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惑星着陸探査のためのレーザー蒸発方式による K-Ar アイソクロン年代計測法の開発
Development of a laser ablation isochron K-Ar dating method for landing planetary missions

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Absolute age measurements of planetary surfaces are extremely important for understanding the evolution of planets. However, no chronological measurements of planetary materials with known geological contexts have been made except for the lunar samples. Although the absolute age estimates for Martian surfaces have been proposed on the basis of the lunar chronology and the orbital calculations of asteroids, there still remain uncertainties as large as 1 billion years. If the absolute ages of rock samples from a geologic unit, where crater number density is known, are determined down to around 10% accuracy, it will make a significant contribution to understandings of the evolution of Mars.

In this study, we developed a new in-situ dating method based on the Potassium-Argon (K-Ar) dating technique toward future landing planetary missions. We propose a simpler and more accurate in-situ K-Ar dating method than those employed in previous mission plans, using laser-induced breakdown spectroscopy (LIBS) and a quadrupole mass spectrometer (QMS). We conducted the following experiments to evaluate the feasibility of the K-Ar dating with the LIBS-QMS method.

In the first part of this study, we measured K abundance using LIBS. First, we irradiated laser pulses on 13 samples with 100 ppm to 5 wt% of K2O and observed the emission lines of K from these samples. We obtained two calibration curves from K emission lines at 766.49 nm and 769.89 nm. Our results show that K concentration can be quantified within the relative accuracy of 10% for 2000 ppm to 5 wt% range. The detection limit was 1000 ppm.

Second, the volumes of laser-ablated craters on rock samples are measured with a microscope. The observations indicate that the crater volumes of basaltic rocks are within the uncertainty of 11% except for some minerals such as olivine. When these results are combined, the absolute abundance of K inside a crater is estimated within the accuracy of 15%.

In the second part of this study, we built a new Ar experimental system optimized for K-Ar dating, based on experimental results from a previously established system. As a first step, we used the previously established gas analytical system to estimate the detection limits and the pulse numbers required to the K-Ar dating. We estimated 40Ar=10ˆ-12 cc/pulse and 36Ar=10ˆ-15 cc/pulse are released from desirable Martian rocks. The blank levels for the system were 5x10ˆ-10 cc and 1x10ˆ-10 cc at m/Z = 40 and 36, respectively, and the electric noise level was 1x10ˆ-11 cc. These blank levels should be 10-100 times lower in order to detect Ar from the rocks within 1000 laser pulses.

A measurement of the blank using the new gas analysis system indicates that the detection limit of 40 and 36 and electrical noise of the detector are on the order of 10ˆ-11 cc, less than 10ˆ-11 cc and less than 10ˆ-11 cc, respectively. This is an improvement by one order of magnitude compared with our former experimental system. These results indicate that a sufficient amount of 36Ar can be evaporated by 1000 laser pulses on the Martian rocks.

These experimental results using our breadboard model strongly suggests that an experimental system that can simultaneously measure K and Ar released from the same laser-vaporized mass of a sample can be built with currently commercially available parts. Thus, the new K-Ar measurement method proposed in this study using a pulse laser, a spectrometer and quadrupole mass spectrometer is a viable candidate for an on-board instrument for a future Mars landing mission.

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