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Short communication

Using fast atomic source and low-energy plasma ions for polymer surface modification

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Abstract

A systematic study was carried out to characterize the effects of argon atomic beam irradiation and low-energy argon ions in plasma for polystyrene (PS) surface modification. The PS samples were exposed to a 1.5 keV, argon atomic beam from a fast atomic source (FAS) at different exposure times. The low-energy (1.5 eV) argon plasma ions were achieved in a two-stage RF discharge and PS samples were exposed to plasma for different times and powers. The surface characterization of these atomic beam and plasma modified PS samples was carried out using X-ray photoelectron spectroscopy. For FAS, the results showed a rapid increase (from 0.01 to 0.18) in oxygen-to-carbon ratio (O/C) at the surface of PS with first 10 s exposure time while further increase in exposure time up to 500 s showed about 50% decrease in O/C. Therefore, first few seconds of atomic beam irradiation useful to increase the O/C at the PS surface whereas at higher irradiation time the surface etching may took places and it could have advantage in surface cleaning. A comparison of O/C with FAS and plasma ions showed FAS is more effective way to achieve oxygen incorporation at PS surface relatively to low-energy flux plasma ions.

Keywords: Fast-atomic source; Low-energy plasma; PS; Surface modification

1. Introduction

Polymers have become very important materials in modern manufacturing processes and offer wide varieties of chemical and mechanical properties applicable in numerous applications [1–4]. It is well known that permanent bonding, coating, printing, etc. are difficult on many polymers without surface pre-treatment. Therefore, after the surface treatment of polymers these have significant benefits in the specific requirements of surface properties while retaining bulk mechanical properties. An example of this is in biomedical applications, where the polymeric materials often undergoes some form of surface treatment to alter surface-wetting characteristics, topography, and to introduce chemical functionality. The physical and chemical surface modifications of polymeric materials without alteration of the bulk properties are of great interest in many applications [4–10].

Low-temperature plasmas are widely used in a growing number of materials fabrication processes including the etching of complex patterns for different micro-electronic, micro-optical components and deposition of thin films. The nature of plasma is very complex due to presence of ions, neutrals and radiation in the discharge. To discuss the role of ion energy, ions flux and VUV component in low-pressure plasma treatment these need to be separated from each other during processing. Groning et al. [11] used separately low-energy ions and VUV lamp irradiation on polymers and showed that much of the chemical modification of polymer surface was due to ions, and the low-energy ion–surface interactions are key in the modification

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process. Dhayal et al. [9] used a pulsed argon RF discharge to study the separate selective effects of ion energy and ion flux in 'on' and 'afterglow' discharge at constant background of VUV for polystyrene surface modification.

Dhayal et al. [10] also used a two-grid separated two-chamber discharge to investigate the effects of low ion energy and flux for the modification of polystyrene surfaces. By controlling the externally applied voltage at the grids they have eliminated the ionic component in the modification process and allowed only VUV and neutral components at the surface. A VUV transparent LiF window was also used to stop ions, electrons, neutrals to study the effects of only VUV in plasma for polystyrene surface modification. The results showed that surface treatment in the discharge was dominated by the photon (VUV) flux [10] and at low power the neutrals may also influence the surface modification.

In this study, the effect of a 1.5 KeV argon atomic beam from FAS on PS surface was studied and compared with low-energy ions treatment in low-pressure discharge. The use of atomic source has advantages for uniform treatment of polymeric materials with time as the use of ion and electron beam may have limitations in surface modification due to surface charging of polymeric materials.

2. The experimental set up

2.1. Atomic source

The fast atomic beam source (FAB110; MECA 2000, France) was used at Nuclear Science Center, New Delhi. The FAB110 can be used for medium area beam of different atomic neutrals and in this study we have used 1.5 KeV energy argon neutral beam. The neutral source can be described in three parts: First, plasma body, second the system of electrostatic field arrangement and finally the processing chamber where the samples can be treated.

