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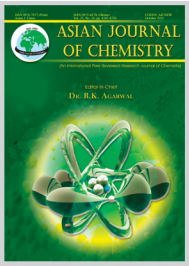

Sizing and Dyeing Property Improvement of Cotton Fabric Treated with Corona Discharge

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In this study, corona discharge treatment is applied to cotton fabric at various discharge voltages and time. Scanning electron microscopic graphs show that the surface of cotton fiber is etched with obvious ridge, uneven and rough trenched structure. The breaking strength and hydrophilic properties of treated cotton fabric are improved evidently after the corona discharge treatment. Surface affinity between the treated fabric surface and the starch sizing is increased at the same time and the dye uptake of treated fabric was increased when the applied voltage and treating time increased. Its effects on surface modification of cotton fabric and its application in finishing are investigated with a range of analytical methods. The results suggest that corona discharge can be successfully applied the finishing of cotton fabric, especially in the green processing of sizing and dyeing.

Key Words: Corona discharge, Cotton fabric, Hydrophilic, Sizing, Affinity, Dyeing ratio.

INTRODUCTION

Corona discharge treatment has been widely applied to modify the surface of polymers. The treatment is simple and practical since the samples can be quickly treated in atmospheric condition[1]. New active groups can be produced and grafted to the as treated polymers during corona discharge treatment[2]. The amount of high reactive free radical oxygen of hydrophilic polymers was increased after corona discharge treatment, which led to the improvement of the surface affinity and sticking strength of the polymers[3-5]. In textile industry, corona discharge has been applied to modify the surface of wool fiber. The printing[6], dyeing[7] and shrink resistant properties[8-10] were greatly improved after the treatment. Corona discharge was also used to treat polyester[11,12] and the hydrophilic and dyeing properties were improved evidently.

As a popular textile material, cotton fibers are subject to complicated finishing such as scouring, bleaching, washing and sizing during the process of fabric production. Large amount of water and chemicals must be used at the process, which is environmental unfriendly and energy wasting[13]. Modification of the surface of cotton fiber will influence the surface properties of cotton fiber and thus may contribute to the green processing of cotton finishing. In this study, corona discharge was applied to modify cotton fabric, the properties of cotton including mechanical, hydrophilic, affinity and dyeing properties were investigated in detail.

EXPERIMENTAL

Samples of 100 % cotton plain weave fabric (average weight 158.27 g/m^2 and thickness 0.45 mm). All the samples (with the size of 15 cm × 5 cm) were washed in deionized water and then dried in conventional conditions (temperature 20 ºC and relative humidity 60 %).

Reactive red K-2G was chosen as the dye. Phenol, chlorobenzne, starch and acetone were bought from chemical market, analytical grade.

Corona discharge treatment: Corona discharge treatment was conducted on a corona discharge machine of SDCD16-2-10 (manufactured by Dalian Number 9 Electronic Incorporation, Dalian, China) with different treating voltages and treating time.

Measurements and characterizations: Scanning electron microscopy (SEM) analysis was carried out on a field emission SEM (Quanta 200, Manufactured by FEI, Holland), the samples were coated with gold before testing.

Infrared spectra of the samples were tested on a infrared reflectoscope reflector (TENSOR27, manufactured by BRUKER, Germany).

Mechanical property of samples tested on an Instron5566 Universal Testing Machine, with a gauge length of 10 cm and strain rate of 50 mm/min. The width of the sample was 15 cm × 5 cm, all the samples were tested for 10 times and the results were averaged.

Wicking properties were tested as follows,one end of the sample was immersed vertically along length direction in a water reservoir, water diffused into the sample by capillary action, the height of the water climbed on the sample, so called wicking height, was tested after 20 min.

The fabric treated by corona discharge at different voltages and time was then treated by the starch sizing solution, the two fabrics were laminated together, the laminated area was 5 cm × 5 cm, after they were dried at 85 ºC, sticking strength was tested.

Instron 5566 was used to test the sticking strength of laminated fabrics stuck by the starch sizing so as to test the affinity of the sample to sizing. In the affinity strength test preparation, two pieces of the treated cotton fabrics (10 cm × 5 cm) were immersed into the boiling starch sizing solution (concentration of the size was 10 %) for 5 min in the length direction, then they were taken out and laminated in the length direction with the laminated area of 5 cm × 5 cm, they were dried up at 105 ºC. The adhesion strength between the two fabrics was tested by drawing in the length direction with strain rate 50 mm/min.

