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Learning Materials for Enhancing Sustainable Colour Fading Process of Fashion Products

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Abstract**—**This study examines the results of colour fading of cotton fabric by plasma-induced ozone treatment, with an aim to provide learning materials for fashion designers when designing colour fading effects in fashion products. Cotton knitted fabrics were dyed with red reactive dye with a colour depth of 1.5% and were subjected to ozone generated by a commercially available plasma machine for colour fading. The plasma-induced ozone treatment was conducted with different parameters: (i) air concentration = 10%, 30%, 50% and 70%; (ii) water content in fabric = 35% and 45%, and (iii) treatment time = 10 minutes, 20 minutes and 30 minutes. Finally, the colour properties of the plasma–induced ozone treated fabric were measured by spectrophotometer under illuminant D_{65} to obtain the CIE L*, CIE a* and CIE b* values.

Keywords**—**Learning materials, colour fading, colour properties, fashion products.

I. INTRODUCTION

TEXTILE and apparel industries are developing colour fading fashion products which are very popular among young consumers [1]. The colour fading process is an essential and important finishing method which provides aesthetic appearances such as the worn and vintage look [2]. As a result, textile manufacturers are currently trying to develop various technologies to improve the visual aspect of fabrics, especially the faded and vintage looks [3]-[5]. However, conventional colour fading technologies involve the use of large quantities of water with chemicals, resulting in environmental problems. Likewise, the colour properties are difficult to control. Since the global community has become increasingly concerned with protection of the environment, textile and apparel industries need to address issues related to different health and environmental problems, as well as other related issues. Plasma treatment with ozone generation, being a dry method, has been proven to be an environment-friendly technology for modifying the surface of textile materials as well as fashion products [6]-[8]. In this study, the effect of plasma-induced ozone treatment on colour levelness of 100% reactive dyed cotton knit fabrics are investigated using instrumental analysis of CIE L*, CIE a* and CIE b* values after treatment. Based on the experimental works, the results can be used for developing learning materials for enhancing the sustainable colour fading process of fashion products which could be used by fashion product designers as reference materials.

II. EXPERIMENTAL

A. Fabric Used

The study used 100% cotton weft knitted fabric. The fabric was single pique structure with weight of 220 g/m^2.

B. Fabric Dyeing

The fabric was dyed with a reactive dye (Levafix Red CA) with a depth of 1.5% (on weight of fabric) and the dyeing was carried out with a liquor-to-goods ratio of 10:1. In the dyeing, salt and soda ash were used, their amounts were shown in Table I. The dye exhausts onto the fabric can be promoted by additional salt and the exhausted dyes fixed on the fabric can be promoted by adding soda ash.

TABLE I
RECIPE OF DYEING PROCESS

Chemical used	Amount
Salt (NaCl)	42.5 g/L
Soda ash (Na_2CO_3)	11.5 g/L

The dyeing profile is shown in Fig. 1. The required amount of salt and fabric were put into the dyebath according to the provided method at a temperature between 25ºC to 30ºC. The salt and fabric were treated in the dyebath for 10 minutes. The reactive dye was added into the dyebath at 20 minutes. The fabric, salt and dye were treated in the dyebath for 10 minutes. The soda ash was added into the dyebath between 15 and 30 minutes. All materials were treated in the dyebath for 10 minutes. The temperature of dyebath was then raised to 60˚C in 30 minutes. The materials were remained in the dyebath for 45 minutes for dye fixation. After dye fixation, the dyeing process completed and the fabric was removed from the dyebath and rinsed with cold water. The dyed fabric was soaped with a weak alkaline detergent solution in a water bath at 90º for 10 minutes to remove any unfixed reactive dye. Finally, the dyed fabric was rinsed with cold water and centrifuged. The dyed fabric was then dried in an oven at 60ºC until completely dried. After drying, the dyed fabric was conditioned at 65±2% relative humidity and 20±2ºC for at least 24 hours prior to use.

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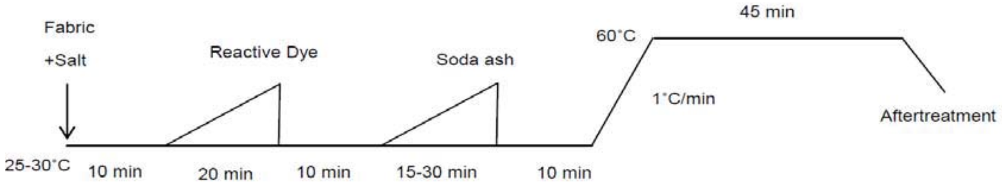

Fig. 1 Dyeing profile

C. Colour Fading Process

In the colour fading process, the reactive dyed fabric was placed in a plasma machine, G2 (Fig. 2) [9], which can generate ozone. The plasma-induced colour fading process was carried out with parameters as summarised in Table II.

