Design, characterization and applications of low-energy ion source for modifying polymer surface properties

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ABSTRACT

In this study, a cold cathode ion source equipped with a Langmuir electric probe was built to generate an ion beam with broad potential uses. By modifying the discharge voltages, electrode gaps, and gas pressure, a stable discharge plasma environment was generated. An electrical probe is inserted into the discharge plasma to capture the I-V plasma graph and determine its parameters. The probe can be aimed to any position inside the plasma. Alterations to gas pressure and probe-cathode distance are used to measure and log plasma characteristics such as electron temperature and density. By analyzing the current discharges as the gas pressure and cathode-probe distances are varied, the discharge characteristics can be fine-tuned and analyzed. The surface properties of the polymeric films are modified by exposing them to the extracted beams. Surface free energy can be increased by lengthening the time under irradiation. This ion source was developed to address the needs of applications including polymeric modification of surfaces, and it is quite efficient at doing so.

INTRODUCTION

Water-soluble, non-toxic, and having a considerable transparency index, polymer substances are highly favored [1]. Carbon clusters are formed and other chemical and structural alterations occur in polymers when they are treated with ions [2]. Quantifiable structural modifications in polymeric substances following ion treatment have increased in significance [3]. Many different changes can be made to polymers by varying the ion types and energies [4]. Ions lost energy in collisions with polymers through ionization, excitation, and collision events (see Figure 1). Polymer properties were studied alongside experimental determinations of ion beam range and stopping force [5]. Chain scission, cross-linking, and the generation of functional groups are the main mechanisms through which the characteristics are altered to make them useful in a variety of contexts [6]. Target temperature, material employed, kind of irradiation ions, ion beam energy, as well as ion flux density all play a role in these transformations of the target substances. Atomic and electronic structures will be displaced and recoiled as a result of all these defects [7].

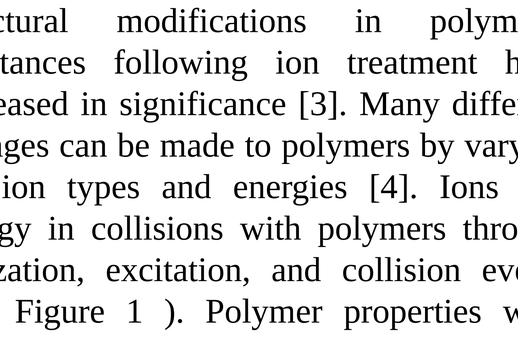

Fig.1: **Effects of oxygen plasma on the activation of polymer surface**

OBJECTIVES

In summary, this study aims to achieve the following specific outcomes:

1.Identifying the optimal ion source operational settings for a given task.
2.The ion spectrum in the colliding polymers is calculated using the SRIM simulation tool.
3.Study the effects of irradiation on the polymer's structure.
4.Learn more about how irradiation affects the surface properties of films.

METHODS

Figure 2 depicts the schematic of the plasma system for producing ion beams. An electrostatic potential variation between the anode and the cathode causes primary electrons to collide with gas molecules, therefore ionizing the gas. Ion diffusion from the discharge, and perhaps ion generation, limit the current that can be extracted, rather than the acceleration process itself. The extracted beam current grows proportionally with the supplied voltage. The form and location of the plasma, which change depending on the magnitude of the negative potential supplied to the extraction electrode, are responsible for this phenomenon [8].

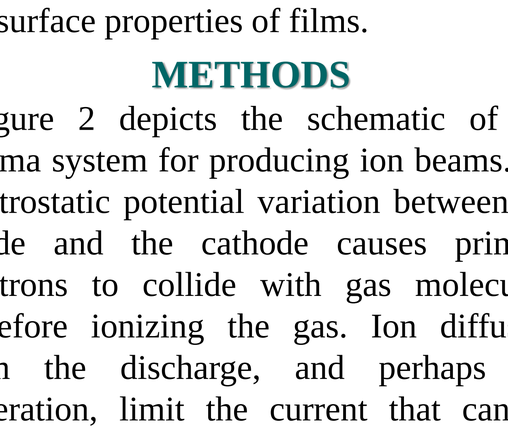

Fig. 2. **Schematic of low energy ion source.**

As previously mentioned [8], Figure 3 depicts the corresponding single cylindrical probe made of tungsten wire covered in glass.

