Available online at www.sciencedirect.com
ScienceDirect
Nuclear Instruments and Methods in Physics Research B 259 (2007) 94–99
NIM B Beam Interactions with Materials & Atoms
www.elsevier.com/locate/nimb

Ion source refinement at VERA

Alfred Priller *, Matthias Auer, Robin Golser, Andreas Herschmann, Walter Kutschera, Johann Lukas, Peter Steier, Anton Wallner

VERA Laboratory, Faculty of Physics, University of Vienna, Währinger Str. 17, 1090 Vienna, Austria

Available online 11 February 2007

Abstract

This paper describes various modifications implemented at the 40-samples MC-SNICS Cs sputter source used at VERA. The pneumatic sample changer was replaced with a stepper motor drive, and also the adjustment collar for the vertical target wheel position was motorized. These two modifications allow now an automatic scanning of the target position with respect to the Cs-sputter beam. It also opens the way to use sample wheels holding more than 40 sample positions while keeping the original dimensions of the wheel. In order to hold the negative ion output constant, the control computer now regulates the Cs-capillary heater while the Cs-oven heater power supply stays fixed. Another modification was the replacement of the original conical ionizer with a spherical one, involving the enlargement of the diameter of the Cs-focus lens. This modification almost doubled the source output. To adapt the new ion optical geometry, we mounted a shield electrode in front of the target.

PACS: 07.77.K

Keywords: Accelerator mass spectrometry; MC SNICS; Ion source

1. Introduction

Since about 10 years, the VERA Laboratory uses a 40-samples MC-SNICS Cs sputter source manufactured by NEC, Wisconsin, USA [1]. Over the years, it was subject to some minor and major modifications. The most important changes were the complete replacement of the pneumatic sample changer with a stepper motor drive, and the installation of a motor-driven adjustment of the vertical target wheel position, because these two modifications allow us to scan automatically the target position with respect to the Cs-sputter beam. They also opened the way to use target wheels with more than 40 positions while keeping the dimensions of the original design.

Following the paper by Weisser et al. [2], we replaced the originally mounted conical ionizer with a spherical one, and enlarged the diameter of the Cs-focus lens. To adapt the radial symmetry of the ion optical geometry, we mounted a shield electrode with a 10-mm opening in front of the target, which is held at target wheel potential. In order to keep the negative ion output of the source constant we found it better to control the Cs-capillary temperature rather than the Cs-oven temperature. For rapid cool-down of the ion-source we have mounted an air lance blowing against the cesium oven.

2. Replacement of the pneumatic target transport mechanism

An important improvement was the replacement of the pneumatic target changer mounted by NEC (Fig. 1(a)) with a stepper-motor driven-one (Fig. 1(b)), as well as the motorization of the adjustment collar (Fig. 1(c)) needed for the vertical positioning of the sample. All transmissions were designed with timing drive belts and pulleys. Since the target has to be positioned accurately, the most critical

* Corresponding author.
E-mail address: alfred.priller@univie.ac.at (A. Priller).

