Characterization of the Corona Discharge Treated Cotton Subsequently Applied With Biodegradable Cationic Softener

Abdul Malik Rehan

Balochistan University of Information Technology Engineering and Management Sciences

Zamir Ahmed Abro (✉ zamirabro@hotmail.com)

Balochistan University of Information Technology Engineering and Management Sciences

<https://orcid.org/0000-0003-4799-8747>

Muhammad Ali Zeeshan

Balochistan University of Information Technology Engineering and Management Sciences

Ahmer Hussain Shah

Balochistan University of Information Technology Engineering and Management Sciences

Syed Qutaba Bin Tariq

Balochistan University of Information Technology Engineering and Management Sciences

Research

Keywords: Corona discharge, Cotton fabric, Cationic softener, Water absorbency, Bending length, Crease recovery

Posted Date: November 15th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-983866/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

In this paper, cotton fabric processed with Corona and different amounts of biodegradable cationic softener are studied. Properties such as bending length, water absorption time, and crease recovery angle are therefore measured. By increasing the amount of cationic softener, bending length is observed to be decreased and time for water absorption and crease recovery angle of the sample increased. Scanning Electron Microscopy (SEM) is carried out for the investigation of surface morphology and the micrographs revealed cracking or etching effect on the cotton fabric treated with Corona. However, Attenuated Total Reflection- Fourier Transform Infrared Spectroscopy (ATR-FTIR) analysis confirmed the chemical change on the surface of the Corona treated cotton fabric which is due to the increase of hydrophilic groups. The results also indicated that the presence of the cationic softener on the Corona treated cotton fabric improved the hydrophobicity. The judgments are in close agreement with the findings of water absorption time, bending length, and crease recovery angle.

Introduction

The modifications of the fibers and polymers, to obtain more compelling properties, such as increasing the capacity of absorption of chemicals and water, have been almost accomplished [1]. Today Corona discharge to modify the surface of polymeric materials and textiles are used without affecting the bulk properties of polymers, moisture content, cohesion, cross-linking and the level of electric charge can be altered. Due to the shortage of water resources in the practical environment, the importance of plasma treatment is growing; however environmental issues are not the subject of this study [2–5]. The main advantages of Corona treatment are low capital cost, use of atmospheric pressure, and high yield [6].

Corona discharge plasma and is applied between the two electrodes by using a high voltage at atmospheric pressure as shown in Figure 2 [3, 7, 8]. Electrons that are generated between the electrodes, with the help of high-voltage, accelerate the effect directly on the fibers and polymers. Electrons moving in the direction of the trajectory air particles collide with the matter and as a result, ozone and nitrogen oxides are formed.

Covalent bonds are broken by the high energy produced during a collision between electrons and the environment. As a result, free radical is produced in the form of ozone and nitrogen oxides that react with the substrate surface yielding oxides and become more polar [9]. This method affects the very thin surface of the material which approaches 100°A [4, 10, 11].

The development of textile softeners as the most important chemical process has been almost accomplished. These softeners when applied on textile substrates make them appropriate and acceptable to wear, better flexible along with inferior properties such as more static and less optimum for the sewing process. The major drawbacks of softeners are a reduction of light and rubbing fastness of the color and yellowing of products [12].

Studies have been done on the subject of softeners and plasticizers on textile substrates. Haberer and Zyschka showed that softeners could change the color of textile materials [13, 14]. Chiweshe indicated that softeners have such diverse properties that they may reduce the friction properties of the fiber [15]. Also, some of the softeners produce the electric charge on the surface of the fiber and make a hydrophilic property to fall [12, 16, 17].

Researchers have observed the effect of ultrasound and Silicon softeners on the properties of Cotton and the effect of plasma and softener on the properties of polyester [18–20]. However, in these studies, the effect of Corona discharge produced on a cotton substrate coated with a Cationic softener was not investigated.

Methodology

Material

In this study, scoured and bleaching cotton fabric is having a density of 140 g/m², warp density of 80 per inch, and a weft density of 64 per inch was used. Biodegradable cationic softener named TETRANYL®CO-40 made by KAO Chemicals Europe, and chemical structure contains Dioleylethyl Hydroxyethylmonium Methosulfate (C₄₀H₈₁NO₉S) and molecular weight 752.137, was used to treat the Cotton fabrics. Together with environmental safety; the selected softener is from the vegetable origin and non-flammable too, the chemical structure of which is shown in Figure 1. For the repetitive washing of fabric, Standard detergent SDCE (Type 1) without optical brightener was used.

