PLASMA SPUTTER NEGATIVE ION SOURCE WITH ECR DISCHARGE

A. Takagi, K. Ikegami and Y. Mori

National Laboratory for High Energy Physics(KEK)
Oho 1-1, Tsukuba-shi, Ibaraki-ken 305, Japan

Abstract

A plasma sputter type of negative ion source with ECR (Electron Cyclotron Resonance) discharge has been developed at KEK. The ECR discharge was produced by a 2.45 GHz microwave source. In this ion source, negative heavy ions are produced at the surface of the metal which is placed in a Xe plasma confined by a cusp magnetic field. In preliminary experiments, a beam current of 6.5 mA for Cu^- was obtained in pulsed mode operation.

Introduction

A plasma sputter type of negative heavy ion source (BLAKE ion source) which makes it possible to generate various species of intense negative ion beams such as H^-,C^-,Si^-,Cu^-,Ni^-,Au^- and so on has been developed at KEK.[1-4] This ion source has used hot filaments to make Xe plasma. There is another efficient technique for generating plasma, which uses a microwave discharge under the condition of electron cyclotron resonance (ECR). The ECR discharge technique has been used in many fields. Since the ECR discharge is based on the non-electrode discharge, it can extend the source life time and simplify the process of maintenance.

The ECR discharge has applied to the BLAKE ion source. We have developed so far plasma sputter type negative ion source with ECR discharge, named BLAKE-IV, the microwave is introduced into the source through a sputter target using a waveguide type of microwave transformer.

Description of the ECR negative heavy ion source (BLAKE-IV)

Figure 1 shows a schematic layout of the BLAKE-IV ECR negative heavy ion source. The main part of the ion source is a cylindrical chamber (I.D.=80 mm, L=80 mm) which is made of stainless steel and it has several vacuum feedthroughs for cesium, xenon gas and a viewing window. The plasma chamber is surrounded by 8 pieces of SmCo permanent magnets which form a magnetic cusp field to confine the plasma. The anode flange is made of copper and 2 pieces of the SmCo magnets are also installed into the anode flange. The magnetic field strength at the chamber wall is about 3 kGauss, and the ECR field of 0.875 kGauss is formed at the position of about 7 mm inside from the chamber wall. The diameter of anode hole is 12 mm. In order to suppress the electrons extracted from the ion source, a small SmCo dipole magnet was placed at the anode hole. Almost all of the electrons were removed from the beam with this dipole magnet. A sputter target was isolated electrically from the source chamber. A negative potential of -0.2 ~ -1 kV was applied to the sputter target. The Xe gas pressure in the ion source was estimated to approximately $4x10^{-5}$ Torr at a gas flow rate of 0.1 CCM , and not measured directly.

The waveguide was attached to the back side of the source as a resonator whose length was approximately 1.5 times of a microwave wavelength. A water cooling rod for the sputter target was connecting to the waveguide resonator, and the microwave leakage to the outside of the source through the cooling rod was protected by an RF choke geometry. Microwave coupling between plasma and microwave can be achieved by adjusting a short stub tuner of the waveguide resonator. Thus the microwave is introduced into the source through a sputter target using a waveguide type of microwave transformer.

The microwave power was supplied by a magnetron microwave source (2.45 GHz, 3 kW, pulsed mode : 0.5 msec, 20 ~ 50 Hz) to the ion source through a flexible coaxial line. Impedance matching between the coaxial line and the magntron was attributed by adjusting a triple stub tuner.

