The discrimination experiment of meteorites using LIBS for the Martian Moons Explorer mission

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Phobos and Deimos are the two satellites of Mars. It is suggested that they originated either through asteroid capture or giant impact [1]. The Japan Aerospace Exploration Agency (JAXA) is planning to launch the Martian Moons Explorer (MMX) in 2022 that aims to return samples from Phobos. It is hoped that these samples will reveal the origin of Phobos and, thereby, will constrain the theory of Solar System formation. The sampling site will be selected based on Phobos' entire reflection spectra to return optimum samples containing intrinsic materials to Phobos. However, the reflection spectra may not provide sufficient information on the composition of Phobos because of space weathering. In addition, the composition of Phobos's surface in particle scale has unknown and isn't known until the samples are returned to the Earth. Therefore, we focused on in-situ measurement of elemental composition, which isn't affected by space weathering. We proposed mounting a laser-induced breakdown spectroscopy (LIBS) on the MMX lander for measuring the elemental composition of the Phobos's surface.
We conducted LIBS experiment to evaluate the feasibility of LIBS measurement on Phobos. We investigated the capability of distinguishing carbonaceous chondrite from Martian meteorites by LIBS, which provides a clue to knowing whether the surface of Phobos is composed of asteroid-like or Martian-like materials. Our experimental system simulated an actual setup for Phobos exploration. We used a small laser with an output of about 12 mJ/pulse and a wavelength of 1534 nm. The wavelength range of the spectrometer was 195 nm to 1128 nm. The distances between the lens to converge the laser beam and the sample, and between the condensing lens of the spectrometer and the sample were both 1.5 m. The effective diameter of the light collection optical system was 20 mm. The samples were placed in a vacuum chamber. We verified the feasibility of LIBS measurement including signal-to-noise ratio under such realistic conditions. The samples were Allende (a carbonaceous chondrite), NWA1068 (a Martian meteorite), and Zagami (a Martian meteorite). The sample was irradiated 150 times on each measurement point with 10 Hz. The exposure time of the spectrometer was 1 s. We measured 16 points per a sample to obtain the bulk composition of the meteorites. The emission spectra of the major elements, Fe, Ca, Al, Mg, Si, and Ti, were detected in the average spectra of 16 measurement points. By subtracting the spectra of the Martian meteorites from that of the carbonaceous chondrite, we found that the intensity of the emission lines of Fe and Mg, which are abundant in the Allende meteorite, exhibit positive values. In contrast, the intensity of the emission lines of Al and Ca, which are abundant in the NWA1068 and the Zagami meteorites, exhibit negative values. Those results show that LIBS can distinguish between asteroid-like and Martian-like materials.
Since the MMX lander can stay on the surface of Phobos for only about 1 hour, we evaluated whether LIBS can conduct the same measurement as our experiment in such a short time. It was assumed that the focus adjustment and image acquisition takes 10 s, and moving from one measurement point to another takes 20 s. The laser irradiation frequency is 2 Hz to save the electric power consumption. Then, it takes 28 minutes to conduct the same date acquisition as our experiment (i.e., measuring 16 points with 150-times laser irradiation per point).This indicates that LIBS can obtain sufficient data within the operation time of the lander. Our results suggest that LIBS can reveal

whether Phobos is similar to asteroids or Mars.

Reference

[1] Fraeman, A. A., et al. (2012), J. Geophys. Res., 117, E00J15.

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