DEVELOPMENT OF NEGATIVE ION SOURCE FOR SIMS

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Abstract

A small and compact Au^- ion source for SIMS has been developed to make a precise measurement of the abundance of oxygen isotopes in meteorites. We have tested this source with the copper sputter target and almost 900μA Cu^-ion beam was obtained in DC mode operation. Illustrative example of beam intensity versus sputter target voltage, mass distribution of ion beam extracted from a Cu sputter probe and emittance data, along with description of the source and experimental apparatus are presented in this report.

Introduction

Secondary ion mass spectrometer (SIMS) is an instrument in which a sample bombarded by an energetic finely focused beam of positive or negative ions, and secondary ions thereby sputtered from the sample are analyzed in a mass spectrometer. Figure 1 shows an ion-optical schematic of the SIMS which has been used by us. In general, SIMS can provide point-by-point analysis of a surface and show much lower detection limits for trace impurities; it detects all element including hydrogen; and it reveals isotope information. We are studying at the moment oxygen isotope anomaly in meteorites by SIMS to get pre-solar nebula information. Since meteorites formed, they have been met some events in solar nebula. In order to elucidate the relationship between crystal growth and oxygen isotope anomaly, we will make a scenario of the solar nebula history. Normally an O^- ion or Cs^+ ion beam have been used for SIMS. In case of using an O^- ion beam, secondary ions were contaminated by primary ion and in case of using positive ion beam like Cs^+ion, electrical charge-up problem was occurred.

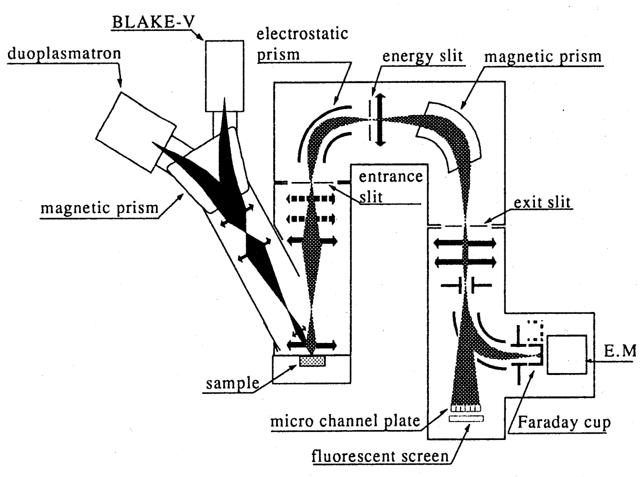

Fig. 1. Schematic diagram of ion optics for SIMS .

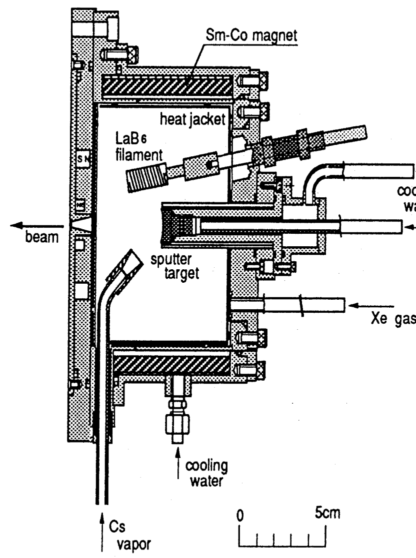

Fig. 2. Schematic drawing of the BLAKE-V negative ion source.

Our study purpose is to develop a negative ion source which makes possible to analyze oxygen isotope anomaly without primary ion contamination.

Source description

Recently, a very intense negative heavy ion source with plasma sputtering has been developed at the National Laboratory for High Energy Physics (KEK)[1-4]. This type

Table 1. Typical DC-mode operating parameter of the BLAKE V.

