SOLAR WIND BORON OBSERVED IN A HAYABUSA SAMPLE AND A GAS-RICH METEORITE. W. Fujiya[1], P. Hoppe[1], U. Ott[2], M. M. M. Meier[3], and P. Bochsler[4]. [1]Max Planck Institute for Chemistry, Hahn-Meitner-Weg 1, 55128 Mainz, Germany (wataru.fujiya@mpic.de), [2]University of West Hungary, Hungary, [3]Lund University, Sweden, [4]Physikalisches Institut, University of Bern, Switzerland.

Introduction: Elemental and isotopic compositions of the Sun, representative of the solar system (SS), are key to understanding Galactic chemical evolution and the process of the SS formation. Solar wind (SW) is the only direct sample from the Sun. NASA's *Genesis* spacecraft collected SW for 2.3 years and returned SW samples to the Earth. So far, elemental and isotopic compositions of several elements in the SW samples have been determined [e.g., 1-3]. However, elemental and isotopic fractionations between SW and the Sun must be taken into account to infer the solar composition. The Inefficient Coulomb drag (ICD) model [4] has successfully been invoked to explain the isotopic fractionation during the acceleration of SW in the inner corona. This model explains the isotopic fractionation of Ne and Ar between slow and fast SW [1] as well as the relation between the isotopic ratios of O in SW and CAIs reasonably well [2]. Boron is a suitable element to further investigate the isotopic fractionation of the SW because its isotopic ratio in the Sun is likely to be chondritic, and large fractionation expected from its relatively light atomic mass should be easily detectable. However, its low abundance in the Sun, and therefore, in the SW makes it difficult to analyze B implanted in the *Genesis* samples.

In contrast to the *Genesis* samples, regolith samples on asteroids and the Moon possibly provide opportunities to analyze SW components with low abundances because of their much longer exposure times. Shallowly implanted SW on lunar soil was detected by acquiring depth profiles with secondary ion mass spectrometry (SIMS) [e.g., 5].

In this study, we analyzed SW Li-B, N and light noble gases on two kinds of asteroidal regolith samples. One was brought to the Earth by the Hayabusa spacecraft from the Itokawa asteroid, which is known to contain abundant solar gas [6], while the other is a solar gas-rich regolith breccia, the Ghubara L5 chondrite [7].

Samples and experimental methods: Two Hayabusa olivine grains ~50 μm in size (RA-QD02-0167 and RA-QD02-0209; hereafter 0167 and 0209) were allocated for this study. The Ghubara meteorite is composed of a light and dark lithology, and the light lithology is more gas-rich [7]. We crushed a chunk of Ghubara, and hand-picked FeS grains ~50 to 150 μm in size. They were pressed into Au foils and analyzed with the NanoSIMS 50 at the MPI. We obtained depth profiles of secondary $^{6,7}Li^+$, $^{10,11}B^+$ and $^{30}Si^+$ ions produced by an O^- primary ion beam (100 pA for the Hayabusa grains and 1 nA for the Ghubara grains) by acquiring 200 to 300 sets of ion images for the five ion species (10×10 μm^2 for the Hayabusa grains; 25×25 to 50×50 μm^2 for the Ghubara grains). For the Ghubara grains, no reliable Li isotopic ratios were obtained because of an unexpectedly high background of the detectors for $^{6,7}Li^+$. The sputtering rate was estimated from the analysis of a SiC wafer doped with ^{7}Li and ^{11}B of known implantation energies. We assumed the same sputtering rate for SiC, olivine and FeS. Therefore, the estimated depth should not be taken with care. The instrumental mass fractionation was corrected by using standards of San Carlos olivine for the Hayabusa grains and NBS 611 glass for the Ghubara grains.

Because the Ghubara FeS grains were relatively large, we measured N isotopic ratios of them prior to the B analysis on different areas. We obtained depth profiles of secondary $^{12}C_2^-$, $^{12}C^{14}N^-$, $^{12}C^{15}N^-$ and $^{28}Si^-$ ions produced by a Cs^+ primary ion beam of 1 nA. A synthetic SiC standard with a known $^{15}N/^{14}N$ ratio was used for normalization.

Finally, we measured He and Ne isotopes on the Hayabusa grains with the compressor-source noble gas mass spectrometer at ETH Zürich. Detailed measurement conditions are given in [8].

Results and discussion: We analyzed seven Ghubara FeS grains from the light lithology for N, among which we found three grains with ^{14}N enrichments of up to ~87 ± 47 (2σ) ‰ (grains 3_#11, 4_#9 and 4_#13; Fig. 1). Boron isotope and abundance measurements were made on the two Hayabusa grains, the three Ghubara grains enriched in ^{14}N, and additional four Ghubara FeS grains from the dark lithology. Among those we found three grains with ^{10}B enrichments; one Hayabusa grain (grain 0167; Fig. 2) and two Ghubara grains from the light lithology (grains 4_#9 and 4_#13; Fig. 3). The Hayabusa grain 0167 shows a ^{10}B enrichment from ~30 nm in depth and $^{10}B/^{11}B$ of up to 0.288 ± 0.023 (2σ; solar = 0.248). The B concentration is ~250 ppb in the region deeper than ~30 nm. The Ghubara grains 4_#9 and 4_#13 also show ^{10}B enrichments from ~30 nm in depth and $^{10}B/^{11}B$ of up to 0.274 ± 0.007 and 0.275 ± 0.007 (2σ), respectively. Unfortunately, we cannot determine the B concentration of the Ghubara FeS grains because of the lack for a suitable standard. We found no Li isotopic anomalies throughout the depth profiles of the Hayabusa grains. He and Ne isotopic ratios and abundances of the Hayabusa grain 0167 are similar to those obtained by [6], although with much smaller errors in this study. He and Ne are dominated by solar gas, and from the ^{20}Ne abundance and SW ^{20}Ne flux [9] a SW irradiation age of ~340 years is calculated.

