THE STATUS OF SMCAMS AFTER UPGRADINGS*

Yonghao Liu†, Maobai Chen, Deming Li, Shengli Wang, GuoSheng Chen, Wenhong Jia
Shanghai Institute of Applied Physics, Chinese Academy of Sciences, 201800, Shanghai, China

Abstract

Several upgrade programs have been carried out on the Shanghai Mini-Cyclotron based Accelerator Mass Spectrometer (SMCAMS) in the last few years. A new multi-cathode Cs sputter negative ion source with a modified design from MC-SNICS of NEC was developed and put into use. The features and performances of this homemade device will be introduced in this paper, some of which are critical to AMS measurements including rapid cathode change and precise, repeatable positioning without cathode exposure to air. A new control system based on RS-485 multi-drop network was also established to automatically control the sequential accelerations and measurements of different C isotopic ions and routine operations. The efforts ever made on homogenizing the consistency and quality of the sputtered samples and the preliminary measurement results will be described, too.

INTRODUCTION

Since the first ^{14}C negative ion was detected on SMCAMS in 1993 [1], great efforts had ever been made on improving its beam transmission and stability and meanwhile overcoming excessive X-ray induced backgrounds so as to develop SMCAMS an applicable AMS tool. Until 1998, we had been able to obtain a maximum $^{14}C^{-}$ count rates of 25 cps for the Chinese Sucrose while operating about 40~50 μA of the primary beam currents. Meanwhile the X ray induced backgrounds had been decreased to no more than 0.04 cps, nearly a factor of 100 lower than before. That October a batch of unknown samples could be put into the ion source for evaluation measurements. The results were very encouraging after comparing them with the sample provider's, Peking University and Arizona AMS laboratory. The measurement precision of 1% and old sample capability as old as 40,000 yrs were evaluated, competitive with the routine measurements of tandem AMS facility [3][4]. Since then, tens of geology and archaeology samples have been dated on SMCAMS [5].

In order to further improve its AMS performances, several upgrade programs had been carried out on such a minicyclotron AMS prototype in the last few years, including building a new multi-cathode Cs sputter negative ion source, establishing a more robust control system and purchasing several equipments for sample preparation. In this paper, the features and performances of the new Cs sputter negative ion source will be introduced followed by a description of the new control system. Finally, we describe briefly our efforts ever made on homogenizing the consistency and quality of the sputtered samples and the preliminary dating results.

*This work is supported by Chinese Academy of Sciences.
† liuyonghao@sinr.ac.cn

THE NEW MULTI-CATHODE CS SPUTTER NEGATIVE ION SOURCE

Features

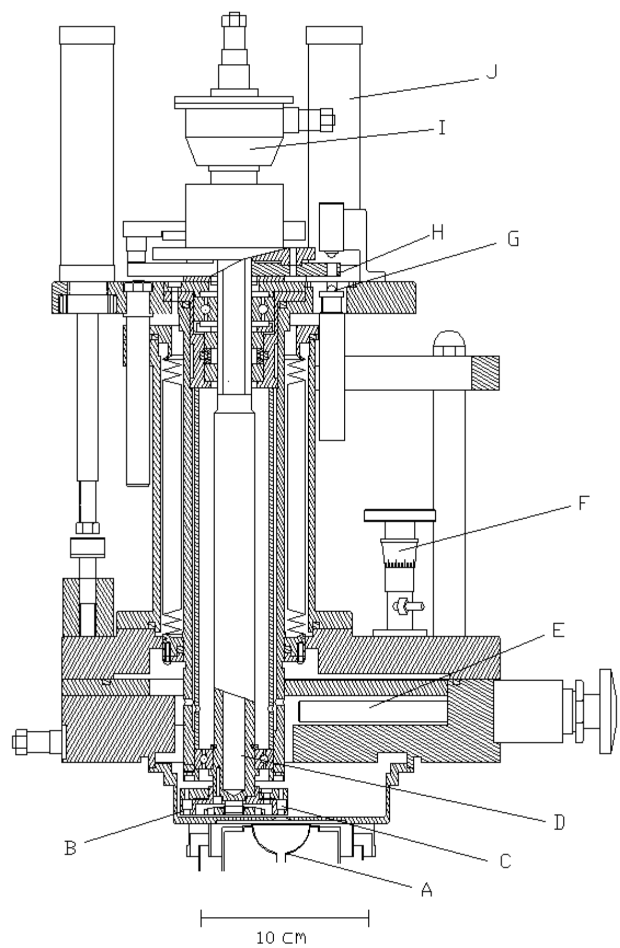

Figure 1: Schematic side view of the SMCAMS multi-cathode device. A: Ionizer; B: Cathode wheel; C: Sample holder (-17.5 kV); D: Rotary shaft; E: Gate valve; F: Pinhole valve; G: Positioning bolt; H: Ratchet wheel; J: Gas cylinder; I: Coolant head

