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In-situ K-Ar dating using Vacuum Ultraviolet LIBS

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Laser-induced breakdown spectroscopy (LIBS) is widely used for chemical composition analysis. A high-intensity pulse laser is focused to ablate the surface of the target material in order to form light-emitting plasma. The composition of this ablated material can then be analyzed using atomic emission spectroscopy. This technique has already been successfully used in ChemCam onboard Mars Curiosity (Wiens et al., 2012, Maurice et al., 2012). We can see the first spectrum on the mission website. It clearly shows the emission lines of major elements-Mg, Si, Ca, Fe, Ca, Na, K, and Al-and light elements-H, C, and O. This new technique will be the standard for future planetary exploration. We can also expect an innovative performance of LIBS on the surface of Ganymede since in principle, it can be used for ice as well.

Since the concentration of K on the surface of the planet or satellite can be estimated using LIBS, measuring the amount of Ar enables us to date the age of the surface. However, it is difficult to estimate the amount of degassed Ar. In the method adopted in Curiosity, the amount of K and Ar are measured by different instruments. Although a large sample is necessary for measuring Ar, it is difficult to measure bulk density using LIBS. Moreover, this method requires much resource, e.g., LIBS composed of a laser unit and a spectrometer, as well as a mass spectrometer, and a vacuum chamber with a window capable of being opened and closed.

To solve this problem, we are studying an in-situ K-Ar dating method that uses LIBS with vacuum ultraviolet (VUV) spectroscopy. Ar has no strong emission line in the near UV?near IR range. However, the result of a past LIBS experiment in Ar gas shows the detectability of Ar emission lines in the VUV range. If the amount of Ar in a target rock or ice can be determined using LIBS with VUV spectroscopy, in situ K-Ar dating could be feasible at a smaller mass budget. Additionally, this method enables K and Ar to be quantified at the same area ablated by a high-energy laser pulse, which reduces the uncertainty caused by target nonuniformity.

We have already started to simultaneously design the LIBS instrument as well as the VUV spectrometer. The conceptual design of the LIBS instrument is similar to that of ChemCam. However, a refractive optical design was adopted instead of the reflective optical design of ChemCam in order to increase the focusing effectiveness of the high-intensity pulse laser and to minimize the size of the instrument and therefore its mass. Additionally, we are developing a small piezoelectric linear stage to move the secondary lens. The stroke is 8 mm; the step, 0.1 um; and the mass, 87 g. The prototype model has been developed, and we plan to conduct the vibration test in ISAS/JAXA. In the preliminary design, the mass is estimated to be 3.55 kg, which is approximately one third the mass of ChemCam (~11 kg). The objective distance is limited to 1.5 m, which is shorter than that of ChemCam (1?7 m). The objective distance of this instrument may not be long enough for a huge rover such as Mars Curiosity; however, its size and mass are suitable for a small- or middle-size rover or lander.

We have also finished the preliminary design of the VUV spectrometer for Ar emission. The VUV spectrometer is composed of a concave grating and a micro channel plate with a multi-anode detector. The dimensions of the instrument are 25x25x62.5 mm, and its mass is ~50 g without the electronics. The objective distance is 10 cm. If the Ganymede lander has a high-energy pulse laser for ablation, this instrument could potentially measure the amount of Ar.. We are preparing the VUV spectroscopic experiment for detecting Ar in a rock or ice, including Ar that is artificially mixed in the sample. In this presentation, we will introduce the design of the LIBS and the VUV spectrometer and report the preliminary results of the experiment.

Keywords: LIBS, Chronology, Planetary Exploration