Effect of Plasma Treatment on Plain Woven Cotton Fabric

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Abstract: ***Plasma treatment has an explosive increase in interest and use in industrial applications as for example in medical, biomedical, automobile, electronics, semiconductor and textile industry. It is applicable to most of textile materials for surface treatment. Plasma treatment improves wet ability, hydrophobic finishing, adhesion, product quality, functionality in fabrics without alteration of inherent properties of the textile material. It is a dry treatment without expenses on effluent treatment. In this study an attempt has been made to study the effect of Plasma treatment on plain woven cotton fabric. The bleached and dyed fabrics were treated with oxygen and argon gases. The effect of plasma treatment on absorbency, fabric weight, tensile strength, elongation, thickness, stiffness, crease recovery, abrasion resistance and drape of the fabric were investigated and compared to the grey fabric. Plasma treatment with oxygen gas was found superior to argon gas as it improved the absorbency, drape and air permeability. As the treatment time was increased most of the physical properties improved. Tensile strength decreased with increased exposure to the plasma gas. Plasma treatment done after dyeing seemed to improve the qualities of the fabric better than when done before dyeing.***

Keywords: Plasma treatment, oxygen, argon, dyeing, tensile strength.

1. Introduction

Plasma is quite a new technology for the textile industry. It offers an attractive way to add new functionalities. 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. It is a gaseous state of matter that contains excited species, such as ions, free electrons, and large amounts of visible, UV, IR radiation. This ionized form of gas can be created using a controlled level of AC or DC power and an ionizing gas medium. It is an ensemble of randomly moving, charged atomic particles with a sufficient particle density to remain, on average, electrically neutral.[1] Plasma an ionized gas is a distinct fourth state of matter where at least one electron is not bound to an atom or molecule converting the atoms or molecules into positively charged ions, as temperature increases the molecules become more energetic and transform matter in the sequence solid, liquid, gas and finally plasma which justifies the title fourth state of matter[2]

The plasma gas particles act on the fabric surface in nano scale so as to modify the functional properties of the fabric [3]. The Plasma modifies the surface of the fabric by the bombardment with high energy electrons and ions [4]. Plasma treatment have been used to induce both surface modification and bulk property enhancement of textile material, resulting in improved textile products ranging from conventional fabric to advanced composites [5]

Plasma has been broadly classified into low pressure plasma and atmospheric pressure plasma. Atmospheric pressure plasma is further classified as Corona Discharge (CD), dielectric barrier discharge (DBD) and atmospheric pressure glow discharges (APGD) [6]. Plasma processes can be grouped into two main classes — low-density and high-density — according to their electron temperature versus electron density. Properties of the plasma will be determined by the gasses used to generate the plasma, as well as by the applied electrical power and the electrodes (material, geometry, size, etc.)

Low pressure plasma is one of the oldest types of cold plasma. It is produced in a vacuum vessel having reduced pressure in the range of 10-2 to 10-3 mbar, created by a vacuum pump, [6]. The gas to be ionized is supplied into the vacuum vessel, between two electrodes connected to a high voltage (0.4-0.8KV) and high frequency electro-magnetic field (40 KHz -2.45 GHz) and gets ionized[7] .A specific characteristic of plasma is the visible glow discharge with colours ranging from blue – white to dark purple depending on the type of gas. The high reactive particles react with the surface of the substrate. The advantage of this plasma is that it is a well controlled and reproducible technique, [8]. And also the low pressure plasma technology is such an alternative where on a dry, environmental friendly and cost-efficient way the surface is modified on microscopic level without manual operations or the use of chemical products [1].

Atmospheric pressure plasma is used in a variety of material processes. There are a number of forms glow discharges, corona dielectric barrier discharge. The advantage of atmospheric pressure plasma are continuous treatment can be given and it is cost effective process. Corona Discharge method, in which plasma gas is produced at atmospheric pressure by applying a low frequency pulsed high voltage over an electrode pair. Dielectric barrier discharges method is in which plasma gas is produced by applying a pulsed voltage over an electrode pair of which at least one is covered by a dielectric material. Dielectric barrier discharge (DBD) is also called silent and atmospheric pressure glow discharges [9]. Gas plasma treatments of materials alter their surface character without affecting their bulk properties. The depth of the surface treatment is only a few nanometers. The surface of the material is roughened and surface chemical properties may also be changed. So, for textiles, gas plasma treatment offers an alternative method of surface treatment to the coating technologies conventionally applied. There are many gases, or mixtures of gases, used for plasma treatment. By varying the process of parameters such as the type of gas, time and pressure, different finishes can be obtained. Air, nitrogen, argon, oxygen, nitrous oxide, helium, tetrafluoromethane, water vapor, carbon dioxide, methane, and ammonia or their mixtures can be used as plasma medium. Each gas produces a unique plasma composition and results in different polymer surface properties. Although the gas is same, if the fibre type is different, the result will be different [10]