0168-583X/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.nimb.2007.01.249

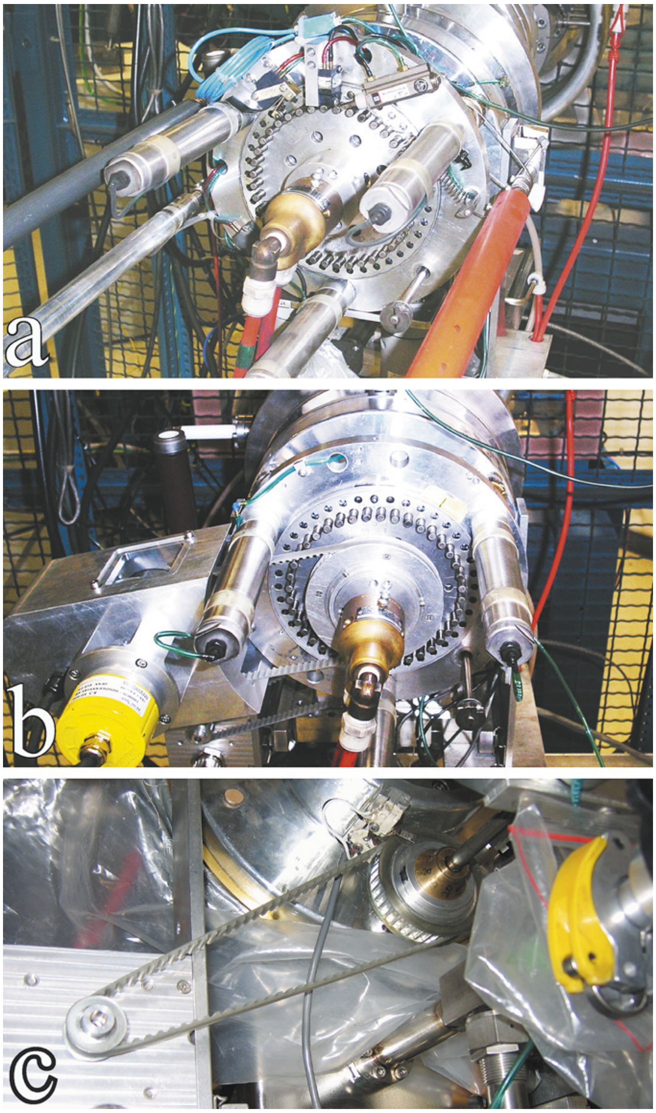

Fig. 1. (a) Original pneumatic target changer together with a preliminary target positioning system (controlled by using Lucite or plastics rods); (b) newly installed stepper-motor drive for changing targets; (c) stepper-motor driven adjustment of the target's *y*-position.

point is the reduction gear between stepper motor and timing drive of the target wheel. The gear chosen has a reduction of 160 with a repeat accuracy better than ± 0.1 angular minutes (Harmonic Drive, http://www.harmonicdrive.de/). Together with the 200 steps of the driver motor the angular (horizontal) positioning of a target mounted on a standard NEC 40-position target wheel is better than 1/100 mm. The vertical positioning (drive reduced by a factor 3) can be done by controlling the setting of the original adjustment collar in 1/600 turns, which corresponds to steps of about 1/1000 mm. The pneumatic cylinders of the target wheel's retraction mechanism are pressurized in a way that they reduce the load on the brass adjustment collar. To avoid collisions of the target wheel inside the source housing, safety switches are mounted at the driving pulley of the adjustment collar (Fig. 1(c)). The readout of actual values for the rotation angle of the target wheel and the *y*-position is done via an absolute angular encoder (resolution 32768/turn) and a 10-turn potentiometer, respectively. On the source platform, controller, motor driver boards, communication computer, and power supply are mounted in a 19″ housing.

3. First results using the new target changer

In order to test the potential of the stepper-driven target-positioning system first tests were performed using standard 40-targets wheels. In Fig. 2(a), the individual target positions were scanned for maximum $^{12}C^{-}$-currents in the offset cup after the injection magnet. Shown are their

