CO_2 LASER MODIFICATION OF SYNTHETIC FIBRES: EFFECT ON DEYING PROPERTIES

F. Esteves, H. Alonso

ABSTRACT

Infrared lasers, like CO_2, appear to be advantageous due to their large beam size, high efficiency, easy operation, use of non-toxic gases and low cost. However, they have been less used than others for the surface treatment of polymers, likely due to the thermal damage effects caused by infrared radiation. This shortcoming can be overcome by use of pulsed lasers. CO_2 pulsed laser can be considered as a non-contact and environmentally friendly treatment technique for modification of surface of polymers. Morphological modifications can result in changes on physical and chemical properties of the materials, such as water absorption and dyeing. In this work, polyester (PES) and polyamide (PA 6.6) fabrics were treated with a CO_2 pulsed laser and then dyed with different commercially available dyes. Dyeing properties were investigated, as changes in the dye ability of laser treated fibres are expected, namely an improvement in those properties. In fact, laser treatment creates a certain roughness on the fibre surface, resulting in an increase of the overall surface area and a subsequent enhance of dye adsorption.

1. INTRODUCTION

Laser technologies can create morphological changes on polymers surface, such as synthetic textile fibres (polyamide or polyester), resulting in changes in its physical and chemical properties. Modifications induced on polymers by laser radiation is now a significantly well known subject, as the treatment of polyamide fibres with pulsed UV-laser refered in Yip et. al (2003) and Yip et. al (2004). Since late 90's different types of commercial lasers are available for surface modification of materials, as presented in Ozdemir et. al (1998).

UV laser treatment applied to synthetic fibres like polyamide and polyester is extensively reported but less information is available concerning CO_2 laser treatment of the same kind of polymers. In Dadsetan et. al (1999), Dadbin (2002) and Bormashenko (2000) we can find this technology used in polymer films treatment, where surface modifications in polyethylene terephthalate, polyethylene and epoxy resin are investigated.

After UV laser irradiation polyamide fibres present ripple-like structures on the surface, as indicated in Yip (2002), as well a remarkably change in dyeing properties, this fact being closely related with the appearance of these structures. In the case of CO_2 laser treatment a similar surface modification can also be identified by SEM analysis, meaning a possible improvement in dyeing properties.

In this work, after CO_2 laser treatment in different experimental conditions, polyester and polyamide irradiated fibres were dyed with disperse and acid dyes, in order to compare dye adsorption and dyeing results in untreated and treated polyamide and polyester fabrics.

2. EXPERIMENTAL PROCEDURES

2.1 Test Materials

In this study, 100% polyamide (PA 6.6) and 100% polyester (PES) fabrics were used in all experiments.

2.2 Laser irradiation

Irradiation was carried out using a commercial pulsed CO_2 laser (MARCATEX 150/250 FLEXI, EasyLaser), used for cutting and marking textiles, providing a laser beam of wavelength 10.6 µm. Different experimental conditions concerning laser radiation were tested, in order to select the most adequate situation or situations to surface modification of polyamide and polyester, with pulsed CO_2 laser, without visible thermal damage of the fibre surface. In all situations, irradiation was performed only in one side of the fabric and within a specific marked area.

2.3 Scanning electron microscopy

Surface morphology of untreated and treated polyamide and polyester fibres were analysed with a Scanning Electron Microscope, SEM, (JEOL JSM 35C), operating typically at 15 KV, WD 15 mm.

2.4 Dyeing experimental conditions

Polyamide and polyester fabrics were dyed with commercially available reactive, acid and disperse dyes, according each specific dyebath composition and in experimental conditions presented in Table I.

Table I. Experimental conditions for fibre dyeing

Fibre	Reactive dye		Acid dye		Disperse dye	
	Conc. (% owf)	T (ºC)	Conc. (% owf)	T (ºC)	Conc. (% owf)	T (ºC)
Polyamide	2	60	2	90	2	130
Polyester	2	60	2	90	2	130

3. RESULTS AND DISCUSSION

3.1 Laser irradiation

Data summarizing the experimental conditions considered in CO_2 laser irradiation and observed results are given in Table II. The indicated parameters are directly related to commercial equipment and modification of those factors caused significant changes on experimental conditions and final results.

