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LOW-PRESSURE RF PLASMA AND CORONA DECOLOURISATION OF INDIGO DYED DENIM FABRICS

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Abstract. This study was aimed to investigate the influence of low-pressure RF plasma (gas, treatment time and power) and atmospheric pressure corona (number of passages and power) parameters on decolourisation of indigo dyed denim fabrics. CIEL*a*b* colourimetric system was used for determination of colour difference between untreated and differently plasma treated denim fabrics. The morphology of plasma treated fibres was assessed by SEM analysis. The results showed that decolourisation was highly affected by plasma parameters and desired "worn look" effects could be designed by adequate control of plasma processing.

1. INTRODUCTION

The popularity of the "worn look" of denim products lasts more than two decades. Originally, this effect was achieved by abrasive action of pumice stones on the garment surface. This process was replaced by more efficient enzymatic stonewashing i.e. biostoning . Recent reports indicated that "worn look" can be provided by DC plasma and corona treatments (see e.g. Ghoranneviss et al. 2006, Nourbakhsh Alizadeh et al. 2006). In this study the influence of RF low-pressure plasma (LPP) and corona (COR) parameters on the decolourisation of indigo dyed denim fabrics was considered.

2. EXPERIMENTAL

The experiments were performed on indigo dyed 100% cotton denim fabric (twill, 377 g m^{-2}).

Glow-discharge treatment of denim fabric was carried out in a low-pressure capacitively-coupled RF-induced (13.56 MHz) argon and air plasmas. The power applied to the CCP reactor was 100, 200 and 300 W, treatment times were 5, 10 and 15 min while the pressure was maintained at the constant level of 0.27 mbar. Corona treatment of denim fabric was carried out at atmospheric pressure by using a commercial device Vetaphone CP-Lab MK II. Samples were placed on the electrode roll covered with silicon coating, rotating at the minimum speed set to 4 m/min. The distance between

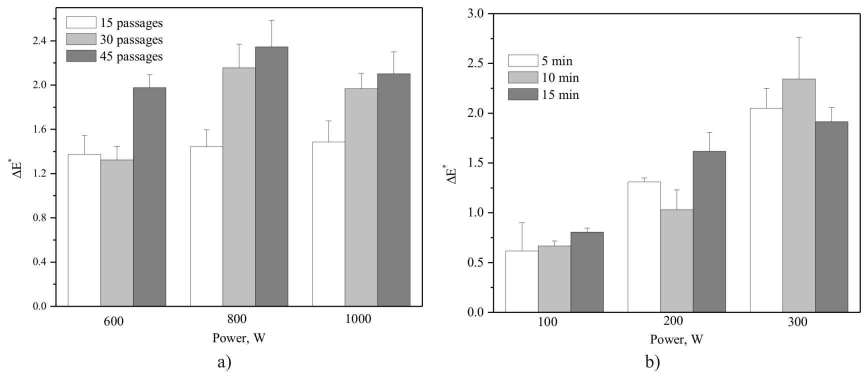

Figure 1: Colour difference (ΔE^*) after a) COR treatment and b) LPP treatment of denim.

electrodes was 2 mm. The effect of power (600, 800 and 1000 W) and the number of passages (15, 30 and 45) on the fabric properties were assessed.

CIEL*a*b* colourimetric system was used for determination of colour difference between LPP/COR treated and untreated samples. L*, a* and b* colour coordinates (D65/10°) of samples were determined by using a Datacolor SF300. Colour difference (ΔE^*) is expressed as:

$$\Delta E^* = \sqrt{(\Delta a^*)^2 + (\Delta b^*)^2 + (\Delta L^*)^2} \tag{1}$$

where:

ΔL^*- the colour lightness difference between treated and untreated samples; Δa^* - red/green difference between treated and untreated samples; Δb^* - yellow/blue difference between treated and untreated samples.

Fibre topography was assessed by scanning electron microscope JEOL JSM 6460 LV. Prior to the analysis, the samples were coated with a thin layer of gold

3. RESULTS AND DISCUSSION

Colour change of denim fabrics after COR and LPP treatments was expressed via colour (Fig. 1), lightness, red/green and yellow/blue (Table 1) differences. Fig. 1a revealed that prolongation of the treatment time (i.e. increase in the number of passages) caused considerable increase in ΔE^* between COR treated and untreated samples independently of the applied power. ΔE^* was only slightly affected by the increase of power during shorter treatments (15 passages). However, the influence of power was more pronounced in the case of 30 and 45 passages. COR treatment increased the lightness of fabric regardless of power and number of passages, indirectly indicating the removal of indigo dye from the surface of the denim fabric. The results on Δa^* showed that all COR treated samples were greener in comparison with untreated samples. The higher the power, the greener the fabrics. COR treatment induced an increase in fabric yellowness, which was more pronounced at more severe treatment conditions.

Table 1: ΔL^*, Δa^* and Δb^* of COR and argon LPP treated denim. P-power, N-Number of passages, t-time in minutes.

