A New Design of the Sputter type Metal Ion Source and its Characteristics of Ion Beam Extraction

W. Kim, B.H. Choi, J.T. Jin, K.-S. Jung
Korea Atomic Energy Research Institute, Taejon, 305-606, Korea
S.H. Do
Pusan National Fishers University, Pusan, 608-737, Korea
and
K.H. Chung
Seoul National University, Seoul, 151-742, Korea

Abstract

In an attempt to get a high current metal ion beam of various solid elements including refractory metals, a gaseous duoPIGatron ion source was modified by placing a grid type cathode and a sputter target in the PIG chamber. Tungsten mesh was adopted as the cathode grid, and Ar gas was used for a support gas for sputter induction. For Cu, Fe, and Al, ion current and ratio of the metal ion were obtained at various conditions of sputtering voltage, support gas pressure, arc current, magnet current, and beam extraction voltage. Results showed that the metal current density is linearly changed with the sputtering voltage and magnet current. Ratio of the metal ion in the total current is larger at lower support gas pressure. Current densities for Al, Cu, and Fe were 4 mA/cm^2, 5.5 mA/cm^2, and 2 mA/cm^2, respectively, at an arc current of 3 A, extraction voltage of 20 kV, and a sputtering voltage of 1 kV. Ratios of the metals in the extracted ion currents were 9%, 8%, and 5% for Al, Cu, and Fe, respectively.

I. INTRODUCTION

Metal ion source technology has been devloped for the separation of isotopes, preparation of isotope targets for nuclear physics, doping of semiconductor materials, and the injector section for the heavy ion accelerators. Studies on the modification of surfaces as metals, ceramics, or polymers were started more than twenty years ago and parts of the results are applied to the industry[1]. For example, ions of Cr, Mo, and Ti are used to strengthen the corrosion resistances and wear properties of engineering materials like steels[2].

Ion sources capable of producing currents of tens of mA or current densities of a few mA/cm^2 are required for the wider utilization of the technology in industries. However, those ion sources as Freemann type or CHORDIS type[3,4] thus far developed until now have extraction current capabilities for the metal ions of only a few milliamperes. The conventional heating-evaporation type ion sources have the problem of metal condensation. The trend of the development of ion sources are thus centered on those producing large currents like MEVVA type ones[5].

II. PRINCIPLES OF PLASMA GENERATION BY THE ION INDUCED SPUTTERING

The concept and principle of the sputter type plasma generator with a single discharge chamber are shown in Fig.1. Arc discharge is maintained in the chamber filled with an inert gas by applied voltage between the filament and the mesh-type grid. Application of a few kV between grid and the target induces ion acceration from plasma to the target. Sputter-generated electrons and neutral particles enter the chamber through the grid spacings. The neutral particles further ionizes in the chamber, thus being extracted as ion beams or induces next sputtering. For a cylindrical target, average sputtering angle of the secondary neutral particles is normal to the target surface and particle density is expected to be maximum at the centre of axis.

III. SPUTTER TYPE ION SOURCE

A variance of the dual discharge chamber DuoPIGatron ion source is made for the implementation of the ion induced sputtering[Fig.2]. This modification composed of the intermediate electrode with a filament inside, the main Penning discharge chamber for the plasma generation, and the ion beam extraction system.