D is a parameter related with applied power and represents the ratio between laser activation and inactivation time; the highest value of this parameter, 50%, corresponds to a maximum power. As frequency F increases, power radiation decreases. Therefore, controlling D and F values it was possible to establish the best experimental conditions, with this specific equipment, without significant thermal damage of the surface of both fibres.

After irradiation under these selected experimental conditions, the fibres were dyed with reactive, acid and disperse dyes.

Table II. Selected experimental conditions used in CO_2 laser irradiation on polyamide and polyester fabrics

Test #	D (duty cycle, %)	F (frequency, Hz)	MS (mark speed, bits/ms)	Obs.
3	10	30	50	✔
4	10	25	50	✔
5	10	24	50	✔
6	10	23	50	✔
7	10	21	50	✔
12	50	110	100	✔
13	50	105	100	✔
15	50	101	100	✔
16	50	102	100	✔
17	50	103	100	✔
18	50	104	100	✔
22	10	5	100	✔
23	8	5	100	✔
24	7	5	100	✔
25	6	5	100	✔
26	5	5	100	✔
27	4	5	100	✔
28	3	5	100	✔
29	2	5	100	✔
30	1	5	100	✔

Note: ✔ - No visible thermal damage on the fibre

3.2 Scanning electron microscopy

In scanning electron microscopy analysis of untreated and treated polyamide and polyester fibres it was observed a modification on fibre surface, corresponding to a certain roughness, caused by the thermal effect of IR radiation. As an example, in Figures 1 and 2 SEM images of untreated and treated polyamide, in that order, are presented. This change in the fibre surface morphology results, probably, in an increase of the overall surface area and a subsequent enhance of dye adsorption.

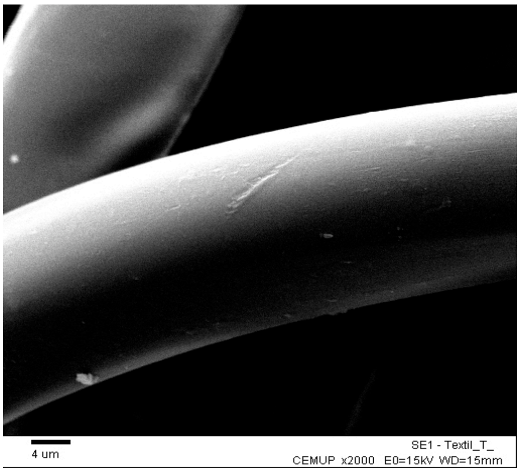


Figure 1 – SEM image of untreated polyamide

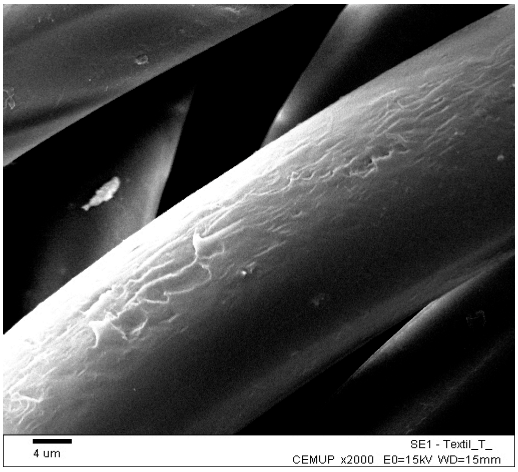


Figure 2 – SEM image of irradiated polyamide in test #3 experimental conditions

3.3 Dyeing results

Table III presents dyeing results considering different laser irradiation conditions for polyamide fibre; #3, the first irradiation conditions without damage and #22, the best dyeing results for polyamide fibre, with all dyes. Nevertheless, acid and disperse dyes are the more suitable dyes for polyamide, although a significant change is also visible with reactive dye, after irradiation.

