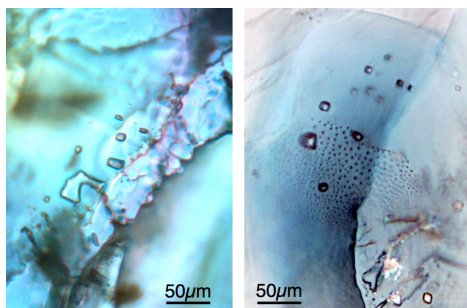




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### RECENT STUDIES AT THE ISOTOPE IMAGING LABORATORY (IIL), HOKKAIDO UNIVERSITY

The origin of water on Earth remains one of the great mysteries of planetary science. Carbonaceous chondrite-like materials are the most likely sources of Earth's water (e.g. Alexander et al. 2012). Fluid inclusions in halite from ordinary chondrites are the only direct samples of extraterrestrial liquid water available for laboratory measurements (Zolensky et al. 1999). At Hokkaido University's Isotope Imaging Laboratory (IIL), we measured the H and O isotopic compositions of halite fluid inclusions (Fig. 1) using secondary ion mass spectrometry (SIMS) and a cryogenic apparatus for sample cooling (down to  $-190^{\circ}\text{C}$ ). The isotopic compositions of the fluid inclusion's brines vary greatly among the individual inclusions ( $-400\text{‰} < \delta\text{D} < +1,300\text{‰}$ ,  $-20\text{‰} < \Delta^{17}\text{O} < +30\text{‰}$ ), indicating that the equilibration of the isotopes of these aqueous fluids started in the asteroidal fluid before they were trapped in the halite (Yurimoto et al. 2014). The isotopic correlation between  $\delta\text{D}$  and  $\Delta^{17}\text{O}$  suggests that the mixing of the inner Solar System water (chondritic water) with outer Solar System water (cometary water) occurred in the planetesimals in the early Solar System and that water-rock interactions proceeded in these planetesimals to produce planetary water. This might be a fundamental mechanism in the evolution of modern planetary water, including Earth's water, causing the variations in the isotopic composition of the water from planets, asteroids, comets, icy satellites, and other Solar System objects.

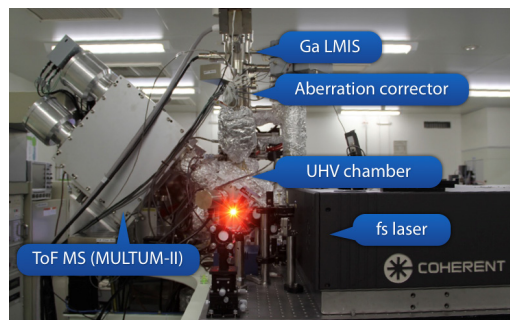


**FIGURE 1** Fluid inclusions in halite crystals found in two ordinary regolith chondrites. (LEFT) Monahans (H5). (RIGHT) Zag (H3-6). IMAGE FROM YURIMOTO ET AL. (2014).

The energy distribution of solar wind is an indicator of solar activity and correlates with the implantation profiles of solar wind particles in solid materials that are directly irradiated by the solar wind. Solar wind He is one of the best candidates for measuring the implantation profile because He is the second most abundant element of solar wind and almost free from terrestrial contamination. But measuring implantation profiles of solar wind He is difficult because conventional depth-profiling methods have extremely low He ionization yields or they require extremely large sample volumes. At IIL, we measured the solar wind He implantation profile of a sample from the NASA *Genesis* solar wind sample return mission (Burnett 2013; Bajo et al. 2015). The implantation profile of a  $10\ \mu\text{m}^2$  surface area of the *Genesis* diamond-like carbon film was obtained using novel secondary neutral mass spectrometry (SNMS) and post-ionization with a strong-field laser (Fig. 2). The projected range, peak concentration, and concentration at a given depth of the solar wind He implantation profile are consistent with the energy distribution accumulated during the solar wind irradiation periods of the *Genesis* mission. Therefore, solar wind implantation profiles provide a new approach to determining solar activities without direct monitoring. Using He depth profiling on asteroid, lunar, and meteorite samples, we can potentially decode ancient solar activities, such as records of superflares, which have been astronomically observed for other solar-type stars but not for the Sun (Maehara et al. 2012).

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**FIGURE 2** A laser ionization mass nanoscope (LIMAS). It is a laser post-ionization sputtered neutral mass spectrometer (SNMS) developed for measuring solar wind particles from extraterrestrial materials. (Tonotani et al. 2016).

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