



The effect of working pressure on the chemical bond structure and hydrophobic properties of PET surface treated by N ion beams bombardment

Wanyu Ding^{a,b,c,*}, Dongying Ju^{d,1}, Weiping Chai^{a,b,2}

^a Engineering Research Center of Optoelectronic Materials & Devices Education Department of Liaoning Province, Dalian, 116028, China

^b School of Materials Science and Engineering, Dalian Jiaotong University, Dalian, 116028, China

^c Key Laboratory of Materials Modification by Laser, Ion and Electron Beams (Dalian University of Technology), Ministry of Education, Dalian, 116024, China

^d Department of Material Science and Engineering, Saitama Institute of Technology Fukaya, 369-0293, Japan

ARTICLE INFO

Article history:

Received 2 March 2010

Received in revised form 20 April 2010

Accepted 28 April 2010

Available online 5 May 2010

Keywords:

Polyethylene terephthalate

Ion beams

XPS

Chemical bond

Contact angle

ABSTRACT

Polyethylene terephthalate (PET) surface was bombarded by N ion beams at room temperature. Varying the working pressure of the ion beams, PET surfaces with different composition and properties were obtained. Characterization by X-ray photoelectron spectrometry showed that only on film surface, ester bonds, especially C–O bonds, were broken and N element chemical bonded with C. The influence depth was less than 5 nm because of the lower ion energy (about 10^3 eV). Contact angle results revealed that with increasing the working pressure of ion beams, the contact angle of PET surface to pure water increased from 51° to 130° . With these results, one conclusion could be deduced that the hydrophilic and hydrophobic properties of PET surface could be influenced by N atom chemical bond with C, which in turn is controlled by the working pressure of N ion beams.

© 2010 Elsevier B.V. All rights reserved.

1. Introduction

Since the artificial synthesis of polyethylene terephthalate (PET) films by Whinfield and Dickson in 1941 [1], PET films have been widely used as substitute for the traditional engineering materials like steel and aluminum in manufacturing, owing to their good performance in mechanical, chemical, electronic, and biocompatibility properties [2–5]. Recently, PET films have become an ideal substrate layer for flexible organic light emitting diode display (FOLEDs) because of their high light transmission and flexibility, especially their chemical inertness, which can be used in atmosphere for long time [6,7]. For the application in the fields of FOLEDs, it is necessary to couple PET with other functional films, such as indium tin oxides (ITO) film as electrode, silicon nitride (SiN_x) film as permeation barrier film. So, most studies focused primarily on the properties of those composite thin films. However, PET was innately hydrophobic and low surface energy materials. So, PET

did not adhere well to other functional films used in FOLEDs [8,9]. Some reports have revealed that the degradation of FOLEDs mainly caused by the split between PET and SiN_x film or ITO film, which in turn results in the cracking of SiN_x and ITO films [6]. Therefore, it was necessary to modify PET surfaces without the change in their bulk physico-chemical properties in order to improve the adhesion between PET and other functional films. For example, it is possible to improve the adhesion between PET and SiN_x film by introducing N element onto PET surface.

PET films surface has been modified by various techniques, such as chemical, laser, mechanical, and electrical treatments [10,11]. By controlling the modification parameters, PET films surface can have a wide range of composition and physico-chemical properties. Recently, research on the use of plasma treatments has grown in interest, since they are parameters controlled, treatment depth controlled, and environment friendly [12–14]. The ion beams treatment is one of the popular plasma techniques since it is a dry process and allows better uniformity in the modified surface, and hence treatment depth could be effectively controlled. The mechanisms of ions reacting with PET surface are very complex, such as breaking chemical bond, activation, sputtering, and in most cases, combining new element onto the surface. Furthermore, depending on the kinds of ions and the ion beams working parameters, it is possible to control the content and the influence depth of new element combined onto the surface, which can result in the changing of physico-chemical properties of PET surface, such as hydropho-

* Corresponding author at: School of Materials Science and Engineering, Dalian Jiaotong University, Dalian, 116028, China. Tel.: +86 411 84105696; fax: +86 411 84105118.

