EVALUATION OF STANDARDS FOR SILICON ANALYSIS IN GERMANIUM GENESIS COLLECTORS BY SIMS-AMS.

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Introduction: Recent efforts at the NRL SIMS-AMS facility have focused on silicon measurements to evaluate the possibility of Si analysis in Genesis collectors. Silicon, along with Na, Mg, Fe, Ca, and Cr, is one of the key elements for studying the influence of first ionization potential on elemental fractionation of solar wind (SW) in its three regimes.

The intended Genesis substrate material for SW Si analysis was semiconductor-grade Ge. However, only ~6% of the collector arrays were Ge, and a significant portion of this material was lost at landing. Accordingly, we first evaluated the diamond-like-carbon material as an alternative matrix [1], but its Si background content appears to be higher than that of Ge. Another option for Si analysis is using the sapphire substrates, which would need Au coating, which in turn might introduce additional contamination. Given these analytical challenges for alternate substrates, we started investigating the use of the Ge substrate material. The expected mean implantation depth of SW Si in Ge is below 100 nm with a total expected fluence of 1.9 10^{12} atoms/cm^2 from the 2-year flight period.

Experimental Technique: The SIMS-AMS facility at NRL [2] uses a modified Cameca 6F to provide a Cs primary beam, sample chamber, and secondary extraction optics. Desired ions, in this case ^{28}Si and ^{70}Ge, are selected through a mass-filtering recombination magnet and injected simultaneously in a 3-MV tandem Pelletron accelerator. The breakup of molecules during the acceleration process assures removal of most molecular interferences. After acceleration, only ions in a given E/q charge state are sent to the spectrograph magnet for parallel detection. The terminal voltage was set at 2.4 MV, and charge state 3+ was selected, yielding 9.6 MeV ions. Both low-concentration ^{28}Si and matrix ^{70}Ge beams were monitored simultaneously in ETP14140 electron multiplier detectors mounted in shielding boxes and placed 83 cm apart along the focal plane of the spectrograph magnet. The background could be additionally reduced by energy analysis of the mass-28 beam in a silicon-implanted energy detector. If a molecular fragment were present, it would have to be in a different charge state, and thus have a different energy than the 9.6 MeV atomic beam.

Implanted Standard Analysis: Initial results were obtained from two sets of standards consisting of ^{28}Si implanted in Ge at two energies (84 keV and 35 keV) with three different doses (1.5x10^{14}, 4x10^{13}, and 1x10^{13} atoms/cm^2). The blank was non-implanted Ge. For this first set of measurements the non-implanted standards and control Ge material were not cleaned prior to mounting in the sample holder since a specific procedure for Ge cleaning has not yet been established.

Typical depth profiles obtained from the set of six ^{28}Si implanted in Ge standards are presented in Fig.1, with the three doses at 84 keV shown in Fig.1a, and the 35 keV ones in Fig. 1b.

