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Solar wind and cosmic-ray irradiation history of surface materials on small asteroid Itokawa

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Surface materials of small asteroids are exposed to various energetic particles such as solar wind (SW), solar cosmic rays (SCRs), and galactic cosmic rays (GCRs). SW particles (with energy of ca. keV per nucleon) are implanted into thin layer, smaller than micro-m from the grain surface. SCRs are composed of more energetic solar particles (1-100 MeV per nucleon), whereas GCRs have even higher energies of larger than 0.1 GeV. The high energy protons from SCRs penetrate several centimeters, and GCRs penetrate up to 1 meter or more beneath the surface of asteroid. Nuclear reactions caused by these energetic cosmic rays can produce noble gases with characteristic isotopic compositions (cosmogenic noble gases) on their passages in solid materials. SW and cosmogenic noble gases can be easily identified because of their characteristic isotopic and elemental compositions [1-4].

The Hayabusa samples are pristine undamaged grains collected from the unconsolidated surface of small asteroid Itokawa with micro-gravity. The samples are essentially different from other extraterrestrial materials such as micrometeorites (MMs) and stratospheric interplanetary dust particles (IDPs) recovered on Earth. They have experienced frictional heating and ablation of the surface layer during passage through the atmosphere and have then suffered from contamination of terrestrial atmospheric noble gases [5, 6].

We have measured noble gases for three Hayabusa grains [7] as an initial investigation, and are continuing for additional Hayabusa samples as an international AO investigation (JAXA). They were olivine grains, and their sizes and weights were as small as 40-60 micro-meter (SEM observation) and 0.05-0.1 micro-gram (estimation from their shapes and density of olivine), respectively.

Variable amounts of light noble gases of SW origin were measured for the samples, which are clear evidences that the grains had been exposed directly to SW particles on the uppermost surface of Itokawa. The detection of SW noble gases is relatively easy because of the high fluxes of SW-light noble gases (He, Ne and Ar). Observed abundances of SW gases in the samples could be accumulated if they were exposed to SW particles for 100-1000 years [7].

On the contrary, cosmogenic noble gas isotopes were difficult to be detected for these tiny samples. Fluxes of SCR and GCR are much smaller than those of SW, and production rates of cosmogenic isotopes are very small, i.e., estimated production rate by GCR in a single grain weighing 0.1 micro-g is as small as 3500 atoms /My. Even in the case, we can give an upper limit to the time span of cosmic-ray irradiation (cosmic-ray exposure age) for each grain. Combining the production of ^{21}Ne by SCR and GCR [8] we obtained 8 My as an upper limit for the RA-QD02-0065 sample [7]. These data can provide unique chronological information about the grains in surface layer of small asteroids.

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