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Effect of Nitrogen Gaseous Plasma on Cotton Fabric Dyed with Reactive Yellow105

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***Abstract*—**In this work, a bleached well cotton sample was dyed with reactive yellow105 dye and subsequently, the dyed sample was exposed to the plasma condition containing Nitrogen gas at 1 and 5 minutes of plasma exposure time, respectively. The effect of plasma on surface morphology fabric was studied by Scanning Electronic Microscope (SEM). CIELab, K/S, and %R of samples (treated and untreated samples) were measured by a reflective spectrophotometer, and consequently, the experiments show that the sample dyed with Reactive yellow 105 after being washed, with the increase in the operation time of plasma, its dye fastness decreases. In addition, the increase in plasma operation time at constant pressure would increase the destructing effect on the surface morphology of samples dyed with reactive yellow105.

***Keywords*—**Cotton fabric, cold nitrogen plasma, reflective spectrophotometer, electronic scanning microscope (SEM), reactive yellow105 dye.

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I. Introduction

COLD gaseous plasma is often used for surface modification of polymers and recently also for modification of natural and synthetic-based textile fabric. Plasma modification is of great interest for application since polymers are generally characterized by a low surface energy and hence poor adhesive properties. Plasma treatment can effectively change the polymer surface characteristics, such as wettability, surface energy, and adhesive [1].

Recently, there has been a surge in interest in the development of plasma technologies to improve the properties of textile surfaces without changing the bulk textile properties. Plasma treatment has shown an enhancement of dyeing/printing [2], color fastness [3], coating adhesion [4], and wicking [5], and can offer considerable savings of water, energy and effluents discharge to the environment [6], [7].

Two major types of reactions possible with non-equilibrium the plasma are (1) surface modification of polymer and (2) polymerizations of the monomers in the plasmas. The basic difference between plasma and another form of ionizing radiations is that plasma radiation effects are limited to the fiber surface [8]. In general, the main advantages of plasma technology are the extremely short treatment time and the low application temperature, along with the fact that it is regarded as an environmentally friendly process since no chemicals are involved, water and solvents can be avoided, and no or fewer chemicals are required [9]. In this study, the effect of Nitrogen cold gaseous plasma on cotton fabric dyed with reactive yellow 105 (Reactive yellow HE-4G) was investigated.

II. Procedures

A. Materials

The cotton fabric used in this study was supplied from Babakan Textile Factory. The desired fabric has a 25-weft density, and a 35-warp density and a weight of 192 g/m^2. Reactive yellow105 (Reactive yellow HE-4G) was purchased from Dyestar Co (Fig. 1). Before the plasma treatment, the samples were washed and dried respectively. After washing and drying, the samples were dyed with reactive yellow 105 as shown in Fig. 2.

B. Low-Temperature Plasma Treatments

The first dying stage, as shown in Fig. 1, was performed with %1 of Reactive yellow 105 dyes, namely reactive yellow 105, with molecular structure in Fig. 2. For investigation of plasma on dyed fabrics, two dyed samples, each with 5 × 5 cm^2 dimension, were placed at vacuum condition for one hour; then the samples were exposed to the Nitrogen gas plasma condition, one of them for one minute and the other one for five. The schematic view of this system is shown in Fig. 3.

The K/S, Lab and %R rate of samples were measured by spectrophotometer ColorEye-7000A system with UV D65 standard light source, and then 1×1 cm^2 pieces were cut out of experimented samples and were put in Sputter Coater machine to coat samples with a layer of gold. Then the untreated dyed and plasma-treated samples were scanned for 1 and 5 minutes using electronic scanning microscope, model LEO440 made in England with x3000 magnification power, to determine the effect of plasma conditions on surface morphology of fabrics.

C. Washing Fastness of the Samples

In this experiment, samples weighing 5g, treated with plasma and dyed with reactive yellow105 at exposure time of 1 and 5 minutes, were washed 5 times for 30 minutes at 80°C heat in a soap bath and the K/S, Lab. %R rate of washed samples were measured using a reflective spectrophotometer machine to determine color fastness of fabrics.

III. Results and Discussion

Table I shows display of difference samples that to be shown in Figs. 4-7. As shown in Fig. 4, the peak increase in the curve of sample dyed with Reactive yellow 105, treated with plasma at plasma exposure time of 1 and 5 minutes, indicates that when the time of plasma operation increases, the peak of the curve increases, although the difference in this

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range is slight for K/S coefficient. Thus, the plasma used for Reactive yellow 105 does not have a significant effect on the results.

