Surface Modification of Spandex Fiber Using Low Temperature Plasma

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Abstract: ***In this paper the surface of spandex (20D) fiber was modified by the DC glow discharge plasma. The Plasma treatment alter and etch the surface of the top most nano layer of the materials. The properties of crystal structure, particle size, and surface morphology of products were analyzed by FTIR, XRD and SEM. It was found that the plasma treatment modified the surface both in crystallinity and etching. The treated fiber was more elastic, when compared with untreated fiber.***

Keyword: Glow discharge plasma, Spandex fiber, XRD, SEM

1. Introduction

Spandex (20D) or Lycra is a synthetic fiber know for its exceptional elasticity. It's a strong, but less durable than its major non-synthetic competitor. The spandex is a co-polymer of polyurethane-polyurea [1]. Generally it used as competitive swimwear, cycling jerseys and shorts, dance belts worn by male ballet dancers and other netball body suits, wet suits, swimsuits/body suits etc... [2]. The core-spun yarns containing spandex provide designers with broad possibilities, such stretchable yarns can be constructed with a wide range of properties using virtually any type of hard fibers as the cover yarn. Lycra is the registered trademark for du-point's elastane yarn of coalesced filament with high stretch and recovery power. Spandex yarn or Lycra has variable properties which ensure its high utility as the core in elastic core-spun yarn. These includes high modulus, fine and very fine yarn counts, capacity to heat set, clear, dull and bright lusters, capacity to dye, etc.. The surface modification methods to be applied in the plasma treatment. DC-cold plasma surface treatment is a powerful method used to modify surface characteristics of thin layers and surface without bulk.

Plasma is an ionized gas including both charged and neutral particles, such as electron, ions, atoms and molecules and radicals [3].Plasma treatment has an explosive increase in interest and use in industrial applications as for example in medical, bio-medical, electronics and textile industries [4-7].The general reaction to be achieved by plasma treatment are the oxidation of the surface of a materials, the generation of radicals, and the edging of the surface when using atmosphere gas. In this study it has been shown that atmospheric pressure glow discharge cold plasma treatment can simultaneously increase the rate of absorption of both hydrophilic and hydrophobic fluids in textile substrates [8]. A cold plasma technique is optimum for this modification because the depth of deposition of plasma-induced treatment is a few nanometers. Now a day's application of cold plasma exists including, strengthening of tools, manufacturing of semiconductors integrated circuit, and coating for anti-corrosion, thermal and electrical improvement.

2. Experimental

2.1 Materials

The pure spandex fiber was purchased from Allie-Tex. Pvt.Ltd. India.

2.2 Glow discharge plasma treatment

The glow discharge plasma reactor used in the study consist of a stainless steel chamber, 50cm length, 30cm diameter and 6 mm thick, and a pair of aluminum electrodes. The electrodes were square in shape with a diameter 10 cm. Electrodes were fixed in the chamber axisymmetric and perpendicular to the axis and were separated by 6 cm. The discharge chamber was thoroughly cleaned and air tightened. The chamber was initially evacuated to the pressure of 10^{-3}mbar using vacuum pump (HPVT-PS). Through an air inlet (fine control gas needle valve) the required low pressure was maintained and measured by a pirani gauge. A DC potential was applied between the two electrodes and adjusted until a stable glow discharge plasma was generated [9].

The spandex fiber was inserted with its surface perpendicular to the discharge axis between the parallel disc electrodes. The exposure time, discharge potential and base pressure were kept constant at 10 min, 400V and 0.3mbar. After plasma treatment, the fiber was kept in an air lock cover and analyzed. The plasma processing parameters are shown in Table.1.

Table 1: Plasma processing parameters

Discharge potential	350-400V
Pressure	0.03mbar
Exposure time	10 mins
Electrode separation	6 cm
Plasma gas	Atmospheric gas
Sample nature	Synthetic fiber

2.3 Characterization

The plasma treated fiber were characterized for the FTIR spectra and measured on an IR AFFINITY-I (SHIMADZU) spectrometer with a wave number range of 4000 to 400 cm^{-1}. The crystalline structure was studied by using Advance X-ray diffraction meter (SHIMADZU-6000) at room

temperature. The crystal size was calculated by Scherrer's formula. Surface morphology was studied by using SEM (Model JSM 6390V, JOEL, JAPAN).

