A study on polypropylene fabric using ion irradiation

J. Payamara[1], S. Shahidi[2 *], J. Wiener[3]

[1]Basic Science Research Center, Shahed University, Tehran, Iran
[2]Department of Textile, Faculty of Engineering, Islamic Azad University, Arak, Iran.
[3]Department of Textile Chemistry, Faculty of Textile, Technical University of Liberec, Liberec, Czech Republic

Abstract

The main goal of this work was examination of structural and compositional changes in the Polypropylene (PP) fabrics caused by ion irradiation. In this work, the PP fabric were irradiated with CO_2 ions. The Implantation conditions (i.e, exposure time, beam current, and discharge power) were changed to control the extend of surface modification and the effects of irradiation were studied using different instruments. Also dye ability of the untreated sample and treated under different conditions were investigated by using a 3% wt aqueous solution of a basic dyestuff.
The obtained data show that, ion beam processing of PP fabrics allows an adjustable modification of their surface properties. The functional groups on the surface of samples were examined using FTIR spectrometer. Moreover, dyeing properties for treated fabrics has been tested. Significant increase in color strength has been achieved. Morphology of samples was examined by Scanning Electron Microscopy (SEM).

Keywords: Ion Beam, Surface modification, Polymer, Polypropylene, Fabrics

Introduction

Polypropylene fibres have such excellent properties as low specific weight (0.91 g/cm^3 only), high strength (42–53 cN/Tex), and good resistance to acids and alkalis, and they also possess good thermal resistance and anti-bacterial properties. PP fibres have been widely used in sports wear and industrial textiles, such as for filtration, composites, biomaterials and electronics. In these applications, the surface properties of the fibres are particularly important. The poor wettability (only 0.05% at 20 ^{0}C), and dying ability have, however, limited the application of these fibres in garments and other industries.

It is of importance to improve the wettability of PP fibres for many applications. Chemical treatment has been traditionally used to modify fibre materials but it has some disadvantages, such as influence on bulk properties and environmental pollution. As a type of environmentally friendly physical surface modification technology, Ion Implantation is now common in industry for it is a very effective way to give the hydrophilicity to a polymeric fibers.[1-4] Ion implantation is a technology for modifying surface properties of materials. In current material research and development, high priority is given to the surface modification techniques for improving surface properties for specific application requirements. Ion implantation is an important tool for producing improved materials.[5-9, 13-23]

The effects induced by energetic ions in polymers strongly depend on ion mass. In the case of heavy ions, when the ions loose their energy mainly in elastic collisions with target nuclei, the dominant mechanism is the chain scission leading to degradation of the material. For light ions, which loose their energy mainly in inelastic collisions with electrons, the degradation is thus limited and the ionization processes make possible the cross-linking of the polymer chain [10, 11].

The use of ion beam surface modification technique can provide a differential partition or a layered structure in terms of tribological, chemical, physical and mechanical properties in a sample without changing the bulk properties [12].

Recently, our research group has focused on the ion implantation in enhancing the wettability, surface adhesion, and electrical properties of a variety of polymer surfaces. It has many advantages over other methods. First, it is an environmentally safe dry process and does not need additional manipulations, for example, sample manipulation or beam rastering. Second, it provides a very thin coating that does not significantly affect the bulk properties of the polymer, but provides proper surface energy to the surface. Third, the Ion Implantation (II) treatment is more stable according to the aging time than traditional plasma treatment because this treatment provides more functional groups and deeper modified layers.

We have chosen polypropylene for our present investigation because of a wide range of utilization and its simple structure consisting of only carbon and hydrogen atoms. In order to functionalize PP membranes with respect to the capability of solute permeation, we have chosen an ion implantation technique to change its physical and chemical properties.

Materials and Methods

Polypropylene plain-woven fabric with a fabric density of 20.1 ends/cm and 11.1 picks/cm were prepared from Yazd Baft Co., and used in all experiments. The fabric was weaved by 350.2 denier warp and 300.2 denier weft yarns. The PP fabric was mounted on a sample holder and placed inside a vacuum system Fig1. Carbon Dioxide ion beams at energies of 1 and 2 keV were implanted, using an Ion Beam