Fig. 2 G2 [9]

TABLE II
PROCESS PARAMETERS

Parameter	Variables
Air Concentration (%)	10, 30, 50, 70
Water Content (%)	35, 45
Treatment Time (minutes)	10, 20, 30

D. Colour Properties

Colour properties of the fabric samples were measured by using a spectrophotometer (GretagMacbeth Color-Eye7000A). The measurement was conducted under illuminants of D_{65} daylight with a 10° standard observer. The CIE L* value (refers to lightness in the range of 0-100, where 0 = yields black and 100 = indicates white), CIE a* value (refers to redness to greenness, when (+) a* = red and (-) a* = green) and CIE b* value (refers to yellowness to blueness, when (+)b* = yellow and (-)b* = blue). Based on the CIE L*, a* and b* values, the values of ΔL* (lightness difference), Δa* (red/green difference) and Δb* (yellow/blue difference) can be calculated according to (1), (2) and (3), respectively. With the use of the ΔL* (lightness difference), Δa* (red/green difference) and Δb* (yellow/blue difference) values, the colour difference between the untreated sample (original) and the plasma-induced ozone treated samples (sample) can be calculated by (4).

$$\text{CIE } \Delta L^* = \text{CIE } L^*_{\text{sample}} - \text{CIE } L^*_{\text{original}} \quad (1)$$

$$\text{CIE } \Delta a^* = \text{CIE } a^*_{\text{sample}} - \text{CIE } a^*_{\text{original}} \quad (2)$$

$$\text{CIE } \Delta b^* = \text{CIE } b^*_{\text{sample}} - \text{CIE } b^*_{\text{original}} \quad (3)$$

$$\Delta E^* = [(\text{CIE } \Delta L^*)^2 + (\text{CIE } \Delta a^*)^2 + (\text{CIE } \Delta b^*)^2]^{\frac{1}{2}} \quad (4)$$

III. RESULTS AND DISCUSSION

A. CIE L* Value

Table III shows the CIE L* values of the sample before and after the plasma-induced ozone colour fading treatment under different combinations of process parameters. It is found that the original sample has the smallest CIE L* value among all CIE L* results of colour faded samples, which indicates that the untreated sample has the lightest colour shade. A longer treatment time causes a generally increasing trend in the difference between colour lightness of the treated and untreated samples. The CIE L* values increase more as air the concentration increases from 10% to 30%, and then 50%, while there is only a slight increase after the air concentration is increased further to 70%. This proves that lightness is more pronounced until the air concentration reaches 50%. However, lightness is only slightly affected when the air concentration is further increased to 70%. When water content is increased from 35% to 45%, the CIE L* values increase, which means the fabrics treated with a water content of 45% are lighter than when the water content is 35% [2], [7], [8].

TABLE III
CIE L*, A* AND B* VALUES OF DIFFERENT SAMPLES

Water Content (%)	Air Concentration (%)	Treatment Time (minutes)	CIE L*	CIE a*	CIE b*
35	Original		51.9	59.3	3.6
	10	10	52.8	58.2	3.9
		20	53.7	56.2	4.2
		30	54.8	54.4	4.6
	30	10	52.6	58.2	4.2
		20	53.0	56.7	4.6
		30	54.2	54.8	4.9
	50	10	54.2	55.3	4.5
		20	56.6	51.0	5.7
		30	58.8	47.4	6.9
	70	10	53.5	55.9	4.9
		20	55.5	51.7	5.8
		30	57.8	47.5	7.0
45	10	10	54.5	53.9	4.8
		20	57.9	47.7	7.3
		30	60.7	44.0	8.2
	30	10	54.1	54.5	4.8
		20	56.6	49.8	6.4
		30	58.8	45.5	8.2
	50	10	54.5	55.1	4.4
		20	58.6	47.8	6.7
		30	60.6	45.0	8.4
	70	10	54.7	53.2	5.5
		20	58.7	45.6	7.3
		30	62.3	39.1	9.3

B. CIE a Value*

According to Table III, it is found that the original sample has the highest CIE a* value which means the untreated samples are the reddest in colour. Prolongation of treatment time causes considerable decrease in the redness or increase of greenness. The CIE a* values decrease more as air concentration increases from 10% to 30% and then to 50%, while a slight decrease is observed after air concentration is increased to 70%. It shows red/green colour change is more pronounced until air concentration reaches 50%, and after that, the red/green colour change is only slightly affected when the air concentration is increased further to 70%. A comparison of the effect of water content of 35% and 45% shows that the CIE a* values decline when the water content is increased from 35% to 45%. This means fabrics treated at a water content of 45% are relatively greener than when water content is 35% [2], [7], [8].