3. Results and Discussion

3.1 FTIR Spectroscopy Analysis

The FTIR spectrum of pure spandex is shown in figure 1. The absorption peaks 964.45cm^{-1} and 671.28cm^{-1} are described to the C-H bending mode and 1361.80cm^{-1} is O-H bending. After plasma treatment the FTIR spectrum of the spandex reveals the presence of strong bonds around 638.79cm^{-1} to 3950.38cm^{-1}.

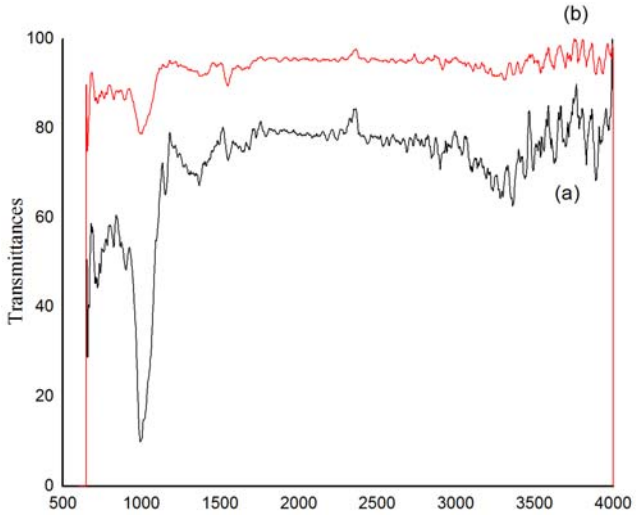


Figure 1: (a) & (b) FTIR Spectrum of Spandex Fiber

The bond around 2927.10cm^{-1} and 1313.58cm^{-1} are described to the C-H vibration mode in spandex [10]. The bond 1366.62cm^{-1} is O-H bending. The spectrum also shows that the bond at 1223.89cm^{-1} is attributed to the sacch aride structure [11]. The absorption peaks can be observed at 1102.37cm^{-1} and 683.79cm^{-1} corresponding to the C-O stretching and the –CH2-S-(C-S) stretching.

3.2 Structural analysis: XRD results

Fig-1 (a) and (b) illustrates that the x-ray diffract gram of untreated and plasma treated spandex fiber surface. The result of XRD fiber indicated that the experimental data are in good agreement. The Broadening of the peaks indicated that the particles were of nanometer scale. The particle size can be estimated from the XRD pattern using Scherrer's formula [12].

$$D=\frac{k\lambda}{\beta\cos\theta}$$

Where **D** is the crystalline size, ***k*** is a geometrical factor taken to be 0.89, λ=1.5406 Å is the X-ray wavelength, θ is the diffraction angle and β the peak width at half maximum of the most prominent peaks. Clearly, there was no significant change in the shape or position of the diffraction peaks, except that the peaks were more intense for the treated spandex fiber.

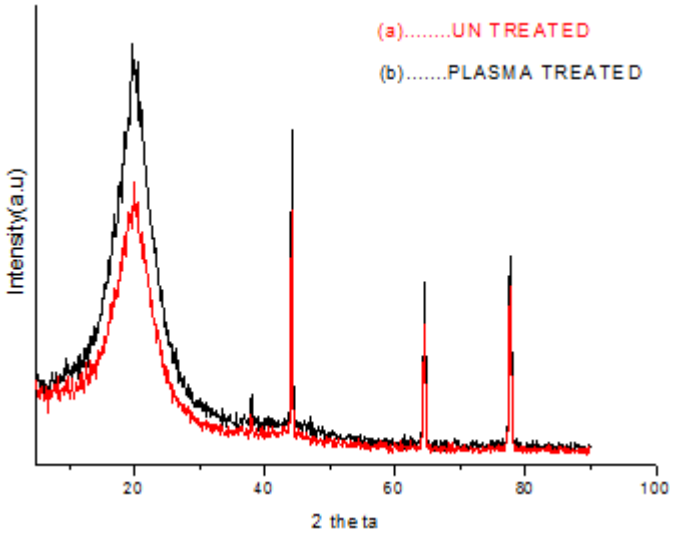


Figure 2: (a) & (b) X-Ray Diffraction of spandex fiber the crystal size (c) and the lattice spacing (d) for the crystal plane