Experimental results

The beam intensity of the Cu^- ion beam was measured by a Faraday cup in pulsed mode operation. Schematic drawing of the experimental apparatus is shown in Fig. 2. In order to remove electrons completely from the ion beam, two sets of the permanent magnet were placed at the beam line; one was placed just after the beam extraction and the other at the front of the Faraday cup, respectively. The beam intensity of Cu^- ions increased to 6.5 mA after cesium was injected into the source. It was found that the beam intensity was very sensitive to cesium reservoir temperature. A good control of cesium reservoir temperature was important to obtain a stable beam. According to the converter voltage increase, the beam

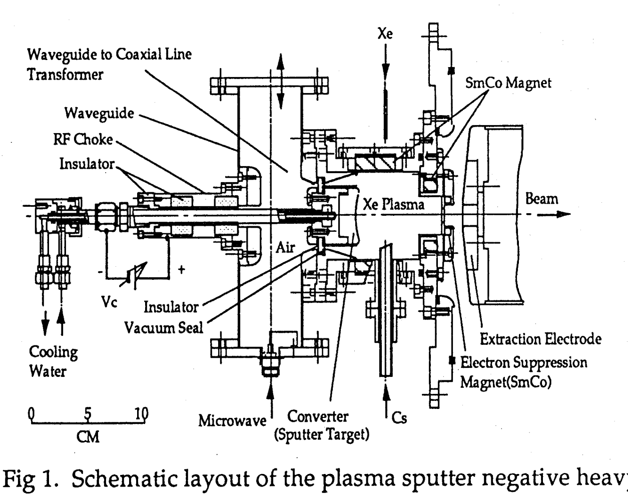

Fig 1. Schematic layout of the plasma sputter negative heavy ion source with ECR discharge (BLAKE-IV)

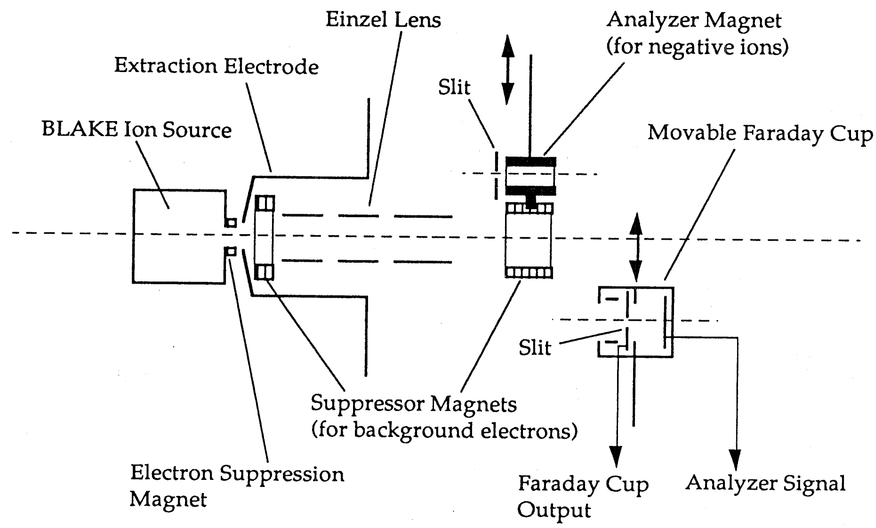

Fig. 2. Schematic drawing of the experimental apparatus used to evaluate the source for negative heavy ion beam generation.

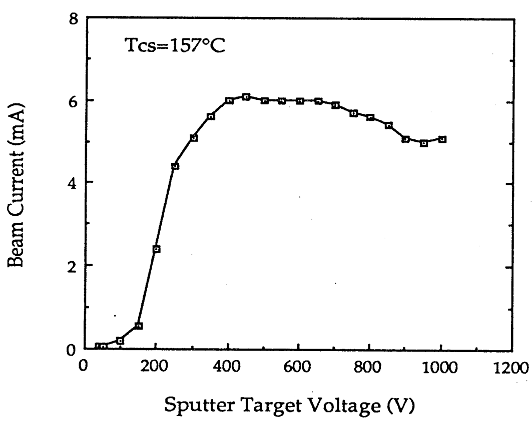

Fig. 3. The beam current of Cu^- ions extracted from the BLAKE-IV ion source as a function of the sputter target voltage.