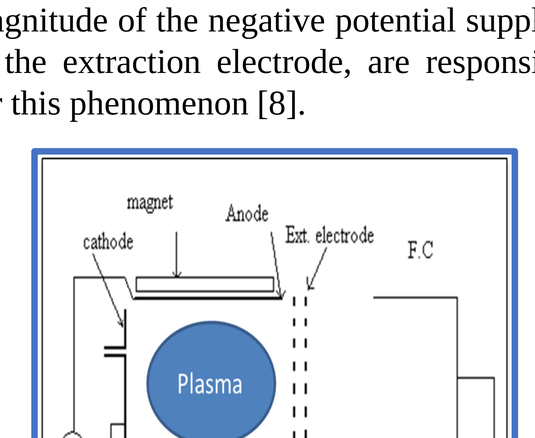

Fig.3: ***A schematic diagram of plasma source with Faraday cup***

It's 1 mm in length and has a 0.5 mm diameter. The probe is movable in each of the radially and axially directions, allowing it to be directed to an accurate position.

RESULTS

1.Atta et al. [9] explore the impact of magnetic field intensities on beams current distribution for a broadly cold cathode plasma source, as seen in Figure 4. By applying a strong magnetic field, electron mobility is decreased close to the anode, leading to a more concentrated beam. Advances in electron energy, capable to ionize a greater number of gas atoms, account for the observed partial rise in beam current as the magnetic field is increased.

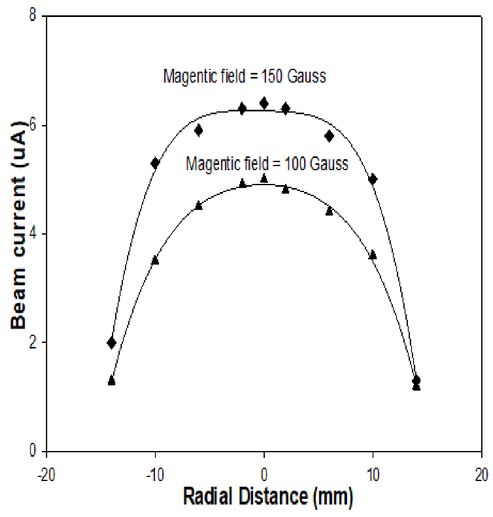

Fig.4: **Radial distribution plasma bam profile as a function magnetic field**

Figure 5 displays the previously discussed dependency of beam distribution of current on gas pressure of a cold cathode plasma device [9]. They have been found to have a Gaussian distribution. It also demonstrates that a raise in pressure causes a marginal rise in beam current. Beam diameter shrinks at elevated pressure (4x10-3 torr) with no change in intensity profile. Since extra gas atoms are bombarding the surface, the secondary electron generated from the surface is thought to be the main cause for ionization [9].

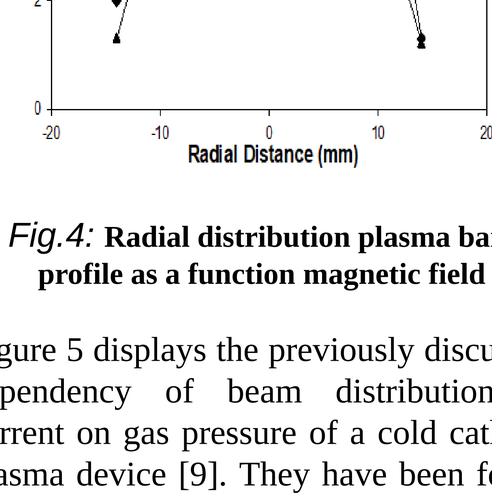

Fig.5: **Radial distribution plasma bam profile as a function of gas pressure**

CONCLUSIONS

In the present work, we show how to create a plasma discharge environment with a significant output beams current that is easy to tailor to a specific usage. The plasma source's specifications have been brought up to par through some investigating. This plasma generator is small in stature, and its use of inert and reactive gases allows for simple and long-term stable operation. A powerful plasma beams and a consistent discharge current make this plasma generator ideal for etching, sputtering, as well as other kinds of processes. The beam profile was utilized to analyze the plasma source's output current densities distributions. Beam profile curves provide a greater sensitive manner for detecting variations in extract beam current across a range of experimental situations.

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