THE DEPTH PROFILE OF SOLAR WIND MAGNESIUM IN Si AND DIAMOND-LIKE CARBON COLLECTORS RETURNED BY GENESIS.* M. J. Pellin[1], B. V. King[2], I. V. Veryovkin[1], C. E. Tripa[1], M. R. Savina[1], and D. S. Burnett[3], [1]Materials Science Division, Argonne National Laboratory, 9700 S. Cass Ave., Argonne, IL 60439 (email: pellin@anl.gov), [2]University of Newcastle, School of Mathematical and Physical Sciences, Callaghan 2308, Australia, [3]Division of Geological and Planetary Sciences, Mail Code 100-23, California Institute of Technology, Pasadena, CA. 91125.

The samples returned to Earth by the Genesis Discovery Mission[1] contain a record of the elemental and isotopic abundances of the solar wind. This record is implanted in the near surface region of the sample collectors allowing the solar wind material to be distinguished from terrestrial contamination. Because depth the key parameter for isolating solar wind atoms from terrestrial contamination, it is important to understand the solar wind implant profiles. This is challenging due to the relatively shallow depths of the implants and complicated by the abrupt landing of the Genesis spacecraft and the subsequent contamination of the solar wind collection materials.

Preliminary studies of solar wind Mg implanted in Genesis Si collectors showed implant profiles that were shallower than either similar terrestrial standards (when corrected for different implant energies) or predictions by standard semiconductor implantation models.[2, 3] Here we show that the depth profiles can be understood as arising from three factors. First solar wind implants are not mono-energetic, but possess a broad energy distribution in comparison to standard semiconductor-style implants. Second, Genesis implants are not single element implants; rather the solar wind has implanted orders of magnitude more hydrogen (among other elements) than Mg. Finally, the Genesis collector samples have a relatively high temperature thermal history (~18 months at near 200 C).

Among the various high-purity materials which acted as collectors for the solar wind are silicon and diamond-like carbon (DLC).[4] As a test of our depth distribution model these two very different materials are useful candidates, since they have disparate behaviors under energetic ion irradiation. Experimentally, several depth profiles were taken of standards and Genesis flight materials. Each of these profiles, as well data for the Mg isotopes (24, 25 and 26) were averaged together to give the profiles depicted in **Figs 1 and 2**.

The depth profiles were taken using a secondary neutral mass spectrometry instrument implementing resonance enhanced multiphoton ionization of ion-sputtered and laser-desorbed neutral species, allowing quantitative analysis of metallic elements at ultra trace levels in the solar wind collectors returned to Earth by the Genesis spacecraft. This resonance ionization mass spectrometry (RIMS) instrument has been described elsewhere in detail. [5] Since accurate quantitative analysis is compromised by sample contamination, several features have been built into the new RIMS instrument to allow depth profiling at high lateral and depth resolutions [6] The main advantages of the RIMS instrument are its sensitivity, accuracy and selectivity. The RIMS technique has been shown to be capable of quantitative sub-parts per billion determinations while consuming little sample.[7]

The abundances of the various metallic elements range from above one part per million ($>10^{-6}$) to below one part per trillion ($<10^{-12}$) and are contained within 50 nm of the surface, [1] making analysis a challenging proposition, but one well suited for RIMS. As can clearly be seen in **Figs 1 and 2** by the surface peaks in both implanted standards and Genesis flight samples, the sample surfaces are contaminated with Mg. In the case of the Genesis samples, it is known that a thin film was deposited during flight. Previously, we demonstrated that the SARISA instrument can distinguish the surface contamination from the implanted ions.[3] At a second talk at this conference we will also show that particles introduced when the Sample Return Capsule was breached during its crash landing also give rise to anomalous depth profiles. The sample imaging capabilities of the SARISA instrument allow us to avoid many of the larger grains. Smaller grains give

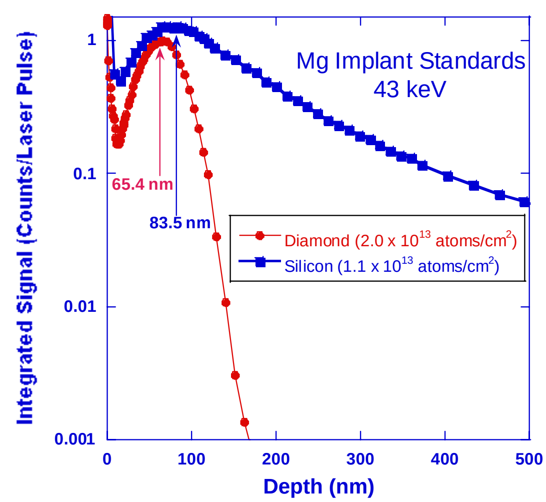

Figure 1. RIMS depth profile of implant standards. Each data point represents an individual RIMS measurement.

