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Study of Corona Discharge Treatment on Physical and Chemical Properties of Cotton Fabric

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In this study, cotton fabric was treated by corona discharge under different powers and number of passages. Corona treated cotton was dyed with direct and reactive dyes. pH and wettability of samples were measured and surface morphology of cotton fabric was determined by SEM and FTIR/ATR analysis. Results indicate that corona treatment causes some cracks on the surface of cotton cuticle layer and water can penetrate rapidly into the cotton structure. FTIR/ATR analysis shows when the power and the passages of corona treatment increase the carboxylic acid groups are created. This result is in agreement with pH results that acidification occurs on the surface of cotton.

Key Words: Corona discharge, Cotton, SEM, FTIR/ATR, Wettability.

INTRODUCTION

One of the important plasmas used in textile industry is corona discharge which is applied in air at atmospheric pressure. Corona discharge treatment is an electrical technique that uses ionized air to modify surface of fibers and polymeric material in a dry system without water. Corona discharge consists on the application of an electrical discharge of high voltage between two electrodes. It produces electrons, neutral particles, ions, photons and radicals which react with air and substrate that is exposed to them. The high energy electrons can split substrate covalent bonds and produces radicals on the surface of the fiber. These radical sites react with ozone and nitrous oxide which are products of air oxidation and the surface of the fiber is oxidized[1-4]. Corona treatment improves hydrophilicity, sorption and electro-kinetic properties that are related to the comfort properties and smoothes

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the surface of the wool fiber. Corona discharge can change the substrate surface properties without affecting the bulk properties of the fibers. Some textile applications of plasma and corona are sterilization, desizing, wettability and hydrophobicity, anti-shrinkage, finishing, dyeability improvement, antimicrobial properties, adhesion promotion, printability and decolourization[5-18].

In this study, cotton fabric was exposed to corona discharge under a variety of powers and passages. Corona treated cotton fabrics were dyed with reactive and direct dyes. Then the effect of power and time of corona discharge has been investigated on wettability, dyeability, pH and surface properties of cotton fabric.

EXPERIMENTAL

Knitted (scoured, bleached) cotton fabric, reactive dye: remazol brilliant blue R, direct dye: solophenyl bordeaux 3BL, sodium carbonate 99.5 % (Merck), sodium sulphate (Merck), sodium hydroxide 97 %, Detergent Tinegal W (Ciba).

Horiba M-12 pH meter (Japan), Datacolor spectrophotometer (Switzerland), Bruker Equinox 55 FTIR/ATR equipment (Germany), Scanning electron microscope LEO 440 I (England), Corona discharge generator (Azad Electrical Industries, Iran).

Corona generator: Corona equipment consists of 2 electrodes: metal electrode roll with silicone coating and aluminum electrode that is parallel with electrode roll. Distance between electrodes is 3 mm. The velocity was set at 2 m/min.

Methods

Corona discharge treatment: Knitted (scoured, bleached) cotton fabric was exposed to corona discharge under 2 powers: 600, 800 watts and 2, 4, 6, 8 and 10 passages. After corona treatment, samples were washed and dried.

Dyeing methods: Corona treated cotton fabric was dyed by two types of dyes: Reactive and direct dyes.

Reactive dyeing: Dyeing was carried out using remazol brilliant blue R 1 %, sodium sulphate 20 g/L, sodium carbonate 5 g/L, sodium hydroxide (32 %) 2 cc/L at 60 ºC for 1 h. The liquor ratio of dye bath was 30:1. After dyeing, samples were washed and dried.

Direct dyeing: Dyeing was carried out by solophenyl Bordeaux 3BL 1 %, sodium sulphate 20 g/L at boiling temperature for 1 h. The liquor ratio of dye bath was 30:1. After dyeing, samples were washed at 40 ºC and dried.

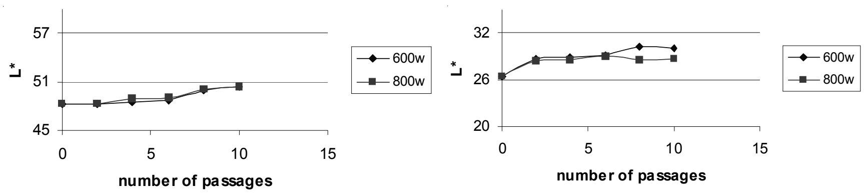
Wettability test: The wettability test was carried out according to AATCC-39-1980 test method. According this method, a drop of water was allowed to fall from a fixed height onto the taut surface of specimen. The surface of the taut textile was held about 1 cm below the tip of the burette. The time required for the specular reflection of the water drop to disappear was measured and recorded as wetting time.