Meier et al. [8] found one Hayabusa olivine grain with a clear cosmogenic ^{21}Ne excess corresponding to an exposure age of ~1.5 Ma. However, such an age is way too short to explain the abundance of anomalous B in the Hayabusa olivine grain as due to cosmic ray spallation. Thus we invoke SW implantation rather than cosmogenic B to explain the observed high ^{10}B/^{11}B ratios. This scenario is supported by the observed ^{14}N enrichments in the Ghubara FeS grains, which are consistent with the addition of a ^{14}N-rich component as observed in the *Genesis* SW samples [e.g. 3] and on the surface of lunar soil [5]. However, the inferred implantation depth was greater than expected for typical SW ions (~a few tens of nm), although this may be attributed to the uncertainty of the depth estimation and/or geometry effects due to the irregular sample surfaces. Also, the inferred SW B abundance was much greater than expected from the SW irradiation time (~0.3 ppb). These observations throw doubt on the SW scenario and it is premature to draw a definitive conclusion.

Neither gravitational settling within the Sun [10] nor nuclear burning at the base of the Sun's convective zone [11], which modify the elemental and isotopic compositions of the SW source material, can explain the ^{10}B-enrichment in our implied SW component relative to the solar ratio. It is possible, therefore, that the observed enrichment reflects isotopic fractionation during the acceleration of SW in the inner corona. The ICD model [4] predicts enrichments in ^{10}B relative to ^{11}B, which depend on the charge state of B in the inner corona. In the inner corona with $T > 10^6$ K where the isotopic fractionation is believed to occur, the most abundant (>80 %) charge state of B would be +5. Under these conditions, the predicted ^{10}B enrichment is only <5 % (^{10}B/^{11}B < 0.260), which is significantly smaller than observed in the Hayabusa and Ghubara grains. Therefore, if the ICD model is correct, the acceleration of SW would have to occur at a lower altitude than previously thought, where temperature is lower so that the B is predominantly in a lower charge state. For example at $T \sim 5 \times 10^5$, the mean charge state of B would be +3.5 and the predicted ^{10}B enrichment is ~13 % (^{10}B/^{11}B ~ 0.281). However, this possibility is likely excluded by in-situ Si isotope measurement of SW [e.g., 12], which indicates smaller isotopic fractionation (<4 %/amu) than predicted by the ICD model (~7 %/amu) under these conditions.

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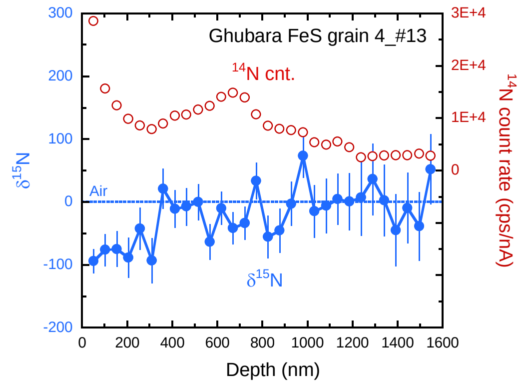

Figure 1. Depth profiles of δ^{15}N and the ^{14}N count rate of the Ghubara FeS grain 4_#13. Errors are 1σ.

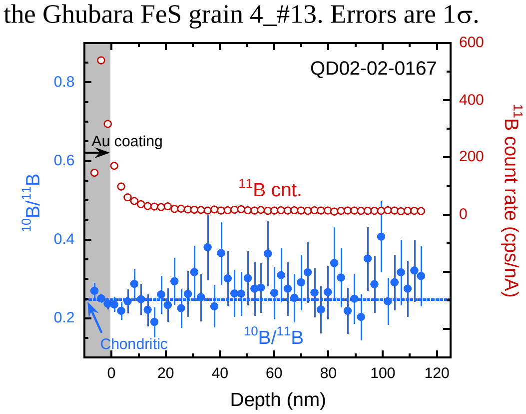

Figure 2. Depth profiles of ^{10}B/^{11}B and the ^{11}B count rate of the Hayabusa olivine grain 0167. Errors are 1σ.

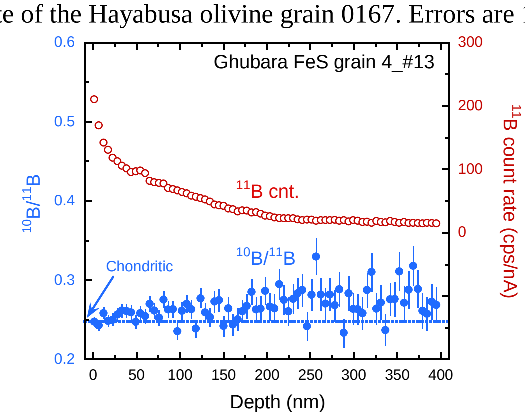

Figure 3. Depth profiles of ^{10}B/^{11}B and the ^{11}B count rate of the the Ghubara FeS grain 4_#13. Errors are 1σ.