes and available in wide range of colors and prints. Besides, cotton has good strength especially when it is wet and it drapes well too. It has good resistance to high temperature, strong alkali and chlorine. However, there are limitations including cotton wrinkle easily because of its relative low elasticity (deformation recovery) as well as it can be attacked by bacteria and fungi under warm and humid condition. It can be burned easily giving out smell of burning paper.

III. Preparation of Sample

All the fabrics were cut to size 30cm x 30cm and then scoured with acetone for 10minutes to remove contaminants on the fabrics surface. After that, the fabrics were rinsed with deionized water for 5minutes. Water was extracted from fabrics in a hydro extractor for 3 minutes. Lastly, the fabrics were dried in an oven at 60℃ for 10minutes.

After scouring the fabrics, the fabrics were conditioned under the standard atmospheric pressure at 65% +/- 5% relative humidity and 21℃+/- 1℃ for at least 24 hours before other procedure processed.

In the scouring process the cotton cellulose material is treated for the removal of metal ions and polyacrylates or polyphosphonates as special surfactant free dispersing agents, at high temperature.

The material after scouring is more absorbent, free from natural impurities and colouring matter. This treatment can be carried out on filaments, yarns and fabrics. After the Cotton is scoured, then Washing of Cotton is done and thus prepare it for the further process.

IV. Fabric Information and Machine Specification

Fabric Information:

EPI= 40

PPI=28

Crimp%= 6.66 and 3.33

Where,

EPI= Ends per Inch

PPI= Picks per inch

Crimp% means, when warp and weft yarns interlace in fabric they follow a wavy or corrugated path. Crimp percentage is a measure of this waviness in yarns.

Machine Specification:

Electrodes distance: 8cm

Distance between Electrodes: 20cm

V. Gas involved during Plasma Finishing

Gas involved during Plasma Finishing: Argon and Oxygen

Argon:

With a volume of 0.9325%, argon is the only inert gas that can be produced commercially using air separation technology. As an inert gas it is chemically neutral. Owing to its high atomic weight (39.95), argon promotes expulsion of the molten material from the kerf through the high impulse density of the plasma jet produced.

With a low ionisation energy of 15.76 eV, argon is relatively easy to ionise. For this reason, pure argon is often used for igniting the plasma arc.

Argon Treatment: Plasma Treatment condition for Argon gas:

Sample: Cotton sample (30s)

Gas: Argon

Power: 100w, 13.56GHz (atmospheric plasma)

Time: 30 min.

Sample size: 18cm (Electrode dia.)

Plasma density: 10^7 – 10^16 / cm3

Base pressure: 9*10^-3 mbar

Working Pressure: 5*10^-2 mbar

Oxygen:

Oxygen treatment: Plasma treatment condition for Oxygen gas:

Sample: Cotton sample (30s)

Gas: Pure Oxygen

Power: 100W, 13.56GHz

Time: 1 hr.

Sample size: 18cm

Plasma density: 10^14-10^16 / cm3

Base Pressure: 9*10^-3 mbar

Working Pressure: 5*10^-2 mbar

VI. Weight and Spectrography

Weight: Test Specimen (30s Cotton Handloom made)

(17*17) S1 (3.5433gm) Ar $\longrightarrow$ 3.5433gm

(15*18) S2 (3.4842gm) O2 $\longrightarrow$ 3.4842gm

Spectroscopy:

VII. Testing Terms and Definitions

Tearing Strength:

The force necessary to tear a fabric is measured by the force necessary to start or continue a tear in a fabric.

Crease Resistance:

Creases are a fold in a fabric introduced unintentionally. Crease resistance is the ability of a material to resist, or recover from, creasing.

Spray Test:

Water Repellency Tester is used to check the water repellency of the fabric by spray test in textile testing laboratory.

Stiffness:

Stiffness is a special property of fabric. It is the tendency of fabric to keep standing without any support.

VIII. Calculations

Crease resistance test:

(S1)		(S2)	
Warp	Weft		
		Warp	Weft
82° → 76°	104° → 101°	82° → 81°	104° → 103°
105° → 100°	101° → 90°	105° → 104°	101° → 100°
107° → 106°	109° → 80°	107° → 104°	109° → 105°

Result: Crease Resistance in (S2) > (S1).

Spray Test:

S1 (untreated):- 70(ISO2)

S1 (treated):- 70(ISO2) but slightly less

S2 (treated):- 70(ISO2)

S2 (untreated):- same
Result: Water Spreading in (S1) > (S2).