The new ion source (Fig1. shows its multi-cathode device) virtually is a modified design from MC-SNICS of NEC. One of the most desirable features of the MC-SNIC Cs sputter negative ion source design is the smaller sample cathode geometry because no sample actuation is needed for changing samples, which allowed us to design 24 cartridge positions in the cathode wheel while keeping the size of the cathode wheel even smaller than the carousel in the original source. The surface diameter of the pressed samples in the Al sample holder is reduced from 2 mm to 1.5 mm. The sample holder is offset relative to the optic axis of the source so that a simple rotary motion of the cathode wheel can move individual sample to beam position. The ion source consists of five main assemblies: the beam extraction assembly; the ionizer part; the vacuum-air-lock assembly; the H_2O cooled, rotary-motion cathode wheel; and the sample indexing and positioning mechanism assembly.

The cathode wheel is attached to the end of the coolant shaft, to which the upper ratchet wheel is also attached coaxially but with a vacuum seal. The coolant (deionized water) head is located at the top with a low-friction connection so as to keep quiet while rotating the ratchet wheel. The ratchet wheel is driven and precisely positioned by the pneumatic system, which consists of some gas cylinders, gas pressure-electricity transducers, mechanical action parts and the pneumatic control unit. The pneumatic system controls cathode changing, sample positioning and cathode wheel retraction for replacement. The pneumatic control unit, located at ground potential, is controlled locally by an 8031 SCM (Single Chip Micyoco), which further communicates with the host computer via its RS-232 port so that an automatic sample indexing could be made. Through an involatile PROM chip in the 8031 SCM enclosure, the sample number at the beam position can be recalled at anytime. This arrangement avoids complications associated with indexing mechanisms that rely on electronic power supplies located at high potential.

For replacement of the cathode wheel, the cathode wheel is retracted through the gate valve, which is then closed to protect the vacuum in the cesiated area. Afterwards the pinhole gas valve is opened to refill the cathode wheel chamber with atmosphere to balance pressure difference so that all the parts above the flange connection could be lifted. After replacing the cathode wheel, the cathode wheel chamber is pre-evacuated via the pinhole valve before opening the gate valve, in this way, excessive vacuum disruption in the ion source after the replacement of the cathode wheel could be prevented.

The original source and extraction assembly in the old 846 model ion source are kept intact and reused in the new ion source structure, which means that the original spherical ionizer is still used here instead of a conical one commonly used in the MC-SNIC ion source. We could not see the necessity of redesigning the source and extraction geometry. In fact the Cs focusing has been changed a little after upgrade, but the difference is only that the sample holder is uplifted by 0.25 mm higher than before and now hides behind the Cs baffle plate, in this situation, the baffle plate and the cap of the ionizer constitute an immersion lenses, which, as we understood, would further focus the Cs beam rather than defocus it. The observation on the old ion source indicated that a position 2~3 mm higher rather than the normal sputter position was the optimum position for maximum extracted beam currents, which supported our speculation.

Performance

Once the source being assembled and installed properly, the sample-positioning bolt under the ratchet wheel will guarantee the sample positioning. However, immediately after its first time installation in 2000, cesium spot marks were consistently found about 1 mm outwards from the sample surface center. The problem was solved by modifying the geometry of the cathode wheel to move the sample holder hole 1 mm outwards. Thereafter, the original ionizer fused in an accident and had to be replaced by a new one, however we surprisingly found that the cesium spot marks moved back inwards about 1 mm. The original-style cathode wheel was then put in again and in result the cathode could be centered in the cesium beam. We, therefore, concluded that too long time use of an ionizer might distort its spherical interior surface and thus affect its Cs focusing.

During more than two years of its operation since 2001, one severe mechanical failure arose from a careless operation during the process of replacing the cathode wheel. We updated a solenoid valve in the pneumatic control unit with one with self-lock function to avoid such accident forever. Besides, some minor modifications were also made to the cathode wheel for easy installation and the precision loadings of the sample holders into it.

After years of improvements and explorations, we are now certain that the new source with its multi-cathode device updated has as a whole met the requirements for routine AMS measurements. A beam current of 80 μA could be extracted at the routine source operating parameters without observable emittance deterioration. The time needed for changing the sample to the next one is less than 4 seconds. The sample-positioning precision and reproducibility have been verified by both the isotopic ratio measurements and a specially designed mechanical calibration process soon before, in the latter we concluded the sample-positioning precision and reproducibility is within 0.05 mm.

