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Titanium and Magnesium Ion Beam Extraction in a Metal Ion Beam Facility

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1. Introduction

As demands and interests in applications of ion beams in materials science and engineering have increased, even greater diversity of ion beams is required in order to utilize the more dramatic interaction characteristics of metal ions with materials. KOMAC has providing the metal ions such as Cr^+, Fe^+, Co^+, and Cu^+ metal ions to users [1]. Additionally, we extracted Ti^+ and Mg^+ metal ions to satisfy increasing user needs. The optimal extraction conditions for Ti^+ and Mg^+ ion beams were acquired successfully and we are planning to provide new metal ion beam to beam users.

2. Methods and Results

2.1 Metal Ion Beam Facility

The metal ion beam facility consists of a bernas-type ion source, a mass separation magnet, a slit, an acceleration tube, a magnetic quadrupole, an X-Y electrostatic scanner, a Faraday cup and a target chamber, as shown in Fig 1. The metal ions extracted from the ion source are accelerated with a maximum 150 keV/1 mA. Also, the desired beam shape and size were obtained by adjusting the electrostatic scanner and the magnet quadrupole. At present, the metal ion beam facility supports beam service for chromium (Cr^+), cobalt (Co^+), iron (Fe^+) and copper (Cu^+) ions and we are planning to adds one or two ion species annually [2].

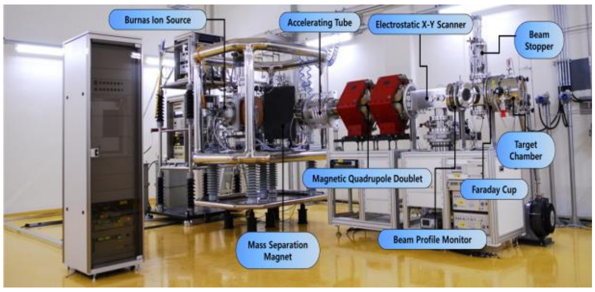

Fig. 1. Metal ion beam facility at KOMAC (150keV / 1mA)

2.2 Vapor Pressure Temperature

Pure elements tend to be compounds in the ionization process in case of the temperature applied to the crucible from the heater of the ion source does not match and plasma is difficult to keep stable. Therefore, vapor pressure temperature is one of the most important parameters to extract the metal ion beam and we confirmed it through literature research by vacuum pressure change as shown Table Ⅰ.

The alumina crucible was indirectly heated by the radiant heat of the cylindrical heater inside the ion source as shown in Fig. 2 and the temperature was measured with a thermocouple located at the bottom of the crucible. Generally, it should be heated to a temperature above the melting point a temperature in order to vaporize metal chloride ($CrCl_3$, $CoCl_2$, $FeCl_2$, CuCl, $MgCl_2$, $TiCl_3$ etc.) contained in the crucible. In case of Co^+ ions, the vapor pressure temperature (@ $1x10^{-3}$ Torr) is 487°C as shown Table Ⅰ and it is around 350°C in actual experiment(@ $2x10^{-5}$ Torr). This is expected due to the difference I n vacuum value. All experiments are carried out based on the parameters shown in the following Table Ⅰ. Crucible current is applied current for each experiments. Actually, it is structurally difficult to measure the exact crucible temperature for ion source operation. So there is error value between theory and experiment but the vapor pressure tendency can be confirmed sufficiently.

Table Ⅰ: Vapor pressure temperatures (°C) by ion species

	Crucible Current (A)	Melting Point [°C]	E-3 [Torr]	E-2 [Torr]	E-1 [Torr]	1 [Torr]
$CrCl_3$	104	1,150	512	561	618	684
$CoCl_2$	85	740	487	537	594	660
$FeCl_2$	75	677	360	420	490	570
CuCl	33	430	650	740	852	992
$MgCl_2$	130	714	500	570	660	776
$TiCl_3$	41	425	259	304	358	423

