Color Performance of Cotton Fabrics Pretreated by Low-Temperature Plasma and Inkjet-Printed with Pigment Inks

Anli Tian[1], Kuanjun Fang[2], Xia Zhang[1], Shaohai Fu[1]; [1]Key Laboratory of Eco-Textiles of Ministry of Education, Jiangnan University. 1800 Lihu Road, Wuxi 214122, Jiangsu, China; [2]Laboratory of Fiber Materials and Modern Textiles, The Growing Base for State Key Laboratory, Qingdao University, 308 Ningxia Road, Qingdao 266071, Shandong, China.

Abstract

*Theoretically pigment inks are suitable for inkjet printing of all kinds of fiber fabrics, including polyester, silk, cotton, wool, etc. Besides that pigment inkjet printing has prominent environmental friendly advantages compared with other colorants. But pigment inks exhibit poorer color performance on fabrics than dye inks. Pretreatment of fabrics is one of the effective methods to improve the color performance of pigment inks. In this paper, an environmental friendly method -- low temperature glow discharge plasma was employed to pretreat cotton fabrics and the image quality of cotton fabrics pretreated and inkjet-printed with pigment inks was analyzed. The results show that after plasma pretreatment the K/S values and L*a*b* of cotton fabrics were improved and, the ICC profiles and the color space of pigment inks on cotton fabrics before and after plasma treatment were calculated, which indicate the color performance of pigment inks was enhanced.*

1. Introduction

In recent years, the application of ink-jet printing has increased for its advantages. It offers benefits such as speed, flexibility, creativity, and cleanliness, strike-off, preparation of samples and recently in the production of short print-length textiles [1-5]. As are two kinds of inks in digital printing of textiles, Theoretically pigment inks are suitable for inkjet printing of all kinds of fiber fabrics, including polyester, silk, cotton, wool, etc[6]. But pigment inks exhibit poorer color performance on fabrics than dye inks. Pretreatment of fabrics is one of the effective methods to improve the color performance of pigment inks. Recently, low-temperature plasma (LTP) treatment has been proved to be an effective pretreatment method to change the morphology and wettability[7-14]. Jiangnan University has researched LTP pretreatment on silk and polyester[15-16]. In this paper, color performance of cotton fabrics pretreated by low-temperature plasma and inkjet-printed with pigment inks was study.

2. Experimental

2.1 Materials

The cotton used was a 100% singed, desized, scoured, and bleached cotton fabric with a plain weave structure, 40s×40s, 133 ends/inch×72 picks/inch, and 136 g/m2 fabric weight. The pigment inks were Pinks Cyan, Pinks Magenta, Pinks Yellow, Pinks Black, Pinks Light Cyan and Pinks Light Magenta. All inks are commercial and supplied by Jiangnan University. Oxygen (99.99%) was supplied by Wuxi Taihu Gas Corporation, China).

2.2 Low-temperature plasma (LTP) treatment

A glow discharge generator was employed for the plasma treatment of the samples. Oxygen (O_2) was chosen as the LTP gas. The discharge power and pressure were 80W and 50Pa, respectively. The exposure time was 6 min. In the plasma chamber, a sheet of polyester fabric was placed. Before the process started, air was pumped out by the vacuum pump, thus almost a vacuum level was created in the reaction chamber. Afterward, O_2 plasma gas was introduced into the reaction chamber at certain power level. All samples were treated with6 min.

2.3 Digital printing of cotton fabrics

Printing was carried out on a Mimaki Tx-1600 ink-jet printer with bidirection 8 pass and variable 720 dpi in a low speed, then dried in oven at 150℃ for 3min for color fixation.

2.4 Color calibration

Color management was made on polyester used disperse inks or pigment inks respectively. First, set printer mode bidirection 8 pass and variable 720 dpi in a low speed, and use polyester as printing media whatever disperse dye inks or pigment inks, and then printing the test bar (Offered by Wasatch) which included the limit of every color inks and total inks. Secondly, inks limit were set according to test bar. Thirdly, print patches and create the ICC custom profile using X-rite MonacoProof software package, and install it to Wasatch RIP software. So the color gamut could be seen by Wasatch RIP software.

