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月着陸探査におけるその場 K-Ar 年代計測の可能性: 月試料からの示唆
Applicability of a laser-ablation in-situ K-Ar dating method on the Moon: insights from lunar samples

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We have been developing an in-situ K-Ar isochron dating method for future landing missions. Potassium-argon ages are measured with the combination of laser-induced breakdown spectroscopy (LIBS) and mass spectrometry using a quadrupole mass spectrometer (QMS). In our previous studies, we reported that isochron ages for gneiss samples with 30% accuracy and 10-20% precision.

However, such experimental results using test samples do not guarantee the applicability of our LIBS-QMS isochron method for actual rock samples on planetary surfaces. Depending on geologic units, the types of rocks and K concentration vary greatly on planetary surfaces.

Thus, we assess the capability of our in-situ K-Ar dating method taking the petrologic properties including K abundance and possible age range of the lunar surfaces into account. First, we examined the global maps of K obtained with the Gamma Ray Spectrometers onboard remote sensing satellites. We found that the concentrations of K and Ar of KREEPy materials are well above the detection limits of our LIBS-QMS approach. Then, the elemental compositions and textures of KREEP basalt were investigated. We found that Si-rich glasses contained in mesostasis are measurable with K-Ar dating on the Moon because of the high K concentration (~7 wt%), while other minerals (i.e., pyroxene, olivine, and plagioclase) contain virtually no K. Since the textures of these samples were heterogeneous at the scale of laser spot (~500 microns), the "isochron" ages would be obtained by measuring the different portions containing K-bearing phases in various ratios.

The major problem concerning in-situ K-Ar dating is partial 40Ar loss due to thermal events after crystallization. This suggests that K-Ar dating only yields the lower limit for the real crystallization age. Furthermore, brecciation by impacts and contamination by solar wind will inhibit accurate in-situ dating. In order to avoid such problems and obtain meaningful age data by in-situ dating, we aim to measure fresh impact melt rocks exposed by a very recent (tens of Ma) impact on the Aristillus crater floor.

Finally, we evaluated how our method can constrain the absolute chronology models of the Moon and Mars based on the precisions of age measurements achieved by this study. For example, the absolute age of impact melt rocks in Aristillus crater, whose ages correspond to the "missing ages" of the current lunar crater chronology model (i.e., between 3.0 Ga and 0.1 Ga), would be measured with ~20% precision when the K concentration of the glass in KREEP basalt is assumed. Then, our method would be able to discriminate the constant flux model [Neukum, 1983] and the decreasing flux model [Hartmann et al., 2007]. The implications of in-situ dating in Aristillus crater include refining the crater chronology model, determining the age of the youngest mare basalts, and understanding the dynamical evolution of the asteroids in the last three billion years.

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