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Surface Modification of Low Temperature Plasma Treated Polyester and Rayon Fabrics

KEYWORDS: Plasma, grafted, maleic acid, wettability

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ABSTRACT *In this study polyester and rayon fabrics were treated with plasma application. Polyester fabrics after initiated by plasma were grafted with maleic acid in order to enhance wettability. Structural and surface changes were analyzed using XRD, FTIR and SEM. Wettability and dye absorption were also investigated. The percentage of crystallinity was decreased on the surface of plasma treated polyester fabric. No significant change was observed in case of rayon fabrics. From FTIR studies, it was found that (-OH) group was induced in case of grafted polyester fabric. Deposition of a thick film on the surface of polyester fiber and hence a change in morphology of the fabric surface was confirmed by scanning electron microscope. The wetability of polyester and rayon fabrics was improved by plasma treatment.*

1. Introduction

Low-temperature plasma treatment has been shown to be a useful and suitable technique to modify a polymer surface, especially natural polymers like cellulose, in a dry and pollution-free system. Plasma is on the average an electrically neutral gas consisting of free particles, in which the potential energy of a typical particle due to its nearest neighbor is much smaller than its kinetic energy [1]. Plasma processing of materials is a quickly developing area of applied physics. In this field, low pressure plasma treatments have been proposed to modify many surface properties of polymers, such as adhesion, friction, penetrability, wettability, dyeability, or biocompatibility, in order to adapt them to specific applications [2]. An interesting aspect of plasma treatment is that the changes are confined to a depth of a few nanometers at the surface because of the low level of penetration. This opens up possibilities for producing a wide spectrum of surface chemistries with desired compositions. As the industry searches for safer, more environmental friendly methods to treat fibers, surface modification by plasma techniques for improving fiber- polymer adhesion is becoming more popular. When polymeric materials are exposed to plasma, radicals are created in the polymeric chains. These radicals can initiate reactions when they are in contact with monomers in a liquid or gaseous phase. Inelastic collisions of electrons in plasma with a polymer surface generate radicals at the surface of the polymer through excitation of the polymer molecules. As a result, a grafting polymer is formed on the surface of the polymeric material [3]. In this study, polyester and rayon fabrics were subjected to low temperature plasma treatment. Polyester fabrics after initiated by plasma were grafted with maleic acid in order to enhance wettability.

2. Materials and methods

2.1 Materials

Polyester and rayon fabrics of size 5 x 5 cm inserted into the plasma reactor and were subjected to air low temperature DC plasma treatment. Maleic acid (99 %) supplied by Ranbaxy Chemical company, New Delhi was used as a grafting medium. Dyeability of fabrics was carried out with dispersive dyes.

2.2 Plasma Treatment

Plasma treatments were carried out in a glass tube of 10 cm diameter and 30 cm long. The chamber consisted of two flanges and discs of diameter 15 cm and of thickness 0.4 cm. By means of rotary and diffusion pumps, the discharge chamber was evacuated down to 10^{-3} Pa. All investigations were carried out in dry air. Dry atmospheric air was let into the discharge tube through a needle valve. The discharge chamber was operated using 1000 V.

2.3 Grafting technique

After activation of polyester fabric by plasma treatment modification by grafting of maleic acid (Mac) was carried out. Grafting of maleic acid was realized by immersing the polyester fabrics into water solution containing Mac for 60 min and then dried for 30 min at a temperature of 70 °C.

2.4 XRD Analysis

Samples were analyzed by a Bruker AXS D_8 automated X-ray diffractometer, scanned at a rate of 0.3 sec with Cuk_α radiation and were analyzed in the 20°-30° (2α) scale angle range. The generated raw data files were then computer processed to smooth data points and to remove amorphous background scatter. Integrated intensities were calculated using a software package that performs mathematical modeling of the diffractogram pattern.

