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AUSTRALIS: PROGRESS REPORT

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SUMMARY

The first stage of the development of AUSTRALIS, a microbeam AMS system at the HIAF laboratory at North Ryde, Sydney has been completed. The system is designed to enable in-situ microanalysis of geological samples for ultra-traces and for isotopic data for minerals exploration research. The negative ions for analysis are produced by sputtering with a microbeam of Cs^+ from a modified General Ionex model 834 HICONEX ion source. The source features a novel intermediate or 'screen' electrode to correct for the effect of the secondary ion extraction field on the trajectory of the primary beam, in order to bring the primary beam to the geometric centre. The high energy analysis system of AUSTRALIS features a pair of deflector systems to permit fast switching of isotopes without altering the magnet setting. The paper describes the initial tests' results showing good agreement with the design parameters.

1. INTRODUCTION

A microbeam AMS system suitable for in-situ microanalysis scale of ultra-traces and of isotopic ratios for geochronology is being developed at the HIAF (Heavy Ion Analytical Facility) laboratory at North Ryde, Sydney. Based on a 3 MV Tandetron accelerator, the microbeam AMS system, known as AUSTRALIS (AMS for Ultra Sensitive TRAce eLement and Isotopic Studies), features a microbeam primary ion source and a high energy mass spectrometer capable of analysing actinides at >~2 MV terminal voltage.

2. AUSTRALIS

A general description of the AUSTRALIS system has been given elsewhere previously [1]. Special features that set it apart from most other AMS systems are the microbeam source, and the facility for fast isotope switching at the high energy side using deflector plates [1,2].

A diagram of the AUSTRALIS injector system is shown in figure 1. The sample chamber features two ports at + and -45° angle with respect to the secondary ion beam axis, allowing installation of two primary Cs beam sources, the proposed mass analysed primary beam system and the modified HICONEX source. The secondary negative ions sputtered from the sample at the center of the chamber are extracted at normal angle, and focused by an einzel lens at the first set of slits to form the object for a double focusing, 45° bend spherical electrostatic analyser (ESA) with a 30 cm mean radius and 3 cm gap. A second set of slits follows the Faraday cup, designed to reduce beam halo. The image of the ESA serves as the object of a high resolution, double focusing 90° magnet corrected to the second order, with a 30 cm mean radius and 2.5 cm gap, designed to operate with a demagnification of 2. The magnet beam box is insulated to permit application of the usual 'bouncing' technique. Since the secondary ions are produced by microbeams, the ESA and the magnet can be operated with narrow slits settings. At 0.5mm slit setting an energy resolution of 600 and a mass resolution of 1200 will be obtained with this injector system.

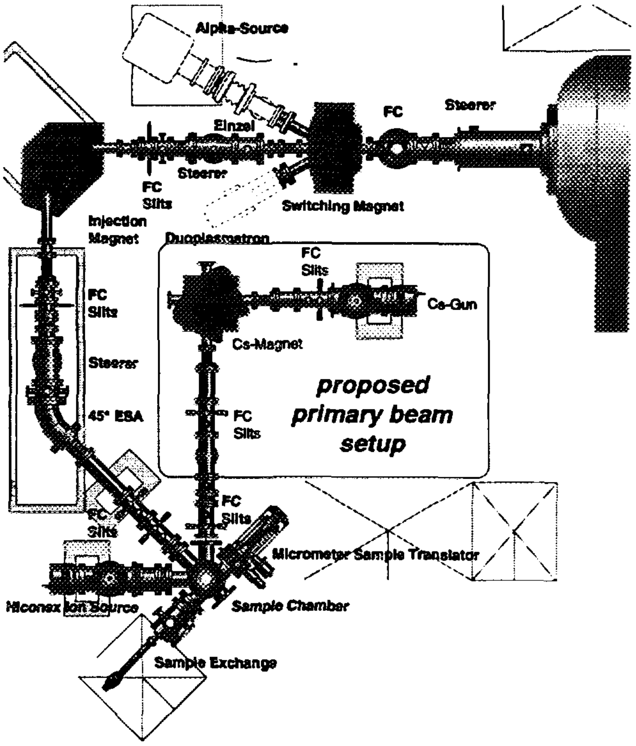

Fig. 1. Plan view of the AUSTRALIS injector system. The sample is mounted at the centre of the chamber on a 3 axis microstage.

