MAGNESIUM ISOTOPIC COMPOSITION OF SOLAR WIND AS TEST FOR ISOTOPICALLY FRACTIONATED SOLAR WIND : A PROGRESS REPORT. V.S. Heber[1], A.J.G. Jurewicz[2], P. Janney[2], M. Wadhwa[2], K.D. McKeegan[1], & D.S. Burnett[3]. [1]Dept. Earth and Space Sciences, UCLA, Los Angeles, CA, USA, heber@ess.ucla.edu; [2]Arizona State University, Tempe, AZ, USA; [3]CalTech, Pasadena, CA, USA.

Introduction: Several observations suggest that the solar wind (SW) is an isotopically fractionated sample of the Sun's photosphere for elements in the SW up to about mass 36 [1]. Evidence supporting this fractionation comes from comparing measurements of fast and slow SW. Space borne instruments detected a clear ^{3}He over ^{4}He enrichment of several percent in slow relative to fast SW [2, 3]. Genesis fast and slow SW regime data confirmed the He results and also supported enrichment of light isotopes in Ne and Ar of 4.2‰ per amu and 2.6‰ per amu, respectively [1]. The Ne isotopes further indicate that the fractionation between fast and slow SW is mass-dependent [1].

The isotopic composition of highly volatile elements (e.g., O, N, C) in the SW is of high priority because: i) those data constrain their solar nebula composition and ii) the SW is the only source of precise information for the isotopic composition of highly volatile elements in the Sun. Measurements of SW O and N isotopic composition were accomplished [4,5]; but, to deduce solar nebula N and O isotopic compositions, assumptions had to be made regarding isotopic fractionation during SW formation [e.g. 4].

In this work we present preliminary results for using the SW Mg isotopic composition in Genesis collectors to quantify the isotopic fractionation between the SW and the Sun's photosphere. We hypothesize that the "terrestrial" Mg isotopic composition is representative of the solar photosphere. We assume this because, with exception of evaporation effects in CAI's, the mass dependent fractionation of Mg isotopes is small, as evidenced by Mg isotopic compositions of terrestrial igneous and meteoritic samples that agree within ~1‰ [6]. If, for example, the inefficient Coulomb-drag model is correct (a theoretical model of SW isotopic fractionation based on He/H fractionation in the lower solar corona [7]), then the Mg isotopic composition of SW should be lighter by ~ 10‰ per amu relative to terrestrial composition.

Experimental. Genesis bulk-SW silicon targets (Fig. 1) and a reference ^{25,26}Mg implant into silicon (Fig. 2) were analyzed in depth-profiling mode with the UCLA Cameca SIMS 1270.

Genesis sample: To avoid the complications of surface contamination and the shallow implantation depth of SW (<200 nm) we used the technique of backside depth-profiling [8]. Two carefully selected samples were commercially made into "ultra-thinsections"; ie., mounted face-down with epoxy on a Si substrate and ground from the backside to 400nm (#60760) and 2.5µm (#30767) thicknesses, respectively. Analyses using this inverted geometry produce complete SW implant profiles (Fig. 1) and avoid surface contamination as well as the transient sputter effects encountered when sputtering SW from the front side. Both samples, however, were not perfect. 400nm was too thin to measure the true background level (area A in Fig. 1), thus a blank of probably a factor 3 too high was subtracted from measured data. The 2.5µm sample had measureable Mg at the epoxy-target interface (probably a residue of acid cleaning of this sample, not observed in the 400nm sample), which may have contaminated the SW profile as the edges of the 2.5µm-deep raster were slightly over-dwelled. Thus we discard the 2 analyses of 30767.

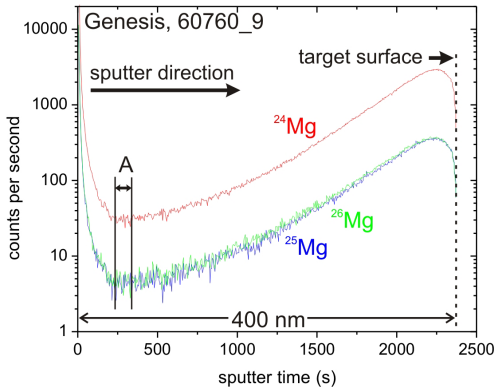

Fig. 1. Genesis target 60760 sputtered from the backside. "A" represents the range of blank composition.

Standard: The ^{25,26}Mg implant standard was homogeneously irradiated (within 3‰ for ^{25}Mg/^{26}Mg across 5cm). The ^{25}Mg/^{26}Mg ratio was calibrated by solution MC-ICPMS at ASU to be 0.9571±0.0051 (2σ stdev). The 2 minor Mg isotopes were used to attain a high enough signal above blank for the ICPMS measurement, while maintaining a signal low enough that the analytical conditions by SIMS were identical for standard and Genesis sample. We also deduced the ^{26}Mg/^{24}Mg ratio of the implant of 122.62 (Fig. 2) from 3 mono-collection SIMS runs applying a correction for mass fractionation based on the MC-ICPMS data.