Table III. Dyeing results of treated polyamide fibre in different experimental conditions of laser irradiation

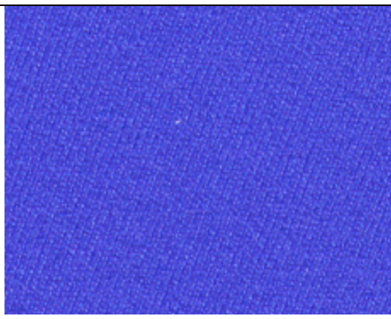
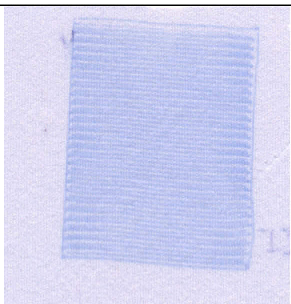
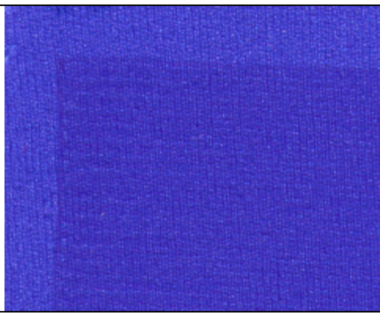
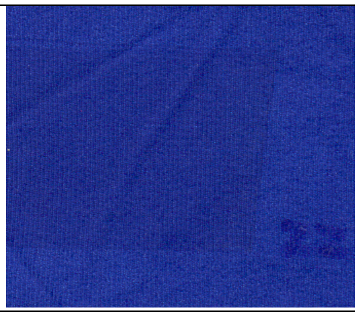
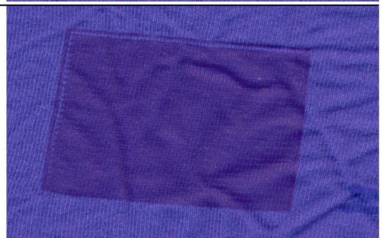
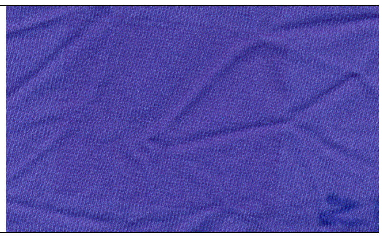
Test #	Reactive dye	Acid dye	Disperse dye
3			
22			

Table IV presents dyeing results considering different laser irradiation conditions for polyester fibre; #3, the first irradiation conditions without damage, #22, the best results for all dyes, #23 and 24 good results with acid and disperse dyes, and #25, also a very good dyeing result for disperse dye. Then again, reactive dye was not adequate for polyester; acid and disperse dyes gave the best results after dyeing specially disperse dye.

Table IV. Dyeing results of treated polyester fibre in different experimental conditions of laser irradiation

Test #	Reactive dye	Acid dye	Disperse dye
3			
22			
23	No detectable difference		
24	No detectable difference		
25	No detectable difference	No detectable difference	

In all situations, treated polyamide and polyester fabrics presented differences in dyeing results only in the irradiated side of the fabric. The reverse side presented a homogeneous aspect as irradiation with CO_2 laser in the selected conditions only had a superficial effect.

4. CONCLUSIONS

As observed in Figure 2, SEM image of irradiated polyamide, a modification of the filament surface is perceived predicting a more intense dye adsorption in the treated area. However, neither polyamide nor polyester presented such a dyeing result when irradiated in experimental conditions represented by test #3, as shown in Tables III and IV. A possible explanation is the fact that considered conditions for CO_2 laser radiation, being sufficient to cause a morphological modification of the polymer, were not enough for a perceptible improvement in dye adsorption.

A different situation can be observed in the conditions of test #22, for both fibres and all three dyes, where the best dyeing results were obtained. It is clear that CO_2 laser irradiation enhanced the capacity of dye adsorption of the dye, without visible thermal damage of the fibres.

In the case of polyester fibre, an improvement in dyeing properties with acid dye was also observed in other experimental conditions, corresponding to tests #23 and 24, as also with disperse dye, tests #23, 24 e 25. For polyamide fibre, acid and disperse dyes provided also the best results after dyeing procedure.

Considering all experimental results, it is possible to conclude that pulsed CO_2 laser can be a powerful tool in polyamide and polyester surface modification, in order to improve dye adsorption and final dyeing results, without severe damage of the material.

5. REFERENCES

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RESPONDENCE ADDRESS:

Department of Textile Engineering
School of Engineering,
University of Minho,
4800-058 Guimarães, Portugal