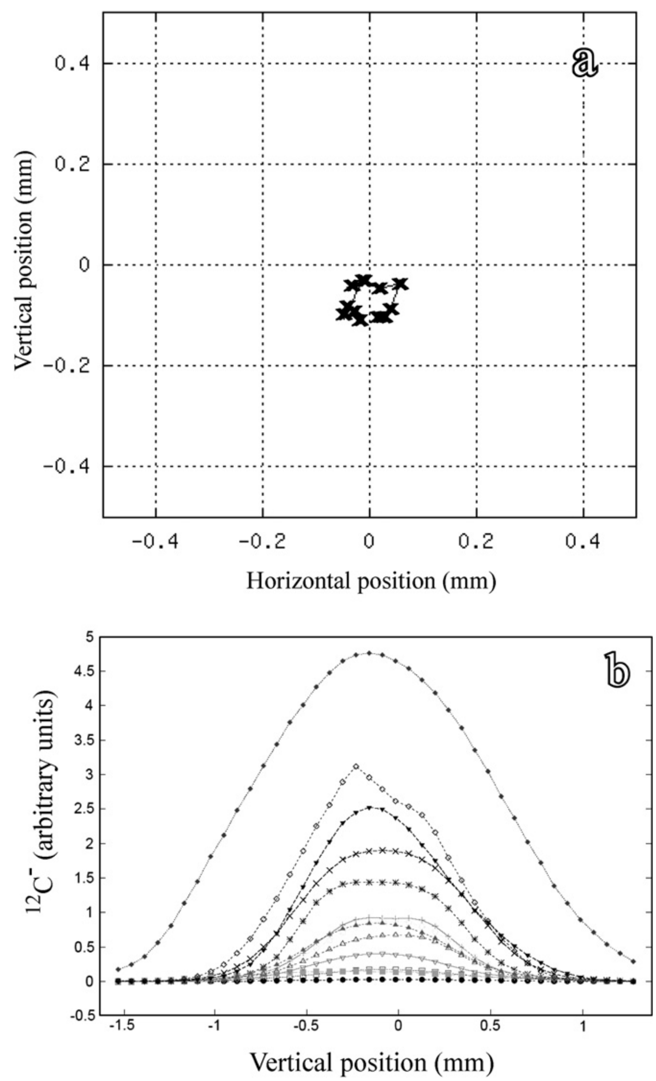

Fig. 2. Scans of $^{12}C^{-}$ into the low-energy offset cup after the injection magnet: (a) Central positions of 12 targets around the target wheel (angular difference between the individual targets is 30°). Plotted for the individual targets is their difference in rotational (horizontal) position with respect to their nominal rotational position versus their vertical position; (b) scans of differently cratered targets. Plotted are the $^{12}C^{-}$ currents versus the vertical displacements of the individual targets.

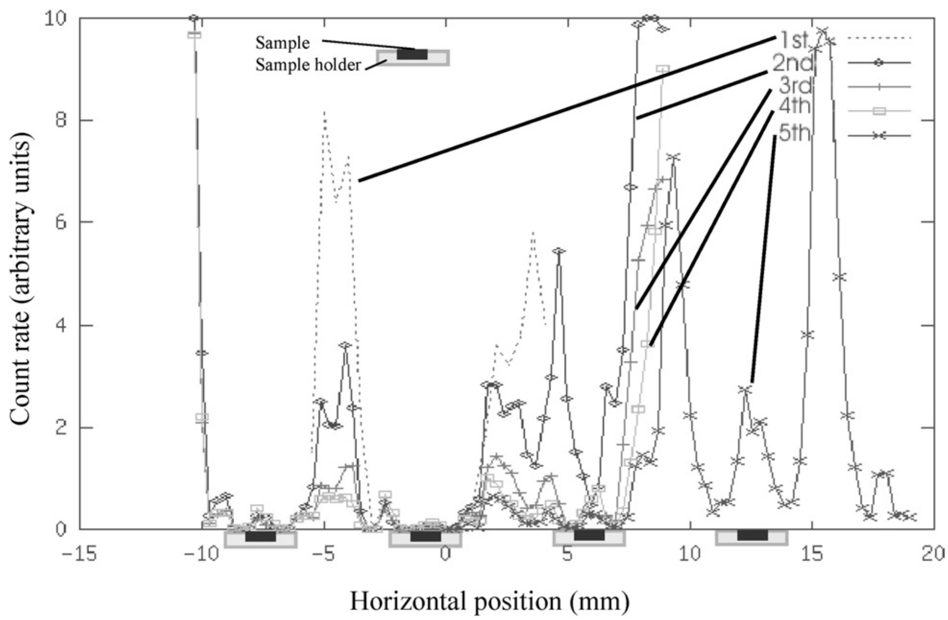

Fig. 3. Successive scans of mass-41 background versus angular position. The plot range covers five targets.

absolute distances to their corresponding default positions. Whereas the horizontal positions of the maxima scatter around the nominal zero position, the vertical positions scatter around −70 μm, which can be easily corrected now. The plot depicts also a small variation in the position of the individual targets. In the case shown, this is possibly due to a small eccentricity in the target transport mechanism (e.g. wheel, wheel mounting, rotating shaft assembly). Fig. 2(b) shows the scans of used, differently worn targets in the low-energy offset cup after the injector magnet. These targets were re-used from different measurements and target wheels. Scanned is the vertical displacement of the individual targets with respect to the default zero position. One can see that: (1) the maxima of the $^{12}C^-$ currents for the different targets do not exactly match, which possibly reflects that the targets were cratered in different measurements and no attention was paid to their orientation when mounting; (2) the shapes of the scans show the higher the current the smaller the flat top. One possible explanation for this behavior space charge, which widens the beam more for higher currents; (3) the currents from the individual targets are changing clearly when scanning from −1.5 mm to +1.5 mm of the ideal target position (target diameter 1 mm).