An aside: the implant obviously restricts our use to ^{25}Mg and ^{26}Mg (and thus to a predicted SW fractio nation of only 10‰) so we investigated other conductive reference materials that contain Mg with terrestrial

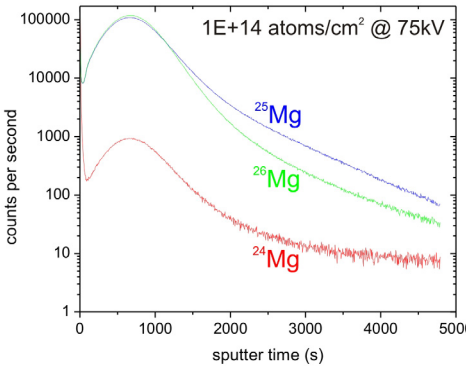

Fig. 2. ^{25,26}Mg implant standard. Note the unintentional implantation of ^{24}Mg as result of low mass separation of the implanter.

isotopic composition. Mg-containing magnetite and aluminum alloys were not suitable as Mg is concentrated in "hotspots" in the former. From the Al alloy large amounts of H were released upon oxidization (because of the O_2 atmosphere in the sample chamber) rendering our MRP (see below) insufficient for this sample.

Other analytical details: 100×100 μm^2 craters in sample and standard were sputtered with a 20nA O_2^+ beam in an O_2 atmosphere (1.2E-5 torr). 7.5keV impact energy and a field aperture of 45×45 μm^2 were applied to improve depth resolution. Mg isotopes were collected simultaneously on electron multipliers (EM). The deadtime of each EM was measured and the duty cycle determined (i.e. the ratio of instantaneous to average count rate); all data were corrected for the effective deadtime. A mass resolving power (MRP) of 2000 was applied that partially resolved ^{24}MgH from ^{25}Mg. Higher MRP was avoided as the H level was low (^{24}MgH was ~0.03% of ^{24}Mg) and the count rate for the Genesis sample had to be maximized to obtain sufficient statistical precision.

Results and Discussion With back side depth profiling we obtained complete SW Mg profiles for each isotope. After subtracting a constant blank (within uncertainties of terrestrial composition) the signals from each isotope were summed. The integrated blank contributes 4 to 6% to the integrated sample signal. The resulting sample ^{26}Mg/^{25}Mg ratio is corrected for instrumental mass fractionation using the ^{26}Mg/^{25}Mg fractionation factor from the implant standard.

Uncertainties of the SW data presented here are 5‰ from the ICPMS analysis, 3.4‰ statistical uncertainty of ^{26,25}Mg data and 5‰ standard deviation of the adjacent implant standard measurements. This total error of 7.8‰ must be reduced in future analyses considering our aim to detect a 10‰/amu variation between SW and terrestrial composition. In particular the latter single error can potentially be reduced significantly: the reproducibility of the standard was <1 ‰ (6 analyses) during first two days of the session.

At first glance, considering only the ^{25}Mg and ^{26}Mg isotopes corrected for instrumental mass-fractionation by ICPMS, our data suggest a light ^{26}Mg/^{25}Mg composition of SW relative to terrestrial composition on the order of ~10‰. (The same result is obtained if a 3x lower blank is subtracted.) However, considering all three Mg isotopes, the measured (i.e. not corrected for instrumental mass fractionation) Genesis data are not on a mass-dependent fractionation line. At present we have no explanation for this discrepancy. The deviations to terrestrial composition suggest either a too high ^{25}Mg or a too low ^{26}Mg amount measured in the SW sample. Dead-time correction is irrelevant for Genesis data due to the low count rate. The effect of different EM gains is negligible. The blank would need to be clearly off terrestrial composition to have an effect that was not observed. We investigated unaccounted interferences which would enhance the ^{25}Mg signal, but apart from ^{24}MgH, which is low in Si samples and sufficiently resolved no other interferences seem to be feasible. If, for some reason, the ^{25}Mg signal is indeed artificially enhanced we could employ the ^{26}Mg/^{24}Mg ratio of the implant standard (see above), which is however not independently calibrated, to correct the ^{26}Mg/^{24}Mg of the SW sample. This approach also results in a light isotopic composition of SW relative to terrestrial composition.

Summary: The preliminary ^{26}Mg/^{25}Mg data suggest a light isotopic composition for SW Mg relative to terrestrial composition. Moreover, the magnitude is similar to what is expected from the inefficient Coulomb drag model. Thus, applied correction of the O, N isotopic compositions for SW fractionation in [4,5] are feasible. However, at present, the data must be taken with caution until future measurements prove a mass-dependent behavior of the three Mg isotopes. Also, we will employ a new backside sample with an optimum thickness of 1μm, thick enough for correct blank characterization but thin enough to ensure uniform sputtering. We also continue to look for an appropriate, matrix-matched, conductive Mg standard.

References [1] Heber, V.S., et al. (2009) *40th LPSC* #2503; [2] Gloeckler, G., et al. (2000) *IAU Symp., 198,* 224-233; [3] Bodmer, R., et al. (1998) A&A. 337: p. 921; [4] McKeegan et al. (2011) Science, 332, 1528; [5] Marty et al. (2011) Science 332, 1533; [6] Young et al. (2004), Rev. Min. Geochem. 55: 197; [7] Bodmer, R., et al. (2000) JGR 105: p. 47; [8] Heber et al. 2011, 42nd LPSC #2642.