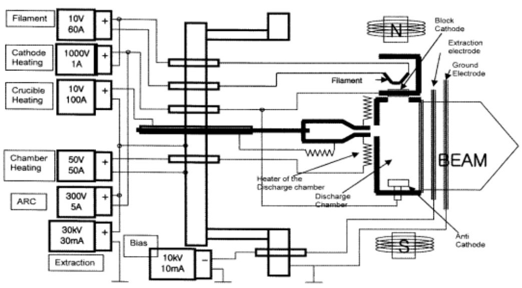

Fig. 2. Bernas type ion source schematics

2.3 Ti^+ Ion Beam Extraction

The mass separation magnet was a 90° dipole [2-3]. Fig 3 shows the mass separation magnet current by atomic mass when it is extracted at 9 kV from the ion source. Ti^+ ions was observed at around 10 A of electromagnet current as shown Fig 3. Through Table Ⅰ, the melting point of $TiCl_3$ is similar to the melting point of CuCl chloride. Therefore, we performed experiment under the condition similar to Cu^+ beam extraction. In the Ti^+

experiment, the plasma was stably maintained when the crucible current was 41~43 A (The applied current was 36~39 A in the Cu experiment). It is around 390 °C in actual experiment (@ $2x10^{-5}$ Torr). As a result, Ti^+ beam extraction was successfully performed based on the Cu^+ experiment. Fig 4 shows Ti+ ion beam experiment conditions and Fig 5 shows Ti^+ beam irradiated polymer (left) and measuring uniformity using the RGB scan method (right). The uniformity is about +- 2% at 4cm x 4cm size.

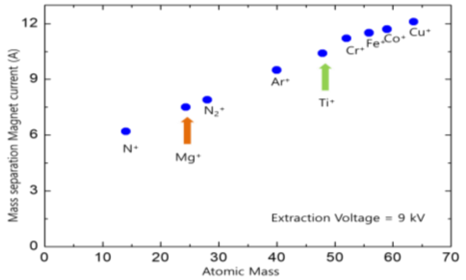

Fig. 3. Magnet current dependence of the Atomic mass

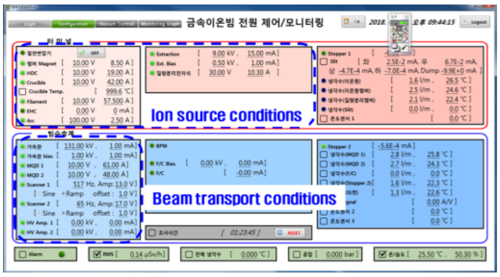

Fig. 4. Experimental conditions for Ti^+ ion beam

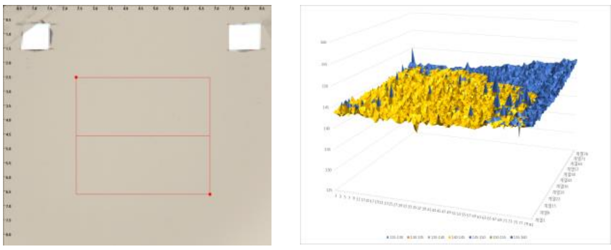

Fig. 5. Ti^+ beam irradiated polymer (left) and uniformity measurement (right, red area of left)

2.4 Mg+ Ion Beam Extraction

The melting point (714℃) of $MgCl_2$ is similar to the crucible current (82~86A) in the cobalt beam experiment and boiling point (1412℃) of $MgCl_2$ is similar to the crucible current (100~104A) in the chromium beam experiment. However, the melting point is a condition in which the chloride starts to melt, and in order to maintain the plasma stably, it must be operated at a higher temperature. Therefore, when the arc current was confirmed at 85 A near the melting point, no plasma was generated. After that, the crucible current was continuously increased (120A or more) until arc current was stable for experiments. Mg+ ions was observed at around 7.5 A of electromagnet current as shown Fig 3. However, we still need more feasibility study for more stable and high intensity Mg^+ beam.

3. Conclusions

We have successfully extracted Ti^+ and Mg^+ metal ion beam using $TiCl_3$ and $MgCl_2$ chloride. Vapor pressure temperature is one of the most important parameters to extract stable and high intensity metal ion beam. Based on the needs of users in the future, we plan to add 1~2 metal ion species every year.

4. Acknowledgments

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