Infrared spectra were collected using a Bruker-Equinox 55 system FTIR/ATR spectrometer for detecting of surface functional groups. All data were recorded using a ZnSe Internal Reflective Element. Spectra were collected over a range of 4000-500 cm^{-1} with a resolution of 4 cm^{-1} that 32 scans were co-added. All the samples were gold coated prior to SEM examination for 2 min. Surface morphology of corona treated and untreated cotton was studied by SEM using LEO440I. SEM photographs were at magnification of × 1500. The pH of the samples was assessed by Horiba pH meter. Samples were immersed in distilled water for 1 h at room temperature. The extracted solution was used for pH measurement.

The colour of the untreated and treated cotton fabrics was determined using a colorimeter (Datacolor spectrophotometer), working with D65 (day light) at 10 visual angle, being used CIELab colour parameters. The colour parameter of samples was expressed as value of lightness (L*).

RESULTS AND DISCUSSION

Colorimetric results of corona treated fabric dyed with reactive and direct dyes have been shown in Fig. 1a and 1b, respectively. In Fig. 1a, in untreated sample, L* value (lightness) is 48.28. After 2 passages of corona treatment, L* value increases to 49.99. Since the L* value has increased the colour of sample becomes lighter. With increasing number of passages up to 10 passages, L* value (lightness) increases and sample become lighter. In 800 watts, there are same results for corona treatment. Fig. 1b shows that in untreated sample dyed with direct dye, L* value is 26.52. After treatment under 600 watts and 2 passages, L* value increases to 28.66 and sample becomes lighter than untreated fabric. With increasing of passages up to 10, there is not any significant changes for L* value. There are same results for corona treatments under 800 watts. It means increasing the corona passages and power haven't influenced on direct dye sorption.



(a) (b)

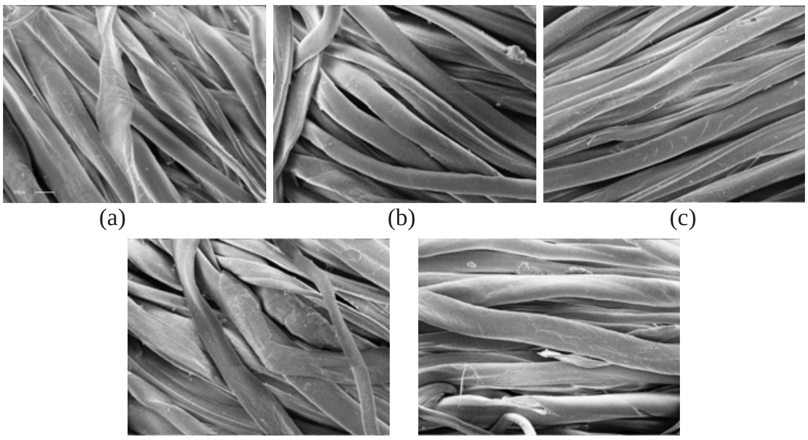
Fig. 1. Effect of power and passages of corona on colour variations of dyed corona treated cotton by: (a) Reactive dye: Remazol brilliant Blue R, (b) direct dye: Solophenyl Bordeaux 3BL

The pH results of untreated and corona treated cotton fabrics have been demonstrated in Table-1. As shown in Table-1, in untreated samples, pH value is 6.28. After corona treatment, with increasing of power and number of passages, pH values decrease. As indicated, in 800 watts corona power by increasing the number of passages, the pH value reduces considerably as compared to treated sample on 600 watts corona power.

