THE NEGATIVE CARBON ION SOURCES FOR ACCELERATOR MASS SPECTROMETER

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The cesium sputter and Penning negative ion sources were developed and built for isotopic analysis of solid and gas samples by accelerator mass spectrometry. The results of test experiments with ion sources are presented.

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1. INTRODUCTION

The accelerator mass spectrometry (AMS) facility is under construction at BINP for several SD RAS institutes. The AMS is mainly dedicated for dating of archaeological, paleontological and geological samples by measurements of the ratio between carbon isotopes. Ion sources are the most important part in AMS facilities. The tandem accelerator of AMS requires sources of negative ions. Two types of negative ion sources have been developed and built. A sputter ion source is required for analysis of solid samples. A relatively simple Penning negative ion source with extraction of ions from anode in a direction perpendicular to the magnetic field has been developed for adjustment of ion-optics system of AMS facility at first stage. This source is to be used for dating of gas samples at the next stage. The ion sources operate in the continuous mode.

2. NEGATIVE ION SOURSES

2.1. CESIUM SPUTTER ION SOURCE

Negative ions are produced by bombarding a graphite target with positive cesium ions. A photograph of the ion source is shown in Fig.1.

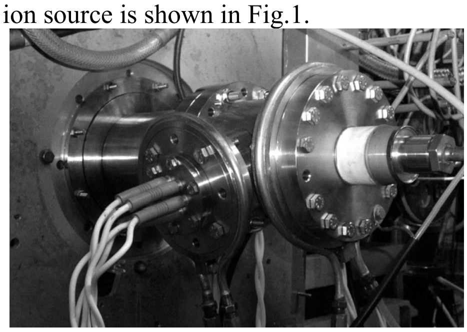

Fig.1. Cesium sputter ion source

A cesium vapor is formed by heating of the reservoir with $CsCr_2$ pellets. Then the vapor via a pipe rises from the reservoir to the ionizer. The positive charged Cs ions are produced on a hot tantalum ionizer with temperature of about 1100°C. The outer side of the ionizer cup is surrounded by a five-layer tantalum heat shield to minimize thermal losses. The typical current of cesium ions is about 1 mA when the temperature of cesium oven is about 600°C. The cesium ion beam is focused on a carbon sample placed on the cathode because the working surface of ionizer is a spherical-shape cup. A copper sample holder has the inner diameter of 2 mm. The holder is water cooled to reduce sample heating. The cesium ions leaving the ionizer are accelerated by the 8 kV potential. The negative carbon ions are accelerated by the same potential and extracted through a 6 mm diameter hole in the center of the ionizer. A permanent magnet is placed at the exit of the ion source to reflect the electrons away from the ion beam. A three-electrode electrostatic lens is located at the exit of the source. The power consumption of the ion source does not exceed 150 W.

2.2. PENNING ION SOURCE

The cold cathode Penning ion source is of the transverse extraction type. A photograph of the ion source is shown in Fig.2.

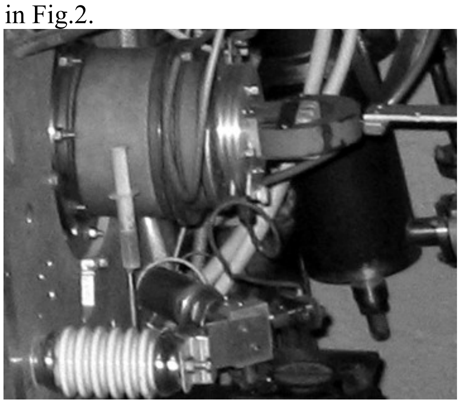

Fig.2. Penning ion source

The ion source is operated by producing an arc discharge in a longitudinal magnetic field. The diameter of plasma chamber is 12 mm and the length is about 25 mm. The cathode was made of duralumin and the anode was made of copper. The gas is fed through a piezoelectric flow dozer, which is mounted inside a high voltage terminal. The negative ions are extracted from a 0.8 mm diameter hole in anode through the extraction electrode with the hole diameter of 2 mm at the distance of 1.5 mm from the anode hole and then again accelerated to the ground potential. The dipole magnetic field strength at the plasma chamber of about 1kG is produced by permanent magnets. The current and voltage sources are located inside the high voltage terminal under the potential of the ion source anode. The arc voltage and current during the normal operation were 800 V and 300 mA, respectively. In order to avoid excessive heating of the ion source, the plasma chamber cover is water cooled. The three-electrode electrostatic lens is located at the exit of the source for ion-optics adjustment.