The plasma treatment has a lot of benefits compared with classical wet chemistry finishing. It is applicable to all substrates suitable for vacuum processes, ie., almost free choice of substrate materials. The consumption of chemicals is very low due to the physical process .The process is performed in a dry, closed system, and excels in high reliability and safety, environmentally friendly and it increases abrasion resistance, dyeing speed. It is a green process without generation of chemicals, solvents or harmful substances [10].Other advantages of plasma treatment are it requires no water for treatment, it is done in the gas phase only, there is virtually no waste production. The treatment is confined to fibre surface only, process time is short, and the low temperature avoids sample destruction / deterioration. Its dry and eco-friendly in nature [11]

Plasma treatment can be viable substitute to conventional processes and very often it can provide the advantageous effect that can't be obtained by wet processing of textile material. It offers high efficiency economical feasibility environmentally acceptability and flexibility.

It is applicable to most of textile materials for surface treatment. Different kinds of plasma gases provide special functionality to textile materials such as UV-protection, anti-bacteria, medical function, bleaching, flame retardancy, wetability, hydrophobic finishing, adhesion, product quality etc. without any alternation of the inherent properties of the textile materials.

In this study an attempt has been made to study the effect of Plasma treatment on the properties of plain woven cotton fabric. The bleached and dyed fabrics were treated with oxygen and argon gases for 20 and 40 minutes. The effect of plasma treatment on absorbency, fabric weight, tensile strength, elongation, thickness, stiffness, crease recovery, abrasion resistance and drape of the fabric were investigated and compared to the grey fabric.

2. Methodology

2.1 Material

Plain weave 100% cotton, 50s count was selected for the study.

2.2 Pre-Treatment

Grey fabrics or loom state fabrics contains various added and natural impurities which interfere in subsequent processing namely colouration and finishing. So the cotton fabrics were desized, scoured and bleached.

2.2 Desizing

5% of malt extract was used for desizing. Material is to liquor ratio was maintained as 1:20, 2% sodium chloride was added, the fabric was entered and the temperature at 60˚C was maintained for 45 minutes. The fabric was taken out and rinsed thoroughly.

2.3 Scouring

Scouring was carried out using 3% sodium hydroxide, 0.5% sodium silicate and 1%wetting agent was used for scouring. Material is to liquor ratio was 1:20. The fabric was entered at 60˚C and the temperature was raised to 90˚ C and maintained for 45 minutes. Then the fabric was taken and rinsed thoroughly.

2.4 Bleaching

Bleaching was carried out using 3gpl hypochlorite and 1% sodium silicate with material is to liquor ratio as 1:25. Bleaching was carried out for 2 hours at room temperature.

2.5 Dyeing

2.5.1 Selection of dye

Dyes from vegetable source are interesting for two main reasons. The colour of dye is very brilliant and the toxicity is very low [12].Marigold is cultivated all over the world for its decorative flowers, for religious festivals and for its colourant. Considering these facts, Marigold flower was selected for the study.

Botanical name - Terminalia Chebula

2.5.2 Selection of mordants and mordanting techniques

Myrobalan was selected as mordant. Pre-mordanting technique was adopted for this study.

2.5.3 Extraction of natural dye

Marigold Flowers was first dried for 8-10 hrs in an oven. The dried material was then crushed into small pieces and dried again. Finally it was powdered and used for extraction. The dye extraction was carried out with the help of aqueous media. 100g of the material was taken in a beaker containing 2 litre of water and boiled for 1 hour. The solution was allowed to stand for sometime until cooled and then filtered.

2.5.3 Procedure for dyeing

The bleached fabric was soaked for 5 minutes in warm water and excess water was allowed to drip. Then it was treated in mordant solution for 60 minutes at room temperature. Dyeing was carried out in a laboratory jig for 45 minutes. The dye solution was first heated at 50^{o}C then raised to 75^{o}C. The fabric was left for 10 hours to batch. Then the fabric was rinsed in running water and allowed to dry. The plasma treated samples were also post dyed using the same procedure.