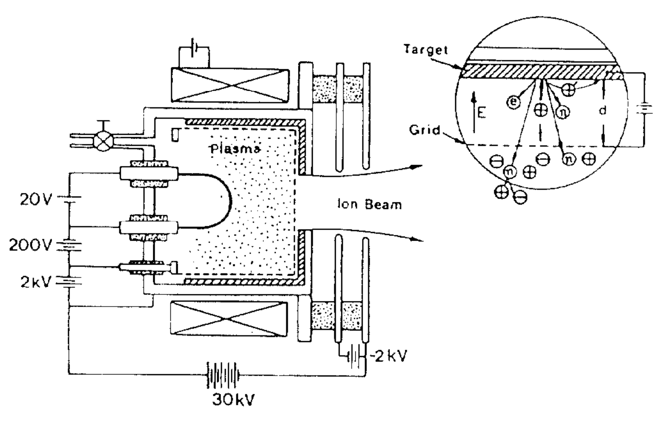

Fig.1 Principle of a Sputter Metal Ion Source

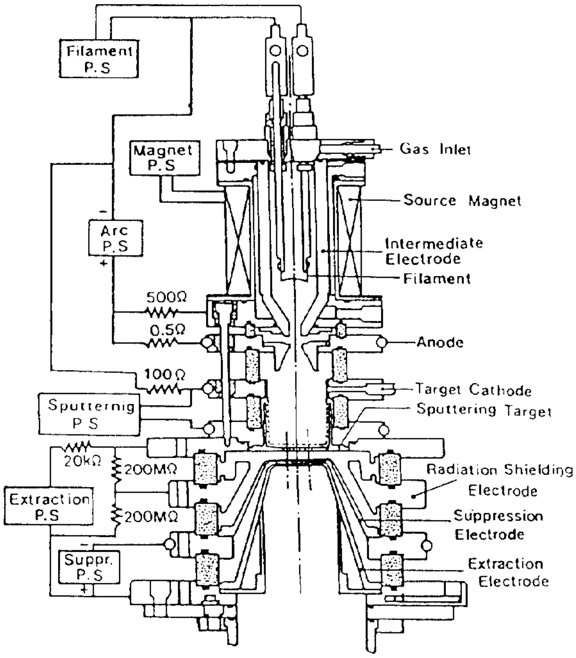

Fig.2 Schematic Diagram of a Sputter-Type DuoPIGatron Metal Ion Source

A. Plasma Generation

The PIG discharge chamber consists of one anode and a grid-type cathode. Electrons entering through the hole of the intermediate electrode to the PIG chamber are accelerated and produce ions through collision with neutral particles. Others reach the cathode and re-accelerated to the anode, making another collisions with neutral particles. This multiple ionization process is enhanced by the axial magnetic field formed by the source magnet. The target section to produce the metal ions consists of a grid and a target. Wall side and bottom side of the grid cathode are meshes of nickel and tungsten, respectively. Target is bucket-shape holding the grid inside and has a hole at the bottom. Application of 1-2 kV between grid and target induces acceleration of ions from the plasma to the target. Secondary electrons, ions, and neutral particles are ejected from the bombarded target and the ejected electrons and neutral particles pass through the grid to enter the PIG chamber, thus making added ionizations. Within the experimental conditions that the yield of the ejected neutral particles is larger than 1, self-sustained discharges with only sputtered particles become possible.

B. Ion Beam Extraction System

Ion beam extraction is made possible by the proper attachment of an accelerating electrode and a decelerating electrode to the rear of the target. The target has a hole of 5.5 cm in diameter and an accelerating electrode is distanced 6 mm from the target. Behind the accelerating elctrode, the decelerating electrode is located at 2 mm apart.

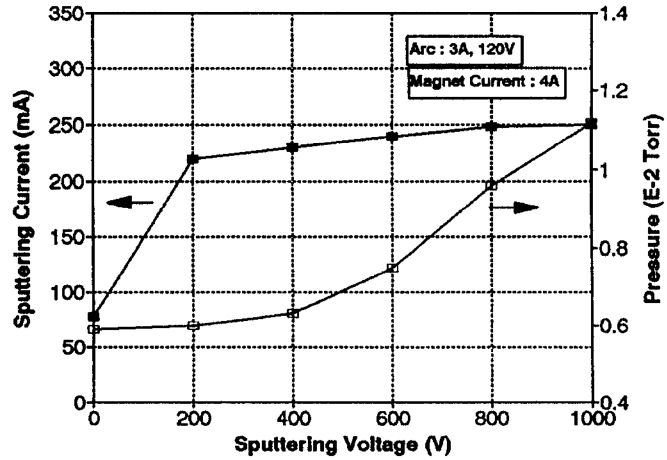

Fig.3 Pressure in PIG Chamber and the Sputtering Current depending on the Sputtering Voltage

Collisional losses of ions with the electrode walls are minimized by the proper ion-optical designing of the electrodes dimensions. Neutral particles through the system were rapidly removed through vacuum slots.