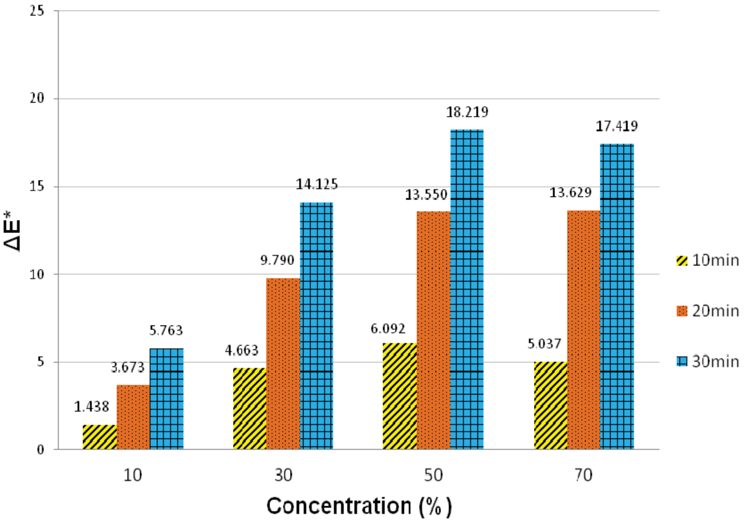

Fig. 3 ΔE* values of samples treated with water content of 35%

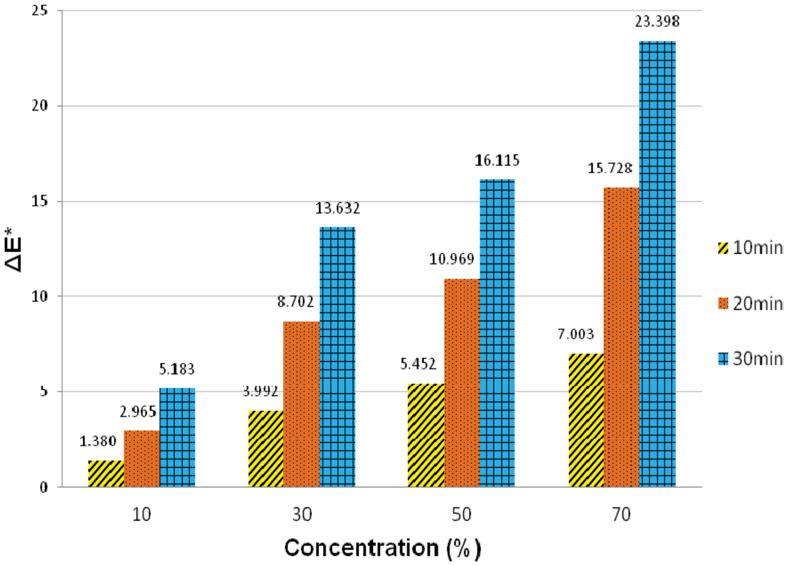

Fig. 4 ΔE* values of samples treated with water content of 45%

C. CIE b Value*

In the case of CIE b* values, as shown in Table III, the original sample has the smallest CIE b* value, which means the original has the bluest color shade. Prolongation of treatment time causes a considerable increase of yellowness or decrease of blueness. The CIE b* values increase as air concentration is increased from 10% to 30% and then to 50%, while only a slight increase occurs after air concentration is further increased to 70%. This proves that yellow/blue colour change is more affected by a decrease of air concentration before 50%, while slightly influenced after air concentration of 70%. Also, CIE b* values increase when water content is increased from 35% to 45%, indicating that fabrics treated with water content of 45% are yellower than when water content is 35% [2], [7], [8].

D. ΔE Value

ΔE* takes into account the difference between CIE L*, CIE a* and CIE b* values of untreated and plasma-induced ozone treated samples, according to the equation: $\Delta E^*= [(\text{CIE }\Delta L^*)^2+(\text{CIE }\Delta a^*)^2+(\text{CIE }\Delta b^*)^2]^{½}$. Figs. 3 and 4 reveal that a longer treatment time causes considerable increase in the color difference (ΔE*). This indicates that the colour difference between treated and untreated samples increases as the treatment time is increased. According to Figs. 3 and 4, the difference between the ΔE* values increases as air concentration is increased from 10% to 30% and then to 50%, but the change is less after air concentration is increased to 70% [10]-[14].

IV. CONCLUSION

Experimental results revealed that plasma-induced ozone treatment is good for the colour fading of reactive dyed cotton knitted fabrics. Generally speaking, the results show that the change increases when the treatment time is increased. A common result among the different process parameters tested is that the treatment effect increases until the air concentration is increased to 50%, and that increasing the air concentration beyond 50% has only a slight effect on the colour values. These experimental results can be used as learning materials for enhancing the environmental sustainability of the colour fading process in the manufacture of fashion products. These results can be used by fashion product designers as referencing materials and can be further developed.

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