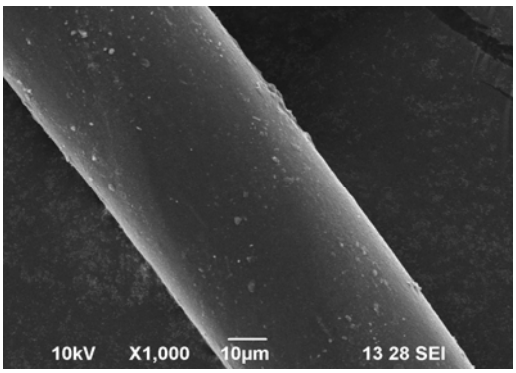
Table 2

Sample	D(A^0)	d(A^0)
Un treated	1.36133 3.055198 3.39355 3.49891	4.46220 2.05226 1.44497 1.23038
Plasma treated	1.353727 3.087769 3.39307 3.50204	4.48314 2.05518 1.44513 1.23039

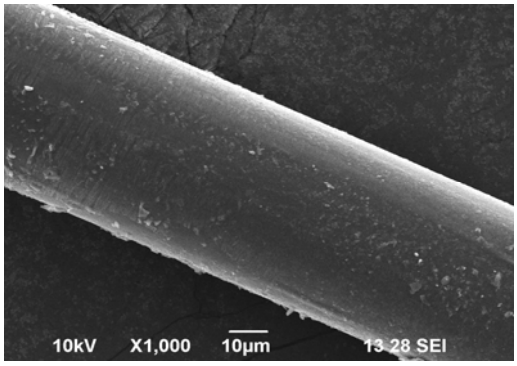
The crystal size and lattice spacing of untreated and plasma treated sample is shown in Table.2. The results higher degree of crystallinity of the spandex fiber surface after plasma treatment [9].

3.3. Surface Morphology Analysis: SEM results

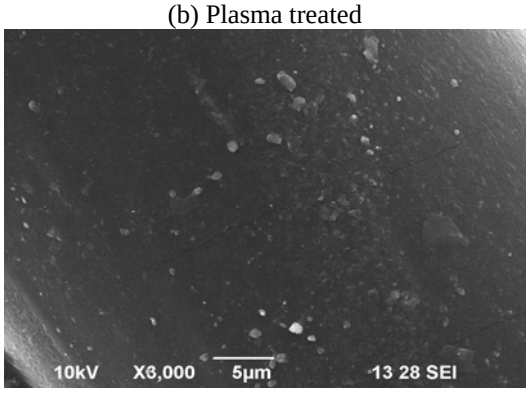
The SEM images of plasma treated and untreated spandex fiber are shown in fig (2). SEM was used to analyze the change of the surface morphology of the fibers treated by air plasma with fixed time duration of exposure. In figure (a) and (c) is untreated sample and (b) and (d) is plasma treated sample.



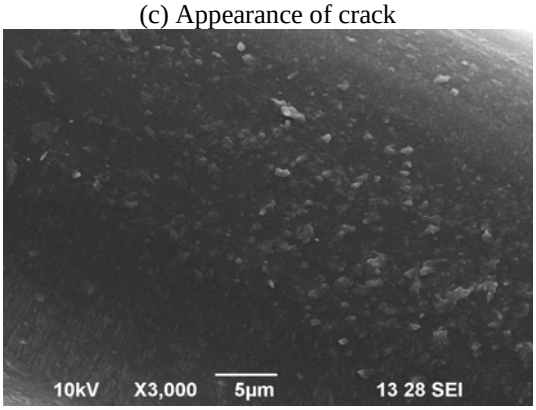
(a) Untreated



(b) Plasma treated



(c) Appearance of crack



(d) Disappearance of crack

Figure 3: (a), (b), (c), (d) SEM Micrograph of the spandex fiber

The images of the fibers illustrates the progressive change of the surface morphology with the treatment time and air flow rate. A crack appears on the surface before plasma treatment. The formation of the crack on the spandex fiber surface was modified after plasma treatment. In addition to that some spots and small fragments begin to appear. This indicates that the more obvious effects of plasma bombardment and eteting. The change in the surface morphology after plasma treatment can be explained by the localized ablation of the surface layer [13]. The etching effect on the sample surface is not noticeable when the flow rate is small. The etching effects become more obvious and the crack becomes modified.

4. Conclusion

Low pressure glow discharge plasma treatment has been used to modify the spandex fiber surface. It was found that the plasma treatment modified the surface both in crystalline and etching. The spectral analysis gave the information related to the chemical spectroscopy which showed a various bonding nature corresponding to different frequencies varied between 638.79 –3950.38cm^{-1}. The FTIR Spectra showed in absorption bonds increase in plasma treatment. XRD characterization studies shows the increase of surface roughness and crystallinity on the spandex (20D) fiber. The SEM results conform the change in surface morphology of the spandex fiber by the localized ablation of the surface layer.

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