A HIGH ENERGY SECONDARY ION MASS SPECTROMETER FOR THE ANALYSIS OF CAPTURED SOLAR WIND. K. D. McKeegan[1], C. D. Coath[1,2], P. H. Mao[1], G. Jarzebinski[1], and D. Burnett[3] [1]Dept. of Earth & Space Sciences, UCLA, Los Angeles, CA. 90095-1567 USA (mckeegan@ess.ucla.edu); [2]Dept. of Earth Sciences, Univ. of Bristol, Bristol, BS8 1RJ, UK; [3]Div. Geol. & Planetary Sci., Caltech, USA.

Introduction: The GENESIS Discovery Mission [1] seeks to measure the average elemental and isotopic composition of the solar system to a precision and accuracy sufficient to address important questions in planetary science. It will accomplish this by returning samples of the solar wind (SW), captured in ultra-pure target materials, for analysis in terrestrial laboratories.

The two most important scientific objectives of GENESIS are the analysis of the isotopic abundances of SW oxygen and nitrogen with an accuracy of ~1‰ and 10‰, respectively. The spacecraft carries an electrostatic mirror designed to enhance the signal-to-background as well as depth of implantation of these SW elements in target materials (SiC, ^{13}C CVD diamond, diamond-like C film) chosen for their low intrinsic backgrounds and lack of native surficial oxide layers [2,3]. The concentrator also rejects >90% of the protons, but most of the atoms collected will still be H. Even with the concentrator, only small amounts, ~8 and 0.8 ng of O and N, respectively, will be captured per cm^2 of target and those SW atoms will be not very far removed from possible surface contaminants (mean implantation depth, ~500 Å). Such relatively small amounts of O and N have been measured with good precision in extraterrestrial materials, e.g. by secondary ion mass spectrometery (SIMS) in dust particles, but not in such dilute concentrations spread over a relatively large area.

In order to address these analytical challenges, we are constructing a new instrument that combines the unsurpassed capabilities of SIMS for high-resolution depth-profiling of semiconductor materials (like the GENESIS collectors) with those of accelerator mass spectrometry for overcoming limitations in isotopic abudance measurements caused by molecular ion interferences. Here we report the major design criteria and performance goals for this new micro-analytical instrument, termed the UCLA "MegaSIMS."

Design criteria: Although great pains have been taken to keep the surfaces of the GENESIS collector materials clean, inevitably there will be contamination on collector surfaces. It is clear that any analysis approach must start with a cleaning step to remove surface contamination. MegaSIMS employs a low-energy (>200 eV) Ar^+ ion beam to sputter-clean the surface without removing significant sample or driving in contaminants by atomic knock-on. Capabilites also exist for cleaning by laser desorption. Isotopic analyses are accomplished with a mass-filtered Cs+ beam, which despite its higher impact energy (20keV) still yields sufficient depth-resolution to permit differentiation of the implanted SW signal from possible contaminants on the initial sample surface. Dynamic transfer optics and optical gating are used to enable depth-profiling of relatively large analytical areas thereby improving sample-usage efficiency. Particulate contaminants, (a potentially serious problem for oxygen) are avoided by using the ion microscope capabilities of a modified CAMECA ims 6F, which serves as the front-end ion source of the MegaSIMS. The vacuum system has been improved to minimize background from residual oxygen to acceptable levels (<1% SW equivalent) while maintaining reasonable sputter rates (< nm/s).

The control of background and contamination is a serious issue, especially for O, but there are also stringent requirements on the mass spectrometry. Because the implanted SW ions vary markedly in concentration as a function of depth in the target, analyses must be performed with simultaneous ion detection. Additionally, the H/O ratio in the concentrator targets will likely exceed 100, and measurements of ion-implanted analog materials suggest that this will lead to a hydride interference (^{16}OH) that is several hundred to perhaps 1000× more intense that the SW ^{17}O signal. Such a potent molecular ion interference can be eliminated in conventional SIMS by high mass resolving power, but at a significant cost in transmission (sensitivity). Similar considerations apply to the analysis of nitrogen isotope abundances using the easily ionized CN^- molecule. An alternative approach is to borrow techniques developed by accelerator mass spectrometery (AMS), and strip electrons from a high-energy negative ion beam which results in the destruction of molecular ions to a very high level.

Instrument Description: The MegaSIMS combines a modified low-energy (10keV) ion microscope with a compact tandem AMS (1.2 MV terminal) equipped with a novel injection system that allows for simultaneous analysis of several ion beams of adjacent masses (e.g., 16-17-18 or 26-27). This is achieved by an 'isotope recombinator' and parallel ion counting detection system in a forward-geometry double focusing, high energy mass spectrometer.

The mass separator – isotope recombinator. The function of this device is to transmit a portion of the mass spectrum, containing only the isotopes of interest, along with possible isobaric interferences, to the

object plane of an einzel lens at entrance of the tandem accelerator. The negative ion beam is first in mass and ions in an accepted mass range are then recombined into a single beam whose emittance is properly tuned to the acceptance of the accelerator (Fig. 1). A major goal is to simplify the mass resolution requirements on the high energy spectrometer by eliminating possible interferences due to multiple charge states, which are inevitable in the stripping process. For example, SiC is substantially better than diamond as a low-background collector of N isotopes, but its use would cause complications during analysis because Si^{++} would need to be resolved from N^+ in the high energy beam. Using the recombinator, all the CN^- isotopomers would be transmitted, but Si^- would be excluded, thus avoiding getting any Si into the stripper canal. The $^{15}N^+/^{14}N^+$ can then be determined on the molecular fragments by analysis at low mass resolving power.