The main part of the high energy system of AUSTRALIS is the new larger Danfysik 90° double focusing magnet which is corrected to the second order. The nominal maximum beam product (mE/q^2) of the magnet is 140 MeV.amu, but it can be operated up to 10% above specification. The pole tips are 130 cm in mean radius, 15 cm wide and separated by a 3.0 cm gap. At maximum excitation, the magnet will permit analysis of mass 230, 5+ ions at ~2.5 MV terminal voltage or 4+ at ~2 MV. Following the magnet the beam passes through two electrostatic analysers with 22.5° bend, separated by an electrostatic quadrupole doublet. The quadrupole is situated between the two ESA's to maintain the beam envelope below 25 mm, in order to keep the maximum voltages of the ESA below 50 kV and minimize hazardous background of high energy X-rays. The quadrupole focuses the beam into either a Faraday cup or an ion detector, which can be a proportional counter. A time-of-flight system will be implemented by installing a start detector at the entrance to the first ESA.

Two sets of deflecting plates, 40 cm long with 4 cm gap, at the entrance and the exit ports of the magnet box comprise the high energy 'bouncer' system. Different isotopes are deflected by different amounts transversely in the orbit plane by the entrance plates and returned to the main axis by the exit deflectors by applying common voltages to both sets, without altering the magnetic field setting. Originally devised as an energy modulator [2], this technique adapts well as an isotope switcher. Preliminary tests with 3 MeV proton beam in the energy modulating mode indicate a flat transmission over energy range of up to 1.2% from the mean value, corresponding to similar range in mass difference when used as an isotope switcher. Figure 2 shows the plot of the deflector voltage vs. the accelerator terminal voltage for the proton beam test, and the calculated values as a function of D, the effective mean distance of the plates from the field boundary.

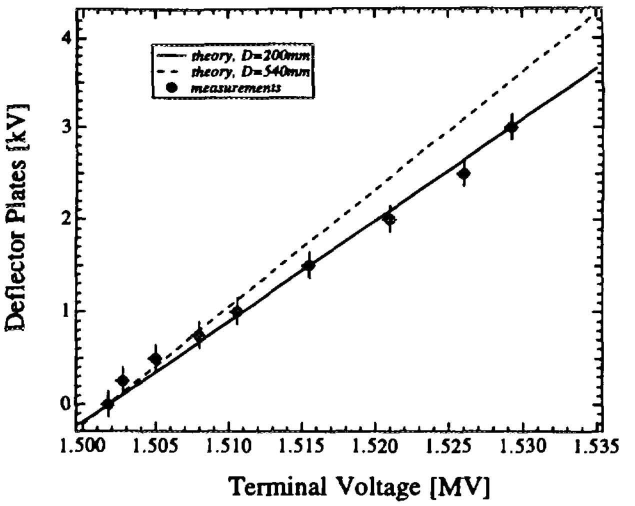

Fig. 2. The high energy bouncing system was tested using 3 MeV proton beam. The plot shows the deflector plate voltage against the proton beam energy represented by the terminal voltage, and the calculated values for various distance D representing the mean distance of the deflector plate to the magnetic field boundary.

3. THE ION SOURCE

The ion source is designed to enable microanalysis of geological samples, where spatial information is crucial. In the AUSTRALIS sample chamber, a high magnification, direct sample viewing system is achieved by means of an zoom microscope with a 71 mm working distance, combined with a prism with a hole coaxial with the secondary beam axis at 25 mm distance from the sample. With a x10 ocular, a total maximum magnification of 70 is obtained. This is further magnified by the lens for CCD camera, approximately by a factor of 2 resulting in a one micron pixel resolution on the video monitor. The prism is located inside the extractor block and can be retracted out of the way and into a position shielded from the sputtered sample material, without affecting the secondary ion optics. This feature will help prolong the service time between prism replacements or cleaning, since it is expected that the reflecting surface would be coated with some material sputtered from the sample during viewing. The sample is mounted on a rugged, computer controlled 3 axis microstage, with 0.5 μm step size. The target mounting is designed such that target exchange can be carried out conveniently through a vacuum lock.