E-mail addresses: dwyysd.2000@163.com (W. Ding),

diju@sit.ac.jp (D. Ju), wpchai@djtu.edu.cn (W. Chai).

¹ Tel.: +81 48 585 6826; fax: +81 48 585 5928.

² Tel.: +86 411 84105696; fax: +86 411 84105118.

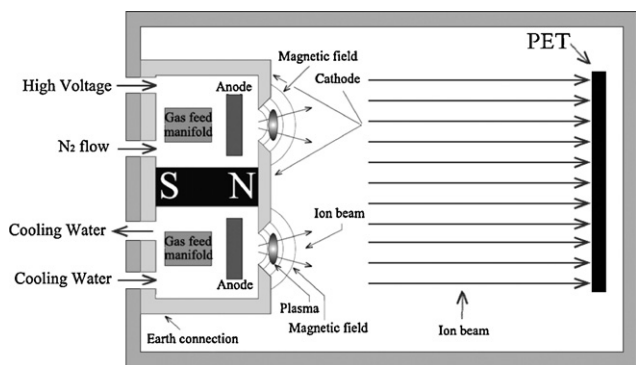


Fig. 1. The schematic diagram of the experiment chamber (cross section).

bic and hydrophilic properties. So, it is necessary to understand the relationship between ion beams working parameters and the changing of composition and properties of PET surface during the treatment process, in order to effectively use PET films as the substrate of FOLEDS. In this paper, PET film surfaces were modified by N ion beams at room temperature. The aim of this work was to systematically study the influence of the working pressure of ion beams on the chemical composition and chemical bonds, as well as the hydrophobic and hydrophilic properties of PET film surface.

2. Experimental details

In our experiments, N ion beams were employed to treat the surface of PET films. The experiment chamber was a cylinder with 520 mm in diameter and 380 mm in height, which the detailed description has been discussed in our previous publication [15,16]. The AE[®] linear ion source was set in one side of the cylinder and PET samples were set in the chamber faced to the ion source, just as shown in Fig. 1. A 175 μm thick PET film purchased from Shanghai Textiang Electrical Insulation Material Co., LTD. was cut into smaller pieces of 50 mm \times 50 mm. PET films were firstly ultrasonically pre-cleaned in ethanol and deionized water respectively, and then dried with N₂ gas. Finally, the substrates were loaded into the processing chamber and the distance between the ion source and PET was fixed at 110 mm for all samples. After the base vacuum was less than 9.9×10^{-4} Pa, high purity N₂ (99.999%) was introduced into the ion source and N ion beams was introduced into processing chamber to bombard the surface of PET films. The N₂ gas flow ratio and the ion beam working power were fixed at 20 standard-state cubic centimeter per minute and 200 W, respectively. PET films surface were bombarded without intentional heating to characterize their intrinsic physical and chemical properties. The bombardment time was fixed at 15 min for all samples. By controlling the metal ultrahigh vacuum gate valve, only the N ion beams working pressure was adjusted from 0.1 Pa to 0.9 Pa, with the step size of 0.2 Pa.

The film surface analytical techniques used in this study include X-ray photoelectron spectroscopy (XPS) and contact angle measurement. XPS spectra were performed by Quantum 2000 system with an Al K α line source ($h\nu = 1486.6$ eV) at an incident angle of 45°. The base vacuum in the analysis chamber was about 2.0×10^{-7} Pa. Two types of spectra were recorded: wide range survey with 117.40 eV in pass energy and 1 eV in resolution, and narrow range survey with 29.35 eV in pass energy and 0.125 eV in resolution, respectively. In order to detect the influence depth of N ion beams, Ar ion bombardment was carried out using a differential pumping ion gun with 2 kV in accelerating voltage, 45° in incident angle, and about 1–2 nm/min in sputtering yield. The narrow spectra of C 1s, O 1s, and N 1s were measured once after every minute sputtering. All spectra were referenced to C 1s line of 284.6 eV. The static contact angles of pure water to treated and untreated PET sur-