2.5 FTIR Analysis

A Fourier transform infrared spectrometer (FTIR-8400s SHIMADZU) and standard settings with a Germanium- coated KBR plate were used in this study to detect any changes in the chemical structure at the fabric surface on untreated and plasma treated polyester and rayon samples. Spectra were recorded from 400 to 4000 cm^{-1} with a 4 cm^{-1} resolution.

2.6 SEM Analysis

The morphology of modified polyester fiber was observed on (model JEOL JSM-T 330A) scanning electron microscope. The samples were mounted and gold sputtered by iron sputter JFC instrument to give the samples electronic conductivity under vacuum prior to observation.

2.7 Wettability

The wettability of the polyester layers and rayon fabrics was determined before and after the plasma treatment using the Capillary rise method. A simple wettability test can be performed on a fabric strip kept vertically with the lower end immersed in dye solution in a small beaker. A spontaneous wicking occurs due to capillary forces and the absorption height is noted down.

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Results and Discussion

XRD Analysis

X- ray diffraction patterns of polymers are used for estimating polymer crystallinity, crystalline size and orientation. In the present study, rectangular polyester and rayon fabrics of size 5 x 5 cm was inserted into the plasma reactor and were subjected to air plasma treatment for 5 minutes at a pressure of 0.08 mbar and at a applied potential of 350 V. Intensity of the diffracted untreated and treated polyester fabric is shown in fig.1 and fig 2. After plasma treatment polyester fabrics were grafted with maleic acid(Mac). Polyester fabrics were immersed into water solution containing Mac for 60 min and then dried for 30 min at the temperature of 70 °C.

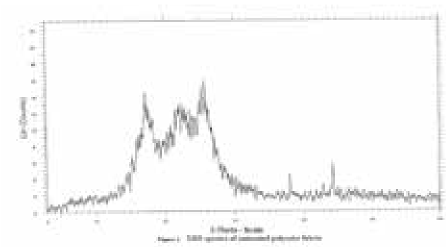


Fig. 1. XRD spectra of Untreated Polyester fabric

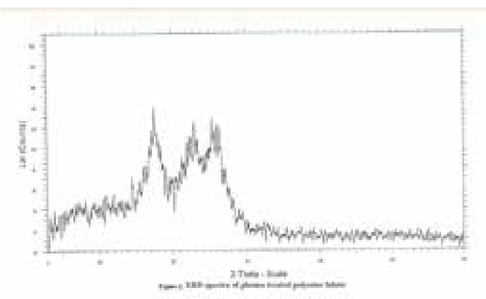


Fig. 2. XRD spectra of Treated Polyester fabric

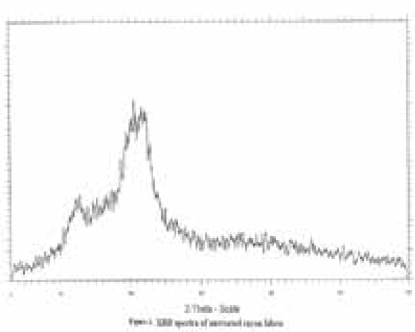


Fig. 3. XRD spectra of Untreated Rayon fabric

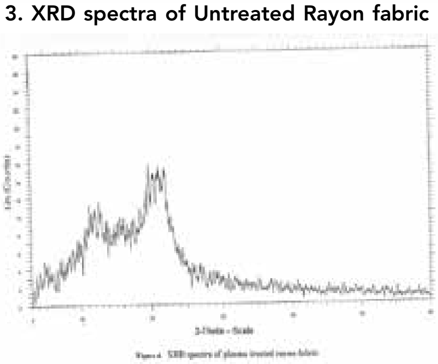


Fig. 4. XRD spectra of Treated Rayon fabric

XRD pattern of control and plasma treated polyester fabrics revealed that there is a slight decrease in the amount of intensity in the diffracted XRD of plasma treated polyester and rayon fabrics. This small reduction is due to decrease in the percentage of the crystallinity on the surface of plasma treated polyester fabric. Since the percentage of crystallinity was not decreased noticeably, so the strength of the treated was not reduced compared with untreated fabric.