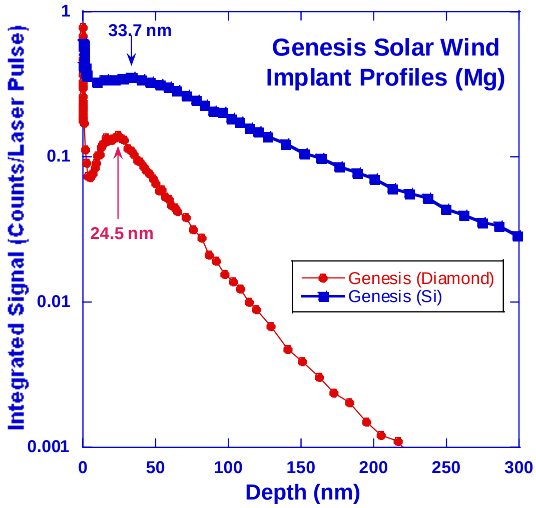

Figure 2. Concentration of Mg versus depth in Genesis Si and Diamond Colectors as determined by RIMS. Each Data Point represents an individual RIMS measurement.

rise to clearly distinguishable anomalies in the Mg depth profile and can be confidently excluded.

The Mg depth profiles were measured in two implant standards. One consisted of a Si wafer implanted with 43 keV ^{25}Mg at a dose of 1.10 × 10^{13} atoms/cm^2. A second consisted of a thick DLC film on a Si wafer implanted with 43 keV ^{25}Mg at a dose of 2.0 × 10^{13} atoms/cm^2. The total dose was determined both by the integrated charge of the implant and by Rutherford Back Scattering. The depth scale for **Figs. 1** and **2** were determined by measuring the integrated primary ion dose and then calibrated by using the expected implant maximum depth. This depth agrees well with expected sputtering yields of each sample. The depth will be confirmed with profilometry measurements of the depth profile craters when analyses of the Genesis materials are complete.

Two Genesis samples from the C or D collector arrays were cleaned using a Megasonic ultra pure water stream at Johnson Space Center (JSC) before being sent to Argonne National Laboratory. JSC has found that this cleaning procedure removes a substantial fraction of the surface particulate contamination (>50%), leaving areas as large as 500 µm in diameter particle-free at the ≥1 µm scale. Both the C and D collector arrays of Genesis were exposed to the solar wind for the entire 27 months that the collection canister was open and thus should represent the average solar wind over that time.

The differences in implantation behavior of the two materials (Si and DLC) are immediately apparent in **Fig. 1**. Si is less dense and therefore has a deeper implantation maximum than DLC. The stopping power differences in Si and DLC are evident in the much broader depth profiles of the Si sample. The crystalline nature of Si also contributes to this width.

Depth profiles of Mg in the Genesis flight materials show similar effects (**Fig. 2**). Three features of the concentration versus depth profile merit comment. First, the Mg concentration near the surface does not extend into the implanted portion suggesting that terrestrial contamination does not dominate the Mg from the solar wind. Second, each depth profile shows a much less pronounced maximum than the standards. The Si samples do show a maximum in these measurements as opposed to our earlier results.[3] This is a result of improved depth resolution in the measurement due to lower energy primary ion bombardment (10 keV Ar^+).[8] However, even when accounting for the implantation energy difference the maxima are less pronounced and the profiles are as broad as or broader than the higher energy implant standards. Finally, the peak maxima are closer to the surface than predicted by implantation models. In fact, the peaks appear at near the damage maximum in the samples caused by solar wind hydrogen irradiation. We propose that these features can be understood in terms of a model where implanted interstitial Mg atoms diffuse and are ultimately trapped substitutionally in the ubiquitous vacancies caused by the concomitant H ion irradiation in these samples.

In summary, the Mg depth profiles in Genesis flight samples can be distinguished from terrestrial contamination. The depth profiles are, we believe, affected by radiation-induced diffusion in the flight samples.

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