2.6 Plasma machinery frame setting

The reactor is a vacuum chamber equipped with vacuum pump, purge plumbing, process gas sources and regulators, a source of electromagnetic energy and a system controller to orchestrate the process. The equipment operation cycle is carefully monitored and controlled by the electronics package, which operates the valves, pressure/vacuum flow gates and the RF source. In the 4th State system the roll product to be treated (up to60"package diameter) is loaded in the payoff chamber and threaded through the chamber to the take-up reel. The plasma treatment operation is then initiated and entirely controlled by the push of a single button. The process steps are:

1) Pump down to predetermined vacuum pressure (base pressure)
2) Introduce process gas and allow to stabilize at a desired process pressure
3) Initiation of plasma by providing RF energy
4) Transport product through the system and
5) After treating the desired length, shutting RF power and process gas delivery
6) Pump down to base pressure to eliminate residual process gas.
7) Vent to atmosphere and
8) Remove treated products

2.7 Plasma application

The usage of oxygen can modify the wettability of cotton and other cellulosic materials. Argon gases modify texture application and increased surface roughness. It also alters the tensile properties and functional behavior of the fabric [13]. It improves air permeability and drape properties. Due to these properties the investigator selected oxygen and argon gases for the study. 20 and 40 minutes was selected as timing for the treatment.

- The machine was set at 600 voltage power.
- The initial pressure was maintained at 0.050millbar.
- The Bleached Plain Fabric was set at room temperature for 12 hours.
- The samples were fixed on 22 X 19 inch frame by clips.
- The frame was fixed at 5 cm distance from bottom rod.
- The machine was closed and the motor started.
- The gas was passed to main chamber through gas cylinder.
- The time duration was set the pressure was raised up to 0.08 millibar.
- After the process are complete machine stops automatically.
- This process was continued for dyed sample.
- The same procedure was followed for oxygen and argon gases

2.8 Nomenclature of samples

The samples were named based upon the treatment as follows

Table 1: Nomenclature of samples

S.No	*Sample based on process*	*Designation*	
1	Grey Fabric	GP	
2	Bleached Fabric	BP	
3	Dyed Fabric	DP	
		Plasma treatment using oxgyen gas	Plasma treatment using argon gas
4	Bleached20 mins plasma treatment	BPO1	BPA1
5	Bleached 40 mins plasma treatment	BPO2	BPA2
6	Dyed20 mins plasma treatment	DPO1	DPA1
7	Dyed 40 mins plasma treatment	DPO2	DPA2
8	Post dyed - plasma treated 20 mins	PDPO1	PDPA1
9	Post dyed plasma treated 40 mins	PDPO2	PDPA2

3. Result and Discussion

3.1 Absorbency

The oxygen treated bleached, dyed and post dyed samples had better absorbency than argon treated samples. The treatment timing did not have any effect on the absorbency of the samples.

Table 2: Absorbency

S. No	Samples	Drop penetration test mean in sec	Capillary rise mean in sec	Sinking test mean in Sec
1	GP	23	21	20
2	BP	4	5	5
3	BPO1	4	5	5
4	BPO2	4	5	5
5	BPA1	12	11	9
6	BPA2	12	11	9
7	DP	4	5	5
8	DPO1	4	5	5
9	DPO2	4	5	5
10	DPA1	12	11	9
11	DPA2	12	11	9
12	PDPO1	4	5	5
13	PDPO2	2	4	5
14	PDPA1	12	11	9
15	PDPA2	12	11	9

3.2 Fabric weight

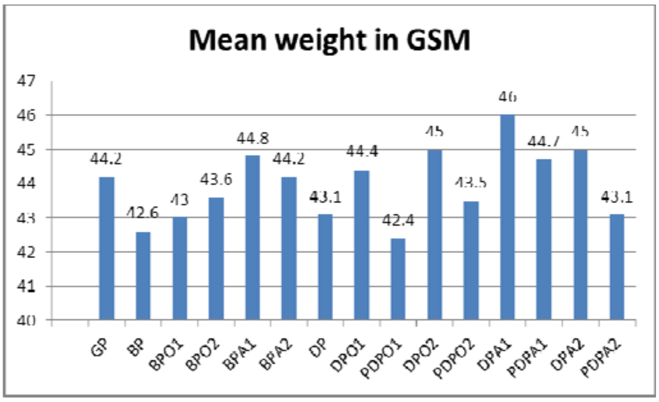

Figure 1: Fabric weight

Most of the samples had gain in weight after plasma treatment. Sample PDPO1 had a loss in weight and PDPA2 had no change. From the figure it is evident that Post dyed samples had less weight gain than pre dyed samples. Oxygen treated samples had less weight gain than argon treated samples. In Oxygen treated samples 20 minutes plasma treated have shown less weight gain than 40 minutes treated samples. Where as in argon treated samples 40 minutes treated samples had less weight gain than 20 minutes treated samples.