3. EXPERIMENTAL SETUP

The sources were tested using an injection channel of the AMS facility under the beam tuning conditions

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for carbon dating. A photograph of the injection channel is shown in Fig.3.

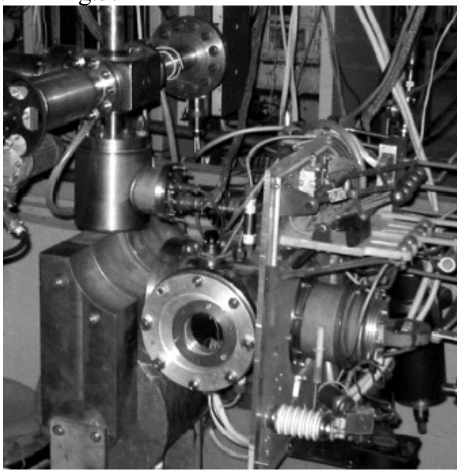

Fig.3. Injection channel

The ion beam extracted from the source passes through the double focusing 90° analyzing magnet, with 15 cm radius and 2.5 cm pole gap. The distance between the electrostatic lens and the front focal plane of the magnet was equal to the double focal length of the magnet so that the parallel beam was obtained at the exit of the magnet. The position and angles of extracted beam are slightly corrected by four electrostatic dipoles. The beam current is measured by offset Faraday cup placed at the exit of the magnet. The inner diameter of the Faraday cup is 10 mm. The 0.5 mm wire with a retarding potential is used for spectrum measurements. The magnetic field is scanned linearly with time by computer control. The field strength is measured by the Hall probe. The beam profiles after the magnet are measured by a single wire profile monitor with the use of the stepping motor. The thickness of the wire is 0.5 mm. The emittance monitor for one direction consists of a single slit and multi-wire profile monitor. The slit is moved by stepping motor. All system parameters and data from the beam diagnostic equipment are displayed online and stored in the database files. The ion sources are pumped by a 400 l/s ion pump.

4. EXPERIMENTAL RESULTS

During the experiment, the beam energy was 15 keV. The vacuum of the injection channel is kept better than $5 \cdot 10^{-6}$ Torr for the Penning source and 10^{-6} Torr for the sputter source. The vacuum in the sputter source is higher because the ion source does not use gas discharge to generate ion beams. The ion sources produce negative carbon ion currents up to 40 μA for the sputter source and to 2 μA for the Penning source. The sputter ion source can operate for about five hours without replacement of a graphite sample or a cesium pellet. The Penning source can operate for about one week without cathode cleaning. Fig.4 shows a typical mass spectrum for a carbonic dioxide gas.

It is seen that the intensity of the mass-13 peak is about 2% per stable carbon isotope, but the natural abundance of ^{13}C is 1.1%. The deviation of the ratio from the known value is observed because the total current of the ^{13}C and $^{12}CH_1$ ions are measured. The mass spectrum obtained of the spirituous vapor is shown in Fig.5.