Methods

The laboratory-scale Corona electric device used in this study is manufactured by Arcotec® GmbH which consists of two electrodes as shown in Figure 2. The samples were placed on the silicon-coated roller in the Corona device. In this test, the fabric sample was passed through the device at 1000W power, having a distance between the electrodes 3mm, at the velocity of the roller 2m/min for 30 revolutions.

Cotton fabric samples of Corona discharge treated and untreated were impregnated with a cationic softener. The impregnation of cotton fabric sample was carried out in four levels 1, 2, 3, and 4% concentrations (relative to the weight of goods) in the bath with liquor ratio to 1:40, at a temperature of 80°C for 45 min and then dried at a temperature 100 °C. For the durability of applied cationic, a frequent household washing test Standard (AATCC-124) was performed. The washing test was carried out with standard detergents for 30 min at the temperature of 47 °C for five times and in the end, the samples were washed with distilled water and then dried.

Test for the time required for water absorption by the fabric sample was performed as per standard AATCC-39-1980 for all the samples before and after washing, in such a way that the distance of burette from the fabric sample was set to 1cm. Then, in 10 different locations, drops of water were poured on the

fabric sample and the time was taken until a drop from spherical to flat mode to be recorded and averaged.

ASTM D1388 standard test, to measure the bending length of the fabrics samples was executed by using Peirce's cantilever tester. In this way, the narrow strip of fabric having dimensions 200 mm to 25 mm length and width respectively was cut. This specimen was slid at a specified rate in a direction parallel to its long dimension until it is leading-edge projected from the edge of a horizontal surface. The length of the overhang was measured when the tip of the specimen was depressed under its mass to the point where the line joining the top to the edge of the platform made a 0.724 rad (41.5°) angle with the horizontal. From this measured length, the bending length and flexural rigidity were calculated.

The standard method AATCC-66, to measure the crease recovery angle of the fabric was used where the fabric specimen with dimensions 15 × 40 mm in width and length respectively was cut. Half of the specimens in the warp and half in the weft direction were cut. The specimens were laid down flat for conditioning at standard conditions of temperature and relative humidity. After folding the face-to-face specimen end-to-end and applying the weight of 500g for 60 s, it was then placed to the instrument's circular scale specimen holder. The reading of the angle made by the free hanging end of the specimen from a circular scale was recorded 5min after inserting a specimen into a clamp.

Surface morphology was investigated with the help of Scanning Electron Microscope (SEM) model TS5130 VEGA manufactured by Company TESCAN® USA. Samples before exposure to SEM were coated with Gold in a Sputter coater under a vacuum environment for 300 s. Then, SEM was operated at a voltage of 23 kV and images were taken with the magnification of 2500 times.

The infrared spectroscopy (ATR-FTIR) of the surface of Cotton fabric samples of Corona treated and untreated as well as samples before and after impregnation with cationic softener was carried out with Bruker Tensor 27 in the range of 500-4000 cm^{-1} scan.

Results And Discussion

Water adsorption

The graph was plotted between the time for water absorption by the samples of cotton fabric treated with Corona discharge and untreated as well as of the samples before and after frequent washing procedures against the applied concentration of cationic softener as shown in Figure 3, where data points are presented with a standard error. As it can be seen by comparing the two charts Figure 3a and Figure 3b that the time required for the water droplet to be absorbed in the surface of the cotton fabric samples after treating with Corona discharge significantly decreases.

The time of water absorption by cotton fabric sample not treated with Corona is 27.4s whereas it reduced to 1.52s for the sample treated with Corona discharge. Corona discharge treatments cause surface modification of cotton physically and chemically that can be observed [2, 10]. By the increasing amount

of cationic softener from 1% to 4%, the time for Water absorption by the fabric sample untreated by Corona discharge was 51.4s to 126.0 s which was then decreased significantly to 2.07s to 3.87s respectively after Corona treatment.

It can also be observed that the time for water absorption by the cotton fabric samples not treated with Corona discharge more sharply increases against the addition of cationic softener as compared to those samples which were treated by the Corona discharge. The application of cationic softener on Cotton fabric samples untreated with Corona consequently produces a hydrophobic layer on the surface. While cationic softener penetrates the fibers in the samples treated with Corona due to the modification of the surface, which ultimately affects water absorption very less.