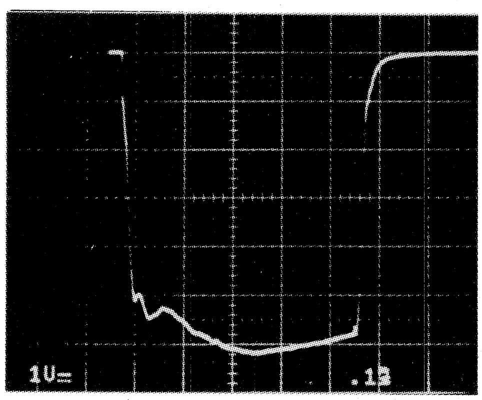

Fig. 4. Intensity versus time distribution of the total negative ion current extracted from a Cu sputter target at a voltage of -450 V and optimum cesium flow rate. Vertical axis: 1 mA/div. Horizontal axis: 0.1 msec/div.

current increased up to the maximum value of it, then the beam current decreased gradually, because xenon ions sputtered out the cesium atoms adsorbed on the converter surface as shown in Fig. 3. The ion source was operated in pulsed mode operation(pulse length: 0.5 msec, repetition rate: 20~50 Hz). A Cu^- ion beam current of 6 mA was obtained at the optimum condition of the source as shown in Fig. 4. The impurities included in the ion beam was also measured by a movable Faraday cup. The impurities were almost removed after long period conditioning (~10 hrs) as shown in Fig. 5.

The typical operating parameters of the BLAKE-IV ion source in pulsed mode operation is summarized in Table 1. The maximum value of the extracted ion current was limited by the beam extraction power supply of 30 kV. It was found that only the 20 % of output power of the magnetron was absorbed by the plasma. The power absorption efficiency was strongly affected by varying the gas flow rate. It is conceivable that the efficiency of the microwave absorption can be improved by modifying the cusp magnetic field configuration. The ion source is going to be operated in DC mode in near future.

Conclusion

Characteristics and performance of the ECR negative heavy ion source (BLAKE-IV) is described. The beam current of 6.5 mA for Cu^- was extracted from the ion source in pulsed mode operation.

Acknowledgments

The authors would like to express their sincere appreciation to Profs. M. Kihara, Y. Kimura and Director General H. Sugawara for their continuous encouragement. They are also indebted to all of members of the PS injector group at KEK.

Table 1.

Typical operating parameters of the plasma sputter negative heavy ion source with ECR discharge (BLAKE-IV).

Beam pulse width	0.5 msec
Repetition rate	20 Hz
Cs reservoir temperature	157 °C
Sputter target voltage	450 V
Xe gas flow rate	0.1 CCM
Microwave Input power	~3 kW
Microwave absorption efficiency	<20 %
Beam energy	30 keV
Beam current	6.5 mA/Cu^-

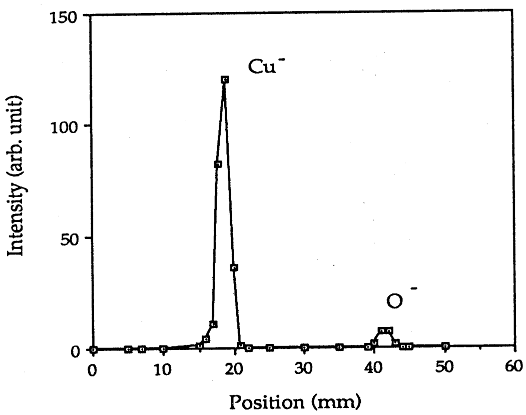

Fig. 5. Impurities in the Cu^- ion beam extracted from the BLAKE-IV ion source.

References

1. Y. Mori, A. Takagi, K. Ikegami and S. Fukumoto, AIP Conf. Proc. No.158 (AIP, New York, 1987), p. 378.
2. G.D. Alton, Y. Mori, A. Takagi, A. Ueno and S. Fukumoto, Nucl. Instrum. Methods A270, 194 (1988).
3. Y. Mori, G.D. Alton, A. Takagi, A. Ueno and S. Fukumoto, Nucl. Instrum. Methods A273, 5 (1988).
4. Y. Mori, A. Takagi, A. Ueno, K. Ikegami and S. Fukumoto, AIP Conf. Proc. No.210 (AIP, New York, 1990), p. 392.