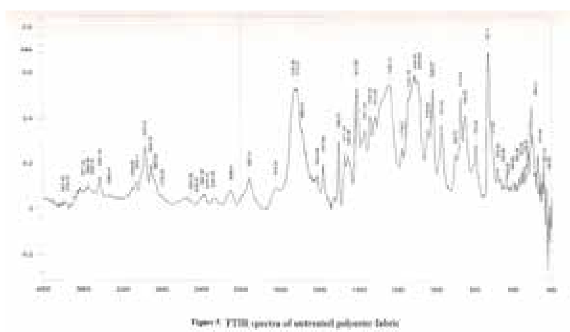
Table 1: Parameters of XRD for polyester samples

Sample	Untreated / Treated	2θ degrees	d(Å)	D(Å)	FWHM
Polyester	Untreated	44.215	2.0467	39.127	0.229
	Treated	14.45	6.1247	29.992	0.279

It is seen from the table that increase in the peaks FWHM magnitude shows that the size of crystals is reduced. The distance between lattices in the crystal after plasma treatment were increased compared with the untreated polyester fabric. No significant change was observed in rayon fabric indicating that the treatment does not give bulk effect.

FTIR Analysis

The infrared analysis carried out with the non-treated and treated polyester and rayon fabrics did not show any relevant difference that could be attributed to the formation of new functional chemical groups [4]. Figure 5 shows that grafted Maleic acid polyester fabrics, initiated by plasma treatment has substantial influence on the surface morphology of polyester fabrics.In grafted polyester fabric increase in peak attribute to asymmetric O-H bonding at 3000 cm^{-1}. Presence of polar groups such as (-OH) will enhance wettability.



Wettability

The wettability of the polyester layers and rayon fabrics was determined before and after the plasma treatment using the Capillary rise method. The wettability of polyester and rayon fabrics were increased by increasing the gas pressure. When the gas pressure was increased, the number of collisions between the charged particles and the neutral atoms increased inside the discharge tube, leading to an increase of the electron density.

SEM Analysis

Figure 6-8 shows the longitudinal SEM micrographs of untreated, treated and grafted polyester fibers. As seen here, surface morphology significantly changes after plasma treatment due to deposition of a thick film on the surface of the fabric fibers.

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Figure 6: SEM image of untreated polyester fabric

Figure 7: SEM image of treated polyester fabric

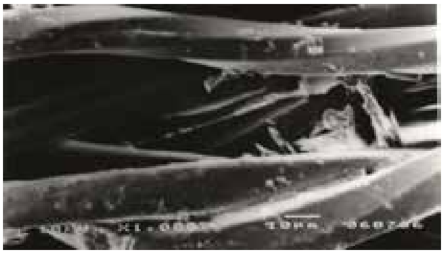

Figure 8: SEM image of grafted polyester fabric

From the SEM micrographs of polyester grafted fibers, a large amount of residue was found on the fibers, which is activated by plasma in the presence of maleic acid. Maleic acid content can improve the polar nature of polyester fibers. Despite that Mac content can improve the polar nature of polyester, the relatively big particles act as concentrator of stresses and therefore have a negative effect on adhesion with the nonpolar rubber matrix.

Conclusion

Surface treatment of polyester and rayon material was performed in the DC glow discharge. The XRD characterization of the treated polyester surface clearly demonstrated that the percentage of crystallinity was decreased on the surface of plasma treated polyester fabric. No significant change was observed in case of rayon fabrics. This revealed that plasma treatment on rayon fabric does not change the bulk effect. From FTIR studies, it was observed that (-OH) group was induced in case of grafted polyester fabric that enhanced the wettability of the fabric. The SEM results show the deposition of a thick flim on the surface of plasma treated polyester fiber.

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