Solar Wind Helium and Neon from Metallic Glass Flown on Genesis – Preliminary Bulk and Velocity-Dependent Data

A. Grimberg[1], F. Bühler[2], D.S. Burnett[3], A.J.G. Jurewicz[4], C.C. Hays[4], P. Bochsler[2], V.S. Heber[1], H. Baur[1] and R. Wieler[1], [1]Isotope Geology, NO C61, ETH, CH-8092 Zürich, Switzerland, grimberg@erdw.ethz.ch, [2]Physikalisches Institut, University of Bern, Sidlerstr. 5, CH-3012 Bern, Switzerland, [3]CalTech, JPL, Pasadena, CA 91109 USA, [4]CalTech, GPS, Pasadena, CA 91125 USA

Introduction: We present noble gas data from the metallic glass (BMG) [1] flown on Genesis [2]. This target sampled the bulk solar wind (SW) at all velocities during the entire 887 days collection period of Genesis. The main motivation for selecting the BMG has been to look for the putative solar energetic particle (SEP) component reported to be present in lunar and asteroidal regolith samples [3]. The BMG is ideal for a depth and thus energy dependent gas release by closed-system stepwise etching (CSSE) [4] to distinguish the SEP component from the lower energetic SW. Here we report He and Ne data measured up to date.

Experimental: We have analysed He and Ne isotopes in five BMG aliquots with three different extraction techniques. For total gas release three pieces of 7 to 9 mm^2 each were melted by pyrolysis. Additionally, one sample was extracted with an UV-eximer laser (λ = 248 nm) at seven spots of 0.006 to 0.033 mm^2. The released He and Ne was analysed at ETH Zürich with an ultra-sensitive mass spectrometer equipped with a compressor source [5]. Finally, to determine the depth distribution of He and Ne one sample of 11 mm^2 was extracted by CSSE in 9 major steps with HNO_3 as the etching agent. Results from a second CSSE experiment will be presented at the meeting. Prior to CSSE the sample surface had to be cleaned by SF_6-plasma etching to remove a molecular film which was deposited in space. Tests discussed below showed that the cleaning procedure did not lead to any gas loss. In contrast to CSSE, no surface cleaning was needed for total extraction experiments.

To correct for losses of ions due to backscattering during the irradiation in space we calculated correction factors for all Ne isotopes with the SRIM code [6]. The same code was used to determine the theoretical depth distribution of Ne isotopes within the BMG. Backscatter correction factors for He isotopes were determined experimentally [7].

Results and Discussion: The three different extraction methods yield slightly different He isotopic ratios. The mean ^{3}He/^{4}He value obtained for laser ablation is (4.62±0.04)×10^{-4} compared to (4.38±0.01)×10^{-4} as measured by pyrolysis and (4.49±0.03)×10^{-4} by CSSE. On the other hand, ^{20}Ne/^{22}Ne ratios deduced by all methods are in very good agreement with each other: 14.03±0.09 for laser ablation, 14.00±0.05 for pyrolysis and 14.08±0.11 for CSSE. The uncertainties are given as 2σ of the mean and the adopted backscatter correction factors are 1.02 for ^{3}He/^{4}He and 1.01 for ^{20}Ne/^{22}Ne. The ratios for all methods are slightly higher than the mean values of the SWC foils given by Geiss et al. (^{3}He/^{4}He =(4.26±0.22)×10^{-4} and ^{20}Ne/^{22}Ne = 13.7±0.3) [8]. However, regarding the large variation of the single SWC values, results of both missions are consistent with each other.

Also elemental ratios and abundances determined by all three methods agree well with each other, as can be seen in Fig. 1. The ^{4}He/^{20}Ne ratios show very little variation, ranging from 490±10 for CSSE to 530±22 for pyrolysis. They are slightly lower than, but consistent with the SWC mean ^{4}He/^{20}Ne ratio of 570±70. The variation for the ^{4}He flux is even smaller with perfectly agreeing mean values of (8.29±0.15)×10^6 atoms/cm^{2}s for CSSE compared to (8.51±0.4)×10^6 atoms/cm^{2}s for pyrolysis and (8.73±0.6)×10^6 atoms/cm^{2}s for laser ablation. The obtained numbers for the Ne flux agree similarly well (adopted backscatter correction factors are shown in Fig. 1).

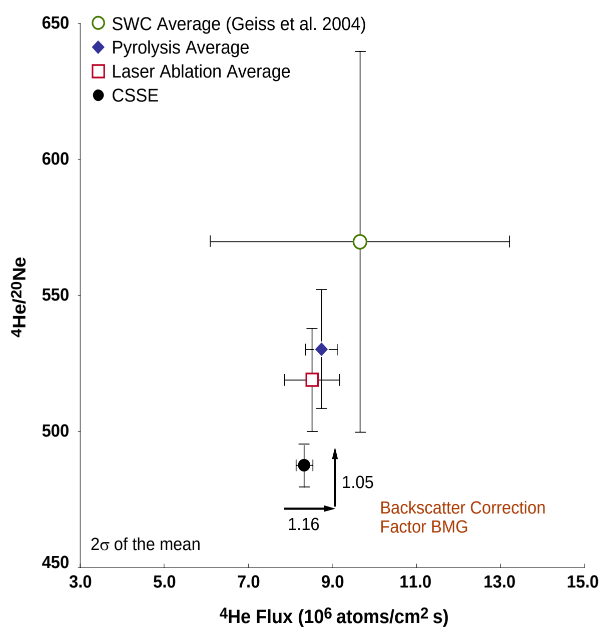

Fig. 1: Good agreement of mean ^{4}He/^{20}Ne ratios and ^{4}He fluxes for all gas extraction methods. The backscatter correction factors are plotted as arrows. All values are slightly different from the SWC mean value, but consistent within the uncertainties. The CSSE ^{4}He flux proves that plasma etching did not lead to loss of trapped gas.