Reactive red K-2G was used to dye the fabric, dyeing ratio was 1:50, dye weight was 2 % of the fabric. A certain weight of the fabric was immersed into the dyeing solution for 10 min at 60 ºC, the solution was then heated up at a rate of 1 ºC/min to 90 ºC and kept constant for 0.5 h. In the determination of dye uptake, the dyed specimens were fully washed by distilled water and then dried at 85 ºC and then the dyed specimen of 0.1g and chlorobenzene-phenol solution (weight ratio 1:1) of 5 mL were put into a flask of 50 mL capacity. The dyed specimen dissolved fully into the chlorobenzene-phenol solution in boiling water bath. Cooled to room temperature, acetone added to deposit fiber flock and then adjusted to gradution. After adequate time, the absorbency of upper clear layer, E_2 was measured. Undyed fiber of the same weight as the dyed fiber and chlorobenzene-phenol solution (volume ratio 1:1) of 5 mL and 2 % (owf) of reactive dyes were put into a flask of 50 mL capacity, shaken, laid aside for some time and then absorbency of its upper clear layer was determined as E_1, dye uptake was defined by eqn. (1):

$$\text{Dye uptake (\%)} = (E_2/E_1) \times 100\ \% \quad (1)$$

RESULTS AND DISCUSSION

SEM photos: Fig. 1 shows the SEM graphs of cotton fibers before and after corona discharge treatment. As shown in photo (a), the surface of fiber untreated by corona discharge was smooth. However, after corona discharge treatment, the surface of fiber was etched seriously, obvious ridge, uneven and rough trenched structure could be observed, as shown in photo (b). This was due to the electrical field created by the high voltage in the treatment, as well as the high energy obtained by the acceleration of some ions and free electrons from the air[14,15]. Parts of molecules and free electrons were ionized into new free ions, electrons and free radicals by collision in the electrical field; the etched surface was thus formed by the collision. The specific surface areas may increase to some extent due to the trenched surface.

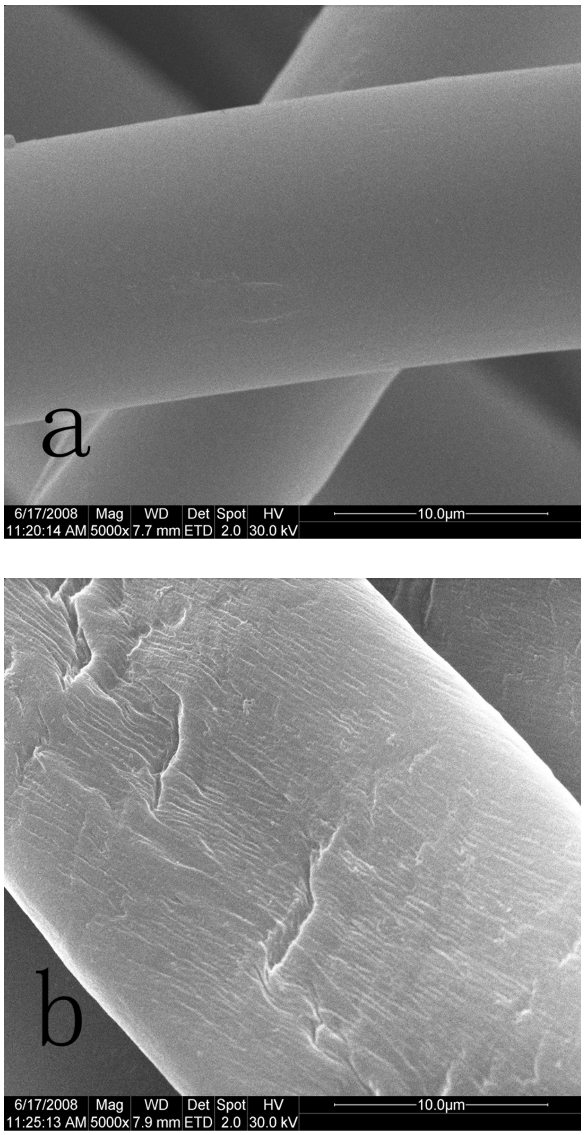

Fig. 1. SEM photos of cotton fiber before (a) and after (b) corona discharge treatment (with applied voltage 10 kV and treating time10 s)

Infrared spectra: Fig. 2 shows the infrared spectra of cotton fiber before and after corona discharge treatment. It is obvious that the absorbing peak of -OH (3336) and C-O-C (1056) of cotton fiber were increased obviously after corona discharge treatment. The absorbing peaks of 1641 and 1433, were ascribed to water molecule, were increased slightly as well. These changes suggest that the amount of hydrophilic groups of cotton fiber were increased after corona discharge treatment and the hydrophilic properties of cotton fiber may increase accordingly.

Mechanical properties: Fig. 3 shows the breaking strength of cotton fabric treated by corona discharge with different applied voltage and treating time. Compared with the untreated sample (data in Fig. 3 with treating time 0), corona discharge treated samples show much higher breaking strength. The increase of the proportion of crystalline region after corona discharge might contribute to the increase of breaking strength[16]. Besides, the friction between fibers increased since the surface of fiber etched after corona discharge treatment, thus the breaking strength increased accordingly.

