Evidence of at least two extra-selenial components accreting on the Moon - In search for the oxygen isotopic composition of the solar component trapped in lunar metallic grains. Ko Hashizume[1] and Marc Chaussidon[2], [1]Dept. of Earth & Space Sciences, Osaka University, Toyonaka, Japan (kohash@ess.sci.osaka-u.ac.jp), [2]CRPG-CNRS, Nancy, France.

The surface of the Moon has been exposed over billions of years to irradiation by solar ions and to contributions of various extraterrestrial sources. Potential contributors include interplanetary dust particles and micrometeorites which dominate the present-day mass flux of meteoritic matter to the Earth's surface, meteorites and comets. For example, from studies of nitrogen isotopes among various lunar soils sampled at different locations, a competition of at least two fluxes with different origins accreting onto the moon surface was clearly observed [1]. The proportions of these components differed largely among samples, or grain-by-grain within the same sample. These proportions appear to differ among different elements, depending on their relative abundances in the respective fluxes and on their trapping mechanism into lunar samples. It is important to note that our current knowledge of the oxygen fluxes reaching the surface of the Moon is very poor, mainly because of the sparse available data. The goal of this study is to better determine the proportion of the different fluxes - potentially, solar, asteroidal and cometary - recorded among lunar grains in the case of oxygen, and to decipher the endmember solar isotopic composition.

Hashizume & Chaussidon (2005) [2] have previously reported the presence among metallic grains from lunar sample 79035 of an oxygen component enriched in ^{16}O (Δ^{17}O (= δ^{17}O - 0.52 x δ^{18}O) < -20 ± 4 ‰). Silicate grains from this sample were enriched in D-depleted hydrogen (δD < -930 ‰) [3] and solar noble gases [1], suggesting not only enrichment of the solar component in this sample, but a relatively low contribution of components that carry the D-rich hydrogen, like the asteroidal components. From this sample, we estimated the protosolar isotopic compositions of solar nitrogen [3] and carbon [4] and we interpreted that the observed ^{16}O-enriched component had a solar origin. However, Ireland *et al.* (2006) [5] came to a contrasting proposition from the finding of a ^{16}O depleted component (Δ^{17}O = +26 ± 3 ‰) at the surface of metallic grains from lunar regolith 10084, which they likewise argued to have a solar origin.

To untangle this contradictory situation, we performed further isotope measurements of oxygen residing at the surface of lunar metallic grains. We measured grains on the same mount than used for our previous analyses [2], >200 metallic 79035 grains embedded in an indium plate, this time mainly small ones which were not previously measured, and also several grains from soil 71501. The two samples 79035 and 71501 were often measured in pair [1,3] for comparison, because of their rather contrasting nature, respectively being exposed at ancient time (1-2 Ga), or recently exposed (100 Ma), and respectively being relatively enriched in ^{14}N and H, *i.e.*, the solar component, or in ^{15}N and D (planetary component), though both samples are enriched in solar noble gases.

In this session, 33 grains from the sample 79035, and 5 grains from the sample 71501 were measured. The depth profiles for all grains are summarized on the δ^{17}O-δ^{18}O diagram (Fig. 1). We were able to reproduce the two extreme O components previously found [2,5]. The range observed this time was -11 ± 4 < Δ^{17}O < +33 ± 3 ‰ (1σ). The negative Δ^{17}O values (-5 ‰ or lower) were detected on 2 grains from 71501, and 2 grains from 79035 including one of the five grains for which we previously reported the negative values [2] and for which some part was left unsputtered. The positive values (+5 ‰ or higher) were observed among 11 grains from 79035. Prominent anomalies with Δ^{17}O higher than +10 ‰ were newly observed in this session among 2 grains.

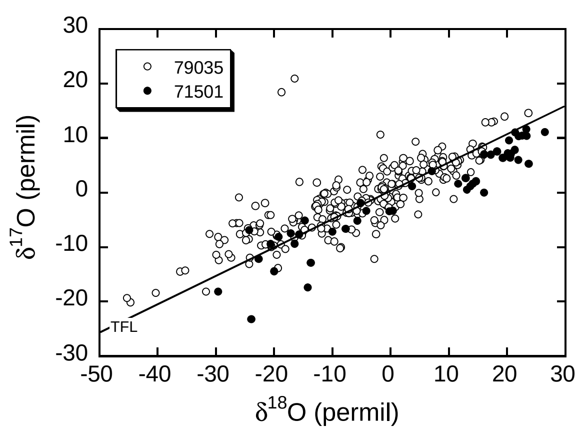

Fig. 1 Depth profiles of oxygen isotopic compositions among surface layers of metallic grains from lunar sample 79035 and 71501. Respective data points represent averages of data taken over ~100 nm or larger depth range. The two data points which show the most prominent ^{17}O enrichment are from the same grain.

A marked difference discriminating these two components seems to be their concentrations (Fig. 2). The maximum O concentration of the positive $\Delta^{17}O$ component was as high as 10 wt%, whereas those for the negative $\Delta^{17}O$ component were 1 wt% at most. From the solar ^{36}Ar concentrations of single grain analyses of size sorted (175-250 μm) 79035 silicate grains [1], the solar oxygen concentration among grains from this sample is expected to be of the order of 1 wt%, or less.

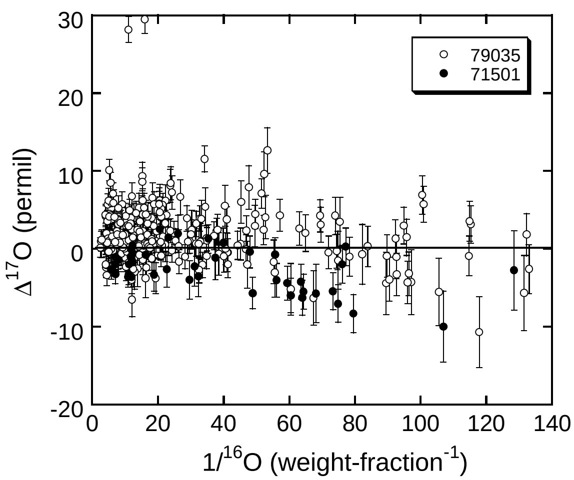

Fig. 2. Depth profiles of the $\Delta^{17}O$ values oxygen isotopic compositions plotted against the inverse of the oxygen concentrations. Error bars are 1σ. Respective data points correspond to the data points in Fig. 1.

Following our previous argument [1], our current results suggest that the solar composition is likely enriched in ^{16}O. Our results further confirm the supply to the Moon of two extra-selenial components with different origins. On the origin of the ^{16}O-depleted component, we may at least infer that it is not the asteroidal component, since we frequently observed this component among the sample 79035, which is depleted in D or ^{15}N, therefore should not record a marked contribution from the asteroidal components. Although the very small number of analyses of the 71501 grains prohibits any firm conclusions, absence of the ^{16}O-depleted component among the grains from the relatively D-enriched 71501 sample is consistent with the above inference. The fact that the extremely high $\Delta^{17}O$ values (>+5 ‰) are very rare among the asteroidal materials, especially in terms of the bulk composition, further supports this inference.

References: [1] Hashizume *et al*. (2002) *EPSL*, 202, 201-216. [2] Hashizume & Chaussidon (2005) *Nature*, 434, 619-622. [3] Hashizume *et al*. (2000) *Science*, 290, 1142-1145. [4] Hashizume *et al*. (2004) *ApJ*, 600, 480-484. [5] Ireland *et al*. (2006) *Nature*, 440, 776-778.