The Multiple Ion Charge State Measurement of the Metal Vacuum Arc Ion Source at the KOMAC

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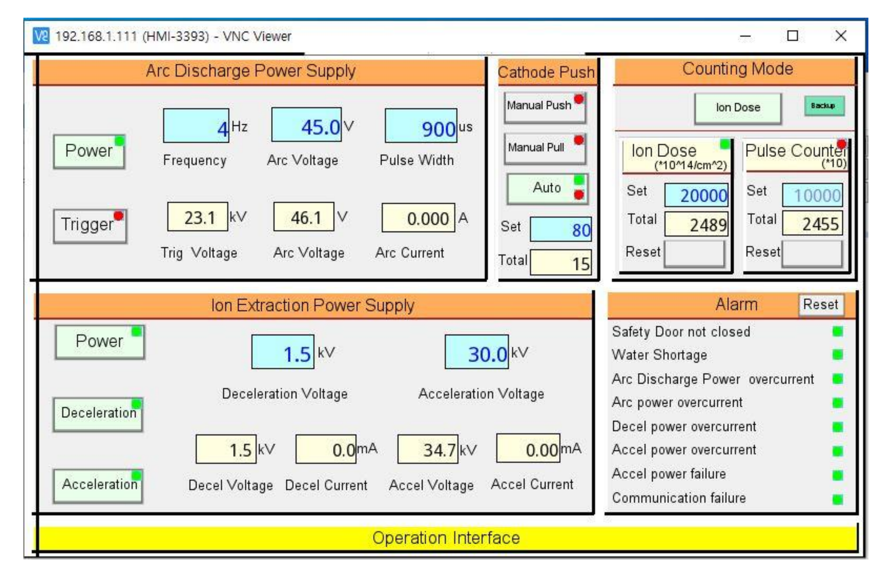
Abstract

The metal vapor vacuum arc (MEVVA) ion source can extract high current metal ion beam using the vacuum arc discharge. The vacuum arc discharge occurs between cathode and anode in the MEVVA ion source, the arc current is concentrated on the cathode surface with small spot. And the cathode surface is melted by concentrated arc current, therefore cathode is heated, vaporized, and ionized into the plasma state. For these principles, the MEVVA ion source can also extract wide metallic ion species such as the high melting temperature materials (tungsten, graphite), pure semi-conductor materials (silicon, germanium) into ion beam. And the MEVVA ion source generates the metal plasma of the multiple charge state. The MEVVA ion source was installed on to the vertical ion beam facility at the Korea Multi-purpose Accelerator Complex (KOMAC). So, the metal ion beam is directly irradiated by the vertical direction from top site (ion source) to bottom site (sample) and the metal ion beam can irradiate large area. Therefore, the metal plasma of the multiple charge state is directly extracted and accelerated by the extraction grid. In these reasons, the metal ion beam has energy distribution. In this study, we conduct the analysis of the metal ion beam charge state with the nickel cathode. The metal ion beam was irradiated by silicon wafer at the same condition, and it is analyzed by the Dynamic Secondary Mass Spectrometry(D-SIMS). Finally, we measure the metal ion charge distribution.

