

## A MULTI-SAMPLE CHANGER COUPLED TO AN ECR SOURCE FOR AMS EXPERIMENTS\*

R. Vondrasek<sup>a)</sup>, T. Palchan, R. Pardo, C. Peters, M. Power, R. Scott, Argonne National Laboratory, Argonne, IL 60439, U.S.A.

### Abstract

A project using Accelerator Mass Spectrometry (AMS) at the ATLAS facility to measure neutron capture rates on a wide range of actinides in a reactor environment is underway. This project will require the measurement of a large number of samples previously irradiated in the Advanced Test Reactor at Idaho National Laboratory. The AMS technique at ATLAS is based on production of highly-charged positive ions in an electron cyclotron resonance ion source (ECRIS) followed by acceleration in the ATLAS linac. The sample material is introduced into the plasma via laser ablation. This should limit the dependency of material feed rates upon the source material composition as well as minimize cross-talk between samples. A new multi-sample changer has been constructed allowing rapid changes between samples. The sample changer has 20 positions and is capable of moving from one sample to the next in one minute.

### INTRODUCTION

Accelerator mass spectrometry (AMS) is a sensitive technique for accurately measuring quantities of long-lived, rare isotopes in the presence of more abundant ones using very small amounts of material. The material of interest is introduced into the ion source of an accelerator, ionized, accelerated, and separated by electromagnetic means. Accelerators offer an advantage over conventional mass spectrometers owing to the total elimination of molecular interference due to the dissociation of the molecules in the ion source plasma. By accelerating the mass of interest to energies of a few MeV/U, it is often possible to use differences in rates of energy loss to separate the isobar constituents into their exact elemental groups resulting in a complete atom-by-atom unique identification over much of the periodic table [1, 2].

AMS often has a limited amount of material that can be provided for the measurement with sample sizes of at least a few mg mass required to be able to handle and control the delivery of the ions into the plasma (and hence to the detector). Also for oven evaporation or even sputtering, the form of the source material determines how easily this material can be introduced into the plasma. So in many AMS cases the success of the project can hinge on the choice of the material chemical form and either the dilution methods employed or the pre-AMS chemical separation techniques used to enrich the element of interest.

Oven evaporation and sputtering can indiscriminately deposit material into the source resulting in an accumulation of material on the source walls. This can

lead to sample ‘cross-talk’ and elevated backgrounds. For many AMS experiments, it has been necessary to develop liners to shield the source plasma from the wall contaminations [3]. This can form the ultimate limitation to AMS sensitivity either because of an inability to discriminate isobar members adequately or due to sample cross-talk.

In an effort to reduce both the cross-talk problem and allow the use of small samples with minimal chemical processing and dilution, the laser ablation technique is being employed to introduce the sample material into the source in a very controlled and precise manner. Laser ablation was first developed at ATLAS [4, 5] and used as a plasma diagnostic tool and has since been used by a number of other labs to explore the coupling of laser produced ions into an ECR source [6, 7]. The controlled release of materials into the plasma by well-focused laser light will eliminate the significant material accumulation often seen in the region of the oven throat or beside the sputter samples. The inefficient and indiscriminate injection of material into the source using the sputter or oven methods reduces the total sensitivity of the AMS method and is a major source of cross-contamination between samples.

### THE ANL ECR ION SOURCE

ECR2 is a room temperature ion source based upon the A-ECRU design [8] with the plasma excited with multiple frequencies between 10 and 14 GHz and a typical bias voltage of 14 kV. The source has radial access utilized for material introduction as well as pumping to the plasma region. Due to source space considerations as well as the desire to have the ablated material traverse as much of the plasma as possible, it was decided to pursue an axial ablation geometry. In this geometry the laser is mounted off of the source high voltage platform at ground potential. The beam is directed up to the high voltage platform through large diameter insulating pipes. The ablation sample is introduced on the injection side of the source with the laser beam entering the vacuum system through a port on the 0° line. The laser enters the ion source plasma chamber through the extraction aperture and strikes the target (Fig. 1).

For the initial on-line tests, the ablation sample was mounted on a simple linear motion feed through. The optimum ablation position during source operation was determined by varying the sample position and observing the intensity of the beam of interest. However, for the experimental program, a large number of sample positions were required with the ability to cycle rapidly between them.

