STATUS OF BINP AMS FACILITY

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Abstract

Present status of the accelerator mass spectrometer (AMS) facility at BINP is described. The AMS facility is dedicated for precise measurements of isotopes ratios. The scheme of the facility includes negative ion source, electrostatic tandem accelerator with accelerating voltage up to 2 MV and magnesium vapors stripper and also includes the high-energy and low-energy beam lines with analyzers. There is an additional beam separator (180°bend) with crossed electric and magnetic fields in high voltage terminal of tandem accelerator. The results of experiments on ion beams acceleration, stripping and selection are given.

INTRODUCTION

The accelerator mass spectrometry is a powerful method of isotopic analysis for archaeology, environment science, biomedical applications and etc.

The specialized building for AMS center is being prepared now. The accelerator will be placed in the underground room for radiation shielding. It will allow operation with accelerating voltage 0.5 MV and higher after May 2007.

The AMS is based on the electrostatic tandem accelerator. The AMS system consists of the negative ion source, low energy beam line, tandem accelerator and high-energy beam line. The low energy beam line is used for initial isotope selection. The tandem accelerator is used for molecular ions removal and, of course to obtain the required beam energy for the final detector.

The negative ion beam is horizontally extracted from the ion source. Then the beam is analyzed in low-energy beam line by 90° double-focusing magnet and injected vertically into the first accelerating tube. After acceleration negative ions are stripped into plus charge state in magnesium vapors stripper. The ions of 3+ charge state will be used for isotope analysis of Carbon–14. It requires 1.5-2 MV terminal voltage for necessary C^{3+} yield. Then they pass through the middle energy separator (180° combined bend with crossed fields) and are accelerated again in the second accelerating tube. The accelerated ions are analyzed in high-energy beam line by 90° double-focusing magnet and putted horizontally to the final detector.

The most distinguishing features of BINP AMS facility are the use of the middle energy separator (180° beam bend with crossed fields in HV terminal) of ion beams and the magnesium vapors target as a stripper. The aim of these innovations was described earlier [1].

LOW ENERGY BEAM LINE

Some modifications of low energy beam-line are to be made very soon. The gate valve will be installed just after the ion source to provide quick replacement of ion sources for their cleaning and samples change. Now the gate valve is located only at the exit of the bending magnet and vacuum conditions can be obtained during three-hour period after attachment of the ion source by 250 l/s turbo pump. In addition, the low-energy line will be equipped with a differential pumping system to decrease the gas flow from ion source to the beam line. The RGA system is installed after bending magnet for residual gas analysis in injection channel. At present time, the vacuum in the injection channel is $\sim 10^{-6}$ Torr with sputter ion source.

TANDEM ACCELERATOR

The AMS tandem accelerator is a folded type vertical machine with 180° bending system in the high voltage terminal where the beam is pre-selected at medium energy in crossed electric and magnetic fields. It consists of electrostatic 180° bending system with 40 cm orbit radius. The cylindrical electrostatic plates with 2.5 cm width and 1 cm pole gap are placed into vacuum chamber. The operation at required 30 kV/cm field of bending system has been demonstrated. The 180° dipole magnet with up to ~600 Gs field surrounds the vacuum chamber with electrostatic plates.

The magnesium vapors stripper has worked more than 600 hours in the BINP AMS facility under 450°C average temperature without refilling the magnesium. The precise system for magnesium target positioning developed in 2006 works well. The transverse position of the target is adjusted by the beam transmission. For this purpose, the bellows are placed at the entrance and exit of the magnesium target. The stripper channel has the inner diameter of 3 mm and puts the main limitation on the beam transfer.

The 500W gaseous turbine generates the power used in the terminal. The circuits of four electrostatic dipoles, 180° bend and three ion pumps are supplied by this turbine. Special unit for magnesium stripper temperature stabilization has been developed and tested. It allows to decrease significantly the pulse load on turbine and its circuits. The control and management of this electronics is realized through optical link by ADAM modules. The 15 l/s ion pump is installed just after 180° bend. The vacuum in tandem accelerator is kept better than 10^{-6} Torr. The gas pressure is measured by ion pump currents. The gate valve is placed after 180° bend. The

terminal equipment works without forced cooling, but it is possible by the turbine gas.

The accelerating voltage is generated by the symmetrical cascade generator with a resonant frequency ~ 20 kHz. The design value of terminal voltage is 2 MV. It is to be achieved with SF_6 insulating gas at 1.7 bar pressure. Now air at normal pressure is used as insulating gas. The maximum terminal voltage of 500 kV was achieved in previous experiments. The SF_6 gas system including gas transfer system, compressor and dryer have been prepared. A special radiation protected room is planned to be prepared by May 2007 in specialized centre for AMS operation with voltage >250 kV.