MEVVA Ion Source & Facility inspection

< Fig. 1 > MEVVA Ion Source of KOMAC

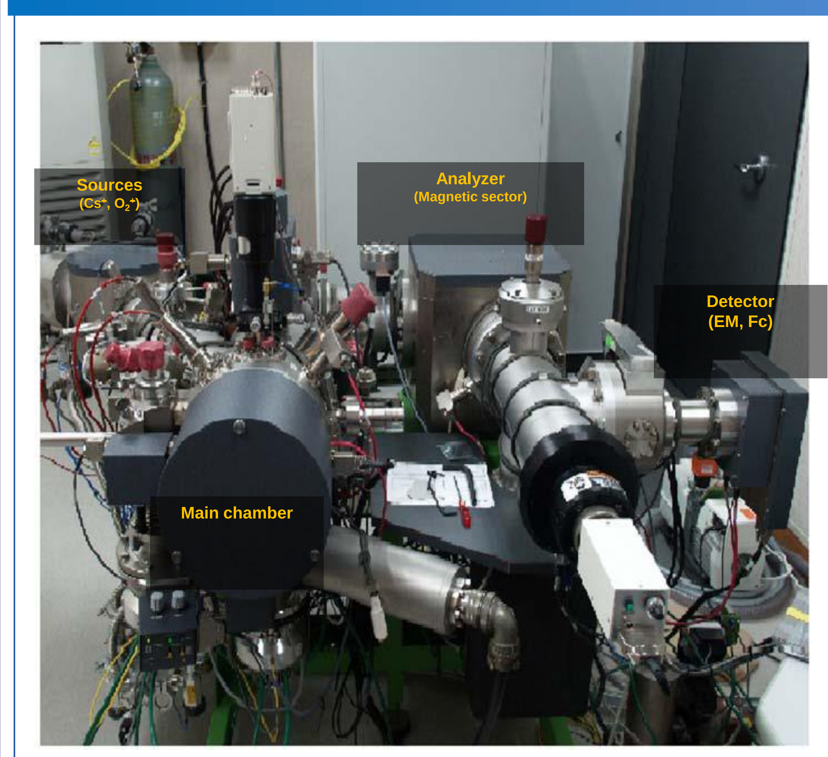
- Fig. 1 shows the MEVVA ion beam facilities. It is consist of ion source, vacuum chamber, vacuum pump and high voltage supply system.
- On the top of chamber, the MEVVA ion source is located and metal ion beam is extracted vertically.
- The MEVVA ion source generates metal plasma by vacuum arc discharge and it is operated pulse mode,
- And Inside of chamber, sample stage is setup and it can be move in two axis.



< Fig. 2 > MEVVA ion source control program

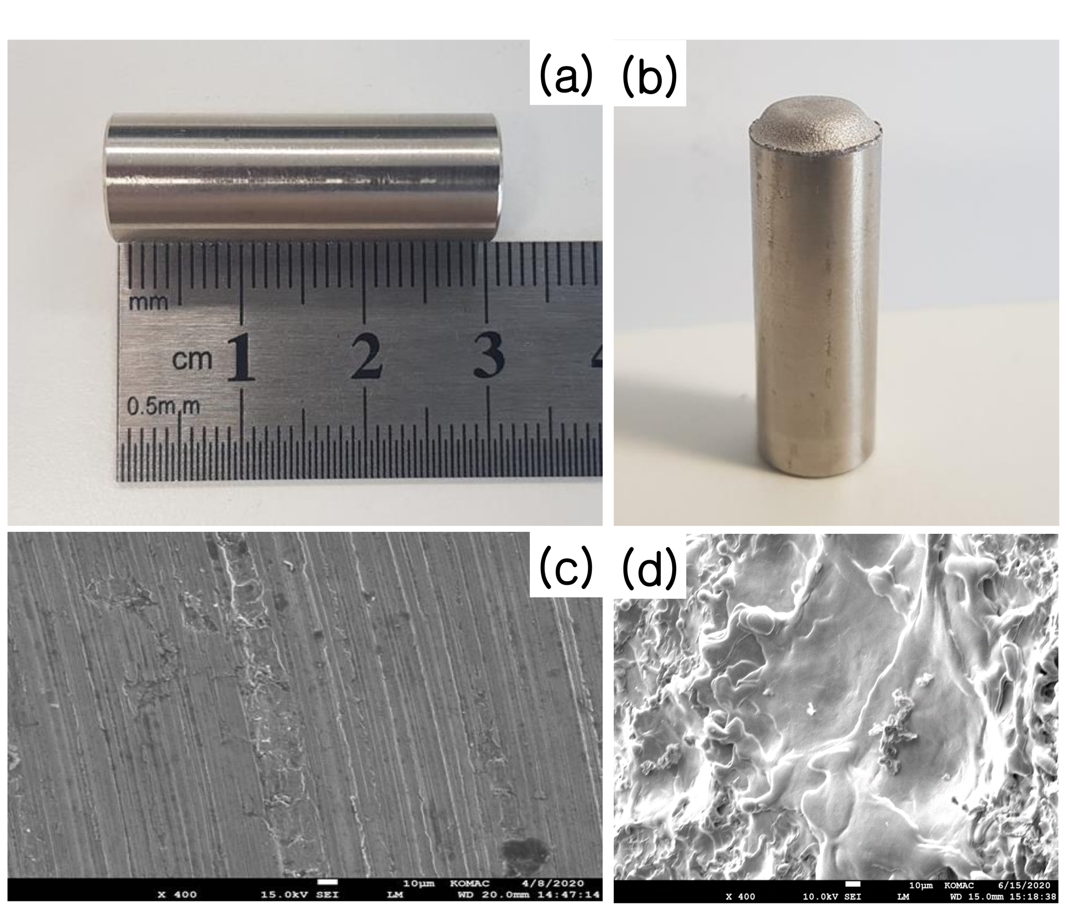
- Fig. 2 shows the MEVVA ion source control program. It mainly controls the arc discharge power and the ion extraction power.
- The arc discharge power can adjust repetition rate, arc voltage and pulse width and these are 1-20 Hz, 40-100 V, 200-1500 usec respectively.
- And ion extraction power can adjust suppress voltage and extraction voltage, and these are 0-2 kV, 30-80 kV respectively.
- Also, it includes an interlock system. If overcurrent in the supply or safety door open, the interlock system is activated and shut down.