During an AMS measurement with ^{41}Ca [3], the new target transport mechanism proved its value facilitating the identification of the sources of suddenly enhanced potassium background. Fig. 3 shows successive scans of the mass-41 count-rate in the rare isotope detector versus the angular target position moving over five targets. One can see that the mass-41 count-rate decreases with sputtering time over the entire range of the scan. The highest rates have their origins between the targets. This means, a mass-41 contamination is present on the surface of the target wheel. In this case, the possible explanation was the installation of an ionizer with a heating wire insulated by a new kind of ceramic beads. Former measurements on the mass-41 background – without these ceramic beads – had yielded much lower count rates (a factor of 10–100). Measuring one of these beads using proton induced X-ray emission (PIXE) showed a clear potassium signal.

4. New design of target wheel and target holders

Fig. 4 shows a rotational scan covering three targets on a standard NEC 40-position target wheel. The distance between the current maxima is 6.7 mm and the full width of the peaks is not larger than 2 mm. So it seems that there is enough space for additional targets in between. However, this needs a completely new design of the target holders and of the target wheel. The newly designed target holders, cylindrical and 7 mm in length, have an outer diameter of 2.5 mm. The target diameter is 1 mm. These holders are cut from standard Cu capillary and their surface is smoothened using a tumbler (trowalizing, http://www.trowal.com/). The backing pins are cut from a copper wire. After pressing the target material into the target holder the back-end of the holder is squeezed a little using a wire cutting pliers. This assures secure fit in the target wheel as well as good electrical and thermal contact. Then, the holder is pressed (from the back) into the wheel. After the measurement the used target holders are pushed out (also from the back) through the wheel. A wheel of this design with 40 samples was already successfully tested. The next step is to machine a new target wheel holding 72 targets, and investigating possible cross talk between the individual targets.

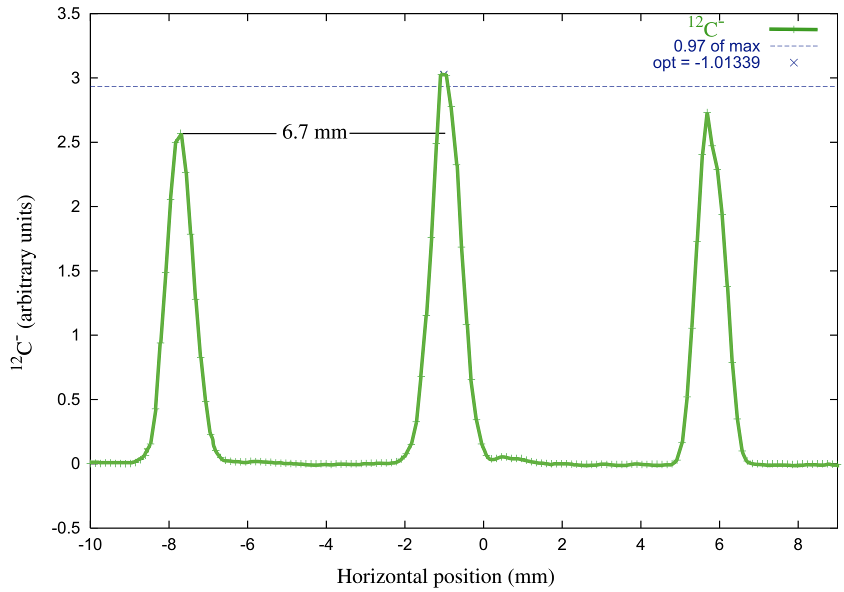

Fig. 4. Angular (horizontal) position scan covering three targets mounted in standard 40-target wheel.

5. Spherical ionizer and target shield electrode

The original conical ionizer of our MC-SNICS source has been replaced with a modified spherical type [2]. We have manufactured tools to convert standard NEC-ionizers to spherical ones, and we are no longer using conical ionizers. Together with the wider opening of the aperture of the Cs-focus lens, the output currents from the source increased by more than a factor of two. However, the wider opening of the Cs-focus resulted in distorted electric field geometry in the vicinity of the target, since the housing on ground potential was more exposed. The source-ground electrode formed by the ionizer surface and the crescent-shaped grounded shield (Fig. 5(a-1)) together with the target on cathode potential (Fig. 5(a-2)) are responsible for this field deformation. This was compensated by mounting directly in front of the target wheel a shield electrode (Fig. 5(b-1)) at the same potential as the targets (Fig. 5(b-2)). The improvement of the field geometry is clearly visible when comparing used targets sputtered with and without shield electrode (Fig. 5(c)). Some remarks about running the source without shield electrode: The distorted field strongly deviated the negative ion beam such that it damaged the ionizer. Its exit aperture was asymmetrically sputtered. Since this aperture is the cathode of the extraction electrode, the extraction field was deformed also, which gave rise to strong steering. At the source slits about 20 cm behind the preacceleration tube the beam was more than 7 mm off axis.