Reflective spectrum values of the experimented samples are graphically illustrated in Fig. 5. Comparison between ΔE and CIE of samples dyed with plasma treated Reactive yellow 105 shown in Table II. It shows that the reflective spectrum curves were coincident and plasmatic conditions do not have any effect on R% rate of samples dyed with untreated and plasma treated Reactive yellow 105. This confirms the results obtained from K/S curves.

TABLE I
DISPLAY OF DIFFERENCE SAMPLES

sample	Dyed with	Time of plasma exposure time before washing	Time of plasma exposure time after washing
a	Reactive yellow 105	untreated	-
b	Reactive yellow 105	1 min	-
c	Reactive yellow 105	5 min	-
g	Reactive yellow 105	-	1 min
h	Reactive yellow 105	-	5 min

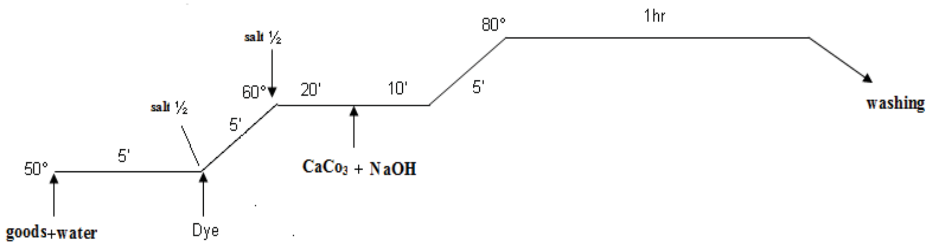


Fig. 1 The process of dying fabric with Reactive yellow 105

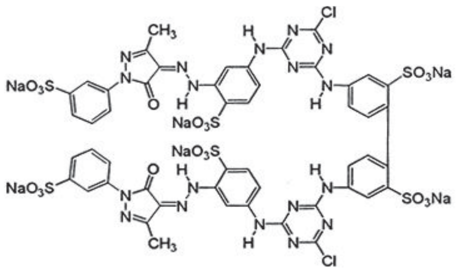


Fig. 2 Molecular structure of reactive dye named Reactive yellow 105($C_{50}H_{32}Cl_2N_{18}Na_6O_{20}S_6$)

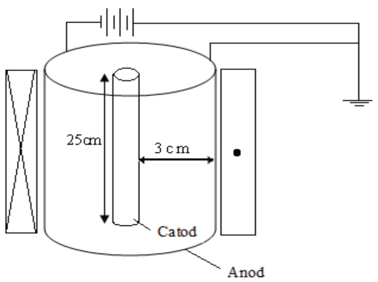


Fig. 3 Schematic view of the plasma system

TABLE II
CIELAB VALUE OF SAMPLES (TREATED & UNTREATED)

	Untreated	Treated (1 min)	Treated (5 min)
λmax(nm)	370	370	370
K/S	3.02	3.14	3.17
L*	88.24	88.27	88.09
a*	-2.79	-2.9	-2.46
b*	54.29	55.61	54.08
C*	54.36	55.68	54.13
h°	92.94	92.98	92.06
ΔE	-	0.42	0.32

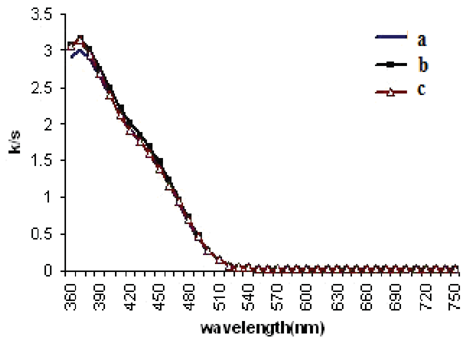


Fig. 4 The K/S graph of samples dyed with untreated and plasma treated Reactive yellow105 at 1 and 5 minutes of plasma exposure time

A. Scanning Electronic Microscope (SEM)

Table III shows the images taken from the surface of dyed samples— untreated and treated with plasma at 1 and 5 minutes of plasma exposure time—by electronic microscope, indicates the difference in surface morphology. Results obtained from these images show that the more the sample is exposed to plasmatic conditions of Nitrogen gas, the more will be the effect of destructive conditions on it.

Table III shows images taken from samples' surface morphology using SEM electronic microscope.

Fig. 6 shows the K/S rate of samples dyed with plasma treated Reactive yellow 105 at 1 and 5 minutes of plasma exposure time before and after washing. This figure also shows that a decrease in the K/S rate happens for curve 7, comparing to their before-washing condition, which is due to the washing effect. This decrease in K/S rate shows the decrease in color fastness. In Fig.7, it could be clearly seen that washing had an insignificant effect on R% rate such that the curves of samples, before and after washing, are rather coincident.

