Faculty of Science
Physics Department

"Production of High Brightness Ion Beam for Different Applications"

Thesis submitted by

Safaa Mostafa Ali Mahmoud

Scholarship from
The Academy of Scientific Research and Technology
in Accelerators and Ion Sources Department
Nuclear Research Center
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For the Partial Fulfillment of the
Degree of Master of Science in Physics

Under the Supervision of

Prof. Dr. Samir Ahmed Nouh
Prof. of Radiation Physics
Physics Department
Faculty of Science
Ain Shams University.

Prof. Dr. Adel Gomaa Helal
Prof. Emeritus in Accelerators
and Ion Sources Department
Nuclear Research Center
Atomic Energy Authority.

Assist. Prof. Hesham El-Khabeary Tawfik
Head of Accelerators and Ion Sources Department
Nuclear Research Center - Atomic Energy Authority.

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<u>Supervisors</u>	**<u>Signature</u>**

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Atomic Energy Authority.

بسم الله الرحمن الرحيم

(سبحانك لا علم لنا الا ما علمتنا
انك انت العليم الحكيم)

صدق الله العظيم

ABSTRACT

In this work, a cold conical cathode ion source has been designed and constructed for production of high brightness ion beam for different applications. It consists of copper anode disc of diameter equals 37 mm and copper conical cathode of inner diameter equals 23 mm, outer diameter equals 37 mm and central aperture of diameter equals 2 mm. Two confinement rings made from perspex insulator of outer diameter equals 37 mm, different inner diameters equal to 5, 7, 9 and 11 mm respectively and thickness equals 2 mm have been used. The two confinement rings are fixed, one on the anode disc inner surface and the other on the conical cathode inner surface to confine the discharge in the central zone between them. The anode disc and the conical cathode are placed inside an insulating cylinder made from perspex material of length equals 5 cm, inner diameters equals 4 cm and outer diameter equals 5 cm.

The working gas has been admitted to the ion source through a hole of 1 mm diameter in the outer surface of the perspex insulating cylinder. The copper collector plate which is used to collect the output ion beam has been situated at a distance equals 4 cm from the ion exit aperture of the conical cathode.

ABSTRACT

The discharge characteristics of the ion source such as discharge current, discharge voltage and output ion beam current have been measured at different anode – cathode distances equal to 6, 8, 10 and 12 mm with different inner diameters of two confinement rings equal to 5, 7, 9 and 11 mm for different pressures using nitrogen and argon gases. It has been found that the optimum anode – cathode distance equals 10 mm with the optimum inner diameter of the two confinement rings equals 7 mm for stable electrical discharge current and a maximum output ion beam current. The maximum output ion beam current which obtained equal to 325 μA and 220 μA at discharge current equals 1.4 mA using nitrogen and argon gases.

The ion collector plate has been placed at different distances from the ion exit aperture of the cathode equal to 2, 3, 4, 4.5, 5, 5.5 and 6 cm respectively at pressure equals 4 x 10^{-4} mmHg and discharge current equals 1.2 mA for obtaining a maximum ion beam current with low divergence angle. It has been found that the maximum value of the output ion beam current emerging from the ion source reaches 340 μA and 255 μA using nitrogen and argon gases at distance between ion exit aperture of the cathode and ion collector plate equals 5 cm which corresponding ion beam divergence angle equal to 1.14^{o} and 2.29^{o} respectively.

Also, the effect of applying negative voltage on the copper collector plate on the output ion beam current has been studied at different distances between ion exit aperture of the conical cathode and ion collector plate equal to 3, 4, 5 and 6 cm at pressure equals 4 x 10^{-4} mm Hg, and discharge current equal 0.4 mA using nitrogen and argon gases. It is found that the output ion beam current increases until reach about 75 % its initial value at negative voltage applied to the ion collector plate equals 1400 volt.

The aspect ratio, S, of the ion source (the ratio between the radius of the ion exit aperture from the cathode to the distance between the ion exit aperture from the cathode and ion collector plate) has been determined at pressure equals 4 x 10^{-4} mmHg and discharge current equals 1.2 mA using nitrogen and argon gases. It has been found that the maximum values of output ion beam current is obtained at aspect ratio equals .02 and reach 340 μA and 255 μA for nitrogen and argon gases respectively.

The feasibility of enhancing the physical properties of Makrofol polycarbonate detector using Ar^+ ion beam irradiation has been investigated.

The effects of Ar^+ ion beam irradiation on the structural and optical properties of Makrofol polycarbonate have been investigated. Samples from 300 μm thickness Makrofol sheet were exposed to Ar^+ ions beam in the fluence range $5 \times 10^{16} – 5 \times 10^{18}$ ion / cm^2.

The transmission of these samples in the wavelength range 250 – 2300 nm, as well as any color changes, was studied. Using the transmission data both the tristimulus and CIELAB coordinates values were calculated for both irradiated and non irradiated samples. Also, the color difference between the non irradiated sample and those irradiated with different doses were calculated. The results indicated that the Makrofol detector has a response to color changes by Ar^+ ion beam irradiation.

In addition, the Ar^+ ions beam induced modifications in the chemical and physical structure of Makrofol polycarbonate were studied using Fourier Transform Infrared Spectroscopy (FTIR). The intensities of the characteristic absorption bands were affected predominantly with the increasing Ar^+ ion dose indicating the degradation followed by crosslinking of this polymer by Ar^+ ions irradiation.

CONTENTS

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INTRODUCTION

Ion sources are devices for production ion beams that may be directly used from the sources or after acceleration. Ion sources have acquired a wide variety of applications. In the field of fusion research, for ion implantation, isotope separators, scientific research, therapy, technical analysis and in a number of industrial fields. The modification induced in polymers due to irradiation can be considered as an important application.

Radiation processing is a useful technology to induce suitable modifications of polymers. In particular, it is an important way to achieve some desired improvements that promise many applications in a wide range of industrial fields. Also, the action of radiations on polymeric solid state nuclear track detectors (SSNTDs) leads to several changes in their properties due to the induced chain scissions and cross-links. Cross linking generally improves the physical properties of polymers and reduces crystallinity, therefore increases the light transmission of the polymer. Degradation has the opposite effect and can be considered as a prompt way to study the aging of polymers and their radiation stability. These modifications depend basically on the type and energy of the incident radiation, the manner in which the incident radiation interacts with the material as well as the type of the polymer used.

Polymers are a familiar part of everyday life that has found widespread applications in many domains of techniques especially in micro-electronics fabrication, space and nuclear technologies. When polymers are exposed to radiation, their properties are changed to a different extent as a consequence of the irreversible modifications occurred in their structure. Some of these changes have been attributed to the scissioning of the polymer chains by incident radiation, breaking of covalent bonds, promotion of cross-linkages, formation of carbon clusters, liberation of volatile species and, in some cases, even formation of new chemical bonds [1-5]. As a consequence of this, the physico-chemical properties like optical, electrical, mechanical and chemical properties of the polymer are modified [6-13].

It has been realized that the radiation-induced effects depend on target properties (composition, molecular weight, etc...), radiation parameters (type, energy, fluence, etc.) as well as on the conditions of irradiation. For example, poly (methyl methacrylate) (PMMA) degraded and became more soluble in solvents when subjected to electron beam or γ-rays. For this reason, PMMA has been used as a positive photo-resist material in lithography for electronic applications. On the other hand, when PMMA was