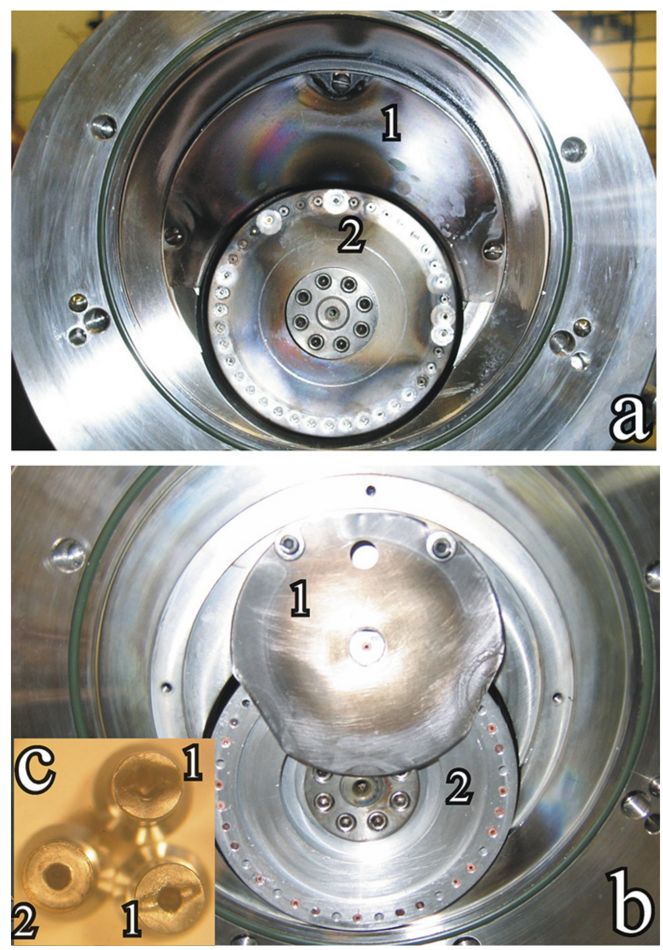

Fig. 5. (a) View in direction of the Cs sputter beam (old configuration). Target wheel with crescent shaped ground electrode; (b) view of the new target shield electrode used to supply symmetric field geometry. The aperture in front of the target has a diameter of 10 mm; (c) targets sputtered with out shield (1) and one target after mounting the shield (2), respectively.

6. New target holders for AMS with ^{36}Cl

^{36}S is the main background in AMS with ^{36}Cl. Since it is now possible to scan the target and its surroundings over a

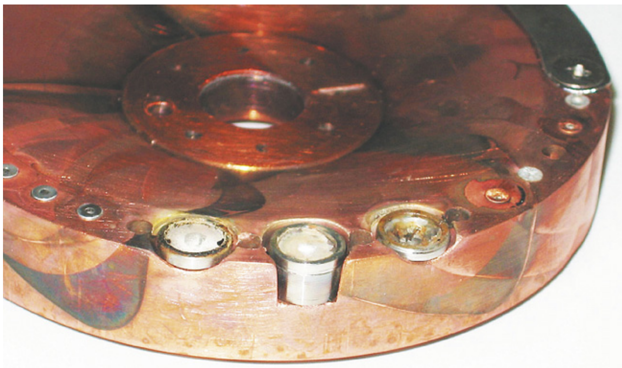

Fig. 6. Modified target holders for AMS with ^{36}Cl after usage.

large range, one can get information on the sources (position and strength) of the disturbing isobar. This information can then be used for finding materials having low content of the disturbing isobar [4]. For previous tests, standard target holders made from copper and aluminum were used. It turned out that the main background observed had its origin from the target holders and wheel. The new design uses large stainless steel target holders mounted in a modified target wheel. The individual holder has a diameter of 9 mm with an opening of 7 mm filled with silver bromide, which is cleaned from sulfur. The pure silver-chloride target is pressed into a small dimple in the center of this silver-bromide bed (Fig. 6).