Stiffness Test:

S1:

Warp	Weft
(I) (F)	(I) (F)
4.0cm → 4.1cm	3.6cm → 3.1cm
3.3cm → 3.3cm	4.4cm → 4.1cm
3.5cm → 3.4cm	4.3cm → 4.3cm
3.6cm → 3.6cm	4.1cm → 4.2cm

S2:

Warp	Weft
(I) (F)	(I) (F)
4.0cm → 4.2cm	3.6cm → 3.5cm
3.3cm → 3.6cm	4.4cm → 4.5cm
3.5cm → 3.6cm	4.3cm → 4.4cm
3.6cm → 3.7cm	4.1cm → 4.2cm

Result: 1. Stiffness in (S2) > (S1).

2. Colour change in (S1) > (S2).

Minute-minute Pressure Change:

S.no.	**Time(min.)**	**Pressure(*10^-2mbar)**
1.	1	9.0
2.	2	8.6
3.	3	8.4
4.	4	8.2
5.	5	8.0
6.	6	7.9
7.	7	7.7
8.	8	7.6
9.	9	7.5
10.	10	7.4
11.	11	7.3
12.	12	7.2
13.	13	7.1
14.	14	7.0
15.	15	7.0
16.	16	6.9
17.	17	6.8
18.	18	6.7
19.	19	6.6
20.	20	6.6
21.	21	6.5

S.no.	Time(min.)	Pressure(*10^-2mbar)
22.	22	6.5
23.	23	6.4
24.	24	6.3
25.	25	6.3
26.	26	6.2
27.	27	6.2
28.	28	6.1
29.	29	6.1
30.	30	6.1
31.	31	6.0
32.	32	6.0
33.	33	6.0
34.	34	5.9
35.	35	5.9
36.	36	5.8
37.	37	5.8
38.	38	5.7
39.	39	5.7
40.	40	5.6
41.	41	5.6
42.	42	5.6
43.	43	5.5
44.	44	5.5
45.	45	5.4
46.	46	5.4
47.	47	5.4
48.	48	5.4
49.	49	5.3
50.	50	5.3
51.	51	5.3
52.	52	5.3
53.	53	5.2
54.	54	5.2
55.	55	5.2
56.	56	5.2

S.no.	Time(min.)	Pressure(*10^-2mbar)
57.	57	5.1
58.	58	5.1
59.	59	5.1
60.	60	5.0

Capillary rise:
1. Argon sample
Capillary rise → 2.9cm/min

2. Oxygen sample
Capillary rise → 3cm/2min

Untreated			**Argon treated**			**Oxygen treated**		
Time	**Rise**		**Time**	**Rise**		**Time**	**Rise**	
20	0.00		20	1.0		20	0.6	
40	0.00		40	1.9		40	0.9	
60	0.01		60	2.9		60	1.7	
80	0.01		80	3.8		80	2.5	
100	0.02		100	4.8		100	3.3	

IX. Results

We have done Plasma Finishing of Cotton fabric by Argon and Oxygen gas. Plasma Finishing of Cotton by Ar takes 30 mins.(Sample 1) While Plasma finishing of Cotton by O2 takes 60 mins.(Sample 2). Sample 1 and Sample 2 showed different results. After performing all the tests on all the samples i.e. **Untreated sample**, **Argon treated sample (Sample 1)** and **Oxygen treated sample (Sample 2)**, we got the following results:

1. In Crease resistance test, Crease resistance in sample 2 comes out to be more than that of Sample 1.
2. In Spray test, Water spreading in Sample 1 is greater than that of sample 1.
3. In Stiffness test,
→ Stiffness of Sample 2 comes out to be more than that of Sample 1 and also,

→ Colour change in Sample 1 comes out to be more than that of Sample 2.

4. In Capillary rise tests, Capillary rise in,
→ Argon treated sample is 2.9cm/min
→ Oxygen treated sample is 3cm /2min

X. Conclusion

In these some months, we have studied on Plasma Finishing and its applications in Textile especially its finishing affects on the properties of Cotton fabric. During performing the project we have come to know about a lot of things and we have gained lot knowledge on this topic. The study has shown that in finishing the Cotton fabric with Plasma treatment, different properties get affected and the especially surface properties changes in a positive way. We have performed four tests due to limited size of sample. Although many other tests can also be performed and can definitely conclude that changes in the properties of those tests can also be seen.

We are very thankful to Head of Department, Textile Technology and Physics department who have helped us through the whole research. We would also like to thank our Principal, SVITS for his cooperation and motivation.

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