There was significant difference in weight between the oxygen treated and argon treated samples at 1% level. The treatment timing and stage of dyeing did not have significant effect on fabric weight.

3.3 Tensile strength - warp

Tensile strength reduced on plasma treatment in warp direction. Extensive strength loss is noticeable in argon treated samples. 20 minutes treated samples had a minimum strength loss compared to 40 minutes in both argon and oxygen gases. Among dyed and post dyed samples, dyed samples had maximum strength loss than post dyed samples. There was significant difference is strength loss at 1% level between the gases. There was no significant difference in strength when the treatment time and stage of dyeing was considered.

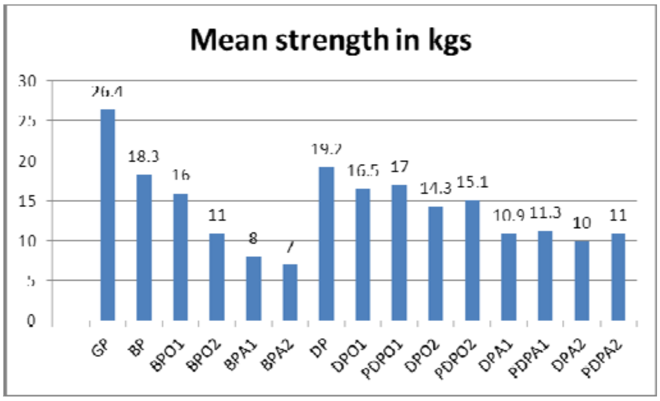

Figure 2: Tensile strength – warp

3.4 Tensile strength – weft

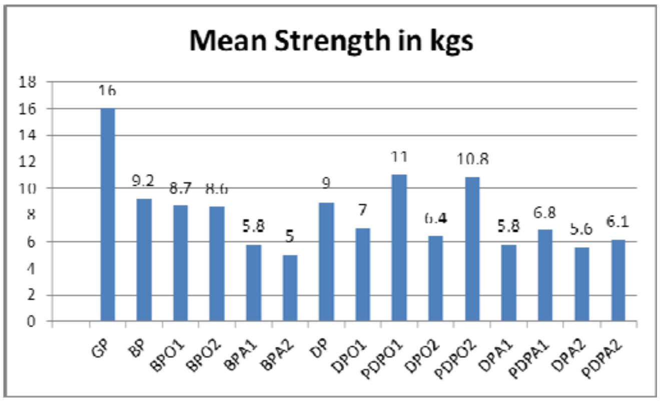

Figure 3: Tensile strength – weft

As regards weft direction all samples show reduction in strength loss expect PDPO1 & PDPO2, oxygen treated samples has minimum strength loss, than argon treated samples. When comparing with timing, 20 minutes treated samples had a minimum strength loss than 40 minutes in both oxygen and argon. Among dyed and post dyed samples, dyed has greater strength loss than post dyed samples. Post dyed oxygen treated samples had gain in strength in weft directions.

There was 1 % level significant difference in strength between gases. But there was no significant difference between treatment timing and stages of dyeing.

3.5 Elongation – warp

As regards elongation in warp direction, all samples showed reduction in elongation expect post dyed samples. There was no difference between treatment timing. When comparing oxygen and argon gases, oxygen had better elongation then argon. In dyed samples, post dyed had better elongation than dyed samples. There was no significant difference in elongation between gases and treatment timing. But there was significant difference at 1% level in stage of dyeing