Using these target holders, the ^{36}S background clearly showed a minimum at the center of the target as well as a drastic increase at the positions where holder or wheel is hit by the Cs-sputter beam (see [4]).

7. Miscellaneous ion sourcery

We now have run the ion source for almost ten years using many differently behaving isotopes (from protons to plutonium). This section is a collection of some lessons we learned and of tools we developed to give the user more information for optimum use of the source.

We found that one major problem is accidentally feeding too much Cs into the source. Often the operator increases the temperature of the Cs oven and/or the Cs capillary with the aim to increase the negative current yield. Experience shows, too much Cs inside the source works against the operator by actually reducing output currents, who may – without any other information – go on to push more Cs into the source worsening the situation.

We found that the source is in good condition, and not spoiled with Cs, if the ratio between extraction current (includes the additional current via a shunt resistance of 12 MΩ) and cathode current is close to 0.5. If this ratio is too high (near unity or above), the operator can often recover the source by turning off the Cs-capillary heating.

At VERA, the temperature of the Cs oven is kept constant. In order to influence the output current of the source the capillary heating is controlled. Keeping the ion current as constant as possible protects against effects due to space charge, e.g. on the transmission through the accelerator [5]. Fig. 7 is a plot of the $^{12}C^-$ current measured on individual targets after the injection magnet and the control value of the capillary heating versus run number (time). The plot shows a case where the capillary control program was not running for about 2 h. After restarting, the program took control over the capillary heating power consump-

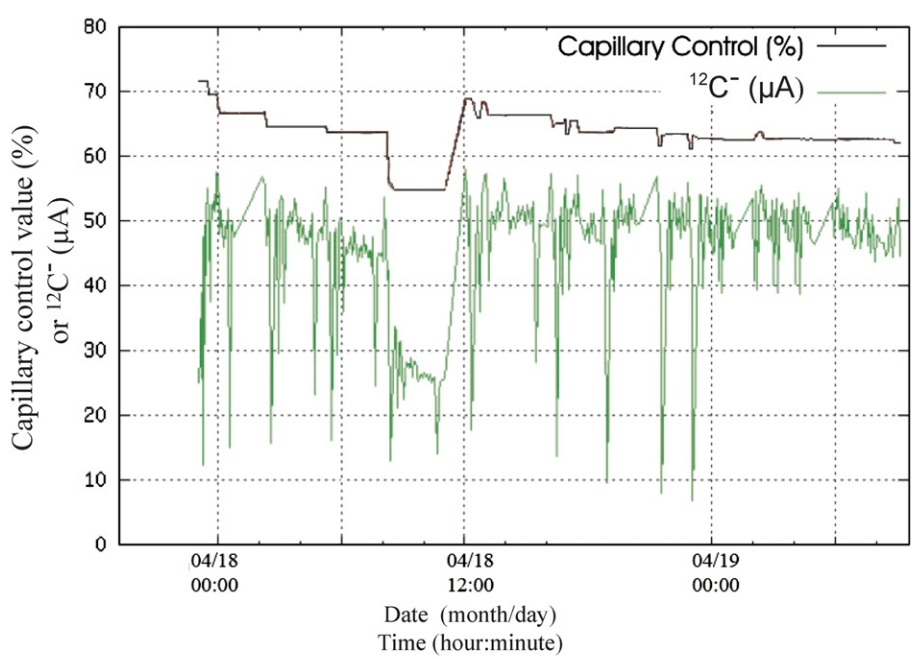

Fig. 7. Demonstration of functionality of the Cs capillary heating regulation program, used for controlling the negative ion output of the source.

