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Measurement of metal ion beam charge distribution depending on the beam radius using MEVVA ion source

Seung-Ho Lee[a, b], Hyeok-Jung Kwon[a*,b]
[a]*Accelerator Development and Research Division, Korea Atomic Energy Research Institute, Korea*
[b]*Radiation Science Accelerator and Quantum Beam, University of Science and Technology*
[*]*Corresponding author: hjkwon@kaeri.re.kr*

1. Introduction

Among the many ion sources, the vacuum arc ion source generates plasma using vacuum arc discharge as the name suggests. This ion source generates plasma through vacuum arc discharge onto the cathode, heating, melting and ionization. One of distinguish is extraction of high current ion beam. In addition, it can be extracted almost metal ion plasma in the Periodic table [1]. Recently, the metal ion beam facility was developed based on the metal vapor vacuum arc (MEVVA) ion source at Korea Multi-purpose Accelerator Complex [2]. When the arc discharge occurs in the ion source, extremely high arc current flows about few tens or few hundreds ampere between cathode and anode. In this study, we report results of metal ion beam charge distribution depending on the beam radius.

2. Experiment and Results

2.1 Metal ion beam facility based on MEVVA ion source

The metal ion beam facility is consisted of the ion source and the irradiation chamber. In general, the MEVV ion source operates pulse mode with repetition rate of few to few tens Hertz and pulse width of few hundreds microsecond. It is installed on the top of the chamber. Figure 1 is shown the MEVVA ion source image and schematic diagram. On the top of the ion source, there is arc discharge part. After arc discharge occurs at this part, the metal plasma is generated, and the metal plasma is diffused space by the plasma density gradient from cathode to drift space. And bottom site of the MEVVA ion source is ion beam extraction site. The three grids are installed, and the ion beam in extracted and accelerated by girds. The configuration of three grids is accel-decel structure. First grid, the nearest plasma, is extraction grid. A positive potential is applied to extraction grid in order to form the electric field for extraction plasma. Middle grid is suppressor gird, and it is generally applied with several few negative potential to prevent backflow of electron from irradiation chamber. And third grid is ground grid [3].

The irradiation chamber is consisted of the sample stage, ion beam diagnosis system and vacuum system. The sample stage was developed for efficient ion beam irradiation. In case of the ion beam facility, metal ion beam can not control, after extraction ion beam, because there is no any component such as charge separation. Therefore, sample is placed on the sample stage, and beam irradiation can be possible on the desired point using control sample stage. And the ion beam parameter such as ion beam current and profile can be measure by ion beam diagnosis system.

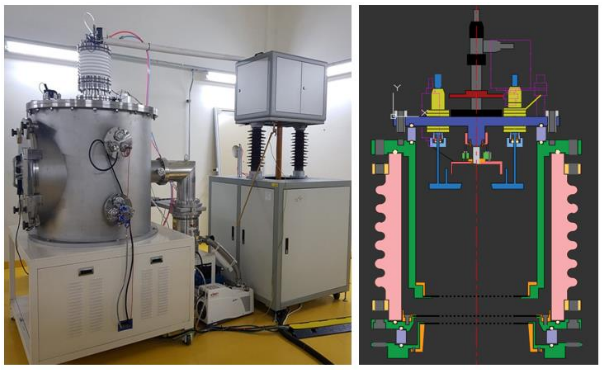

Figure 1. metal ion beam facility (Left : configuration of metal ion beam facility based on the MEVVA ion source, right : schematic of the MEVVA ion source)

2.2 Ion beam profile from the MEVVA ion source

The extracted metal ion beam from the MEVVA ion source moves directly to the sample chamber and is irradiated to the sample through the collimator. The diameter of the beam is 200 mm. Metal ion beams have Gaussian distribution because there is no device such as an electromagnet between ion source and sample.

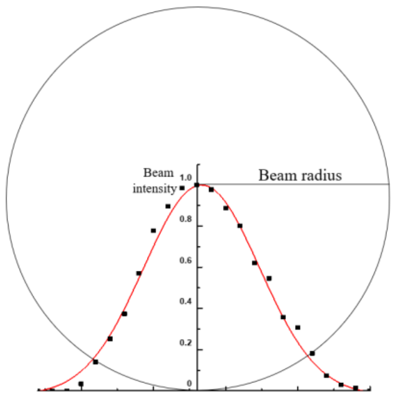

Figure 2. Radial profile of irradiated metal ion beam.

Figure 2 shows the measured metal ion beam profile. The ion beam profile was measured using a multi-wire beam profile and then fitted. The results show that ion beams have Gaussian distribution [4].

2.3 Distribution of ion beam depending on the radius

In general, the MEVVA ion source extracts the multiple charge ion beam between 1+ to 5+ or more. In case of the metal ion beam facility at KAERI, charge distribution is essential to determine the total dose of metal ion beam irradiation. In the last study, we measured the average charge state of the chromium ion beam. However, the diameter of the metal ion beam is approximately 200 mm. Therefore, it is necessary to determine ion beam charge distribution by beam radius.

The charge state of the metal ion beam was measured at 3-points with center, RMS radius and between. The chromium ion beam was irradiated on the silicon substrate, and irradiation parameters were 3 Hz of repetition rate, 700 μs of pulse width, 8 W of arc power, 30 kV of extraction voltage, and ion beam was irradiated for 100 minutes.

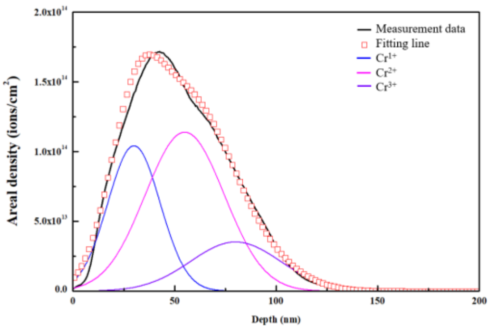

Figure 3. Chrarge distribution at the RMS radius.

Table I: Average charge distribution depending on the beam radius

Position	Center	Between	RMS radius
Average charge distribution	1.8	1.8	1.8

Figure 3 shows the result of charge distribution at the RMS radius. This figure shows that chromium ion beams are distributed from Cr^{1+} to Cr^{3+}, and the fitting curve matches the measurement data well. One of the features of the MEVVA ion source is the cathode spot. The assemblage of cathode spots gives rise to a dense plasma of cathode material that streams away from the cathode as a jet. And the metal plasma diffuses into the drift space due to the pressure gradient. The ion streaming velocity, or drift speed, is typically 1−3 cm /μs [3]. This means that the charge distribution in the metal ion beam exists evenly. Therefore, the charge distribution of the metal ion beam is the same within the beam radius.

3. Conclusions

In this study, the charge distribution depending on the beam radius was measured. The charge distribution in the chromium ion beam was measured depending on the beam radius. As a result, the charge distribution is the same depending on the beam radius. Therefore, the total dose from the MEVVA ion source can be estimated by the beam current with the beam radius.

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