EFFECT OF CO_2 LASER RADIATION ON SURFACE PROPERTIES OF SYNTHETIC FIBRES

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ABSTRACT

Chemical treatment methods are most often used in the present for polymer surface modification; however, these methods are frequently "environmentally unfriendly". So, new technologies are now considered, especially in physical treatment methods. This is the case of laser technologies, like CO_2 laser radiation. Morphological modifications can be produced on the surface of polymers, resulting in changes in the physical and chemical properties of the materials. In this study, different experimental conditions were applied in CO_2 laser irradiation of polyamide (PA 6.6) fibres. Resulting morphological modification of surface and possible crystallinity variation were investigated. SEM (scanning electron microscopy) and DSC (differential scanning calorimetry) analysis were used.

1. INTRODUCTION

The nature of a polymer surface strongly influences its properties, such as water absorption, reflection of light or dyeing. Surface treatments for polymer modification can be classified as chemical and physical methods. Chemical treatments are frequently used but new technologies are now accessible, considered environmentally friendly processes.

Laser technologies can produce morphological modifications on the surface of polymers, resulting in changes in its physical and chemical properties. Induced modifications on polymer surface 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), and different commercial lasers are available for surface modification as presented in Ozdemir et. al (1998).

There is a large amount of literature on UV laser treatment applied to synthetic fibres like polyamide and polyester, but few concerning CO_2 laser treatment of the same kind of polymers. In Dadsetan et. al (1999) and Dadbin (2002) we can find this technology used in polymer films treatment.

Adequate power levels for a specific application are very important in surface modification processes because an excessive amount of energy can be supplied, with the consequent damage of the polymer. For instance, infrared lasers like CO_2 are the most powerful lasers and, with no suitable power level, severe thermal damage can result. However, this shortcoming can be overcome by the use of pulsed-mode CO_2 lasers, easier to control than lasers operating in continuous wave mode.

In this work, different experimental conditions were applied in CO_2 laser irradiation of polyamide fibres, with the main purpose of choose the most appropriate values of the considered parameters.

2. EXPERIMENTAL PROCEDURES

2.1 Test Materials

In this study, a 100% polyamide (PA 6.6) fabric was 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, with pulsed CO_2 laser, without visible thermal damage on the fabric. 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 fibre was analysed with a Scanning Electron Microscope, SEM, (JEOL JSM 35C), operating typically at 15 KV, WD 15 mm.

2.4 Differential scanning calorimetry

Changes in fiber crystallinity was determined by Differential Scanning Calorimetry, DSC, (DSC 822, Mettler Toledo) under thermally controlled conditions with a heating rate of 5ºC min^{-1} in a nitrogen atmosphere. The scanning range was from 220 to 280 ºC.

3. RESULTS AND DISCUSSION

3.1 Laser irradiation

Data summarizing all experimental conditions investigated in CO_2 laser irradiation and observed results are given in Table I. 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 search out for the best experimental conditions with this specific equipment, without significant thermal damage of the fibre surface.

Table I. Experimental conditions used in CO_2 laser irradiation on polyamide fabric

Test #	D (duty cycle, %)	F (frequency, Hz)	MS (mark speed, bits/ms)	Obs.
1	10	10	50	×
2	10	20	50	×
3	10	30	50	✔
4	10	25	50	✔
5	10	24	50	✔
6	10	23	50	✔
7	10	21	50	✔
8	50	50	100	×
9	50	60	100	×
10	50	70	100	×
11	50	100	100	×
12	50	110	100	✔
13	50	105	100	✔
15	50	101	100	✔
16	50	102	100	✔
17	50	103	100	✔
18	50	104	100	✔
19	40	5	100	×
20	30	5	100	×
21	20	5	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; ×- Visible thermal damage on the fibre

3.2 Scanning electron microscopy

Figures 1 to 3 show scanning electron micrographs of untreated polyamide. It can be observed a very smooth fibre surface. In Figures 4 to 7 it is possible to observe the result of CO_2 laser modification on polyamide fibre surface when experimental conditions of test #3 are used, first situation where no visible thermal damage on the fibre was detected.