THE CONTROL SYSTEM

A robust and flexible control system always possesses great significance on SMCAMS. This is not only because more than 30 devices have to be monitored and controlled in the routine operations, but also because over 16 electric parameters have to be switched as fast and accurately as possible to the preset values for the accelerated ions ($^{12}C^-$, $^{13}C^-$ and $^{14}C^-$ etc) in the process of we called 'sequential acceleration'. The principle of sequentially accelerating and detecting various C isotopic negative ions on SMCMAS has been detailed elsewhere [4].

The previous STD centralized control system had been realized to be no longer able to meet the requirements for the reliable, precision and high throughput AMS measurements: All the Data Acquisition and Control (DA&C) modules were crowded into the PC host enclosure and each had to deal with several I/O channels, which would inevitably cause electronic cross talk or ground loops; the analog I/O signals travelled long distance and therefore were subject to interference, especially considering our cyclotron strong EMI (Electro Magnetic Interference) environment; all the controlled devices had to be stacked nearby the PC host computer and its maintenance and function extension also seemed difficult.

The newly established control system is a multi-drop RS-485 network, in which all the commands and data are transmitted through a shielded pair twist (BUS). All kinds of devices are monitored and controlled through the high-speed communications (115200 baud rates) between the host computer (an industrial PC) and various DA&C modules located nearby the devices. The power supplies floated on –17.5 kV is controlled remotely via digital and analog fiber-optics link. The 8031 multi-cathode device control unit working with a different baud rates communicates with RS-485 bus via a baud rate converter. Through a data link between the RS-485 bus and a multi-channel pulsing discriminator card in the data acquisition computer, the host controls the timing of the beam collection and ^{14}C count. The control software run under Window98 is compiled with Inprise Delphi 5.0, which handles the in-time monitoring, tuning and automatic turning on/down of the machine and controls the sequential acceleration measurements. The switch time from one kind of ions to another is less than 5 seconds. The data acquisition PC records the measurement results in a binary file and then an offline data process could be carried out to yield the final dating results.

Meanwhile, in order to improve the stability of SMCAMS, five key power supplies that are of critical importance to the precision measurements have been updated by the Glassman products. An old-fashioned electronic square-wave generator has proved to malfunction and was replaced by an Angilent arbitrary waveform generator with a frequency precision as low as 1 μHz. This device is controlled via a RS-232 port of the host computer.

The new control system has been employed in the routine measurements. Up to now its better reliability and stability has been demonstrated by the greatly reduced spikes in the isotopic ratio measurement curves for long time (6~7 hours) and our everyday observations. Large number of practical radiocarbon measurements in future will further give it an overall examination.

TARGET PRESS

Careful target pressing is crucial for AMS measurements. Poorly pressed target tended to show abnormal beam behaviour (much lower beam currents and/or shorter lifetime). Too high compactness of the C materials in the sample holder seemed also hazardous (see Leibniz-Labor AMS lab website). SMCAMS has also put a lot of efforts into homogenizing the consistency and quality of the sputtered samples. A series of devices and accessories have been developed to press sample materials into the 1.5 mm diameter hole in our Al sample holders from the back. A disposable copper pillow with a convex flat surface of 1.5 mm diameter and 2 mm height supports the sample holder in the holder chamber to form a pit 2 mm deep. Afterwards the sample holder is filled with sample material through a funnel from the back. The chamber with the impact pin inserted is then put in the press device. We press the target in two steps: first with a pressure of 2 Newton·Meter (N·M) to form the material a loose pill; then an Al pin filler of 2 mm long is inserted into the holder and a pressure of 6 N·M is then used to give the final product. The pressure is indicated by the readout on the moment wrench.

However, uneven surface of Al filler was frequently found to be very hazardous, in which a significant non-vertical forces could be resulted in and therefore the pressure readout might be misinterpreted. In order to volume-produce high-quality Al pin fillers, a novel gadget was designed, which is capable of producing 100 Al pin fillers at the expense of only one spark cutting.

MEASUREMENT RESULTS

Soon before, an evaluation radiocarbon measurement was carried out on SMCAMS to test its overall AMS performance after upgradings, in which an IAEA-C7 sample was dated to 49.52 pMC and two aliquots of 1850 wood sample were dated averagely to 101.11 pMC. Both the accuracy and precision were very satisfactory for such a preliminary measurement (table 1). We prospect that the routine radiocarbon measurements could begin soon although more efforts are still preferred to optimize the whole system, especially improve the vacuum condition and reducing the machine backgrounds.

Table 1: Evaluation measurement results

Code	**Material**	**Age (yrs BP) or pMC value**	**Reference**
IAEA-C7	Oxalic	49.52 (±1.3%)	49.54
1850Y-1	1850 wood	102.88 (± 0.9%)	100
1850Y-2	1850 wood	99.34 (± 0.9%	100
Coal-1	Coal	31765 ± 350	No
Coal-T2	Coal	36980 ± 400	No

ACKNOWLEDGEMENT

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