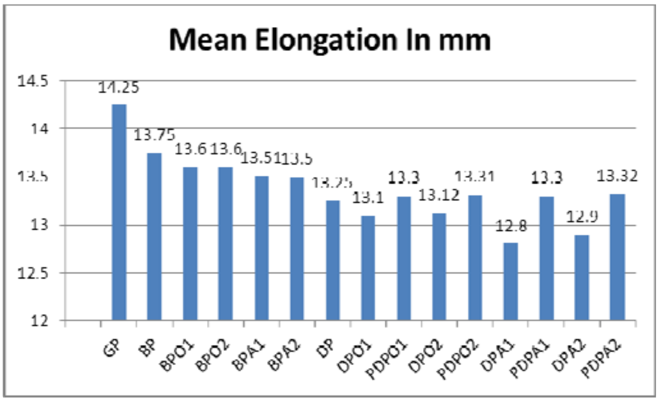

Figure 4: Elongation – warp

3.6 Elongation – weft

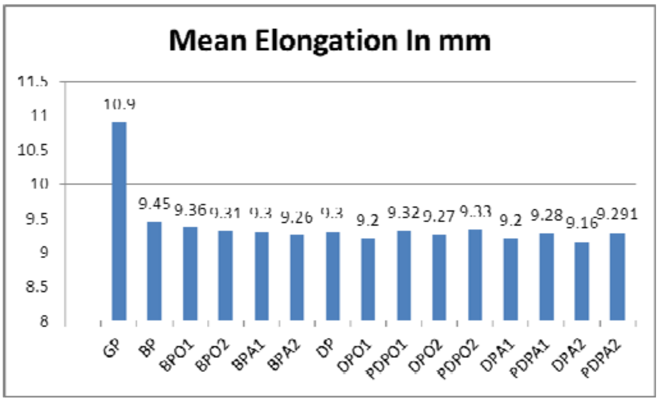

Figure 5: Elongation – weft

In weft direction all the samples show reduction in elongation . There was minimal difference elongation among gases, but oxygen treated samples had better elongation than argon treated samples. When comparing dyed and post dyed, post dyed had better elongation than dyed samples. There was no significant difference between gases and treatment timing. But there was significant difference at 5% level in stage of dyeing.

3.7 Thickness

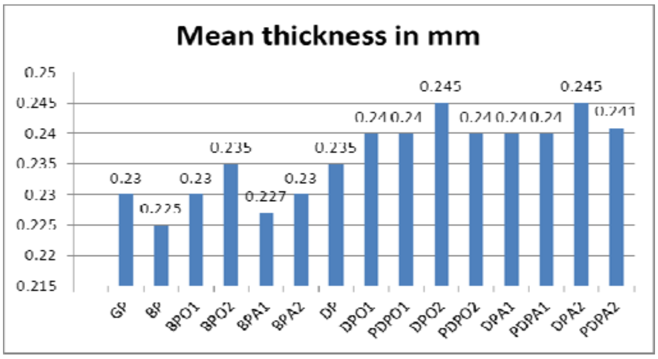

Figure 6: Thickness

In plasma treated samples, there was light increase in thickness in all the samples irrespective of the gases, timing and stage of dyeing.40 minutes treated samples had more gain in thickness than 20 minutes treated samples. There was no significant difference in thickness between gases, timing and stage of dyeing.

3.8 Stiffness

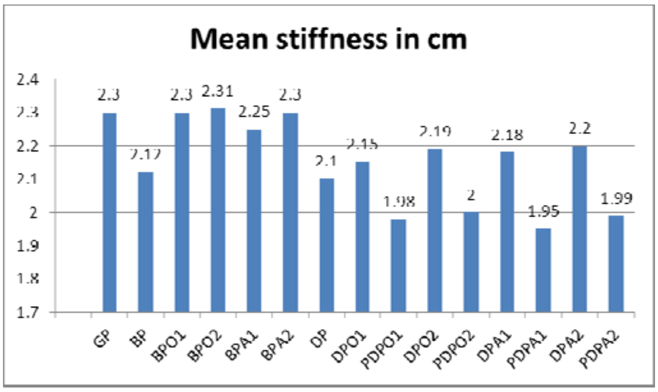

Figure 7: Stiffness

From the above figure it is evident that all the plain weave samples had greater stiffness than their originals except the post dyed samples. 40 minutes treated samples had greater stiffness than 20 minutes treated samples in both oxygen and argon gases. There was no significant difference between the gases and treatment timing but the stiffness varied significant at 5% based on stage of dyeing.