HIGH ENERGY BEAM LINE

The most part of the unwanted particles should be removed by magnet in low-energy beam line and 180° bending system with crossed electric and magnetic fields placed in the high voltage terminal of the accelerator. For the further background damping the 90° analyzing magnet is placed at the exit of the tandem accelerator. Finally, the Carbon-14 particles are measured by silicon detector placed at the end of high-energy beam line. [1]. Also we used scintillation detector (CsI and BGO crystals) in our experiments for the AMS system adjustment (see Fig. 3 below).

EXPERIMENTAL RESULTS

The previous experimental results have demonstrated, that the negative carbon beam can be accelerated and stripped into high voltage terminal of BINP AMS facility. The charge state fractions of carbon beam stripped in the magnesium vapors stripper were obtained [1,2]. Recently, the first accelerated beam has been observed at the exit of the BINP AMS tandem accelerator [2].

In this paper the first tests of isotopes selection are presented. During the experiments, the injection energy of carbon beam was 7.5 keV. The sputter ion source was used for negative carbon ions production. The terminal voltage was mainly 100kV and 250 kV in experiments with C^{3+} ions. The magnesium vapors stripper was heated for obtaining the equilibrium charge state distribution, but not more. The vacuum of the beam line was about 10^{-6} Torr. The current of accelerated beam was measured by "CsI" crystal. The ^{13}C enriched sample of graphite with $^{12}C/^{13}C \cong 1$ was used for clearness. The mass spectrums of the injected and accelerated beams for various fields of injection magnet are presented in Fig.1. There are $(^{12}C)_m(^{13}C)_n$ clusters in the beam.

The settings of tandem electrostatic bend system corresponded to charge state 1+. One can see that molecules and carbon clusters are not greatly destructed at these conditions. The comparison of transmissions of clusters and atoms show that about 90% carbon clusters are being destructed.

The current of accelerated ^{12}C beam as a function of terminal electrostatic bend field, where 1 (unit) of the field correspond to 1+ ions bend, is presented as curve #1 in the Fig.2.

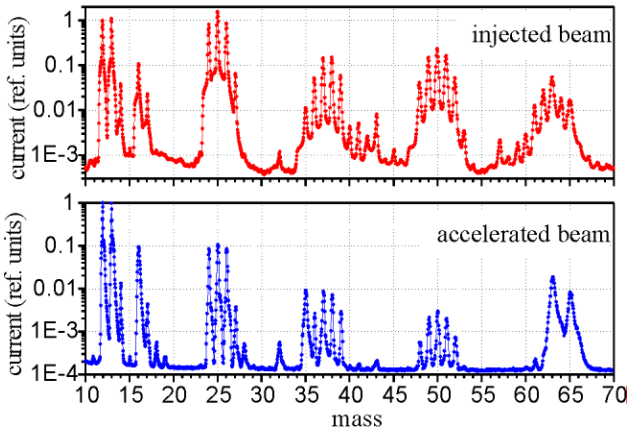

Figure 1: Mass spectrums of the ^{13}C enriched graphite with $(^{12}C)_m(^{13}C)_n$ clusters

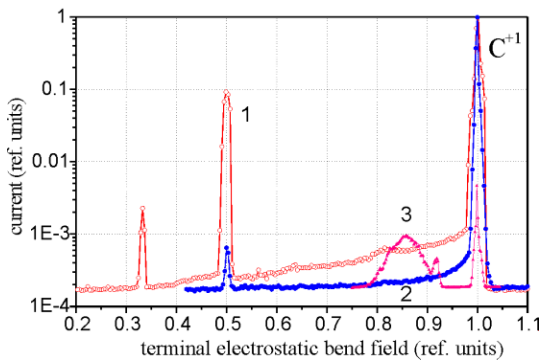

Figure 2: The currents of accelerated beams

One can see the large tail of beam intensity; this tail is caused by energy spread of ions recharged on residual gas in electric field of the first accelerating tube. The fractions 2+ and 3+ of the charge state distribution are also visible. Recently, the high-energy (HE) magnet for selection of accelerated beam was installed at the exit of the accelerator. One can see from curve #2 in Fig.2 that energy tail is cut after HE magnet. The peak at 0.5 value is caused by C^{2+} ions, which are exchanged to 1+ at the entrance of the HE tube on residual gas. The photo of 200kV carbon beam after HE magnet taken from CsI crystal and two transverse beam-profiles from wire monitor are presented in Fig. 3.