2.5 Color yield measurements

The printed fabrics were conditioned before color yield measurement using a Macbeth Colour Eye 7000A Spectrophotometer (Gretag Macbeth, Australia). The condition for measurement was set under specular excluded with large aperture. The fabric was folded two times to ensure opacity and measured twice, i.e. measured on both the warp and weft directions to obtain average results.

The color yield (K/S value) was calculated for wavelengths of 400–700 nm at 20 nm intervals within the visible spectrum. The K/S values were calculated according to Equ.1:

$$K/S = (1-R)^2/2R \qquad (1)$$

Where, K is the absorption coefficient (depending on the concentration of colorant), S is the scattering coefficient (caused by the dyed substrate) and R is the reflectance of the colored sample. The higher the K/S value is, the greater the color yield and dye uptake.

3. Results and Discussion

3.1 Limit inks of cotton fabric with LTP pretreatment

In order to investigate the color properties of cotton fabric pretreated by LTP, the pure inks patches were printed and measured the limit ink of cotton fabric [17].The results were given in Table 1.

Table1. Limit of every kind inks

cotton	C	M	Y	K	All
untreated	90	90	92	95	370
treated	92	92	95	100	400

Table1 showed that every color limit amount of cotton pretreated with LTP was larger than those unpretreated with LTP, what is to say the cotton pretreated with LTP could absorb more inks. The reason of this could explain by Figure 1.

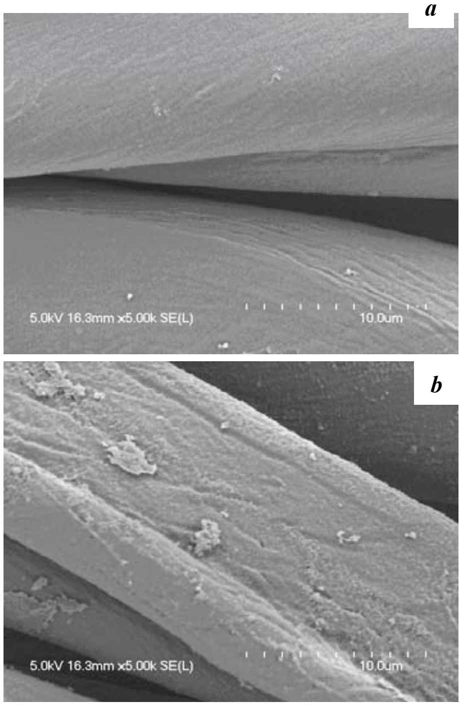


Figure1. SEM microphotographs of cotton fiber surface before and after plasma treatment：(a)untreated cotton fiber; (b) LIP pretreated cotton fiber.

From the Figure1 we can see that LTP treatment could modify the surface of cotton fiber. It was very smooth on the surface of untreated samples, and the cracks formed on the fiber surface after the LTP pretreated. So more ink could be reserve by the surface groove. In addition, with the formation of cracks on the fiber surface, the surface area of fiber would be increased accordingly, thereby facilitating more pigment ink to approach the fiber surface and increase the uptake of pigment ink consequently.

3.2 Sharpness of ink-jet printed cotton fabric

The sharpness of the ink-jet printed pattern was measured by the optical analysis method. The results were shown in Figure2. Obviously, there was a little bleeding on the cotton fabric without pretreatment, and there was almost no bleeding after LTP pretreatment. In fact, the plasma treated cotton caused by the changes in morphology and chemical composition of surface. Morphology changes such as the forming of grooves and cracks on the surface of cotton fabrics shown in the Figure 1, which not only changed the limit of pigment inks but also the wettability of cotton fabric. Plasma oxidation reactions may produce oxygen-containing functional groups (-COOH, -OH, -C=O), which are attached to the fiber surface. These functional groups play an important role in increasing the hydrophilic properties of the fabrics. Therefore, the pigment inks filled in these grooves and cracks and was absorbed quickly, which greatly reduces the permeability of bleeding. Consequently, the LTP treatment on cotton fabric could enhance the sharpness of pigment ink-jet printing.