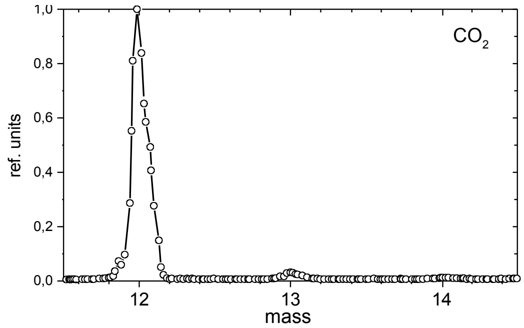

Fig.4. Mass spectrum of the CO_2 gas

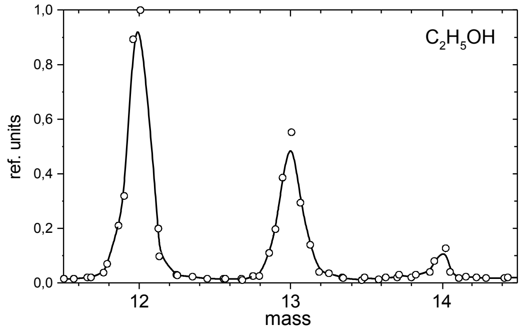

Fig.5. Mass spectrum of the spirituous vapor

As seen from the figure, the relative intensity of the mass-13 peak is increased. It is caused by the presence of hydrogen atoms in the spirituous molecule. The significant mass-14 peak is also visible in the spectrum. It is mainly the $^{12}CH_2$ and ^{13}CH molecular currents. The significant mass-14 peak can be useful for adjustment of carbon radioisotope transmission through the AMS facility. Fig.6 shows the mass spectrum of the graphite target.

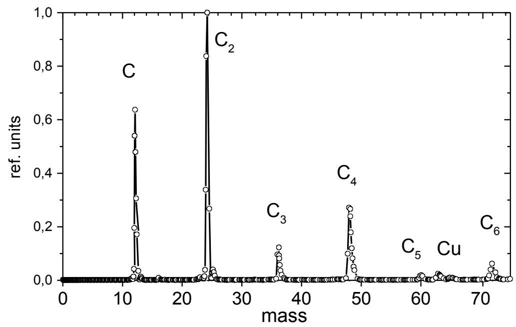

Fig.6. Mass spectrum of the graphite target

As seen from the figure, the cluster ions are produced by energetic cesium bombardment of the graphite target. The relative part of the mass-12 peak is about 30% of the total carbon beam. The stable isotopes of copper are also visible in the spectrum, since the sample holder was made of copper. In order to determine the beam quality, emittance measurements are currently underway. The FWHM of beam size at the exit of the magnet is about 3 mm. According to the measurements, the r.m.s. emittances are 7·p·mm·mrad, corresponding to a contour containing 86.5% of the beam with Gaussian approximation that is in agreement with the AMS project data.

SUMMARY

Two types of ion sources required for BINP AMS facility were developed and built. The sources were tested at low-energy channel of AMS facility.

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REFERENS

1. N. Alinovsky et al. *The project of accelerator mass –spectrometr at BINP.* Proc. of EPAC 2004, Lucerne, Switzerland.

* www.fasie.ru
# (IA 03-59-120)

ИСТОЧНИКИ ОТРИЦАТЕЛЬНЫХ ИОНОВ УГЛЕРОДА ДЛЯ УСКОРИТЕЛЬНОГО МАСС-СПЕКТРОМЕТРА

Н.И. Алиновский, С.Г. Константинов, А.В. Кожемякин, В.В. Пархомчук, С.А. Растигеев

Для изотопного анализа твердых и газообразных образцов ускорительным масс-спектрометрическим комплексом разработаны и изготовлены распылительный источник ионов и источник ионов типа Пеннинга. Приведены результаты экспериментов по тестированию источников ионов.

ДЖЕРЕЛА НЕГАТИВНИХ ІОНІВ ВУГЛЕЦЮ ДЛЯ ПРИСКОРЮЮЧОГО МАС-СПЕКТРОМЕТРА

Н.І. Аліновський, С.Г. Константинов, А.В. Кожемякін, В.В. Пархомчук, С.А. Растігєєв

Для ізотопного аналізу твердих і газоподібних зразків прискорюючим мас-спектрометричним комплексом розроблені і виготовлені розпилювальне джерело іонів і джерело іонів типу Пеннінга. Наведено результати експериментів по тестуванню джерел іонів.