The Effect of Extracted Broad Beam on Target Material

A.M. Abdel Reheem1,2, M.S. El-Nagdy3, M.I.A. Abdel Maksoud1 and A.H. Ashour1
1Radiation Physics Department, National Center for Radiation Research and Technology, Atomic Energy Authority, Egypt
2Accelerators & Ion Sources Department, Nuclear Research Center, Atomic Energy Authority, Egypt
3Physics Department, Faculty of Science, Helwan University, Cairo, Egypt.

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ABSTRACT

A Broad beam ion source was used for extracting argon, oxygen and nitrogen ion beams by affecting negative voltage on extractor electrode and collector plate. The ion source efficiency was obtained without and with negative extraction voltage. Extracting argon ion beam used for prepared the surface of magnesium alloy AZ31 specimens and the surface roughness of the samples was obtained at different exposure times. SEM, Scanning Electron Microscope and CCD Camera (Charged Coupled Device) pictures were used for show and study the surface morphology of the samples. The surface roughness was obtained using surface roughness tester TR110.

Keywords: Cold Cathode, Extraction Voltage, Magnesium Alloy, Surface Roughness, Surface Morphology.

1-INTRODUCTION

An Ion Source is a device that produces a stream of ions, especially for use in particle accelerators, ion implantation equipment, or for producing and/or tailoring the properties of a thin solid film. Ion sources started to exist in 1886 before designing low-current ion sources, which electron-atom collision mechanisms were used for different applications (1). Ion beams created by broad-beam ion sources have an extensive utilization in a great variety of research and technology applications such as dry cleaning and etching(2,3,4), ion surface modification of solids, thin film processing (ion beam sputter deposition, ion-assisted deposition)(5). Broad beam ion Source with uniform current distributions are needed for many industrial applications and development of commercial ion beam technologies for surface modification of materials is impossible without highly efficient, simple, and dependable ion sources. These and other needs have spurred the development of high efficiency ion sources that can produce ion beams with energy and current and require low or no maintenance (6).

The extraction of ions and ion beam formation process seem to be one of the crucial points in ion implantation, electromagnetic isotope separation. Extraction and focusing are strongly influenced by the geometry of the electrode system (7,8), the plasma parameters inside the ion source chamber as well as by the ion beam spatial charge. The last one may significantly disturb the electrostatic field of lenses, especially in the case when extraction current density reaches a few mA/cm². The amount of the extracted ion current and the divergence of the ion beam strongly depend on the shape of plasma surface, so-called plasma meniscus, in the extraction hole, which depends on construction of the ion source, size of the extraction hole, density of plasma in the chamber, extraction voltage, etc.(9) Extracted ion beam effect on magnesium alloy target although the mechanical properties of Mg alloys are being modified by means of grain refinement and alloying, further improvement especially strengthening is highly desirable(10).
2-EXPERIMENTAL SETUP

The schematic diagram of the cold cathode broad beam ion source is shown in Figure (1). The ion source consists of the plasma production and ion beam extraction system. The extractor electrode was placed at 5mm distance from the grid exit aperture. The plasma is produced by cylinder anode with diameter 60 mm and 85 mm long and stainless steel cathode disk with 120 mm outer diameter separated by Teflon flange. A molybdenum hollow cylinder was placed inside the stainless steel cylindrical anode to release of the plasma heat from the surface of the anode. The pressure can be varied by admitting gas through a needle valve. A 10 kV digital positive power supply was used for initiating the discharge between the anode and the cathode which was connected to the earth. The extractor electrode cylinder was connected to a negative power supply and a collector plate.

Fig. (1): Cold cathode broad beam ion source with extractor electrode

3. RESULTS AND DISCUSSION

3-1- The Effect of the Discharge Parameters on Output Ion Beam Current

Figure (2) shows the electrical discharge current, $I_d$, versus the electrical discharge voltage, $V_d$, for different pressures at collector plate distance equals to 6.25 cm. It is clear that an increase of the discharge voltage was accompanied with the increase of the discharge current and the discharge current is of higher value at low pressure, $P = 2 \times 10^{-4}$ mbar, than that at high pressure, $P = 4 \times 10^{-4}$ mbar at constant $V_d$.

Fig. (2): Discharge voltage versus discharge current for different argon gas pressures at 6.25 cm collector plate distance
Fig. (3): Output ion beam current versus discharge current for various pressures at 6.25 cm collector plate distance using argon gas.

Figure (3) shows the output characteristics of the broad beam ion source. This discharge current $I_d$ was studied against the output ion beam current, $I_b$, for various pressures with a collector plate distance 6.25 cm. It is clear that the output ion beam current is higher in case of low pressure than that in case of high pressure at the same discharge current.