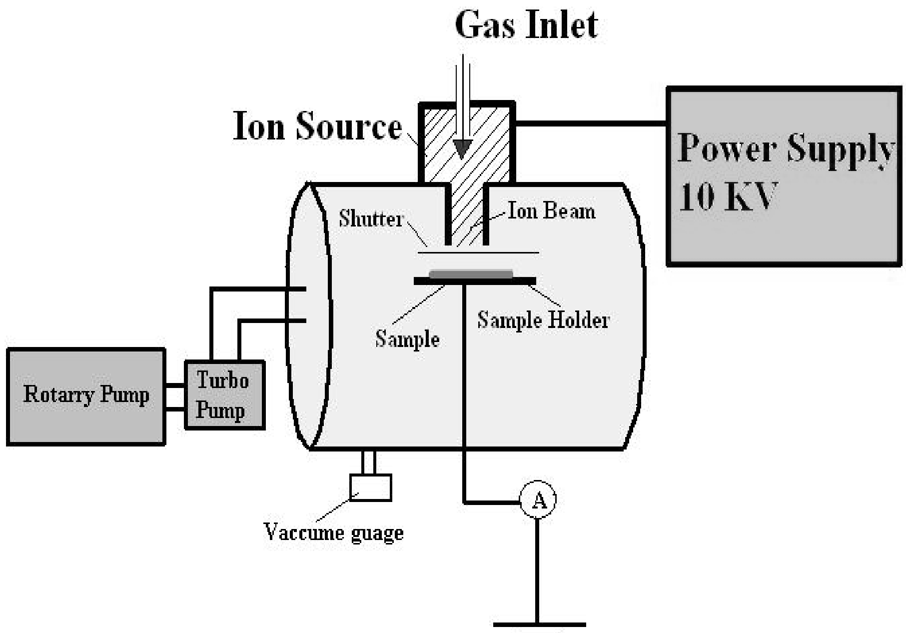

Figure 1: Schematic view of Ion Implantation set up

Sputtering system with Kauffman Ion Source, at the Plasma Physics Research Center (Tehran, Iran).Vacuum chamber was evacuated to the base pressure of 9×10^{-3} torr using rotary pump, and then to pressure of 10^{-5} torr using turbo pump. After filling the chamber with 10^{-2} torr of working gas (CO_2), the filament, Discharge, accelerator and focusing system were generated , respectively. The ions were produced via a multi-step process: that is, ions are initially formed by stripping electrons from source atoms in plasma. The beam of ions is then accelerated using a potential gradient column. A series of electrostatic lens elements shapes the resulting ion beam and scans it over an area in a work chamber containing the samples to be treated. One side of samples was treated for duration of 3 minutes.

The dosage of 1×10^{11} ions/cm^2 was used, and the implantation was done with different beam current below 1mA to avoid excessive heating and thermal degradation. A LEO 440I scanning electron microscope (SEM), from LEO Electron Microscopy Ltd., was used to examine the surface morphology of the fabric in this work. A 15 kV electron beam voltage was used. The fabric samples are highly non-conductive. To avoid charging of the surface, a conductive layer of gold is coated onto the fiber using a sputter coater. While this layer may obscure the true outer surface morphology.

FTIR spectroscopy on irradiated samples was utilized using a Bomem MB-100 (made in Canada) spectrometer in the range of 500–3000 cm^{-1}. For dyeing process, aqueous solutions, containing 3.0 wt.% of the Basic dyestuff (Astrazon Red Violet 3RN) were employed for dyeing PP fabrics. The bath ratio was 1:100 (1 g of fiber in 100 ml of dye solution). For Cationic dyeing process: Initial temperature 40^0C, followed by a temperature increase of 3 ^{0}C min^{-1} up to 80^0C,

holding for 30 min at 80^0C. After dyeing, the fabrics were rinsed with cold hot- cold water and then dried at room temperature.
Colour intensities of the dyed fabrics were measured by using a UV VIS-NIR Reflective Spectrophotometer, over the range of 350-600 nm (The wavelength of Magenta dyes is 500-530 nm, so this area was chosen for investigation). And the reflection factor (R) was obtained. The relative color strength (K/S value) was then established according to the following Kubelka-Munk equation, where K and S stand for the absorption and scattering coefficient, respectively [24, 25]:

$$K/S= (1-R)^2/2R$$

Results and Discussion

Scanning Electron Microscopy
Scanning electron microscopy (SEM) is the best known and most widely-used tool for surface analyses. SEM micrographs of untreated and treated PP fabric with 0.90 mA beam current are shown in Figure 2. It can be seen that, by increasing the beam current and energy of beam, ripple like patterns oriented in a fiber axis are developed (see Figure 2 (b, c)). However, after the ion implantation of 0.59 mA beam current, the surface morphology of the PP fabrics shows no morphological difference compared with the virgin sample.