B. Washing Fastness

Table III, in comparison to Table II, shows that the K/S, C*, h° values have decreased after washing, while ΔE, a*, and b* have been significantly increased. This shows the effect of washing conditions after plasma exposure. In other words, the plasma operation causes a slight decrease in washing fastness can as seen in the Figs. 6 and 7.

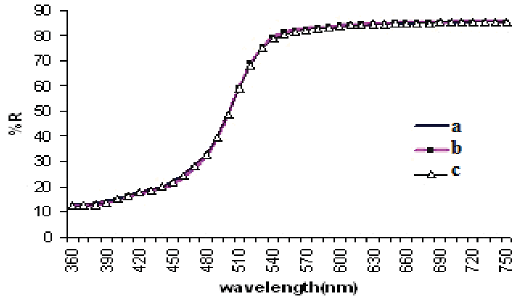
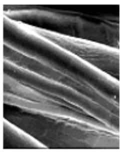
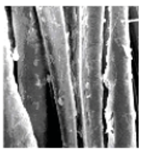


Fig. 5 The R% graph samples dyed with of untreated and plasma treated Reactive yellow 105 with plasma at 1 and 5 minutes of plasma exposure time

Sample	Time (Plasma)		
	Untreated	Treated with plasma at 1 min of exposure time	Treated with plasma at 5 min of exposure time
Dyed with 1 % of reactive yellow 105			

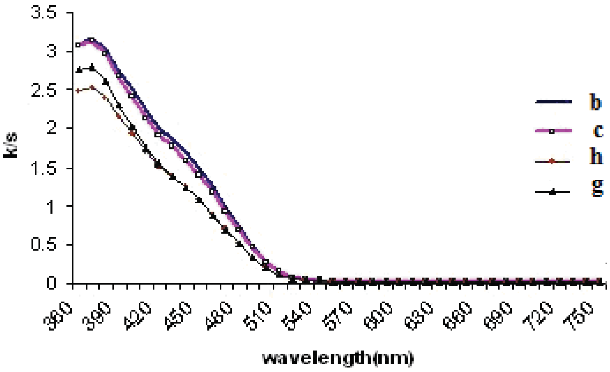


Fig. 6 The K/S rate of samples dyed with plasma treated Reactive yellow 105 at one and 5 minutes of plasma exposure time before and after washing

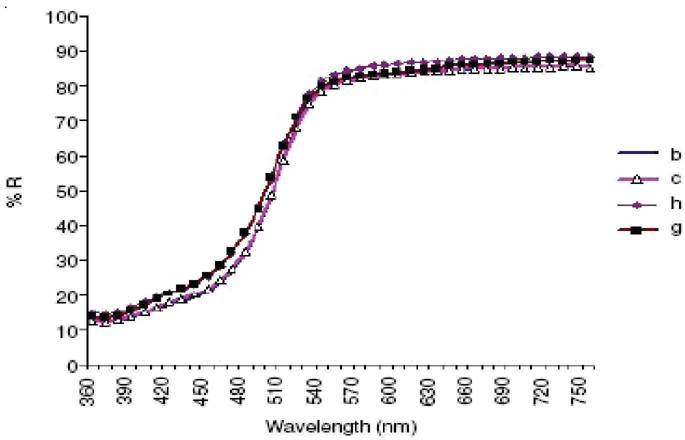


Fig. 7 The R% rates of samples dyed with plasma treated Reactive yellow 105 at 1 minute or 5 minutes of plasma exposure time before and after washing

TABLE III
CIELAB VALUE OF SAMPLES (TREATED & UNTREATED) AFTER WASHING

	Untreated	Treated (1 min)	Treated (5 min)
λmax(nm)	370	370	370
K/S	3.02	2.8	2.53
L*	88.24	89.61	88.89
a*	-2.79	50.43	49.24
b*	54.29	93.36	93.89
C*	54.36	-2.95	-3.32
h°	92.94	50.35	49.13
ΔE	-	66.04	65.38

IV. CONCLUSIONS

In this research, the bleached cotton fabric sample was dyed using reactive yellow 105 dye and then the dyed sample were exposed to plasma condition of Nitrogen gas at times of 1 and 5 minutes and in the next stages, the effect of plasma on destruction of surface morphology was investigated and evaluated using electronic scanning microscope with magnification power of 3000. The results obtained from plasmatic conditions in determining K/S, b*, a*, L* and R% rates, studied using Reflective Spectrophotometer Machine, show that samples dyed with reactive yellow105 dye enjoy dye fastness; however, the washing fastness has partially decreased after cold plasma operation which can be ignored. Also, the images were taken from plasma effect on surface morphology using SEM, shows that the increase in Nitrogen gas plasma operation time will result in an increase of destruction, and this is more visible in the sample treated with the Nitrogen gas plasma at 5 minutes.

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