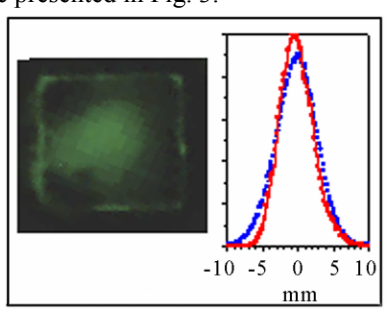

Figure 3: Beam photo from "CsI" crystal and profile at the exit of the AMS.

To test the terminal bend selection, the ^{13}C beam was accelerated and passed through HE magnet, which was set for $^{12}C^{1+}$ ions. As it is seen from curve #3 in Fig. 2, the peak of beam intensity exists at 0.85 of terminal bend value. It corresponds to energy of $^{13}C^{1+}$ and momentum is equal to the $^{12}C^{1+}$ ions. These low-energy ions are filtered by tandem bend at operational bend value + 1, and can not take part in charge-exchanging process in HE accelerator tube. The fragments of the destructed molecules are also filtered by tandem 180° bend system.

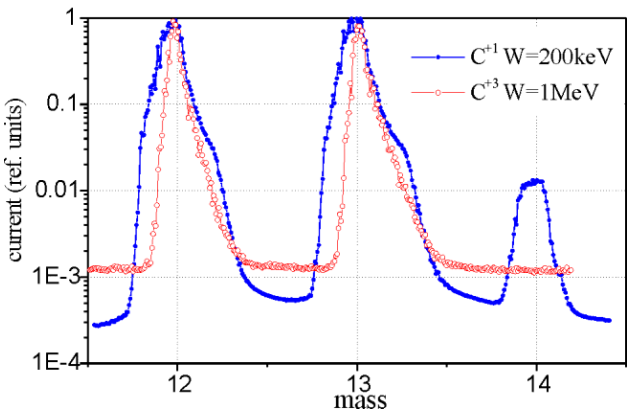

Figure 4: Mass spectrums of accelerated beams. The molecules of 14 mass are destroyed in stripper.

The mass spectrums of the accelerated ions in charge stages 1+ and 3+ are presented in Fig. 4. The HE magnet and low-energy (LE) magnet are being varied together for the desired mass passage. In order to increase 3+ ions output after magnesium stripper, the 250kV terminal voltage was used. The molecules (with mass M = 14) are destroyed in stripper. The intensity peaks at larger energy are narrower due to less ion scattering.

The scans of the HE magnet with ^{12}C and ^{13}C ions injected into the tandem accelerator are presented in Fig. 5.

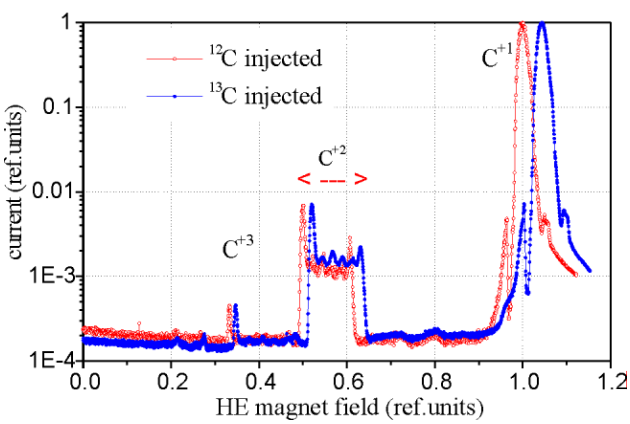

Figure 5: The scans of the HE magnet with 12C and 13C ions

The tandem 180° bend was set for 1+ charge state. The intensity peak from 0.5 to 0.6 ref. u. (HE magnet current) is caused by C^{1+} ions, which are charge exchanged to 2+ in the HE tube. The origin of 3+ state peak is the same. The peaks near the primary 1+ stage peak are also visible. These peaks are displaced about one unit of mass from the primary peak, but not precisely. It is not accountable from charge exchange or molecular breaking processes. Experiments when some of the pumps were turned off showed, what the values of these peaks are not correlated with pressure of residual gas. We assume that, these peaks appear due to scattering of the primary ion beam on vacuum chamber walls in the HE magnet when the primary beam is displaced from the central orbit. For reduction of such a background, the aperture collimator will be installed at the exit of HE magnet.

The detector and electronics for carbon ions counting will be prepared soon.

SUMMARY

- All the basic components of the AMS have been installed and now in operation.
- The magnesium vapors stripper was tested, it has shown 600 hours operation without magnesium refilling. The molecules destruction in stripping target has been observed.
- The first tests of isotopes selection were undertaken. The measurements of several samples (^{13}C enriched graphite, metallurgical silicon and others) have been performed at low energy.

ACKNOWLEDGEMENTS

This work is supported by FASIE Foundation# and by SB RAS*

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