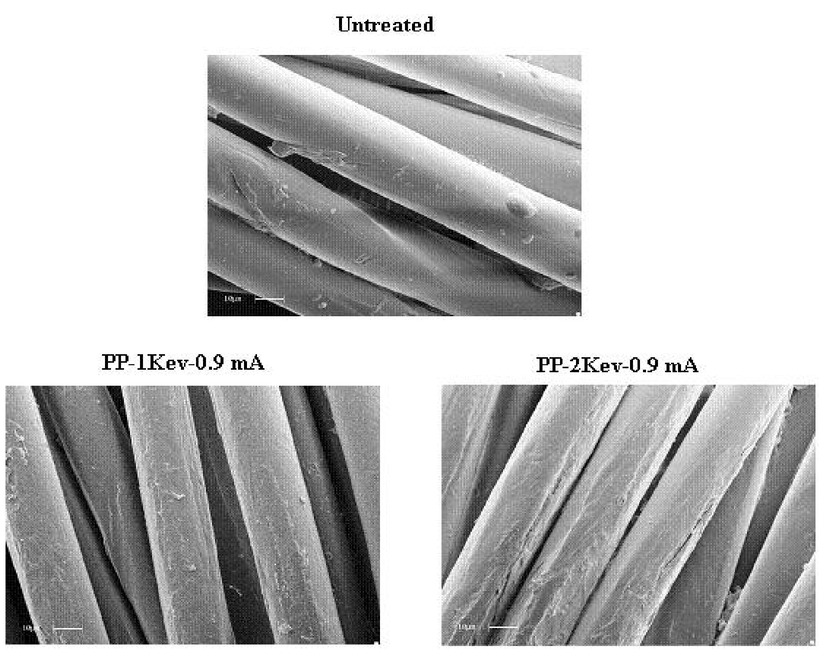

Figure 2: SEM image of untreated and treated samples

FTIR(Fourier transform infrared spectroscopy)

In order to study the structural modification of the implanted polymer fabric, Fourier transform infrared spectroscopy is used. FTIR was used to examine the functional groups of the corresponding samples investigated in Figure 3. As shown only slight increase in absorbance at 1720 cm−1 (C=O) band and 3400 cm−1 (O-H) band after CO_2 ion implantation can be noticed [26, 27]. The improvement of dye-ability properties confirmed that, ion implantation activated successfully the surface of PP fabrics.