The results of water absorption time by the sample after 5 times repeated standard home washing procedure are also shown in Figure 3a and Figure 3b. As it can be seen, after finishing with a cationic softener, the time for water absorption of samples untreated with Corona has significantly decreased. Based on the fact it can be said that the cationic softener particles that are present on the surface of the fibers are removed from the surface by repetitive washing, while the samples after Corona treatment, little difference was observed in the time for absorption of water after washing and this is because of penetration of the softener molecules into the fiber structure. Corona discharge surface modification treatments peel the fiber surface. Thus vents are created through which chemicals are absorbed and surface modification of cotton fibers elaborates the phenomenon in the SEM images shown in Figure 5-B.

These results correspond with the researchers who studied the effect of dye on polyester modified with plasma at different levels. In this way, the plasma causes the fiber surface modification and uptake of dye by the polyester fiber increased [18]. Malik, Carneiro, and his co-worker also showed that plasma and Corona surface modification of cotton results in water and dye absorption. [2, 21]. Therefore it can be interpreted that, this research has resulted in more absorption of cationic softener in the fibers.

Bending length

The bending length of the samples treated with cationic softener and repetitive standard washing procedure are presented in Table 1.

In general overview, it can be perceived that by increasing the amount of cationic softener to the cotton fabric, the bending length decreases remarkably for all the samples both in warp and weft directions regardless of washing. The woven fabric has often contained less weft density as compared to the warp fabric sample is more flexible in the weft direction compared to the warp direction [22]. A similar trend of having lesser bending length in the direction of weft can be observed in this experiment too.

Repetitive washing procedure influenced the drape ability of the fabric a lot causes an increase in the bending length to some extent no matter the samples were Corona treated or not. This is because of the removal of cationic softener from the fiber surface during the washing procedure. The removal of cationic softener is more pronounced in the samples which were not treated by Corona discharge, i.e. the bending

length increases up to 0.3" in warp and 0.18" in weft direction when 4% cationic softener was applied. In comparison, bending length increases less significantly for the samples which are treated by Corona demonstrated by 0.1" in the warp and same figure in weft direction with the same concentration of cationic softener.

As the results of water adsorption show, the effect of Corona discharge treatment on physical modification of the surface, the time for water absorption reduced. It can also be said that the effect on the uptake of cationic softener is also evident [2, 21], and increasing the amount of cationic softener on the fiber causes the reduction in bending length of the fabric sample.

Crease recovery angle

Crease recovery angles of the sample applied with Cationic softeners treated and untreated with Corona discharge as well as before and after frequent washing are shown in Figure 4. It can be observed that the crease recovery angle of samples applied with cationic softener and untreated with Corona increases from 218° to 241° and for Corona treated from 225° to 251° against the concentration of applied cationic softener from 0 to 4% respectively.

In samples that are applied with a cationic softener but not treated with Corona discharge, the particles of softener do not penetrate the fiber surface and remain on the surface without interaction. In contrast, the surface modification treatment with Corona causes the physical revamping of the fibers that help the better penetration of the cationic softener particles which ultimately increase resilience and crease recovery properties. The particles of the cationic softener penetrate the cracks present in the fiber surface generated by the Corona treatment, act as a filling material in the spaces between fibers and molecules in the fiber structure, and hence upsurges the wrinkle recovery of the fabric sample [23, 24]. It can also be insinuated that after repetitive washes, the crease recovery angles for the samples which are applied with cationic softener and untreated with Corona, however slightly decrease.

Surface morphology characterization

The SEM images of samples applied with cationic softener at a concentration of 4% on cotton fabric sample treated with Corona and untreated with Corona as well as of the control sample are Shown in Figure 5. Figure 5(a) represents the SEM image of the cotton fiber sample not treated with Corona as well as without application of cationic softener at the magnification of 2500 and depicts that the untreated cotton fiber surface is smooth. Figure 5(b) denotes the SEM image of a sample of a cotton fiber treated with Corona at the magnification of 2500. Micrograph indicates fractures and gaps appeared on the surface of cotton fiber as a result of physical modification by the Corona treatment. In this operation, high-energy electrons collide with the molecules present at the surface of the fiber, and consequently cracked surface is created. Also, the high energy produced during the Corona treatment could burn the surface of the fiber which leads to the converse results and prohibits the penetration of water and chemicals into the surface of the fiber [25, 26]. As the results of this study formerly suggested an increase in the rate of water absorption and chemical softener, it can be said that cracks on the fiber surface cause

the absorption of softener and confirms the earlier statement. As revealed in Figures 5(c) and 5(d) that cationic softener has somewhat filled the cracks on the surface of cotton produced after Corona treatment.