Arc current	4~7A
Arc voltage	~5V
Filament current	48A
Xe gas pressure	1.1×10^{-6} Torr
Sputter probe voltage	~500V
Beam extraction voltage	10kV~20kV
Cesium oven temperature	200~215 ℃

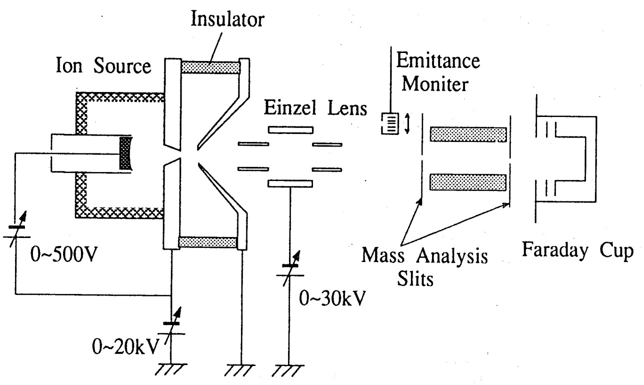

Fig. 3. Schematic drawing of the negative heavy ion source, experimental apparatus and emittance measurement device used to evaluate the source for negative heavy ion beam generation.

of negative ion source has a nickname of BLAKE (**B**erkley **L**os **A**lamos-**KEK**) negative ion source. We modified the BLAKE ion source for SIMS (BLAKE-V). The schematic layout of the BLAKE-V negative heavy ion source is shown in figure 2. The BLAKE-V ion source consists on a stainless plasma chamber and surrounded by the Sm-Co permanent magnets. In order to protect from heating, the permanent magnets are cooled directly by distilled water. A sputter target is set in the center of plasma chamber. In the present experiment, copper was used as a material of the sputter target. For heavy negative ion generation, a high density Xe plasma is generated by an arc discharge using two sets of the LaB_6 hot filaments and from the cesiated surface of negatively biased spherical geometry of sputter target, negative ions are formed by plasma sputtering. The diameter of the sputter target is 16mm and the surface is machined to have a concave configuration whose focal point is set just at the exit point of the anode aperture. The Xe plasma is well confined by a cusp magnetic field. Negative ions created in the sputter process are accelerated and focused through the plasma to a focal point, and then

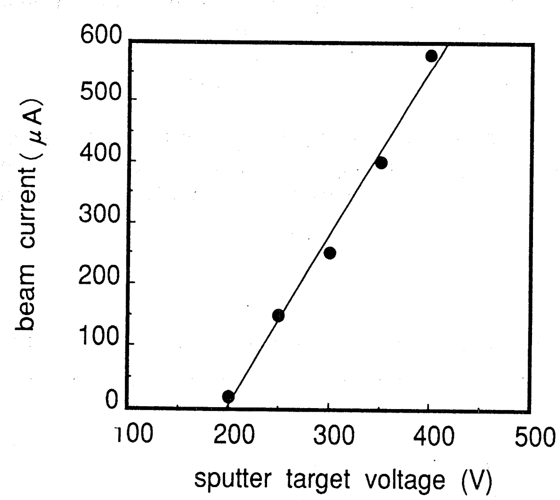

Fig. 4. Peak negative ion beam intensity versus sputter probe voltage from a Cu sputter target. Beam extraction voltage:10kV; cesium oven temperature: 215 ℃.

extracted through the extraction electrode system. Within the plasma, the ion beam is free from space charge effects because a complete space charge neutralization is achieved by the positive ions in the plasma. This ion source is normally operated in DC mode. The DC mode operation requires a large amount of cesium coverage of the sputter target surface because the cesium atoms coatings on the sputter target surface can be sputtered out continuously be Xe ions of the plasma. So the heat jackets attached to the inside wall of the plasma chamber is essential to minimize cesium consumption.

Experimental apparatus and results

The plasma sputter negative ion source is tested at the ion source test stand shown schematically in figure 3. The test stand is equipped with a cylinder einzel lens, an electron suppressed Faraday cup and an automatic emittance

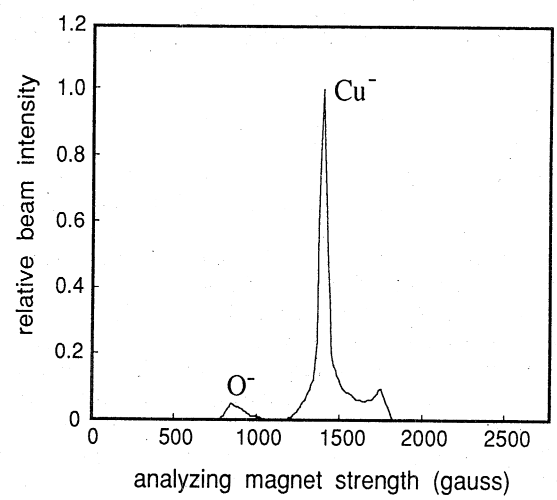

Fig. 5. Relative negative ion beam intensity distribution from a Cu sputter probe as a function of analyzing magnet strength. Sputter target voltage:-400V.