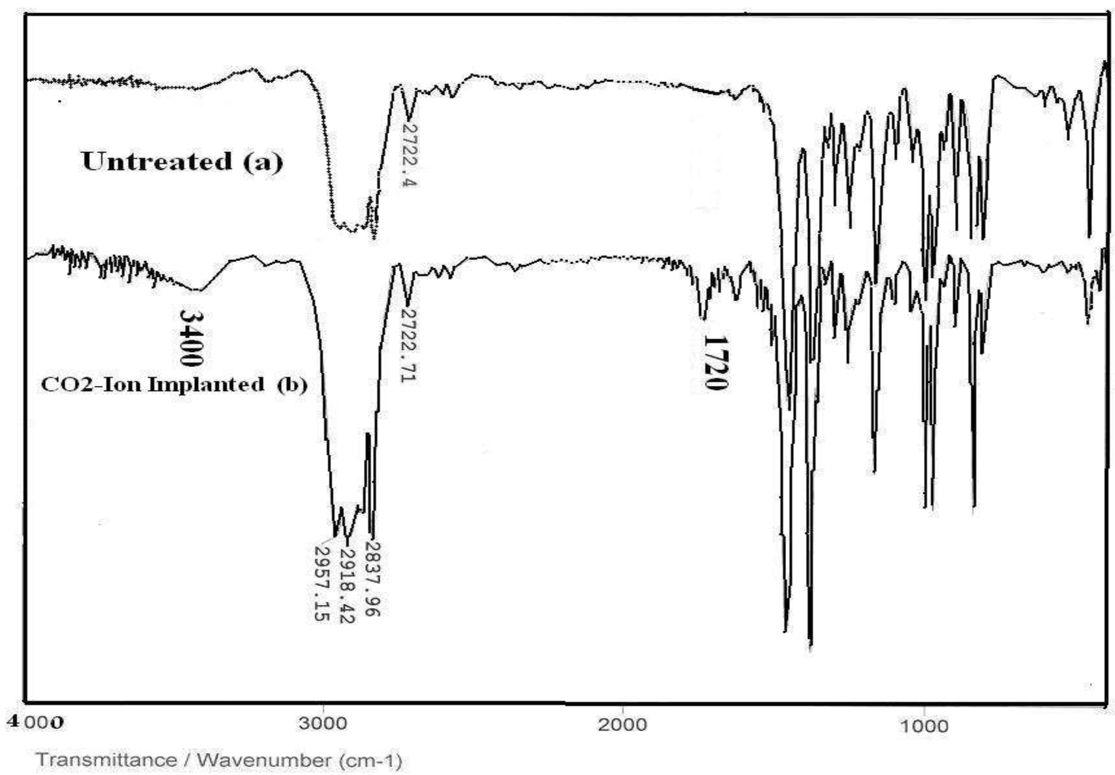

Figure 3: The FTIR spectra of PP-samples.

From these SEM observation and FTIR results, it is concluded that the treatments of PP fabrics with CO_2 Ion Implantation form C=O and O-H bonds which enhance the dye ability. Furthermore, surface becomes rough by a chemical and physical etching. These chemically and physically modified surface result in the high cationic dye ability.

Dye Ability of Polypropylene fabrics

In this research work, PP fabrics were treated with CO_2 Ion Implantation for different beam current. The results show that, the average of K/S between wavelength of 350-600 nm (The wavelength of magenta dye is about 500-530 nm, so this area was chosen) were first increased with increasing the beam current but by increasing the beam current more than 1 mA the samples were melted and destroyed .As it can be seen in Table 1, and as is evident from the FTIR measurement, CO_2 ion beam treated PP incorporates a long oxygen element in form of C-

O and O-H (negative sites) in the fiber surface and increase electro negativity. So the dye exhaustion for cationic (basic) dye with positive sites increases considerably. Also by increasing energy of beam and beam current till optimum condition, the dye ability is increased.

Table 1: Average of R and K/S for treated and untreated samples

Samples	Average of R	Average of K/S
untreated	0.267071	1.005697
PP-1 Kev-0.17 mA	0.230812	1.281675
PP-2 Kev-0.17 mA	0.219752	1.385168
PP-1 Kev-0.59 mA	0.212015	1.464335
PP-1 Kev-0.9 mA	0.185264	1.791488
PP-2 Kev-0.59 mA	0.155554	2.292095
PP-2 Kev-0.9 mA	0.130568	2.89472

Colour fastness

The durability of dyed ion implanted PP fabrics was evaluated in terms of fastness towards washing and lighting, using the gray and blue scale according to I.S.O standard recommendations as shown in Table 2. Assessment of fastness involves a visual determination of either change in shade or staining of an adjacent material. The

Table 2: Fastness properties of dyed samples

Samples	Washing	Lighting
untreated	2-3	4
PP-1 Kev-0.17 mA	3	5
PP-2 Kev-0.17 mA	3	5-6
PP-1 Kev-0.59 mA	3	6
PP-1 Kev-0.9 mA	3-4	6
PP-2 Kev-0.59 mA	4	6-7
PP-2 Kev-0.9 mA	4-5	6-7

graduation of the gray tones in the scales is defined as the smallest difference in depth, which is of commercial significance. Thus, as shown in Table 2, for the washing and lighting properties, the wash and light fastness of untreated sample is worst.The wash and light fastness, by ion implantation pretreatment on PP-fabrics, improved. As It can be seen, by increasing the beam current bellow 1mA, these properties are improved More.

Conclusion

In this research work, the dye-ability of Polypropylene Fabrics is improved by using Ion implantation treatment. The cationic dye-ability of treated PP fabrics by creating OH and C=O groups on the surface of the fabrics increases noticeably. So we can dyes PP-Ion implanted samples with cationic dyes easily. And we can have new usage of PP fabrics as textile garments. The present examples show that Ion implantation technology performed under reduced pressure, leads to variety to processes to modify fiber or textile materials to fulfill additional highly desirable requirements. This process is promising for the compatibility of PP fiber and matrix with various compound in blends and production of multilayered composites for versatile applications such as laminates and supported compound.It is expected that, this technology, which has been known for a long time and is being used in different branches of industry, in the near future will conquer textile as well.