Spectroscopy ATR-FTIR

Figure 6 represents the spectrum of ATR-FTIR of cotton fabric samples treated and untreated with Corona discharge. The absorption by the Cotton fiber untreated with Corona in the region of 3291 cm^{-1} due to stretching of alcohol OH and $1000\text{-}1200\text{ cm}^{-1}$ for the O-C stretching confirms the presence of hydroxyl groups. Corona treated cotton fabric sample absorption in the area of $1000\text{-}1200\text{ cm}^{-1}$ due to O-C stretching and $3200\text{-}3600\text{ cm}^{-1}$ (H-O stretching), endorses the presence of Hydroxyl groups.

Therefore, it can be understood that the cotton surface has been modified with Corona discharge and cause the creation of functional groups and chemical change. The sharp absorption in the region of 2889 and 3345 cm^{-1} is evident in the presence of hydroxyl groups and hydrophilic cotton. The intensity of the absorption bands in the spectrum of the cationic softener impregnated cotton is low, indicating a hydrophobic surface which can be due to the coating of the cotton fiber by the softener molecules.

Figure 8 shows the ATR-FTIR spectrum related to cotton treated by Corona and applied with the cationic softener. The results show that, with the addition of softener, the intensity of absorption bands in the region of 3291 cm^{-1} is increased proves the increase in the number of hydroxyl groups. The increase in the absorption intensity is more significant in the samples which are not Corona treated and applied with cationic softener compared to cotton after treatment with Corona discharge and cationic softener application, therefore, verifies less affected fiber surface. Hence the results of ATR-FTIR are consistent with the results of water absorption.

Conclusion

In this research, the effect of Corona discharge on cotton fabric and application of cationic softener was studied and the bending length, water adsorption, and crease recovery angle were determined. By increasing the amount of cationic softener, bending length drops while the crease recovery angle and water absorption time increase. By using SEM microscopy, physical modification of the fiber surface was analyzed and it was found that the surface of the cotton fiber treated with Corona discharge is changed and accordingly penetration of cationic softener is also increased. The results of spectroscopic ATR-FTIR show that Corona surface modification in addition to the physical and chemical changes creates functional groups on the surface of cotton fibers which cause more cationic softener absorption.

The addition of cationic softener on the cotton fabric samples treated with Corona, increases the hydrophilic groups on the fiber surface and cationic softener penetrates more into the fiber, but the surface is less affected. Therefore, it is interpreted that the surface of the fibers can be modified to

achieve specific properties by Corona discharge without using water and in an environmentally friendly way.

Declarations

Acknowledgments

This project is not supported by any body

Autors Contributions

Abdul Malik Rehan collected the data; Zamir Ahmed Abro drafted the manuscript, Muhammad Ali Zeeshan edited the manuscript and revised grammar, Ahmer Hussain Shah and Syed Qutaba bin Tariq read and approved the final version.

Funding

Funding is not received by any body

Availbilty of data and Material

All materials and data collection was succesfully received from Textile Testing Lab.

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Competing interests

There is no conflict of interest, and this work was not harmful to society and animals.

Author detail

¹Department of Textile Engineering, BUITEMS, Airport Road, Quetta, 87300, Pakistan.

References

1. Deopura, B., et al., Polyesters and polyamides. 2008: Elsevier.
2. Carneiro, N., et al., Dyeability of corona-treated fabrics. Coloration Technology, 2001. 117(5): p. 298–302.