measuring device which can be inserted into the ion beam. A small dipole magnet, located immediately following the einzel lens, was used to analyze mass distribution of the extracted ion beam. In Table 1, the typical operating parameters of the BLAKE-V are summarized. The operation of this source was done by a relatively small arc power. The arc current and the arc voltage for a typical operating condition were 4~7A and less than 5V, respectively when the cesium vapor was introduced into the plasma. This is probably because cesium atoms were efficiently ionized in the plasma and cesium plasma was generated instead of Xe plasma.

Negative ion beam intensity versus sputter target voltage from the Cu sputter target is shown in figure 4. As can be clearly seen from this figure, the beam intensity increased almost linearly as a function of the sputter target voltage.

In order to analyze the mass distribution of the extracted ion beam, the experimental apparatus was modified so that mass analysis could be performed on the extracted ion beam. The maximum magnetic field strength of the analysing magnet was about 2kG and 0.3mm wide slit apertures were placed at the entrance and exit of the vacuum chamber placed into the magnet. Although the mass resolution capability of the system was not adequate for separating individual isotopes, it could on resolve heavy masses from light masses such as O^- ion, which was the major impurity found in the mass spectra of extracted ion beam. The mass distribution associated with the sputter target was determined by measuring the intensity distribution as a function of the magnetic field strength. Figure 5 shows the variation of the relative intensity as a function of the magnetic field strength for the beam extracted from the Cu sputter target.

We have measured the emittance of the Cu^- ion beam. The emittance measurement device is mounted on the experimental apparatus and it consists of a stepping motor-driven detector unit for determining the emittance of an ion beam in either the x or y direction. The typical measured value of the 90% normalized emittance for the 600μA Cu^- ion beam was less than 0.1πmm.mrad as shown in figure 6.

Conclusion

In the preliminary experiments, the intensity level obtained was higher than that of the original ion source, duoplasmatron in the SIMS. We also succeeded in raising intensity up to 1.5mA in a pulsed mode operation. If the Au^-ion beam is used as a taken of primary ion, the problem of the contamination is settled, because the rocks on the earth contain Au rarely. The analysis using this type of ion source would be useful not only for the realm of geoscience but for the realm of material science.

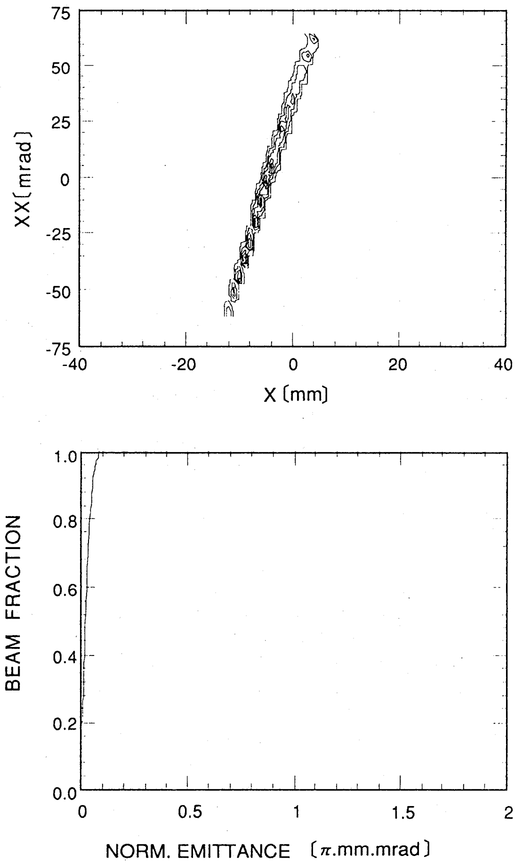

Fig. 6. Measured emittance of Cu^- ion beam extracted from the BLAKE-V negative ion source.

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