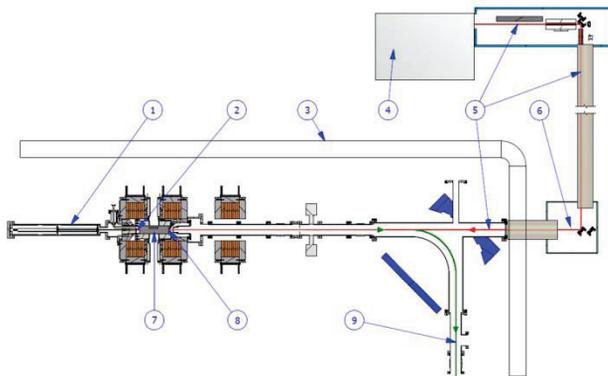


Figure 1: Installation of the laser ablation system at the ECR2 ion source. 1: sample changer chamber, 2: sample ablation position, 3: high voltage platform, 4: laser power supplies, 5: laser path, 6: wobbler mirror, 7: plasma chamber, 8: extraction aperture, 9: ion beam path.

### SAMPLE CHANGER SYSTEM

The sample changer accommodates 20 sample positions and allows the experimental data system to remotely operate the system. The samples are mounted on the end of stainless steel rods 3.16 mm in diameter. The sample wheels are fabricated from PCTFE due to its low outgassing rate as well as its low surface coefficient of friction. The rods are arrayed around a central shaft which is manipulated with a stepper motor augmented with an absolute encoder. In this way, absolute position information is maintained even in the event of a loss of power. Sample position and composition information is entered into a computer data base and is accessible from either the accelerator control system or the experimental data system. The sample is moved into ablation position with a magnetically coupled linear drive which is also equipped with a stepper motor. A variable linear resistor provides position information and IN and

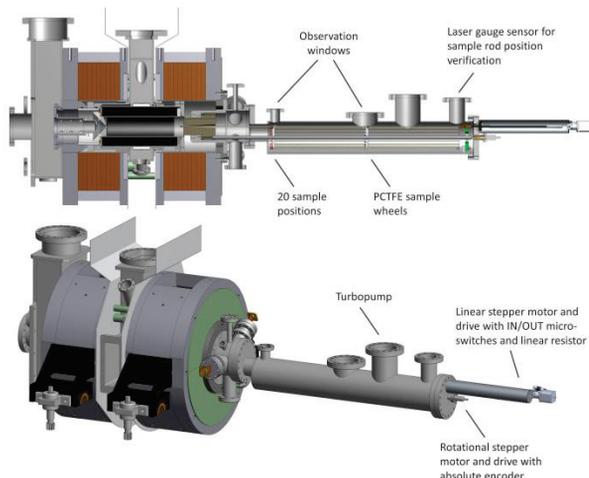


Figure 2: Schematic of ECR ion source with sample changer chamber and associated hardware.

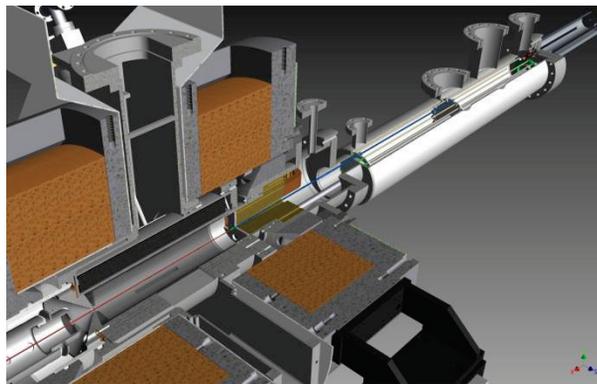


Figure 3: Cut-away view of ECR ion source with sample changer chamber. Sample is depicted in the fully inserted position with the laser beam shown in red entering the plasma chamber through the extraction aperture.

OUT position limit switches control motor power to prevent over driving of the feed through. As an added safe guard to verify that the sample rod is fully retracted before rotation, a laser gauging sensor is used to detect the fully retracted sample rod. Only when this circuitry is closed is power provided to the rotational stepper motor. Fig. 3 shows a cut-away view of the sample changer installed on the ECR source. The sample is in ablation position and the laser beam is entering from the left through the extraction aperture.