TABLE-1
pH VALUES AND DROP WATER ABSORPTION TIME OF CORONA TREATED COTTON (p = PASSAGES)

Watts-p	600-2	600-4	600-6	600-8	600-10	800-2	800-4	800-6	800-8	800-10	Untreated
pH	6.28	6.24	6.20	6.18	6.13	6.24	6.18	5.93	5.71	5.48	6.28
Time (s)	3.00	3.00	2.93	2.76	2.70	2.91	2.63	2.04	1.95	1.70	3.00

Table-1 indicates the wettability of corona treated and untreated cotton; that was measured as absorption time of a water drop. Absorption time of untreated sample is 3 s. After corona treatment under 600 watts and 6, 10 passages it reduces to 2.93, 2.70 s, respectively. By increasing power of treatment, at 800 watts and 10 passages, it decreases to 1.7 s. Therefore by increasing the power and passages of corona, the absorption time of water drop of treated sample reduces significantly. It relates to etching effect of corona treatment that can remove some fragments from the surface of cotton cuticle layer. Another reason might be the changes in surface functional groups of cotton. SEM photographs of corona treated and untreated cotton have been shown in Fig. 2.



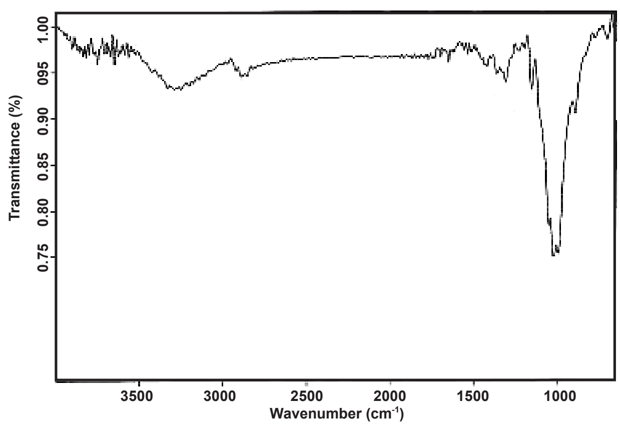
(a) (b) (c)

(d) (e)

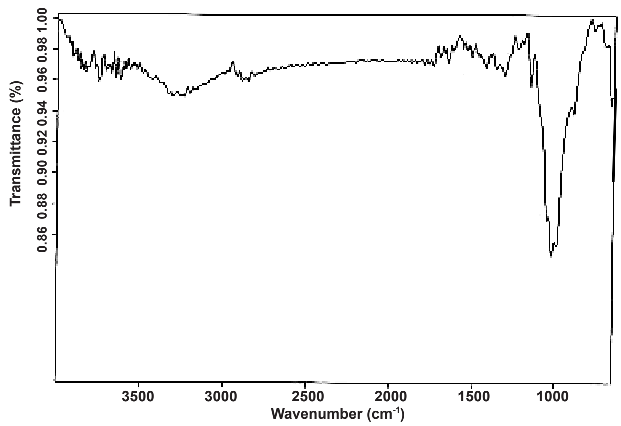
Fig. 2. SEM photographs of untreated and treated cotton (a: untreated, b: 600w-4p, c: 600w-10p, d: 800w-4p, e: 800w-10p) (p = passage)

As shown in Fig. 2, in 600 watts and 4 passages of treatment, there is not any alteration on surface of fibers but in 10 passages of treatment, some cracks appear on surface of cotton. The same results are obtained for 800 watts of treatment. In 10 passages of treatment some areas of cotton surface have some cracks. When the number of passages increases, the time of exposing fabric on corona discharge increases so etching effect on the surface as cracks is appeared.

Fig. 3 demonstrates FTIR/ATR spectra of untreated and corona treated cotton fabrics. In 800 watts, 10 passages of treatment (Fig. 3b) there is a peak in the area of 1708 due to ν(C=O) group of carboxylic acid. This group appears on the surface of cotton using corona treatment. These results are in agreement with pH results that show acidification of cotton surface.



(a)



(b)

Fig. 3. FTIR/ATR analysis of cotton (a) untreated cotton (b) corona treated cotton at 800w-10 passages

Conclusion

Reactive and direct dyeing of treated fabric indicate increase in lightness of samples. pH value of extracted solutions and water absorption time are reduced by corona treatment. pH results are in agreement with FTIR/ATR spectra of samples which carboxylic acid is produced on the surface of cotton fabric. Wettability time of samples increases since the cuticle layer of cotton remove by etching effect of corona treatment.

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