Tandem Accelerator – High Energy Mass Spectrometer. A compact tandem accelerator is being constructed to our specifications by National Electrostatics Corp. The accelerator will be able to use both foil and gas canal strippers, but for the GENESIS samples, we will use an Ar gas stripper because of its demonstrated ability to allow reproducible, high precision analyses in ^{14}C AMS measurements [4].

Although destruction cross sections for OH are not yet measured, analogy with CH [4] indicates that the accelerator will easily reduce the OH intensity by many factors greater than the required 10^8. The mass spectrometer following the tandem is of a standard double-focusing, forward-geometry design. Five movable collectors are positioned on the focal plane of a large magetic sector (140 MeV-amu, B_{max} = 1.37 kG). Either Faraday or ion counters can be mounted on each collector. The overall throughput into the +1 charge state is estimated to be ~ 50%. Ion optical properties have been modeled to third order by TRIO, and beam recombination/focusing focusing properties appear to have reasonable margin to achieve good control on instrumental mass discrimination.

References: [1] Burnett D.S. et al. (2003) *Spa. Sci. Rev.* ***105***, 509-534. [2] Nordholt J.E. et al. (2003) *Spa. Sci. Rev.* ***105***, 561-599. [3] Jurewicz A.J. et al. (2003) *Spa. Sci. Rev.* ***102***, 27-52. [4] Synal H. A. et al. (2000) *Nucl. Inst. Meth. B* **172**, 1-7.

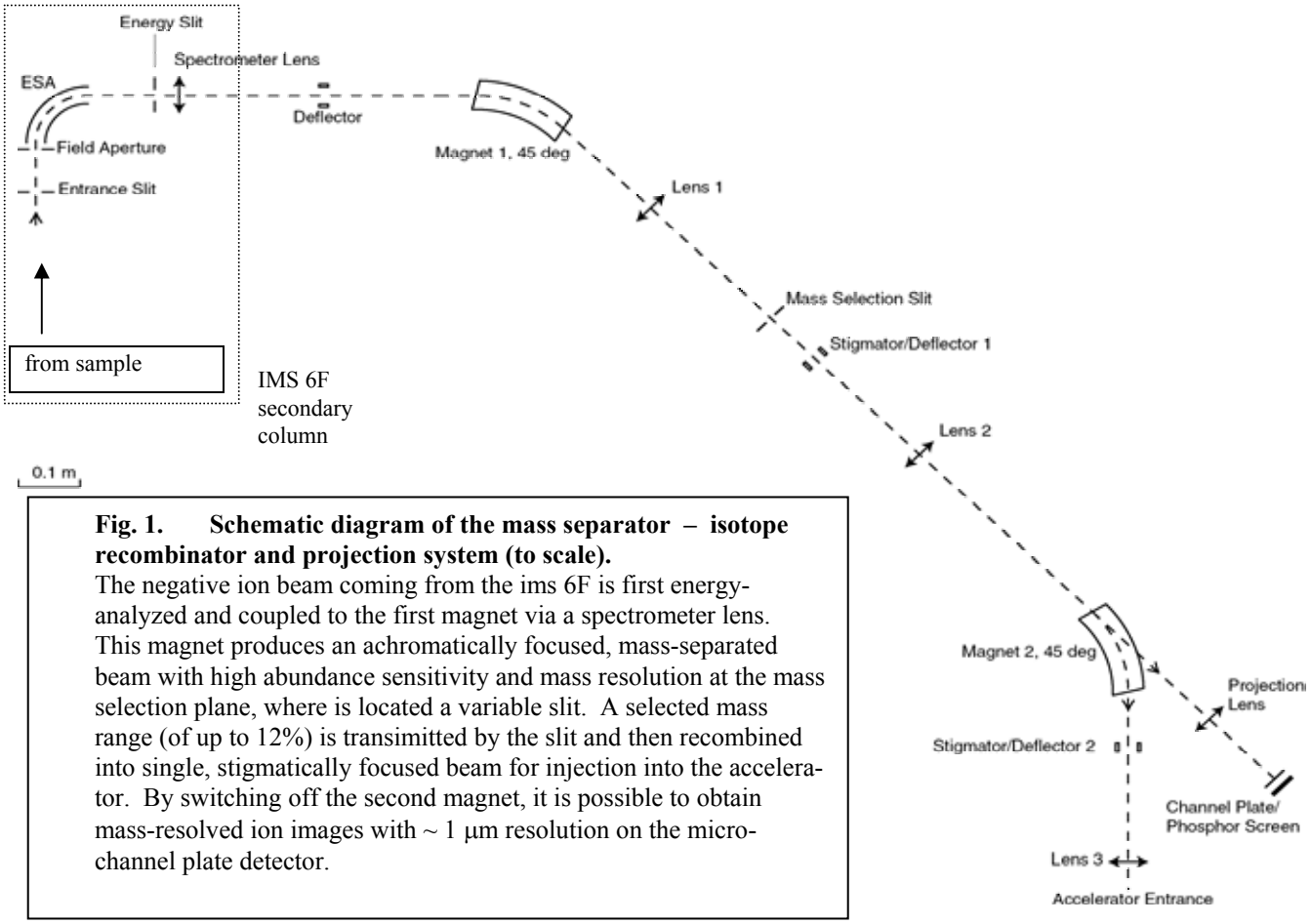

Fig. 1. Schematic diagram of the mass separator – isotope recombinator and projection system (to scale). The negative ion beam coming from the ims 6F is first energy-analyzed and coupled to the first magnet via a spectrometer lens. This magnet produces an achromatically focused, mass-separated beam with high abundance sensitivity and mass resolution at the mass selection plane, where is located a variable slit. A selected mass range (of up to 12%) is transimitted by the slit and then recombined into single, stigmatically focused beam for injection into the accelerator. By switching off the second magnet, it is possible to obtain mass-resolved ion images with ~ 1 μm resolution on the micro-channel plate detector.