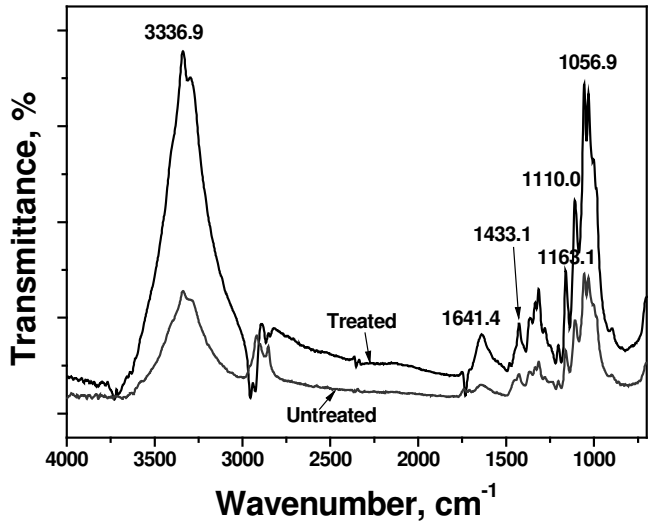

Fig. 2. Infrared spectra of cotton fiber before and after corona discharge treatment (with applied voltage 10 kV and treating time10s)

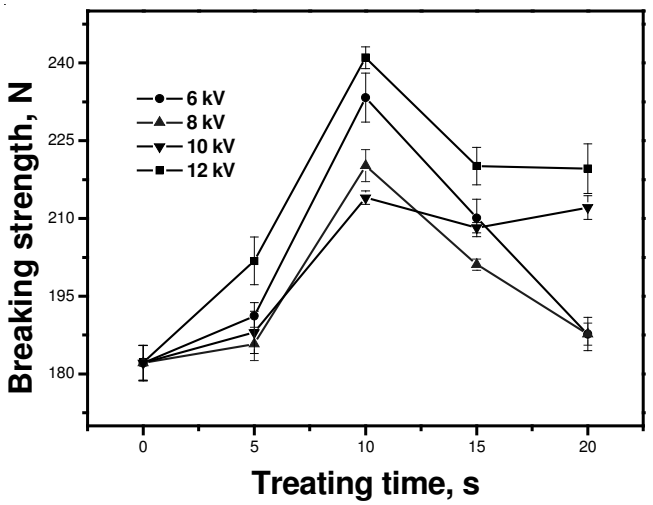

Fig. 3. Breaking property of cotton fabrics treated by corona discharge

The breaking strength fluctuates slightly with the increase of applied voltage, however, sample treated with higher applied voltage, such as 12 kV, shows much higher breaking strength. This is probably due to the more severe etched surface of fiber under much high applied voltage. The highest breaking strength appears when treating time is 10 s for all samples. This may be explained that the surface of fiber was etched at first, then a weak interface and lots of small molecule substances were formed when the treating time was more than a certain time (10 s)[17,18], which hinder the increasing of the processing of breaking strength increasing.

Wicking properties: Fig. 4 shows the wicking height of samples treated by corona discharge with different applied voltage and treating time. It is obvious that the wicking height increases with the increase of treating time and applied voltage. However, when applied voltage is higher than 10 kV and the treating time higher than 15 s, the wicking height fluctuates slightly instead of evident increase. It can be explained that the number of hydrophilic groups was increased at first and the hydrophilic properties were reached the limit point when the treat time above a certain range[13]. This suggests that the hydrophilic properties of cotton fiber are improved to some extent by corona discharge treatment. As we know irradiation treatment on the polymer surface such as by plasma treatment, the treated effect (hydrophilic properties) usually recedes as time goes on[16]. However from present studied results, it is found that the wicking properties of the fabric treated by coron discharge can be kept for a long time.