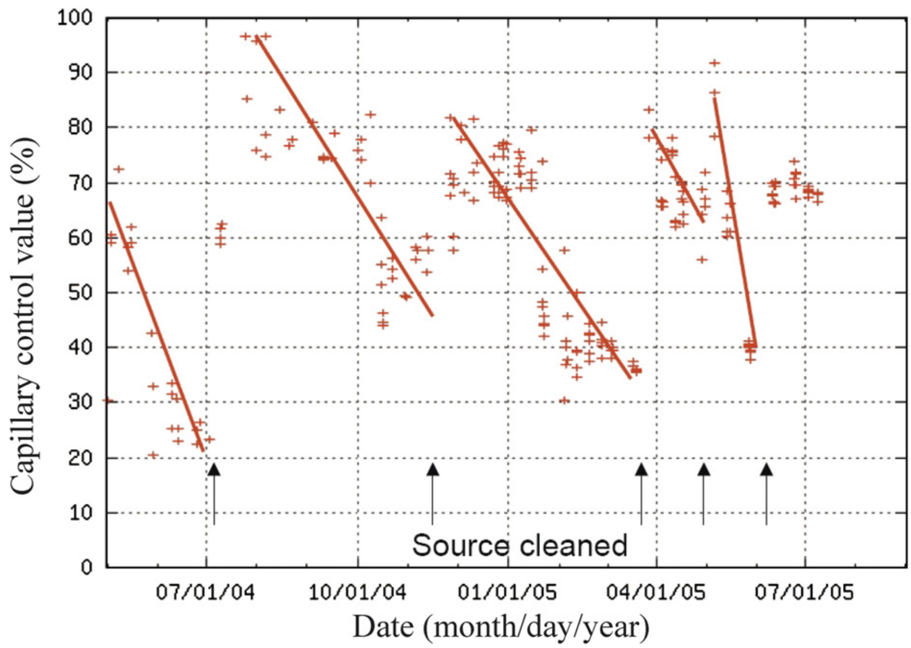

Fig. 8. Plot of capillary heating power supply settings versus time. 100% equals 40 A.

tion. Within about 1 h, the source output reached the proper value of 50 μA $^{12}C^{-}$.

For handling hygroscopic targets we have tailored a glove bag, which can be attached to the source. The bag can be flooded and pressurized with argon. The source can then be opened with the bag attached. Compared to the standard procedure, using this bag also for changing non-hygroscopic targets keeps out moisture and results in a significantly shorter pump-down time.

After source cleaning the power supply feeding of Cs-capillary heater has to be set to rather high values (about 80% of maximum current of 40 A) to get reasonable negative ion currents. By and by its power consumption has to be reduced. This behavior is clearly depicted in Fig. 8. One sees this fading effect even during one measurement period where the source is running continuously. Leaving the capillary constant will finally result in flooding the source with Cs. We do not fully understand this effect, but the varying settings of the capillary are needed in fact to keep the Cs supply to the sample wheel constant. Increasing the capillary above the currently required levels leads to strong deposits of Cs, visible when changing the target wheel.

8. Summary and outlook

We have successfully changed to a new target changing and positioning mechanism, which allows moving the target with high resolution. A few examples of applications, which profited by this technical improvement, demonstrated its functionality. A new target holder design encourages manufacturing and testing a standard size target wheel, which could hold 72 samples.

We are now in the process of installing a second source beam line, which will merge with the old injector beam line at the electrostatic analyzer. A modified version of this device will allow a 45-degree (old) and a 90-degree (new) electrostatic analysis of the negative ion beams from the two ion sources, respectively.

References

[1] G.A. Norton, R.L. Loger, J.E. Raatz, R.D. Rathmell, in: J. Benson, L. Rowton, J. Tesmer, R. Darling (Eds.), Proceedings of the 25th Symposium of North Eastern Accelerator Personnel, Santa Fe, New Mexico, USA, October 16–19, 1991, World Scientific, Singapore, 1992, p. 295.

[2] D.C. Weisser, N.R. Lobanov, P.A. Hausladen, L.K. Fifield, H.J. Wallace, S.G. Tims, E.G. Apushkinsky, PRAMANA J. Phys. 59 (6) (2002) 997.

[3] A. Wallner, I. Dillmann, R. Golser, F. Käppeler, W. Kutschera, M. Paul, A.Priller, P. Steier, C. Vockenhuber, Nucl. Instr. and Meth. B, these Proceedings, doi:10.1016/j.nimb.2007.01.207.

[4] P. Steier, L. Siebert, R. Golser, W. Kutschera, T. Orlowski, A. Priller, C. Vockenhuber, A. Wallner, these Proceedings.

[5] P. Steier, F. Dellinger, W. Kutschera, A. Priller, W. Rom, E.M. Wild, Radiocarbon 46 (1) (2004) 5.