Experimental & Results



< Fig. 3 D-SIMS at KIST>

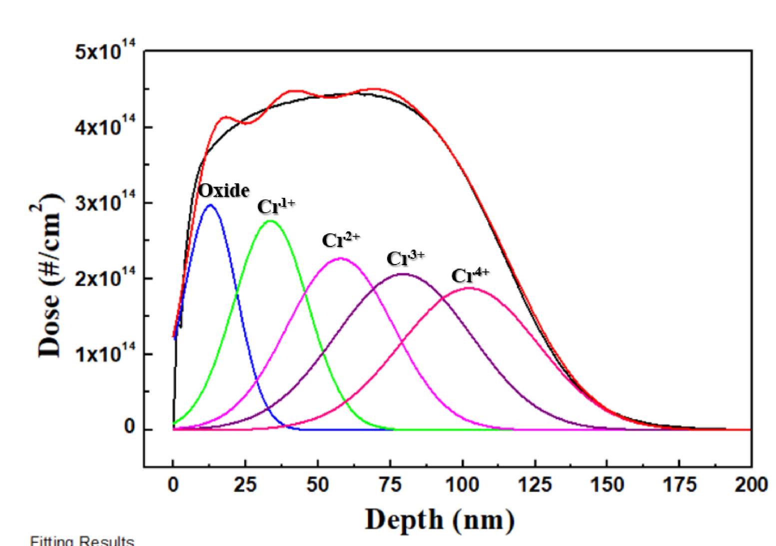
- Fig. 3 shows the D-SIMS analysis facility at the KIST.
- The D-SIMS (Dynamic Secondary Ion Mass Spectrometry) is the mass spectrometry of ionized particles which emitted when a surface is bombarded by energetic primary particles, usually ions.
- We analyzed D-SIMS analysis to determined charge distribution of metal ion beam using MEVVA ion source.
- The samples for D-SIMS analysis were prepared by irradiation of the metal ion beam on a silicon wafer.