3.9 Abrasion resistance

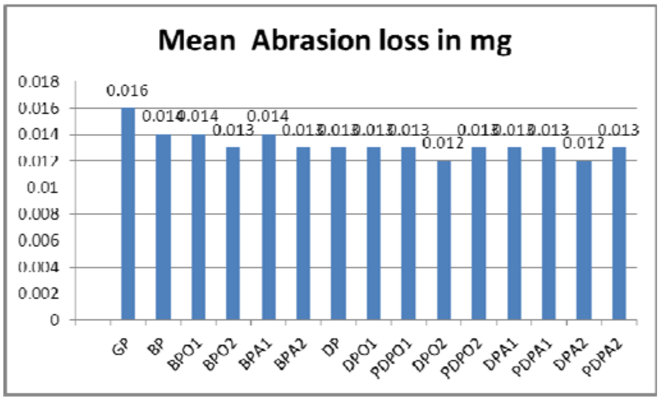

Figure 8: Abrasion Resistance

Most of the samples maintained Abrasion resistance same as that of their original after plasma treatment while the rest had loss in abrasion resistance. 40 minutes plasma treated samples showed loss in abrasion resistance. There was no significant difference between the gases, treatment timing and stage of dyeing.

3.10 Drapability

Drapability is improved on plasma treatment. 40minutes plasma treated samples had better drape than 20 minutes treated sample. Oxygen treated samples has better drape than argon treated samples. Post dyed samples had better drape than dyed samples. Samples PDTA2 had a maximum drape of 6.16%. There was no significant difference between gases and treatment timing. But there was significant difference in stage of dyeing at 5% level.

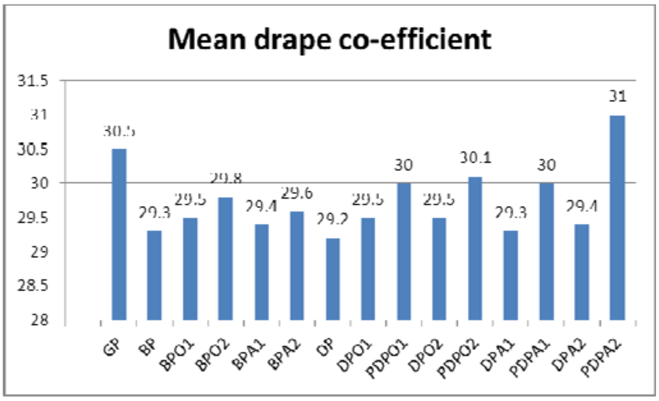

Figure 9: Drapability

3.11 Crease recovery

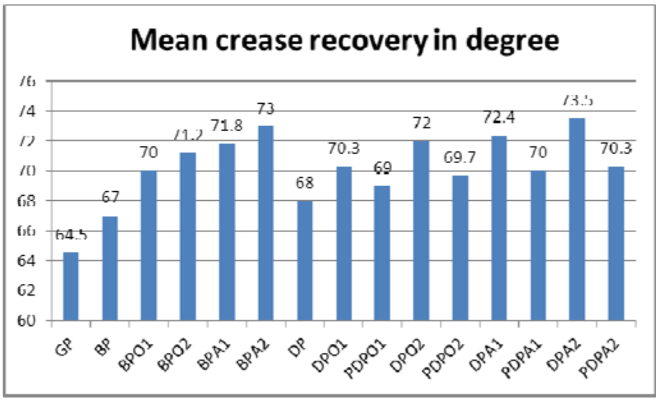

Figure 10: Crease recovery

From the above figure, it is evident that the plasma treatment has improved crease recovery of all samples. Argon treated samples is better than oxygen treated samples. By comparing timing 40 minutes had better crease recovery than 20 minutes when comparing dyed and post dyed, dyed samples have better crease recovery. From the statistical analysis, it is clear that there was no significant difference between gases and treatment timing but there was significant difference in dyeing at 1 % level.

3.12 Air permeability

Table 3: Air permeability

S. No	Samples	Mean value In 100pa 5 cm^2	Gain or loss over previous treatment	Percentage gain or loss
1.	BP	64.67	-	-
2.	BPO2	71.55	6.88	10.63
3.	BPA2	70.43	5.76	8.91

It is evident that the plasma treated samples had better air permeability than bleached. Oxygen treated samples had better air permeability than argon treated samples. There was significant difference between gases at 1% level.

4. Conclusion

Plasma treatment is a good substitute for chemical finishing as it causes no environmental pollution. From the study it may be concluded that plasma treatment with oxygen gases is superior to argon gases. As is improves absorbency, drape and air permeability. As the treatment timing was increased most of the physical properties were improved. Tensile strength decreased with increased exposure to the plasma gases. Plasma treatment done after dyeing seemed to improve the qualities of the fabric better than when done before dyeing.

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