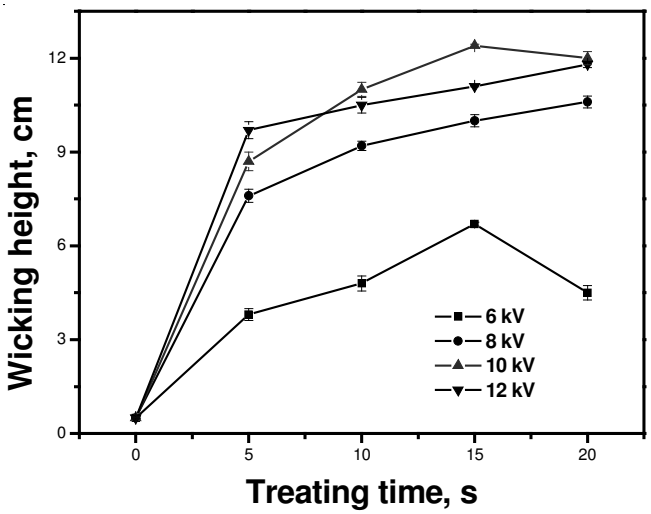

Fig. 4. Wicking property of cotton fabrics treated by corona discharge

Affinity between the treated fabrics and starch sizing: Table-1 shows the drawing strength of two laminated fabrics stuck by starch sizing. It is obvious that the drawing strength increases with the increase of applied voltage and treating time, which suggests that the affinity between the treated fabrics and starch sizing is greatly improved. However, excessive treatment (when applied voltage is higher than 10 kV or treating time longer than 15 s) doesn't bring out with much higher drawing strength, best results were observed under applied voltage 10 kV and treating time 15 s. The hydrophilic properties were greatly improved after cotton fabrics were treated by corona discharge, starch sizing thus shown good surface affinity with the fabrics[19]. Optimization of the treatment enhanced the treating effect and the affinity between fabric and sizing improved accordingly.

TABLE-1
EFFECT OF APPLIED VOLTAGE AND TREATING TIME ON THE DRAWING STRENGTH (N) OF TWO LAMINATED FABRICS STUCK BY STARCH SIZING

Treating time	Applied voltages (kV)			
	6	8	10	12
Untreated	7.43±0.55			
5	8.77±0.32	11.28±0.54	11.80±0.73	10.27±0.47
10	9.23±0.49	11.82±0.67	11.96±0.74	11.70±1.52
15	12.50±1.22	15.57±1.55	12.48±0.41	12.12±0.71
20	8.16±1.07	9.23±0.35	10.06±0.84	8.40±1.66

Currently, most effective sizing agent for high count yarn of cotton fiber is PVA, however, it is not friendly to the environment and necessary to develop new method to size the high count cotton yarn by natural sizing agent. Many researchers only focused their research to develop new sizing agent for high count cotton yarn, however, few researcher paid attention to the cotton fiber surface modification. It is found, by corona

discharge, the cotton fiber surface can be greatly improved to be more hydrophilic and the treated high count yarn can be sized with traditional sizing agent.

Dyeing properties: From Fig. 5, it can be seen that dye uptake of the treated fabrics was greatly improved. As the applied voltage and treating time increased, the dye uptake increased dramatically. It is partly because that the fabric hydrophilic property is increased and the dye can be quickly absorbed onto the fiber surface[13]. As a result, the dyeing energy can be reduced, which is meaningful in green processing of textile dyeing process.

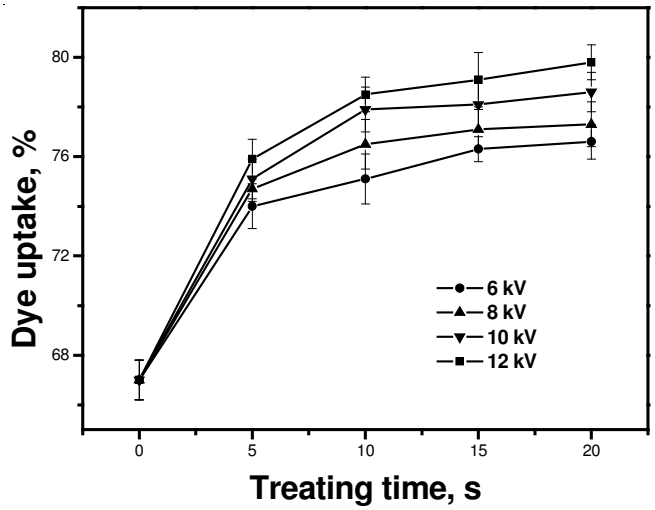

Fig. 5. Dyeing property of cotton fabrics treated by corona discharge

Conclusion

Corona discharge treatment can be applied as a simple, environmental friendly and green processing method to modify the surface of cotton fabric. After corona discharge treatment, SEM photos show that the surface of cotton fiber is etched seriously with obvious ridge, uneven and rough trenched structure. Infrared spectra shows that the absorbing peaks of -OH (3336) and C-O-C (1056) and peaks around 1641 and 1433 are increased greatly, this suggests the increase of the amount of hydrophilic groups of cotton fiber after corona discharge treatment. The breaking strength of corona discharge treated cotton fiber becomes higher than the untreated one, highest breaking strength was obtained when applied voltage was 12 kV and treating time 10 s. Cotton fabric can be modified to be more hydrophilic by corona discharge treatment, increase of applied voltage and treating time and improve the wicking properties further and the best treatment parameters are applied voltage 10 kV and treating time 15 s. After the treatment, affinity of the fabric with starch can be greatly improved. The dye uptake ratio and dyeing speed of cotton fabric was also improved after corona discharge treatment, this can shorten the dyeing time and reduce the dyeing cost.

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