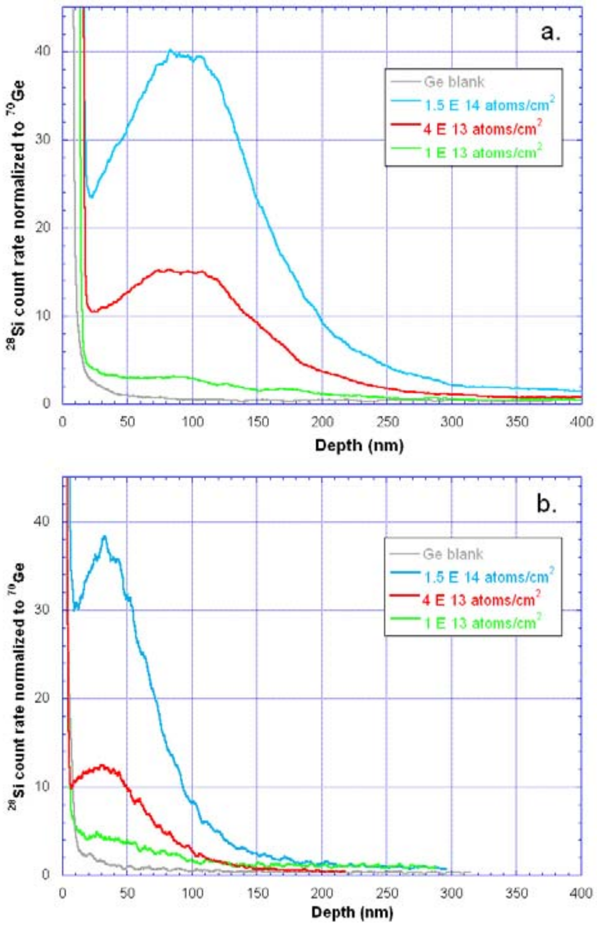

Fig.1. Measured depth profiles for (a) 84 keV and (b) 35 keV ^{28}Si implanted in Ge at 1.5x10^{14} (blue), 4x10^{13} (red), and 1x10^{14} (green) atoms/cm2. A Ge blank is also shown (grey). ^{28}Si counts are normalized to matrix ^{70}Ge counts.

The ^{28}Si counts from non-implanted Ge material are also shown in Fig. 1. For all profiles the ^{28}Si counts were normalized to the matrix ^{70}Ge counts detected simultaneously. Crater wall effects were controlled by use of the field aperture to allow for secondary ion collection only from the middle part of the sputter crater.

The higher-dose depth profiles were fitted with Gaussian distribution functions, the implant depths were thus determined, and compared to values generated by SRIM 2003 simulations. The implant depths were found to be 84.7 nm at 84 keV and 28.8 nm at 35 keV, in reasonable agreement with the calculated values of 79 nm and 33.7 nm, respectively. The lower-energy implant, though very shallow, is still differentiated from surface contamination. For both energies the lowest-dose implant is above the level of the Ge blank. The situation is expected to be further improved by surface cleaning prior to analysis. Both the level of Si on the surface and penetration below by recoil implantation are expected to be significantly reduced.

A composite of sputter depth profile data is shown in Fig. 2, where the integral under the curve is plotted as a function of dose for both energies used. The integration was started at about 10 nm to avoid the signal associated with surface contamination. The data from the low energy implantation falls below that of the high energy data because of lower retention of implanted ions at the lower energy, and because the integral excluded a greater portion of the implantation profile at the lower energy to avoid the surface contamination signal.

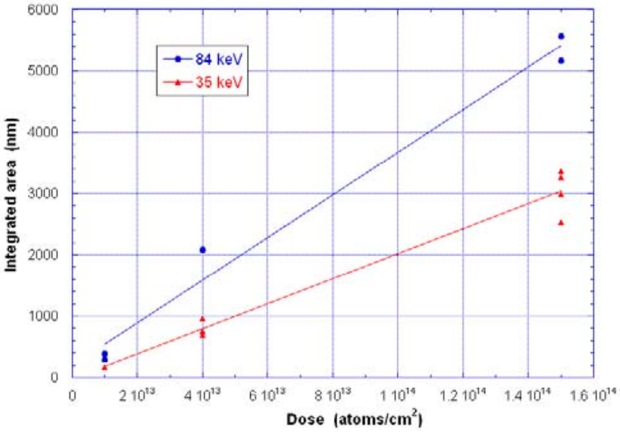

Fig.3. Integral area under the depth profile curves for 84 keV (blue) and 35 keV(red) implants.

Statistical uncertainties were calculated and are smaller than the size of the symbols. Systematic errors have not been carefully estimated at this point. For a given implant energy and dose the spread in the data reflects several issues including sensitivity to system tuning, day-to-day variations, and location of the crater on the sample. While measuring the crater depth we observed tilting of the sample in the sample holder which contributes to sensitivity of crater location. These results are also impacted by surface contamination.

Conclusions. From the results presented above it is still unclear if analysis of Si in Ge Genesis material is achievable by this method. Current data can be considered an upper limit on the systems overall detections limit and improvements that would enable the measurements are possible. A protocol for surface cleaning must be developed and is expected to lower Si background and reduce variability. Because of the design of our unique system, eliminating crater walls using the field aperture is not trivial. An improved method for system tuning will again reduce variability. Better statistics for low-dose samples, as expected in Genesis material, will require the measurement of multiple craters in series. Additionally, it may be possible to lower the background silicon by using energy analysis on the mass-28 beam to verify all counts are produced by silicon and not molecular fragments.

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References: [1] C. Cetina at al., LPSC 2009. [2] D.L. Knies et.al. (2006) *Appl. Surf. Sci.,252,7297.*