An existing HICONEX is modified by replacing the secondary ion extraction electrode with a 'faraday cage' biased at the same Cs extraction voltage as applied to the magazine of cones, to extract the beam through the aperture of the cone, and transport it to another lens for focusing into a microbeam. The cage includes a condenser cylindrical einzel lens at the entry side which is designed to improve the optics of the beam transport. The original target 'cones' assembly is now a convenient set of collimators or object apertures for the microbeam production. The final focusing lens is a cylindrical einzel lens, with end elements at the cage potential. The focused Cs beam passes through an intermediate ('screen') electrode before accelerated to its final energy by the secondary ion extraction potential. Figure 3 shows the beam optics of the modified HICONEX source, computed with the program SIMION [3]. The first extraction einzel lens, together with the condenser lens control the first waist of the Cs beam, either to focus it at the object collimator for maximum beam through the collimator or to illuminate the collimator for a more uniform beam distribution at the target. For minimum spherically aberrated image, the focus can be adjusted such that the rays are parallel after the collimator.

The 'Screen' electrode electrode has two functions: first to screen the primary beam as much as possible from the secondary extraction field that will affect its trajectory, and second to correct the deviation caused by the field by tailoring the shape of the field to return the intersection point to the desired geometric center of the target. The optics of the secondary ion extraction region showing the effect of the screen is shown in figure 4. Because of cylindrical symmetry restrictions, the primary beam is simulated by a bundle of rays converging at the geometric centre. For clearer definition of the centre, two

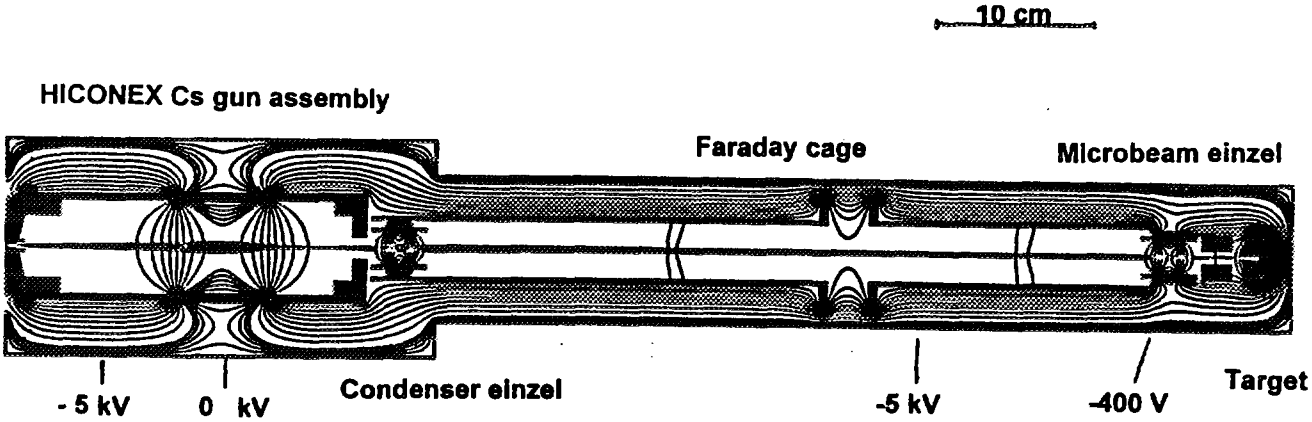

Fig. 3. The beam optics of the modified HICONEX source calculated using the code SIMION in cylindrical symmetry geometry.

symmetric bundles of primary rays are shown. When the screen is set at the same potential as the 'extractor block', the primary beam can be seen to deviate from the centre. The effect would be even larger if the screen were removed. By varying the screen voltage slightly, the spot can be returned to the centre. The displacement is approximately linear with the voltage difference between the screen and the extractor voltage and can therefore also be used to correct deviation caused by residual misalignment of the primary beam axis, provided that it is on the same plane as the secondary axis. Results of the tests show good agreement with the values derived with SIMION of ~400 μm displacement for a 200V change in the screen voltage for Cs beam extracted at 5 kV. The target bias was -10 kV, and the screen voltage was -5.4 kV, indicating the existence of some residual misalignment.