Corona treated denim					LPP treated denim				
P (W)	N	ΔL^*	Δa^*	Δb^*	P (W)	t	ΔL^*	Δa^*	Δb^*
600	15	1.19	-0.17	0.69	100	5	0.68	-0.07	-0.14
	30	1.02	0.07	0.83		10	1.47	-0.17	-0.26
	45	1.62	-0.14	1.12		15	0.71	-0.19	-0.02
800	15	1.15	-0.17	0.84	200	5	1.18	-0.38	-0.42
	30	1.83	0.03	1.13		10	1.01	-0.15	0.14
	45	1.99	-0.18	1.23		15	1.39	-0.53	0.53
1000	15	1.19	-0.18	0.86	300	5	1.47	-0.55	1.59
	30	1.67	0.04	1.02		10	1.83	-0.55	1.30
	45	1.73	-0.15	1.18		15	1.67	-0.43	0.72

Argon LPP treatment induced ΔE^*, which is highly affected by power (Fig. 1). On the contrary, the influence of prolongation of the treatment time was less prominent. Similar trend can be noticed for the lightness difference (Table 1). Argon LPP treatments brought about remarkable decrease in Δa^*, showing that denim became greener particularly after the treatments at higher powers. Similarly, the higher the power, the higher the yellowness .

Air LPP treatment of denim was studied only for the most severe treatment conditions (15 min, 300 W). ΔE^* between air LPP treated and untreated denim was 2.02, ΔL^* 1.37, Δa^* 0.59 and Δb^* 1.31. The comparison of these results with the results obtained with argon LPP under the same treatment conditions indicates that the ΔE^* was almost the same. However, argon LPP treated denim demonstrated higher lightness by about 20%. Yellowness of air LPP treated denim was almost doubled.

The results pointed out that both LPP and corona treatments caused the increase in yellowness. Ghoranneviss et al. reported that no yellowness occurred after treatment of denim in argon low-current d.c. glow-discharge (see e.g. Ghoranneviss et al. 2006), whereas corona treatment induced the appearance of yellowness (see e.g. Nourbakhsh Alizadeh et al. 2006). The results presented in Table 1 revealed that increase in yellowness was considerably more dominant after corona treatments independently on treatment conditions. Additionally, air LPP treatment led to the highest increase in yellowness. Increased yellowness is suggested to be due to possible oxidation of indigo dyes on the denim fabric surface.

SEM images of untreated, COR treated, argon and air LPP treated fibres are shown in Fig. 2a, 2b, 2c and 2d, respectively. Obviously, COR treatment induced the formation of fine striations that are running parallel to the fibre axis. Fig. 2c revealed significant changes in topography of argon LPP treated fibres. The fibre surface became rougher due to existence of numerous pits. Additionally, parts of the fibres are lifting apart from the fibres. Morphological changes were the most prominent in the case of air LPP treated fibres. The formation of numerous widened pits, holes and striations unhomogeniously scattered over the fibre surface is noticeable. Such topography induced by plasma can be attributed to fibre ablation, which occurred as

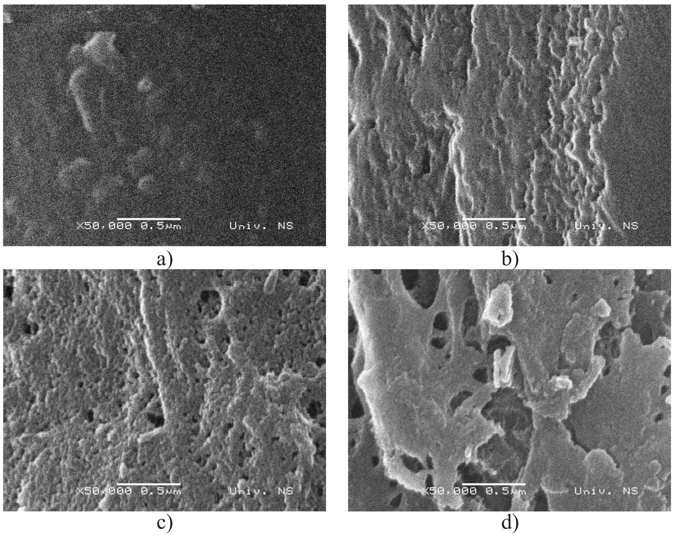

Figure 2: SEM images of a) untreated; b) corona treated (1000 W, 45 passages); c) argon LPP treated (300 W, 15 min) and air LPP treated (300 W, 15 min) fibres.

a consequence of a severe bombardment of fibre surface by energetic particles and by reactive particles generated by the plasma and its sheath. SEM images are in good correlation with the results related to breaking strength of fabrics.

4. CONCLUSIONS

Low-pressure plasma and corona treatments can be a viable alternative to conventional biostoning for obtaining "worn out" look of indigo dyed denim fabric. In addition to satisfactory colour change effects, the main advantages of these treatments are the lack of water consumption and a shorter duration. However, avoiding an increase in yellowness requires a further research.

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