IV. CHARACTERIZATION EXPERIMENTS

The 100 kV gas ion implanter in operation at KAERI was replaced of its ion source by the metal ion source. A power supply(5kV, 1A) was added to the system for the sputtering. Discharge pressure, extraction current, and the ion masses were measured for targets of Al, Cu, Fe, and C. Ion mass separation was performed by a magnetic dipole composed of a permanent magnet. Extraction currents were measured with the scanning Faraday cup.

A. Characteristics of the plasma formation

Each of the targets was tested for the plasma characteristics using Ar as the support gas. Sputtering current and pressure were measured for voltage variations using Al as the target at an Ar pressure maintained at 7.5 x 10^{-3} torr(Fig.3). Increase of the neutral particles with the sputtering energy would be the cause of the increased pressure at high voltages. Saturation of the sputtering current at larger than 200 V is thought to be from the space charge limit effect.

B. Beam Extraction Characteristics

Extaction currents for each kind of ions with the Al target at a constant discharge condition are shown in Fig.4. Total ion current is constant for the sputtering voltage variations, but Al ion current increases with sputtering voltages. The increase can be ascribed by the increase of sputtering yield. In comparision with the Al ion current and the sputtering yield at various voltages, the increase of the current with sputtering voltage is thought to be resulted from the increased sputtering yield with voltage. Efficient confinement of ions and electrons by the strengthened magnetic field can increase the resultant current densities(Fig.5).

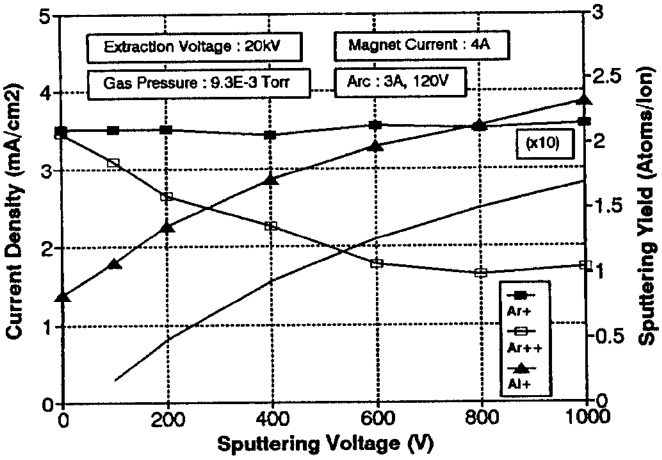

Fig.4 Ion Current Densities and Sputtering Yield as a fuction of Sputtering Voltage

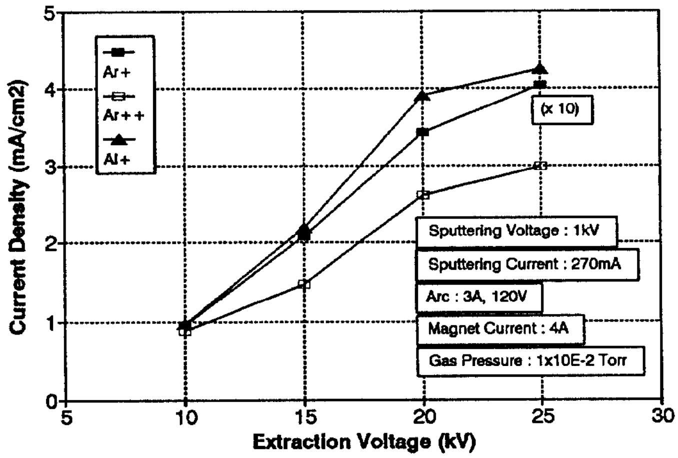

Fig.7 Ion Current Density with Aluminum Target System depending on Extraction Voltage