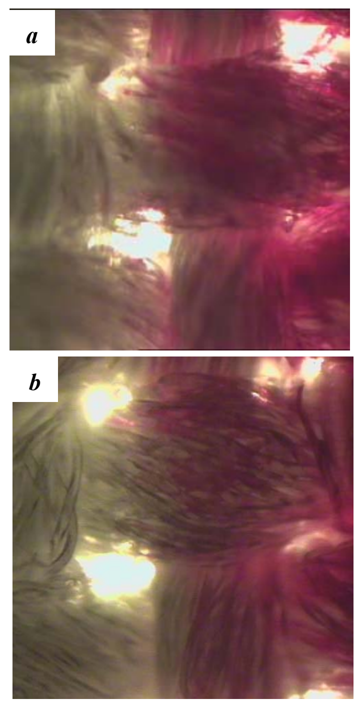


Figure 2. Sharpness of ink-jet printed cotton fabric: (a) untreated cotton fabric; (b) pretreated cotton fabric by plasma.

3.3 Color properties of ink-jet printed cotton fabric

As mentioned, the change of morphology and wettability of cotton fabric after LTP pretreatment caused the change of limit inks and bleeding. Corresponding, the color properties changed also.

Color strength K/S values from Table2 clearly demonstrate that every color of cotton pretreated with LTP was higher than that unpretreated From Table2 it also could be found that L values of cotton pretreated with LTP were higher than that unpretreated. L values which disclosed the lightness of color. That was to say, the LTP pretreated printing cotton was really more brilliant than that unpretreated, which Table 3 also confirmed.

Table2 were the factors effected color gamut after the cotton fabric with plasma pretreated. The results showed that the maximum brightness of ink-jet printing cotton fabric used pigment ink increased after plasma treatment, and the minimum brightness reduced. At the same time the max saturation also improved greatly, which means the dark became darker, the light lighter, and the color more bright. So LTP pretreatment on cotton fabric expanded its inkjet printing color gamut range and could get more bright color.

Table2. K/S value and L*a*b* ink-jet printing cotton fabric used pigment ink

color		K/S	L*	a*	b*
Cyan	untreated	16.15	44.81	-8.23	-45.09
	treated	18.60	46.56	13.44	-33.08
Magenta	untreated	15.32	46.74	42.06	-20.58
	treated	18.49	49.07	50.65	-3.95
Yellow	untreated	13.58	70.69	6.04	48.64
	treated	17.12	74.88	8.35	54.54
Black	untreated	18.19	31.16	2.09	-1.98
	treated	20.08	34.39	-3.48	0.08

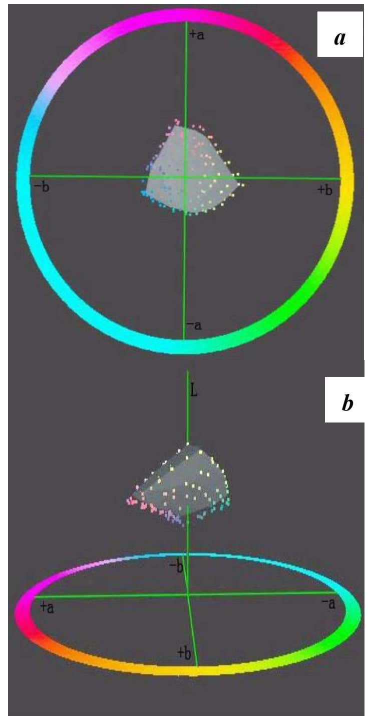
Table3. Color parameter of ink-jet printing cotton fabric used pigment ink

sample	Min	Max	Max saturation	Color gamut
blank	20.731	81.518	78.3925	1.05509 million dE
LTP	20.288	82.386	82.1599	1.445379 million dE

Gamut volume could indicate the total colors in the gamut. Figure2 and Figure3 was color gamut of cotton fabric CMYK profile. It was shown that the color gamut of cotton fabric with LTP pretreated was larger than the color gamut of cotton fabric without LTP pretreated. That is to say, the pretreatment of LTP increased the color gamut of cotton fabric.