The energetic atoms originated as energetic ions in the body of the plasma. The arrangement of the electrostatic field close to the output grid allows the recombination of secondary electrons and ions without any significant loss of the energy. This allows to achieve a purely atomic beam of the argon atoms (as a supply gas used). The FAS plasma chamber and electrodes were made of carbon and coupled with the cold cathode operation. In the experiment first, a base pressure of 10^{-3} Pa order was achieved and polystyrene samples (prepared by spin cast method) irradiated with 1.5 KeV argon atomic beam at a operating pressure of about 0.13 Pa.

2.2. Plasma source

For low ion energy plasma treatment of PS an argon gas discharge was used, similar to Dhayal et al. [12–15]. The schematic diagram of plasma reactor is shown in Fig. 1. Using turbo pump backed by a rotary pump a base pressure of order of 10^{-3} Pa was achieved. The main

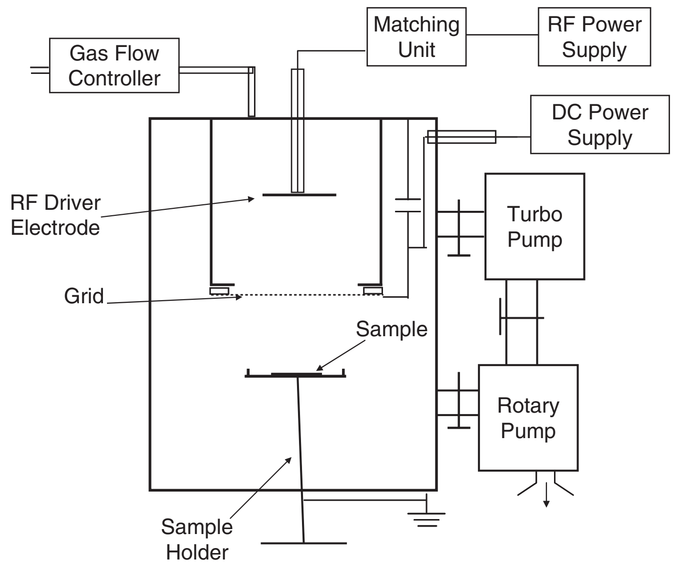

Fig. 1. Schematic diagram of plasma reactor.

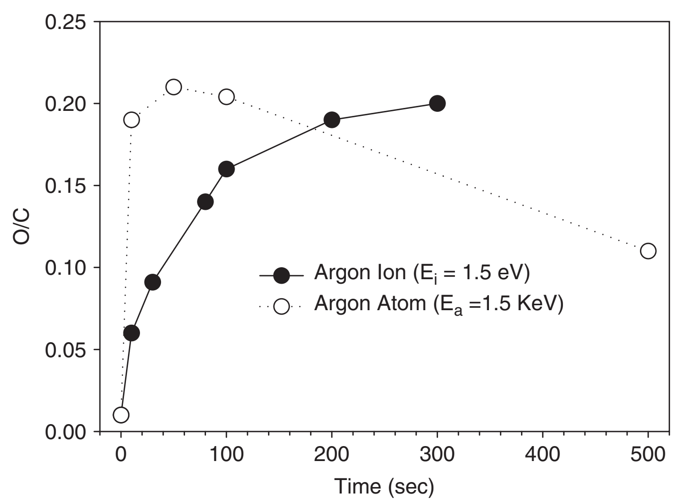

Fig. 2. O/C with different irradiation time of fast atoms and plasma ions of argon.

plasma was sustained through 13.56 MHz RF excitation and reflected power was controlled manually by a matching unit. The control of the plasma parameters in the processing chamber was achieved for different operating conditions such as power and varying applied grid bias voltages at constant 2.6 Pa operating pressure. In this study the polystyrene samples were prepared by spin casting from dilute solution onto a glass substrate and irradiated to atomic beam and plasma ions at different dose.

3. Result and discussion

Using XPS the effects of high-energy argon atoms from FAS and low-energy argon ions in plasma discharge on the polystyrene surface were characterized. PS samples were irradiated to argon plasma and FAS and a systematic study