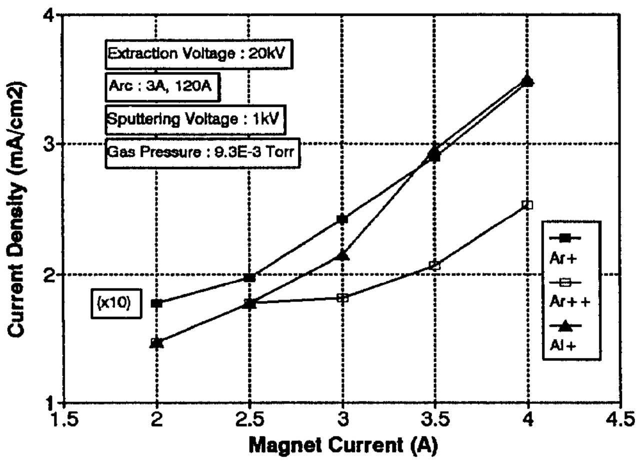

Fig.5 Ion Currents with Al Target System depending on Magnet Current

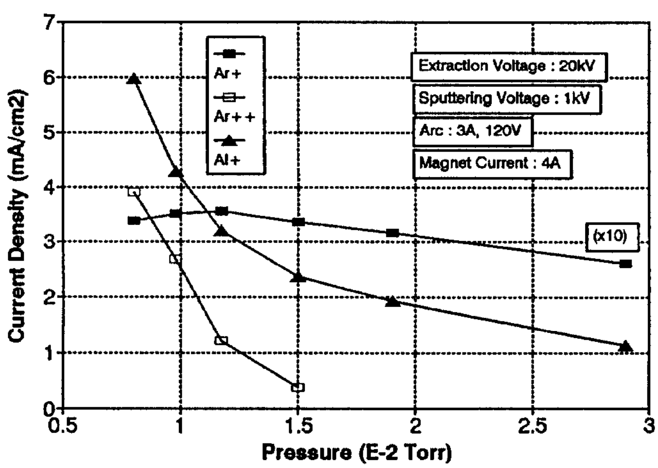

Fig.6 Ion Current Density in Aluminum Target System as a function of Feed Gas Pressure

Each component of the ion current depending on the feed gas pressure is shown Fig.6. The total Ar ion current shown as Ar^+ is constant for the pressure range. The figure shows the self-sustained discharge as the major mechanism for the generation of the neutral particles. Fig.7 shows the ion current densities depending on the extraction voltage. For Al, Cu and Fe, the current densities were 4 mA/cm^2, 5.5 mA/cm^2, and 2 mA/cm^2, respectively, at similar operational conditions.

V. CONCLUSION

A sputter-type ion source which can produce ion beams of the most metallic elements including refractory ones has been devloped by applying the principles of ion induced sputtering and reflex arc discharge. Results of the performance test showed that the pressure of the discharge chamber and the extracted current density of the metal ion components were increased linearly with the sputtering voltage. Extraction current density of the metal ions were a few mA/cm^2 and the ratio of the metal ions and total ions was about 10 %. Continuous metal ion beams with current of a few mA were obtained.

VI. REFERENCES

[1] P. Siosansi, Mat. Sci. & Eng., 90, 373 (1987)
[2] M.I. Guseva, M.V. Atamanov, Private Communications (1992)
[3] D.J. Chivers, Rev. Sci. Instrum., 63(4), 2501 (1992)
[4] R. Keller, P. Spadtke and H.Emig, Vacuum 36, 833 (1986)
[5] I.G. Brown, Rev. Sci. Instrum., 63(4), 2531 (1991)