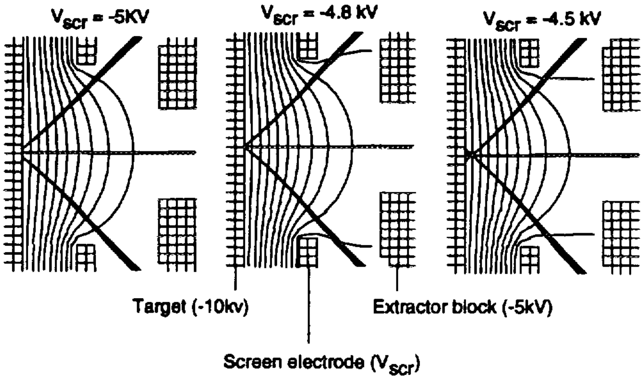

Fig. 4. Beam optics of the secondary ion extraction region calculated with SIMION 5 to show the effect of the screen electrode.

4. THE MICROBEAM

The beam spot can be observed readily in real time on the video monitor, or directly through the microscope ocular, as erosion spots on a thin carbon layer vacuum deposited on a polished Au target, followed by sputtering of the Au itself. The best focus for uncollimated gun, i.e. when there is no cone in place corresponding to an aperture of 10 mm was 300 μm. The spot is an ellipse with its long axis $\sqrt{2}$ times the short axis, consistent with a cylindrical beam intercepting the target plane at 45° incidence. The short axis is taken to be the focus size. With the 2 mm aperture cone, the best focus obtainable was 160 μm. However, a more uniform erosion spot but larger diameter (300 μm) is obtained when the beam intensity is not optimised at the target. This corresponds to the 'Köhler's illumination' mode [4]. Under this condition, the Cs einzel is focused to produce a waist before the aperture and the beam envelope at the aperture is larger than its size. The waist coincides with the focal point of the condenser einzel, resulting in a parallel beam which is further focused by the final einzel lens. Hence spherical aberration effects are minimal and the beam spot scales geometrically with the aperture size. The smallest aperture tried so far is 150 μm, resulting in a 30 μm spot size.

The intensity of the primary beam can only be estimated from the measured secondary ion intensity measured either in the source or the injector magnet Faraday Cup. With the ioniser of the Cs gun at maximum setting and the Cs reservoir heated to 220° C, up to 1 nA of C was measured from the thin C coating at 30 μm resolution. For graphite targets a ~6% yield (12 keV Cs beam, 20 keV extraction) can be obtained [5]. Considering that in the present test the target is not graphite, and the Cs energy and secondary extraction energy are lower, this efficiency may represent only the upper limit. With this proviso we estimate that the intensity of the primary beam is at least 16 nA at this resolution, corresponding to ~2 mA/cm^2 beam density. The Cs gun type used here can generate ~60 μA, and without collimation it can be focused to ~500 μm corresponding to ~30 mA/cm^2 beam density. During this test however the gun was not run at maximum possible output, and it should be noted that the estimate of the microbeam density is a lower limit. Further test with graphitised target with known characteristic ion yield or direct measurement of the primary current will be attempted in the near future.

5. CONCLUSION

The first stage of the AUSTRALIS development is completed and is currently undergoing tests. A number of key features of the system have been successfully tested. The optics of the microbeam system based on a modified HICONEX source behaves according to the model calculation. The source proves to be a versatile device for providing Cs beam spanning the sub-milli and micron range of spatial resolution at maximum possible delivered intensity. The 'screen' electrode in the secondary ion extraction region behaves as predicted and presents a convenient technique for correcting the effect of the secondary ion extraction field on the primary beam, giving a high degree of decoupling of the primary and secondary ion optics. The same electrode can be employed to correct for residual geometric misalignment of the lens axes. A test of the high energy bouncing system shows good agreement with the calculation permitting application of fast bouncing techniques to improve the precision in isotopic ratio measurements not possible by the inevitably slow switching of magnetic fields.

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REFERENCES

1. Sie,S.H. and Suter G.F., [1994], Nucl. Instr. Meth. B92, 221
2. Amsel G., D'Artemare E. and Girard E., [1983], Nucl. Instr. Meth. 205, 5
3. Dahl D.A. and Delmore J.E., [1988], SIMION User's Manual, EGG-CS-7233 Rev. 2, April 1988 and ext. DOS version
4. Liebl H., [1983], Vacuum 33, 525
5. Middleton A., [1989], "A Negative Ion Cookbook", University of Pennsylvania, unpublished.