3-2- The Effect of Applied Negative Extraction Voltage on the Extractor Electrode

In this experiment, the performance of the broad beam ion source was modified by applying a negative extraction voltage on the extractor electrode. Also, the effect of applied negative extraction voltage on the output ion beam current was measured. Figure (4) shows the output ion beam current, $I_b$, versus the negative extraction voltage applied on the extractor and collector plate, optimum cathode exit aperture – collector plate distance, which equals 6.25 cm and $I_d = 1.3$ mA using argon gas. It is clear that the output ion beam current increases with increasing the negative voltage applied on the ion collector plate and reaches more than 100 % its initial values at $V_{ext} = -500$ volt. Also a maximum output ion beam current, $I_b = 440 \mu$A, can be obtained at $p = 2 \times 10^{-4}$ mbar.

Fig. (4): Output ion beam current versus negative extraction voltage for various pressures using argon gas at $I_d = 1.3$ mA
Fig. (5): Output ion beam current versus negative extraction voltage for various pressures using nitrogen gas

Fig. (6): Output ion beam current versus negative extraction voltage for various pressures using oxygen gas

Fig. (7): Output ion beam current versus discharge current for various pressures at $V_{\text{ext.}}$ equals -500 volt using argon gas
3-3- The Ion Source Efficiency Without and With Negative Extraction Voltage

The efficiency of the ion source was calculated without and with the effect of applying the negative extraction voltage on the extractor electrode at different pressures using the experimental results of the electrical discharge current and the output ion beam current. Figure (8) shows the ion source efficiency, \( \frac{I_b}{I_d} \), versus the gas pressure, \( P \), at \( V_d = 5 \text{kV} \) without and with applying the negative extraction voltage on the extractor electrode. It is clear from the figure that the ion source efficiency increases with the decrease of the gas pressure. At \( P = 2 \times 10^{-4} \text{ mbar} \) and without extraction voltage, the efficiency of the ion source reaches 14% while in case of \( V_{\text{ext.}} = -500 \text{ volt} \), the efficiency of the ion source at \( P = 2 \times 10^{-4} \text{ mbar} \) reaches 28% using argon gas.

![Graph showing ion source efficiency versus pressure](image)

**Fig. (8):** Ion source efficiency versus the pressure at \( V_d = 5 \text{kV} \) without and with extraction voltage using argon gas

3-4- The Effect of Argon Ion Beam on Magnesium Alloy Specimen

**Sample Preparation**

Metallic target commercial magnesium alloy AZ31 was used, which is machined into specimens with a size of 1 mm thickness, 15 mm length and 5 mm width. Subsequently, the specimens were polished by Grit 1000 abrasive papers. All the specimens were successively cleaned sequentially in an ultrasonic bath of deionized water and acetone each for 8 min. before being introduced into the vacuum chamber.

**A-** The Effect of argon ion beam at conditions, \( I_b = 800 \mu \text{A} \), pressure equals to \( 2 \times 10^{-4} \text{ mbar} \) and energy 5 keV on magnesium alloy was studied at distance 6.25 cm for one, three and five hour. From figure (10) SEM image for magnesium alloy AZ31 shows the surface microstructure before exposure. Figure (11) shows the surface microstructure of specimen after exposure to argon ion beam for one hour, we can observe the surface roughness. Figures (12) and (13) SEM images of specimens’ surface were showing that the surface roughness increases with increasing the time of sputtering to three and five hours. From Figure (13), SEM image of the surface shows that the surface became smooth and illustrates the homogeneous distribution and reveals some cracks than in blank specimen.

**B-** Measuring of surface roughness: the surface roughness tester TR110 – used to measure the surface roughness of the specimens before exposure and after prepared as shown in figure (9). We can
obtain that the surface roughness increases with increasing the exposure time and decreases again, this means that the ion beam completely etched for the surface after five hour. The surface of magnesium alloy AZ31 photographed picture with magnification 400X using optical microscope with CCD camera (Charged Coupled Device) was used to show the surface morphology.

Fig. (9): Surface roughness of AZ31 Mg alloy at different exposure time

Fig. (10) SEM image of AZ31 magnesium alloy before exposure

Fig. (11): SEM surface morphology of AZ31 magnesium alloy after exposure to argon ion beam for one hour
CONCLUSION

The effect of the applied negative extraction voltage on the extractor electrode and Faraday cup on the output ion beam current was measured at different pressures. It was found that, at $V_{\text{ext}} = -500$ volt, the ion beam current increases to more than 100% of its original value when the gas pressure is $2 \times 10^{-4}$ mbar. However, when the gas pressure is $P = 4 \times 10^{-4}$ mbar, its increase in the ion beam current
is about 90% only. The efficiency of the ion source was determined without and with the negative extraction voltage. It can be concluded that, at $P = 2 \times 10^{-4}$ mbar and $V_d = 5$kV, the efficiency of the ion source reaches 14 % and 28 % with extraction voltage -500 volt using argon gas. The effect of argon ion beam on magnesium alloy AZ31 specimens at 1,3 and 5 hours was studied. The surface roughness of Magnesium alloy increases from 0.18 $\mu$m to 1 $\mu$m with increasing the exposure time up to 3 hours and decreases to 0.45 $\mu$m at five hours exposure time. It can be concluded that after an exposure time of five hours, the ion beam can etch the surface of AZ31 alloy.

REFERENCES