3. Gokarneshan, N., Eco-friendly approaches to textile finishes. *Journal of Textile Associate*, 2004. 303: p. 301–304.
4. Thorsen, W.J., Modification of the Cuticle and Primary Wall of Cotton by Corona Treatment. *Textile Research Journal*, 1974. 44(6): p. 422–428.
5. Wakida, T., et al., Surface Characteristics of Wool and Poly (ethylene Terephthalate) Fabrics and Film Treated with Low-Temperature Plasma Under Atmospheric Pressure. *Textile Research Journal*, 1993. 63(8): p. 433–438.
6. Shishoo, R., *Plasma technologies for textiles*. 2007: Elsevier.
7. Ryu, J., T. Wakida, and T. Takagishi, Effect of corona discharge on the surface of wool and its printing application. *Textile Research Journal*, 1991. 61(10): p. 595–601.
8. Shahidi, S., J. Wiener, and M. Ghoranneviss, Surface modification methods for improving the dyeability of textile fabrics. 2013: INTECH Open Access Publisher.
9. Rouette, H.-K. and B. Schwager, *Encyclopedia of textile finishing*. Vol. 20. 2001: Springer Berlin.
10. Gotmare, V., et al., Surface Modification of Cotton Textile using Low-Temperature Plasma. *International Journal of Bioresource Science*, 2015. 2(1): p. 37–45.
11. Radetic, M., et al., Low-pressure RF plasma and corona decolourisation of indigo dyed denim fabrics. *Publications de l'Observatoire Astronomique de Beograd*, 2008. 84: p. 407–410.
12. Schindler, W.D. and P.J. Hauser, *Chemical finishing of textiles*. 2004: Elsevier.
13. Habereeder, P. and A. Bereck, Softeners in textile processing. Part, 2002. 2: p. 125-137.
14. Zyschka, R., Textiles softeners and their tricky application. *MELLIAND TEXTILBERICHTE INTERNATIONAL TEXTILE REPORTS*, 2001. 82(6): p. 497-500.
15. Chiweshe, A. and P.C. Crews, Influence of household fabric softeners and laundry enzymes on pilling and breaking strength. *Textile Chemist and Colorist and American Dyestuff Reporter*, 2000. 32(9): p. 41–47.
16. Nahta, R., Textile softeners. *American Dyestuff Reporter*, 1981. 70(8): p. 22-+.
17. Wahle, B. and J. Falkowski, Softeners in textile processing. Part 1: An overview†. *Review of Progress in Coloration and Related Topics*, 2002. 32(1): p. 118–124.
18. Dave, H., et al., Surface activation of polyester fabric using ammonia dielectric barrier discharge and improvement in color depth. *Indian Journal of Fibre & Textile Research (IJFTR)*, 2014. 39(3): p. 274–281.
19. Guesmi, A., N. Ladhari, and F. Sakai, Ultrasonic preparation of cationic cotton and its application in ultrasonic natural dyeing. *Ultrasonics sonochemistry*, 2013. 20(1): p. 571–579.
20. Sarioğlu, E. and N. Çelik, Investigation on Regenerated Cellulosic Knitted Fabric Performance by Using Silicone Softeners with Different Particle Sizes. *Fibres & Textiles in Eastern Europe*, 2015.
21. Malek, R.M. and I. Holme, The effect of plasma treatment on some properties of cotton. *Iranian polymer journal*, 2003. 12: p. 271–280.

22. Ghosh, T.K. and N. Zhou, Characterization of fabric bending behavior: a review of measurement principles. *Indian Journal of Fibre and Textile Research*, 2003. 28(4): p. 471–476.
23. Chattopadhyay, D. and B. Patel, Effect of nanosized colloidal copper on cotton fabric. *Journal of Engineered Fiber Fabrics*, 2010. 5(3): p. 1–6.
24. Morris, C.E. and C.M. Welch, Antimicrobial finishing of cotton with zinc pyrithione. *Textile Research Journal*, 1983. 53(12): p. 725–728.
25. Ma, P., et al., Influence of temperature on corona discharge treatment of cotton fibers. *Fibers and polymers*, 2010. 11(6): p. 941–945.
26. Ma, P., et al., Application of corona discharge on desizing of polyvinyl alcohol on cotton fabrics. *Journal of applied polymer science*, 2009. 114(5): p. 2887–2892.

Tables

Due to technical limitations, table 1 is only available as a download in the Supplemental Files section.

Figures

Figure 1

Chemical structure of softener

Figure 2

Labortory based corona Manufacturing

Figure 3

(a) and 3(b). The time required for the water droplet to be absorbed after home washing in the surface of the cotton fabric

Figure 4

Crease recovery angles of the sample applied with Cationic softeners treated and untreated with Corona

(a)

(b)

(c)

(d)

Figure 5

(a) SEM image of the cotton fiber sample untreated with Corona, (b) denotes the SEM image of a sample of a cotton fiber treated with Corona, (c) and (d) SEM of a cotton fiber treated cationic softener

Figure 6

Represents the spectrum of ATR-FTIR of cotton fabric samples untreated with Corona discharge.

Figure 7

Represents the spectrum of ATR-FTIR of cotton fabric samples treated with Corona discharge.

Figure 8

Figure 8 shows the ATR-FTIR spectrum related to cotton treated by Corona and applied with the cationic softener

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [floatimage4.png](#)