< Fig. 4 The metal Cathode of the MEVVA ion source

(a) Image of cathode,
(b) After discharging cathode,
(c) Cathode surface SEM image before discharge,
(d) Cathode surface SEM image after discharge >

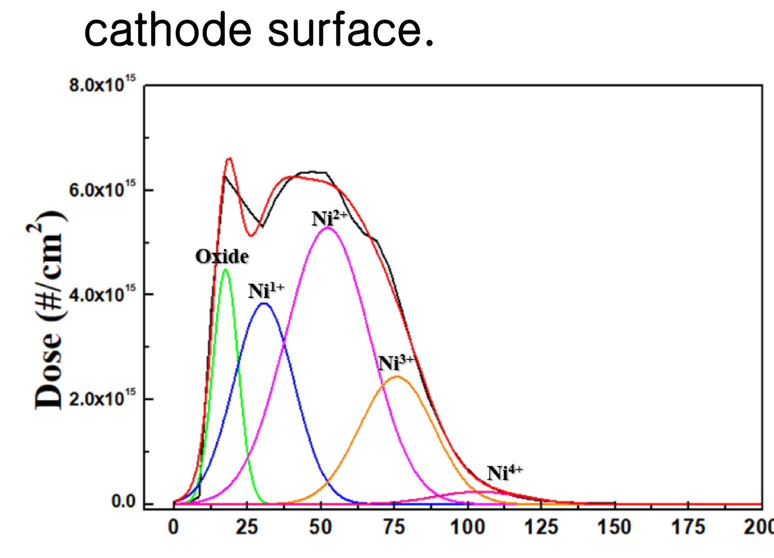
- Fig. 3 shows the metal cathode of the MEVVA ion source. It is cylindrical in shape and has a length of 30 mm and a diameter of 10 mm.
- The vacuum arc discharge is occurred on the cathode surface in the MEVVA ion source. As the discharge proceeds, the cathode surface is gradually etched and the cathode surface after discharge is shown in Fig. 3 (b).
- Before and after discharge, the cathode surface was determined by SEM image, which is shown in Fig. 3 (c) and (d).
- After discharge, the cathode surface shows craters due to vacuum arc discharge. On the crater, the metal plasma is generated and etched.



	SRIM data	Peak (nm)	Area	%
Oxide layer	-	12.81	6.83 E15	13.84
Cr1+	30.6	33.66	8.91 E15	18.05
Cr2+	55.1	57.70	1.04 E16	21.07
Cr3+	79.8	79.50	1.21 E16	24.52
Cr4+	104.8	102.22	1.11 E16	22.49

< Fig.5 D-SIMS analysis results of the Cr ion beam >

- Fig. 5 shows the D-SIMS analysis results of the Cr ion beam. Peaks were deconvolution based on SRIM data, and peak position is similar to the SRIM data.
- The ion charge state are from Cr^{1+} to Cr^{4+}, and average charge state is 2.24.
- There is also on more peak in front of Cr^{1+}, which is the oxide layer on the cathode surface.



	SRIM data (nm)	Peak (nm)	Area	%
Oxide layer	-	17.41	4.48 E15	11.33
Ni^{1+}	29	30.47	3.84 E15	23.35
Ni^{2+}	51.7	52.13	5.28 E15	44.90
Ni^{3+}	74.7	75.64	2.44 E15	18.19
Ni^{4+}	98.3	103.73	2.43 E14	2.2

< Fig.6 D-SIMS analysis results of the Ni ion beam >

- Fig. 6 shows the D-SIMS analysis results of the Ni ion beam. Peaks were deconvolution based on SRIM data, and peak position is similar to the SRIM data.
- The Ni ion beam charge state is also from Ni^{1+} to Ni^{4+} similar to Cr, but it can be seen that the distribution is different. And the average charge state on the Ni cathode is 1.77.
- The Ni also has an oxide peak in front of Ni^{1+}. This is the oxide layer that was first attached to the surface of the cathode. Cathode conditioning is required for a certain period of time to remove that oxide layer.

Conclusion & Future Plan

- In this study, the metal ion charge distribution of the metal ion beam extracted from the MEVVA ion source. Then the calculated data and the experiment data were compared, and the oxide layer peak also was determined.
- In the future, we will conduct the conditioning time for oxide layer removal and the determine ion charge distribution charge with operation condition.

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