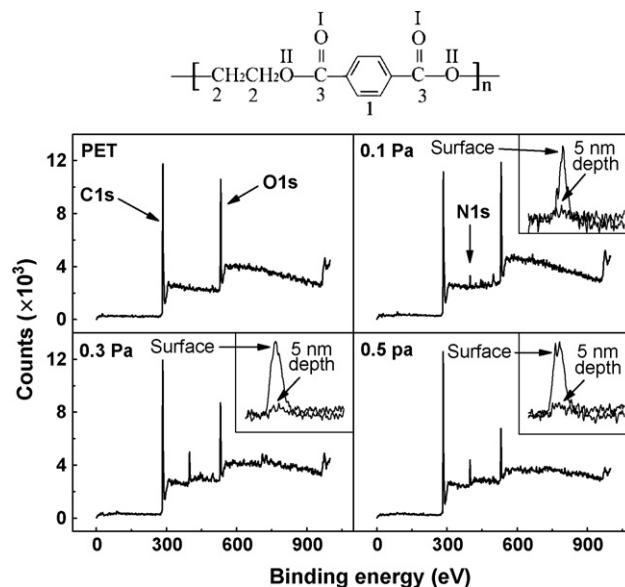


Fig. 2. The chemical structure of pure PET and wide range XPS spectrum of PET surface (the inset figures show the N 1s peak on the surface and the 5 nm depth).

face, were obtained by GS-X150 surface tensiometer, with 3–180° in measurement range and 0.1° in resolution.

3. Results and discussion

3.1. XPS analysis

In order to detect the chemical compositions and chemical bonds structure of PET surface, XPS was carried out on PET. Fig. 2 shows the wide range XPS spectra of PET surface before and after bombarded by N ion beams with different working pressure. From Fig. 2, it can be seen clearly that on the untreated PET surface, only C 1s and O 1s peaks appeared at 284.6 eV and 532.5 eV, respectively, which composed PET with the structures shown in Fig. 2 [17]. However, after N ion beams bombarded, the N 1s XPS peak appeared at about 400 eV. The relative intensity of O 1s and N 1s peaks decreased and increased monotonously with increasing the ion beams working pressure respectively, which meant more C–O/C=O bonds were broken and more N-containing groups combined onto PET surface. The introduction of N-containing groups onto PET surface may be the main reason for the hydrophobic improvement, just as discussed in Section 3.2. From the inset figures in Fig. 2, it can also be seen that the N 1s peaks almost disappeared in the place of 5 nm from surface, which meant the influence depth of N ion beams was less than 5 nm. In our experiments, the ion beams working power was set constant for all. In this situation, the anode voltage of ion source was only influenced by the working pressure. The anode voltage of ion source was less than 2.3×10^3 V, which meant the ion energy was only about 10³ eV. Compared with the other bombardment techniques, such as plasma immersion ion implantation, ion energy of 10³ eV was too low to influence deeper from surface [18,19].

For the purpose of investigating the detailed change of chemical bonds structure on PET surface, high-resolution XPS analysis of C 1s and O 1s peaks were performed for the surface of PET, just as shown in Fig. 3. From Fig. 3, it can be seen clearly that the full width at half-maximum value for all spectra implied the multiple bond states of C and O element. The results of Gaussian peak fitting showed three peaks located at 284.6 eV, 286.2 eV, and 288.7 eV, which are attributed to phenyl C bonds (1C), methylene C bonds (2C), and

Download English Version:

<https://daneshyari.com/en/article/5365513>

Download Persian Version:

<https://daneshyari.com/article/5365513>

[Daneshyari.com](https://daneshyari.com)