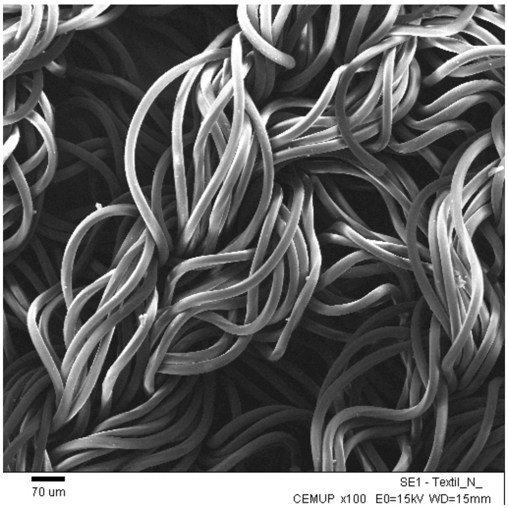

Figure 1 – SEM image of untreated polyamide

Figure 2 – SEM image of untreated polyamide

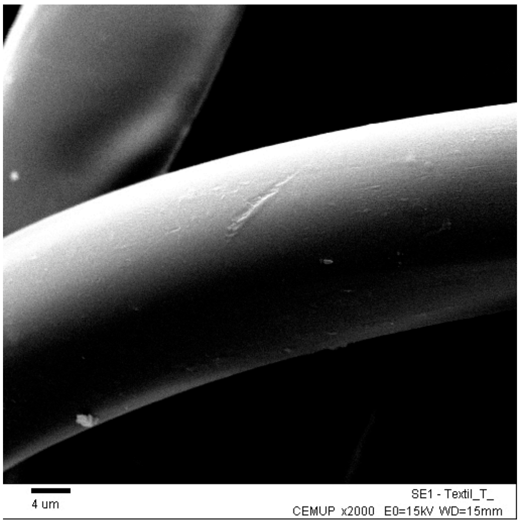

Figure 3 – SEM image of untreated polyamide

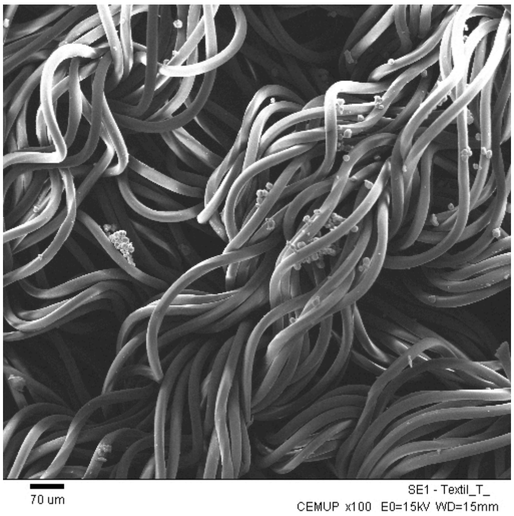

Figure 4 – SEM image of irradiated polyamide in test #3 experimental conditions

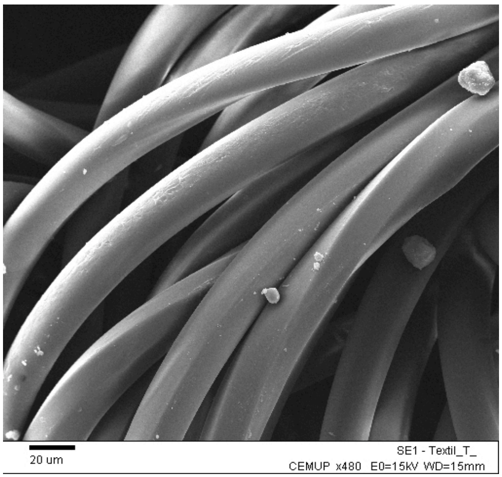

Figure 5 – SEM image of irradiated polyamide in test #3 experimental conditions

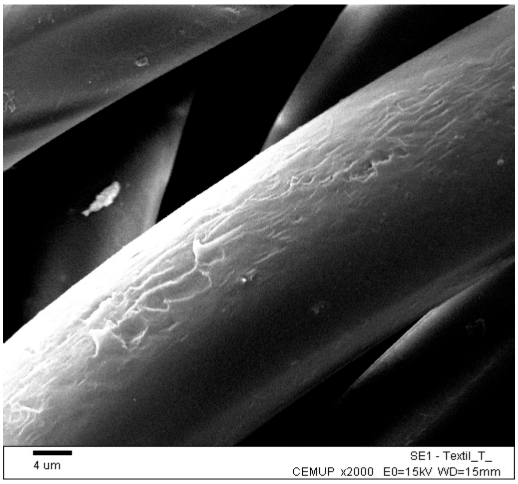

Figure 6 – SEM image of irradiated polyamide in test #3 experimental conditions

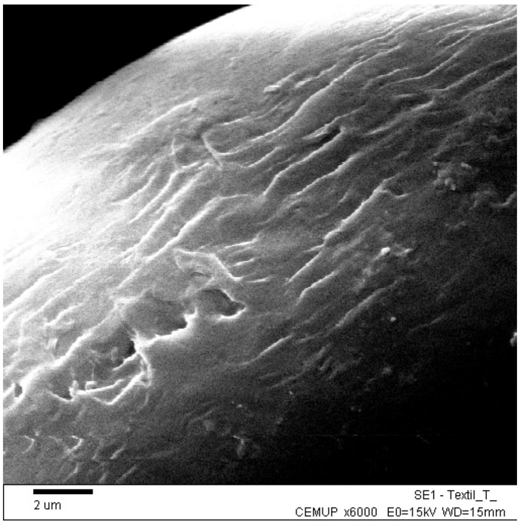

Figure 7 – SEM image of irradiated polyamide in test #3 experimental conditions

3.3 Differential scanning calorimetry

DSC analysis was not conclusive, because no significant modification in crystallinity of polyamide was detected, after CO_2 laser treatment. This fact is possibly a consequence of the selected experimental conditions for analysis after irradiation, test #3, less severe of all.

4. CONCLUSIONS

It was possible to obtain twenty tested experimental conditions concerning CO_2 laser irradiation where no visible thermal damage of polyamide surface was visible or detectable by handle. Among these, results corresponding to experimental conditions of test #3 (the first result with no visible damage) were analysed by scanning electron microscopy.

Comparing untreated and treated material SEM images, a surface morphology modification can be observed after CO_2 laser irradiation, corresponding to a "irregularity" of the surface, a certain roughness, caused by the thermal effect of IR radiation. In appearance, no alteration was detectable on the fabric.

In which concerns DSC analysis, the results were no conclusive in the test #3 experimental conditions for CO_2 laser irradiation.

Considering all experimental results, it is possible to conclude that pulsed CO_2 laser can be a powerful tool in polyamide surface modification, without severe damage of the material. This means that it is possible, with adequate experimental conditions, to have final results similar to those found with UV laser.

5. REFERENCES

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