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BEAM PROFILE MEASUREMENTS OF DECELERATED MULTICHARGED Xe IONS FROM ECRIS FOR ESTIMATING LOW ENERGY DAMAGE ON SATELLITES COMPONENTS

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Abstract

Electron cyclotron resonance ion source (ECRIS) has been constructed for producing synthesized ion beams in Osaka Univ. Xe is used as fuel for ion propulsion engines on artificial satellites. There are problems of accumulated damages at irradiation and sputtering by low energy Xe ion from the engine. It is required to construct experimentally sputtering yield databases of ion beams in the low energy region, since there are not enough data of satellite component materials. Therefore, we are trying to investigate experimentally sputtering yield on materials by irradiating the low energy single species Xe^{q+} ion beams. However, there is a problem that if the low extraction voltage, the amount of beam currents is not enough to obtain ion beam flux for precise evaluation of sputtering yield data. Thus, we conduct to decelerate Xe^{q+} ion beams required low energy region after extracting at high voltage, *e.g.*, 10kV. We measured the decelerated beam profile with x-y direction wire probes. Then we were able to estimate precise dose of ion fluxes. We are going to conduct irradiation experiments to estimate spattering yield damage on various satellite component materials.

INTRODUCTION

An electron cyclotron resonance ion source (ECRIS) are widely applied for plasma processing and ion beam applications [1]. In our ECRIS, we aim at producing and extracting various ion beams in the single device. It plays an important role in medical field of carbon cancer therapy and aerospace engineering field of satellite engine [2, 3]. The satellite engine uses an ion engine, and Xe is widely used as fuel. Recently, life time of satellites is typically required over 10 years. There are problems of accumulation damages at irradiation and sputtering by low energy Xe ion from the engine. It is necessary to predict lifetime of satellite materials for the design of artificial satellites. It is required to construct sputtering yield experimentally since there are not enough data of satellite component materials by ion beams in the low energy region from several hundred eV to 1keV. In recent years, research on the sputtering yield of satellite materials has been conducted. There is a few data the sputtering data of single species Xe^{q+} ion beams. Therefore, we are trying to investigate experimentally sputtering yield on their materials by irradiating the low energy single species Xe^{q+} ion beams. However, there is a problem that if the extraction voltage is 1kV and Xe^{q+} is extracted, the amount of beam currents is not enough for irradiation. Then the ion beams are usually extracted from high voltage about 10 kV and transported. And we decelerate and irradiate ion beams to the materials in the ion beam irradiation system (IBIS) where we have constructed. In low energy irradiation experiments, there is a problem with uniformity of beam profile on the sample about $1cm^2$(10mm×10mm). We first conduct deceleration experiment to measure the current value of the decelerated low-energy ion beam. We confirmed that the enough amount of current in the low energy region (100~200eV). We measure the two-dimensional profiles of the decelerated beam and the beam position. When we determine that the beam position cannot irradiate the center of the target, we correct the beam position by changing the parameters of the laboratory equipment. The full width at half maximum (FWHM) can be measured from the profile. We can calculate the beam area and the current density from FWHM. We estimated irradiation time and the sputtering yield of the material from the current density. We evaluated the dose amount with high accuracy in the low energy region.

EXPERIMENTAL APPARATUS

Figure 1 shows the top view of our ECRIS and the beam line. The magnetic field of the ECRIS consists of octupole magnet and mirror field by two coils (Coil A, B) and additional coil (Coil C). The currents of Coil A and B are usually fixed 150A and that of coil C is adjusted to optimizing the ion beam current. We use the Xe and Ar gas. The Xe and Ar gases are introduced to the vacuum chamber by mass flow controllers. Then the pressures are monitored by a B-A gauge. The typical operation pressure of Xe and Ar gases are from 3×10^{-4}~1×10^{-3}Pa. The z axis shows the distance from center of the ECRIS along to the geometrical axis. 2.45GHz frequency microwaves are launched by the rod antenna through a coaxial window. The microwave powers are usually 10~50W.

The ion beam is extracted with three-electrodes from ECR plasma. The extractor consists of the PE, the E1 and the E2 electrodes. The voltages are V_{PE}, V_{E1} and V_{E2}, respectively. The V_{PE} is usually 10kV and the V_{E2} is grounded. The V_{E1} can change from 0kV to -6kV. We optimize the V_{E1} to extracted multicharged ion beam within wide range of mass/charge numbers and to reduce the loss of the beam current [4]. Einzel lens 1 (EL1) is set between the E2 and sector magnet. The voltage of EL1 is V_{el1}. V_{el1} is used to control transport of the ion beams. Ion beams are transported into the beam line consisting of sector magnet for analysing and acquiring charge state distribution (CSD) of

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the ion beam currents. Beam currents are measured by the faraday cups (FC1, FC).