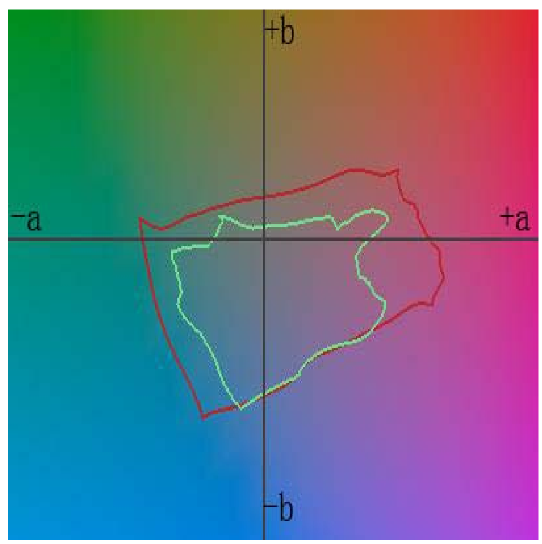
4. Conclusions

The low temperature plasma could be used to pretreat cotton fabrics, it could effect the morphology and wettability of cotton fabric, influence the limit inks and bleeding of ink-jet printing cotton fabric, and the change of color properties enhanced the color performance of pigment inks.



Note: Gray region represent unpretreatment cotton fabric CMYK profile
Dot represents LTP pretreatment cotton fabric CMYK profile

Figure 3 Color gamut of cotton fabric CMYK profile (a) Vertical view; (b)side view



Note: green region represent unpretreatment cotton fabric CMYK profile
red represents LTP pretreatment cotton fabric CMYK profile

Figure4 color gamut plan of cotton fabric CMYK profile

References

[1] Yuen, C W M; Kan, C W.. Coloration Technology, 123, 96, (2007).

[2] Hees, Ulrike; Freche, Mike; Kluge, Michae,eta. International Textile Bulletin, 49, 64, (2003).

[3] May-Plumlee, Traci; JiHyun Bae. Journal of Textile & Apparel Technology & Management: JTATM, l4, 1(2005).

[4] El-Hamaky, Y. M.; Nassar, S. H.; Osman, H. A.,eta. Journal of the Textile Association, 65, 171, (2004).

[5] Sen'i Gakkaishi. Journal of the Society of Fiber Science & Technology, Japan, 60, 40, (2004).

[6] LaPorte, Gerald M.; Wilson, Jeffrey D. etal. Mancke, S. Amando; The Forensic Analysis of Thermal Transfer Printing. Journal of Forensic Sciences, 48, 163, (2003).

[7] .Poletti,F.Orsini,A.Raffaele-Addamo,C.Riccardi,E.Selli. Applied Surface Science, 12, 311,(2003).

[8] Xiaoguang Ma, Xiaolin Zhang, Zhenya Gu. Journal of Donghua University, 1, 1, (2006).
[9] Qufu Wei, Ya Liu, Dayin Hou, Fenglin Huang. Journal of Materials Processing Technology, 3, 89, (2007).
[10] Alenka Vesel, Miran Mozetic, Anton Zalar. Vacuum, 9, 248, (2007).
[11] D. Sun, G.K. Stylios, Journal of Materials Processing Technology, 8,172, (2006).
[12] Saurabh Garg, Chris Hurren, Akif Kaynak..Synthetic Metals,13, 41, (2007).
[13] J.Rahel, M.Cernak, I.Hudec, etal. Plasmasand Polymers, 5, 119,(2000).
[14] M.Stefecka, J.Rahel, I.hudec, etal. Journal of Materials Science Letters, 3, 1869. (2000).
[15] Kuanjun Fang *, Shaohua Wang, Chaoxia Wang, Anli Tian. Journal of Applied Polymer Science, 107, 2949, (2008).
[16] Shaohua Wang, Kuanjun Fang, Anli Tian, eta. Textile Dyeing and Finishing Journal, 1, 24, (2009).
[17] Tian, Anli; Fang, Kuanjun; Zhang, Xia,eta.,NIP 23, 536, (2007).

Author Biography

Ms. Tian received her BS in chemical from Qingdao University (2001) and now a Ph.D. candidate in Jiangnane University. Now is a lecturer in textile chemistry, her research interest focus on image processing and color science.