The consistency of the various flux values prove that plasma etching for CSSE did not affect the trapped noble gases. However, the obtained ^{4}He fluxes are somewhat lower than the 9.72×10^{6} cm^{2}s^{-1} measured by the Genesis ion monitor [9]. Whether this indicates some He loss from the BMG in space or an imprecise He backscatter correction needs further investigation.

The CSSE experiment released in nine steps >97 % of the total ^{20}Ne amount as determined with the bulk analyses. The corresponding ^{20}Ne/^{22}Ne ratios are plotted in Fig. 2. The ^{20}Ne/^{22}Ne ratio monotonically decreases from 15.0±0.2 to 11.8±0.2 with a sudden drop in the penultimate step. The weighted mean value for all etching steps is 14.08±0.11. The lowest value of 11.8 is almost as low as the presumed SEP ^{20}Ne/^{22}Ne ratio of 11.2±0.2 measured by Benkert et al. (1993) in lunar ilmenites [10]. To explain the measured depth distribution we modeled the irradiation of ^{20}Ne and ^{22}Ne with SRIM for a ^{20}Ne/^{22}Ne ratio of 14.0 and a velocity histogram between 275 and 785 km/s, measured for protons by the Genesis ion monitor. As plotted in Fig. 2, the modelled depth profile is very similar to the actually observed pattern. It shows a fractionation of Ne isotopes within the BMG, changing progressively with depth from 15.1 to values below the postulated SEP value of 11.2. The depth-dependent ^{20}Ne/^{22}Ne ratios measured by CSSE could thus be explained by a fractionation due to slightly different penetration depths of the two isotopes. According to SRIM, the Ne released in the very last etching step would have been implanted with a maximum energy of ~3.0 keV/amu. No separate SEP component would be needed in this case. However, this model may not account for the distinct drop in the ^{20}Ne/^{22}Ne ratio of the last two steps.

Conclusion: All different methods used for gas extraction yield essentially identical He and Ne isotopic and elemental ratios as well as abundances. The data reported here from Genesis slightly differ from established SWC values, though the two data sets are consistent within uncertainties. However, the presented bulk SW data are preliminary and need to be confirmed with further measurements.

The decreasing ^{20}Ne/^{22}Ne ratios released by CSSE could be explained with SRIM as a fractionation within the BMG. The SEP component would thus be absent in the gas released from the sample. But, the fraction of a possible SEP component would be below 1% of the total SW fluence [11]. This component could therefore still be present in the minor rest of gas that remained in the BMG after etching. We will attempt to get a larger amount of ions implanted with energies higher than 3 keV/amu doing additional measurements on bigger samples.

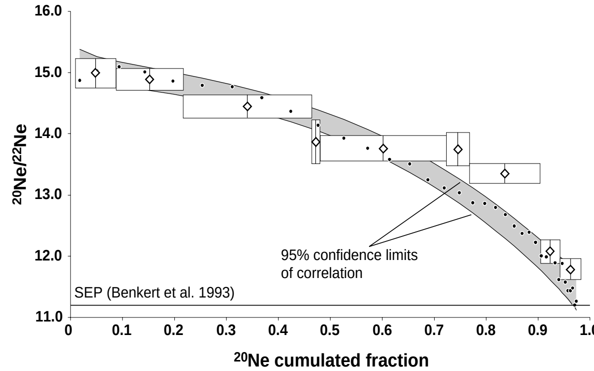

Fig. 2: 20Ne/22Ne release pattern versus the cumulative 20Ne fraction for the nine major etching steps, represented by the open diamonds. Boxes give their 2σ error of the 20Ne/22Ne ratio in y-direction and the released fraction per step in x-direction. The small black circles represent the values as calculated by SRIM with their corresponding confidence limits. Notice the good agreement of the experimental and calculated pattern.

Acknowledgements: This project is funded by the Swiss National Science Foundation.

References: [1] Jurewicz A.J.G. (2003) Space Science Reviews 105, 535-560. [2] Burnett D.S. (2003) Space Science Reviews 105, 509-534. [3] Wieler R. et al. (1986) Geochim. Cosmochim. Acta 50, 1997-2017. [4] Heber V.S. (2002) PhD Thesis, ETH Zuerich. 535-560. [5] Baur H. (1999) EOS Trans. AGU 46, F1118. [6] Ziegler J.F. (2004) Nucl. Instr. Meth. Phys. Research 219/220, 1027-1036. [7] Grimberg A. et al. (2005) LPSC 36, 1355. [8] Geiss J. et al. (2004) SSR 110, 307-335. [9] Wiens R. et al. (2006) in prep.. [10] Benkert J.P. et al. (1993) J. Geophys. Res. 98(E7), 13147-13162. [11] Mewaldt et al. (2001) in: Solar and Galactic Composition, 393-398.