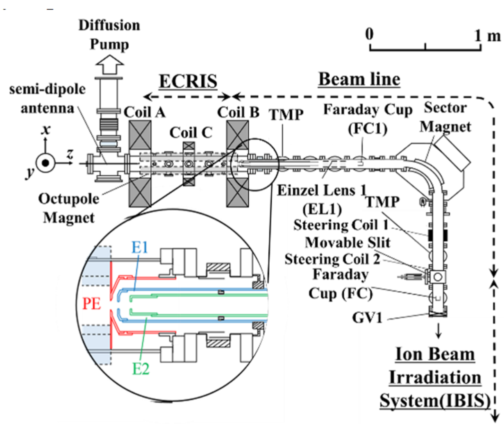

Figure 1: The top view of the ECRIS (Osaka Univ.).

The diameter of the FC is 51mm. The diameter of the FC1 is 50mm. We set the movable slit in front of the FC. It can control absolute value of currents and resolution of the CSD by changing the width with 0~40mm.

Figure 2 shows the side view of the IBIS. The IBIS and the ECRIS are separated by gate valve (GV1). The IBIS is divided by the gate valve (GV2). We call as the beam measurement part from GV1 to GV2, and the beam irradiation part from GV2 or the later. Even during the irradiation experiment, we can exchange irradiation sample easily and quickly by loadlock system of the beam irradiation part. Einzel lens 2 (EL2) is set between the GV1 and GV2. The voltage of the EL2 is V_{el2}. And we use einzel lens 3 (EL3) in the irradiation part. The voltage of the EL3 is V_{el3}.

Figure 3 shows the detail of the beam irradiation part. We measure beam current at FCi in deceleration experiment. The diameter of the FCi is 50mm. X-Y wire probe is used for measuring the two-dimensional profiles of the decelerated beam. Wire probe is made of molybdenum. The diameter of wire probe is 0.5mm. We rotate wire probe when we measure X-direction profile. We move up and down wire probe when we measure Y-direction profile. Casing covers FCi and wire probe. Casing reduces the effects of secondary electrons emitted from FCi and wire probe.

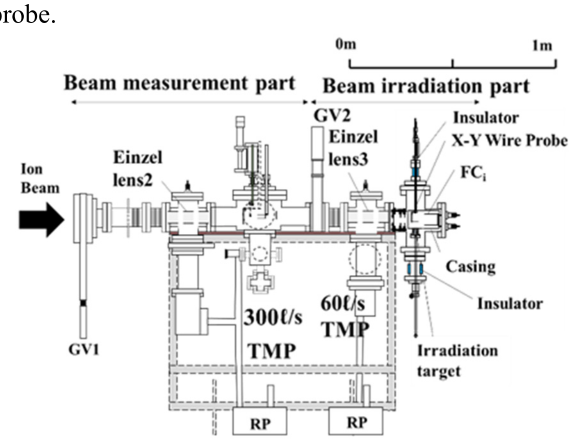

Figure 2: The side view of ion beam irradiation system.

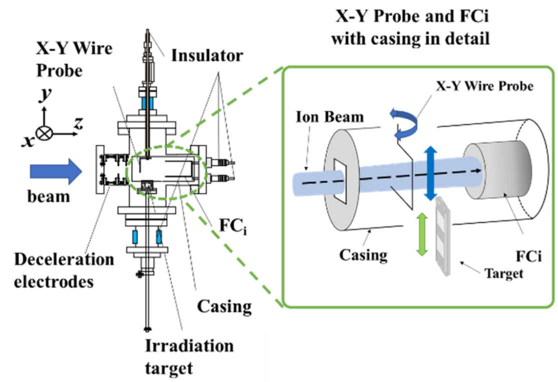

Figure 3: Detail of beam irradiation part.

When we conduct low energy irradiation to the sample, it is necessary to reduce influence of space charge effect of Xe^{q+} ion beams caused by deceleration. Therefore, we construct deceleration electrode (D). We set irradiation target which is rotatable and can apply deceleration voltage. In the irradiation experiment, the target can be irradiated with a decelerated ion beam current by setting the voltage of V_{D} and the target to the same voltage. We apply voltages V_{D} to electrodes. In the deceleration experiment and beam profile measurement, the decelerated ion beam current can be applied to each of the V_{D} voltage and the Faraday cup, Casing and X-Y wire probe at the same voltage.

EXPERIMENTAL RESULTS AND DISCUSSIONS

A. Typical Xe CSD

Figure 4 is typical Xe CSD before deceleration. The *x*-axis represents the magnetic field of the sector magnet, and the *y*-axis represents beam current [μA]. The extraction voltage of ion beam (V_{PE}) is 10kV. Slit width is 40mm. Ion beam is optimized with Xe^{+}. Operating pressure is 1.3×10^{-4}Pa. Incident microwave power is 30W. Reflected microwave power is 10W. Beam currents of Xe^{+} is 66.2μA, Xe^{2+} is 35.6μA, Xe^{3+} is 3.1μA.