Aknowlegments

We should thank to Basic Science Research Center of Shahed University, Tehran, Iran for providing grant of member.

References

[1]. Huang. F., Wei. Q, Wang. X, Xu. W , *Polymer Testing* **2006,** 25, 22–27.
[2]. Lai. J , Sunderland. B , Xue. J , Yan. S, Zhao. W , Folkard. M , *Applied Surface Science*,**2006,** 252 3375–3379.
[3]. Ricky K.Y. Fu, I.T.L. Cheung, Y.F. Mei , C.H. Shek , G.G. Siu , *Nuclear Instruments and Methods in Physics Research B,* **2005**, 237 ,417–421.
[4]. Dworecki. K, Drabik. M, Hasegawa. T, *Nuclear Instruments and Methods in Physics Research B* **2004,** 225 ,483–488.
[5]. Rosin´ ski. M, Badziak. J, Boody. F, Gammino. S, *Vacuum*, **2005,** 78, 435–438.
[6]. Predeep. P, Najidha. S, Sreeja. R , *Nuclear Instruments and Methods in Physics Research B,* **2005,** 240, 850–854.
[7]. Park. J , Sohn. C, *Current Applied Physics,* **2006,** 6 ,188–193.
[8]. Rodríguez. R, Medrano.A, García. J, Fuentes. G, *Surface & Coatings Technology,* **2007**, 201, 8146–8149.
[9]. Kim. Y , Lee. Y, Han. S, Kim. K, *Surface & Coatings Technology*, 200,4763 – 4769 (2006)
[10]. Jagielski. J, Piatkowska. A, Aubert , Thomé. L, *Surface & Coatings Technology,* **2006,** 200, 6355–6361.
[11]. Kima. Y , Leeb. Y, Hanb. S , *Surface & Coatings Technology,* **2006**, 200, 4763 – 4769.
[12]. Kar. K, Wong. H, Zinke-Allmang. M, Wan. W , *Nuclear Instruments and Methods in Physics Research B*, **2006,** 249 , 362–365.
[13]. Dworecki. K , Hasegawa. T. *Nuclear Instruments and Methods in Physics Research B,* **2001,** 185 ,61- 65.
[14]. Zhang. W, Ji. J, Zhang. Y , Yan. Q, *Applied Surface Science,* **2007,** 253, 8981–8985.
[15]. Sakudo. N , Shinohara. T, Amaya. S, Endo. H, *Nuclear Instruments and Methods in Physics Research B*, **2006,** 242, 349–352.
[16]. Bab. K, Hatad. R , *Thin Solid Films*, **2006,** 506– 507, 55 – 58.
[17]. Ivanov. M, Gavrilov. N, Belyh. T, *Surface & Coatings Technology* , **2007,** 201, 8326–8328.
[18]. Wong. K, Zinke-Allmang. M, Wan. W , Zhang. J, *Nuclear Instruments and Methods in Physics Research B,* **2006,** 243, 63–74.

[19]. Park. S , Seo. M, Kim. H, *Journal of Colloid and Interface Science*, **2003,** 261, 393–398.
[20]. Park. S , Seo. M , Rhee. K , 592 *Letters to the Editor* / *Carbon*, **2003,** 41, 579– 625.
[21]. Iskanderova. Z, Kleiman. J, Gudimenko. Y, *Surface and Coatings Technology*, **2000,** 127, 18-23.
[22]. de Juli´an Fern´andez. C , Manera. M, Spadavecchia. J , Maggioni. G , Quaranta. A, *Sensors and Actuators B*, **2005,** 111–112 , 225–229.
[23]. Boldyryevaa. H , Umedac. N , Plaksina. O , *Surface & Coatings Technology*, **2005,** 196, 373– 377.
[24]. Oktem. T , Seven Tekin. N , Ayhan. H, *Turk J. Chem.*, **2000,** 24, 277.
[25] Ghoranneviss. M , Moazzenchi. B , Shahidi. S, Rashidi. A , *Plasma Processes and Polymers*, **2006,** 3, 316.
[26] Carmen. M , Almazan. A , Paredes. J, *Journal of Colloid and Interface Science*, **2005,** 287, 57.
[27] Errifai. I , Jama. C , Le Bras. M , Delobel. R , *Surface and Coating Technology*, **2004**,180-181, 297.