A detail of the injection region is shown in Fig.4. One end of the central shaft is secured in the injection side iron with a CPVC bushing to facilitate smooth operation. The iron was modified with a taper to accommodate any positioning errors and has a coaxial section at the end of the taper to assure accurate and repeatable positioning of the sample on axis. A high intensity lamp in the injection region back lights the sample and allows visual verification of its position. Also seen in the figure are the samples, shown in red, mounted on the ends of the sample rods.

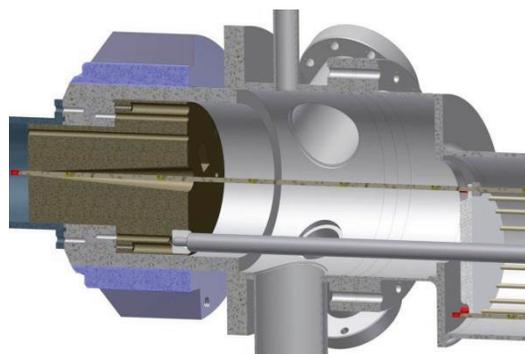


Figure 4: Detail of the taper in the iron plug and the spindle mount in the injection tank region. The RF and support gas also enter the source via this chamber.

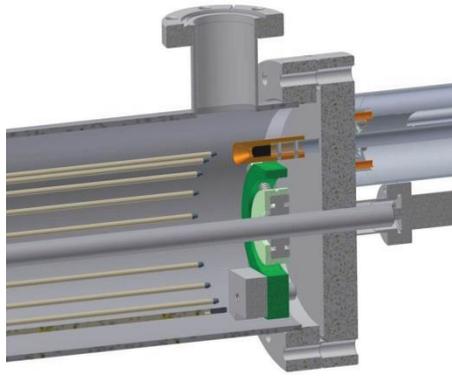


Figure 5: Detail of the spindle mount, the linear drive receptor with magnet, and the iron end tips on the sample rods. The linear drive pushes the sample into position. A permanent magnet allows retraction and decoupling from the sample rod at the full OUT position.

At the other end of the sample shaft is a mount which allows alignment of the overall device. Seen in Fig. 5 are the central shaft and the surrounding sample rods, the shaft mount, and the mounting flanges for the rotary feed through and the linear drive. At the end of the linear drive shaft is a receptor cup. The cup is tapered such that when it moves forward to push the sample into position any misalignment is compensated for with the taper. To secure the sample rod to the linear drive a permanent magnet is used. The magnet engages an iron end tip that is threaded onto the stainless steel sample rods. The magnet strength was specified such that during sample retraction the sample rod remains firmly engaged but once the end of the sample rod travel is reached the linear drive pulls away from the magnet allowing free rotation.

The sample holders are constructed of either stainless steel or high purity aluminium and are 3.16 mm in diameter. The sample volume is recessed so that there is less chance for the sample material to be transferred to source surfaces via direct contact. The interior is tapered such that it minimally intercepts the ablation plume while at the same time self-shielding the plasma chamber walls from the portions of the ablation plume which may not directly intercept the plasma.

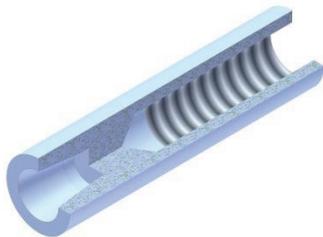


Figure 6: Sample holder.

## OPERATION AND PERFORMANCE

The sample changer has been operated on-line during source ablation tests. Samples of aluminum, aluminum oxide, iron oxide, and uranium oxide were ablated into the ECR source, ionized, and analysed.

During an ablation sequence, a sample is selected and the rotational motor moves it into position with the position being verified by the absolute encoder. The linear drive then pushes the sample into the ablation position, a total travel of 375 mm. The sample linear position is monitored by the linear resistor. After sample ablation, the linear drive retracts the sample with the magnetic coupling disengaging at the end of travel. The laser sensor verifies that the sample rod has been fully retracted before allowing rotation of the sample assembly. The total selection, insertion, and retraction time is one minute.

## ACKNOWLEDGEMENTS

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