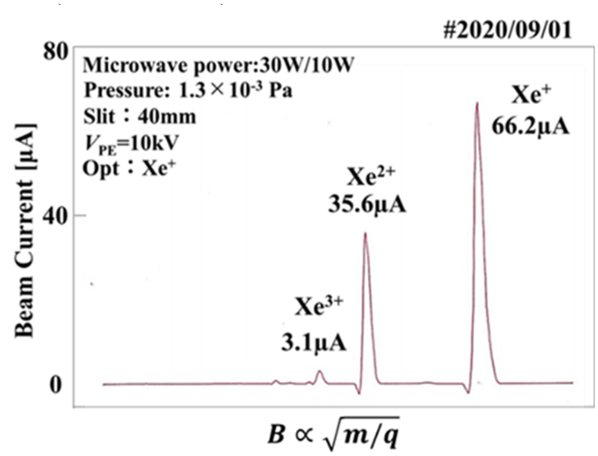

Figure 4: CSD before beam transport.

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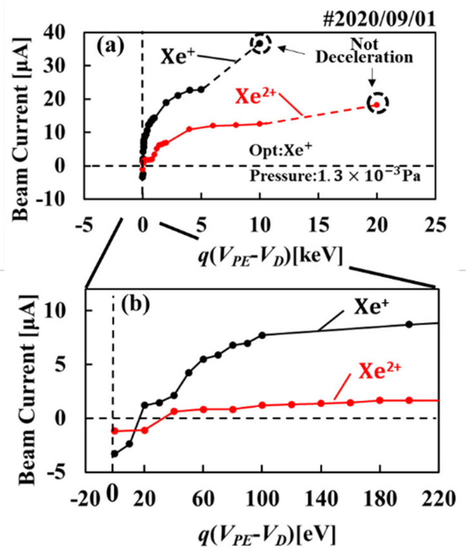

Figure 5: Xe deceleration experiment.

B. Xe Deceleration Experiment

Figure 5(a) and (b) show results of deceleration experiments of $Xe^{+,2+}$. The x-axis represents the energy of the ion beam. V_{PE} is beam extraction voltage and V_D is the beam deceleration voltage. The y-axis is beam current [μA] measured by the FCi. Figure 5(b) shows detail behavior from -20eV to 220eV. The experimental result of Xe^+ is shown in black, and the result of Xe^{2+} is shown in red. We fixed V_{PE} at 10kV and changed V_D from 0kV to 10kV. When we slowed down the beam to reduce the beam energy, the current decreased. We confirmed that beam current is decreased when we decelerated the beam. But we found that there was sufficient current to conduct irradiation experiments in the low energy region.

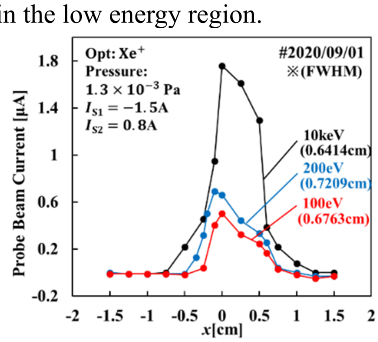

Figure 6: X direction beam profile.

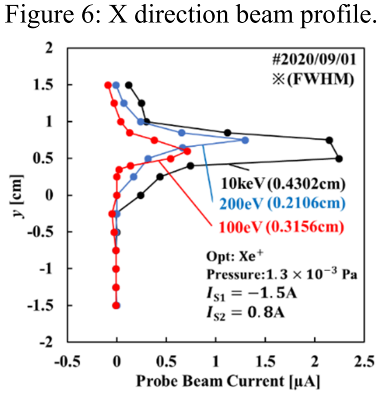

Figure 7: Y direction beam profile.

C. Measurements of Decelerated Xe^+ Ion Beam Profiles

Figure 6 and 7 show profiles of decelerated Xe^+ ion beam. Figure 6 is the x direction profile. Figure 7 is the y direction profile. Black, blue, and red data are 10kV (not deceleration), 200eV (deceleration), 100eV (deceleration). FWHM is descripted under each beam energy. We adjust the beam position by operating currents of steering coil 1 (I_{S1}) and steering Coil 2 (I_{S2}). The current values I_{S1} and I_{S2} are -1.5A and 0.8A. The maximum value of the beam current in the x direction is almost concentrated at x=0. The maximum value of the beam current in the y direction is concentrated at y=0.5~1.0. We need to adjust the beam position so that the maximum value is measured at the center in the future.

SUMMARY AND FUTURE PLAN

We measured the current value of the Xe ion beam in the low energy region by deceleration experiments, and confirmed that sufficient amount of currents for conducting irradiation experiments. We succeeded in acquiring the profile of decelerated Xe^+ ion beam. We evaluate the dose amount with high accuracy from beam profile. In the future, we plan to improve the equipment to obtain a larger dose and conduct irradiation experiments for various materials.

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