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Toward the next TRL of KArLE (in situ geochronology for planetary experiment)

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Abstract

The instrument ‘Potassium (K) Argon Laser Experiment’ (KArLE) is developed and designed for *in situ* absolute dating of rocks on planetary surfaces. It is based on the K-Ar dating method and uses the Laser Induced Breakdown Spectroscopy – Laser Ablation – Quadrupole Mass Spectrometry (LIBS-LA-QMS) technique. We use a dedicated interface to combine two instruments similar to SAM of Mars Science Laboratory (for the QMS) and ChemCam (for the LA and LIBS). The prototype has demonstrated that KArLE is a suitable and promising instrument for *in situ* absolute dating.

1. Introduction

In planetary exploration, *in situ* absolute geochronology is an important measurement. Thus far, on Mars, the age of the surface has largely been determined by crater density counting, which gives relative ages. These ages can have significant uncertainty as they depend on many poorly-constrained parameters. More than that, the curves must be corrected with absolute ages to relate geologic time-scales on Mars to the rest of the solar system. Thus far, only the lost lander Beagle 2 was designed to conduct absolute geochronology measurements, though some recent attempts using MSL Curiosity show that this investigation is feasible [1] and should be strongly encouraged for future flight.

2. Experimental

Developed at the MSFC through the NASA Planetary Instrument Definition and Development Program (PIDDP), KArLE is one of several projects working on in situ geochronology [2, 3, 4]. The protocol is based on several instruments already used in planetary exploration. A laser ablates a rock under high vacuum and creates a plasma, whose spectrum yields elemental abundances, including K (Laser Induced Breakdown Spectroscopy, LIBS). The ablated material frees gases, including radiogenic ^{40}Ar which is measured by a mass spectrometer (MS). The potassium and ^{40}Ar are related by the ablated mass. Because the very small mass displacement cannot be easily measured, the mass is calculated using the ablated volume and the density of the material. The determination of the chemistry, and therefore the mineralogy, is provided by the LIBS spectra and their treatment (univariate calibration, Partial Least Square, etc.) enabling the density to be determined. The volume of the pit is measured using optical imagery, for example, stereo imaging.

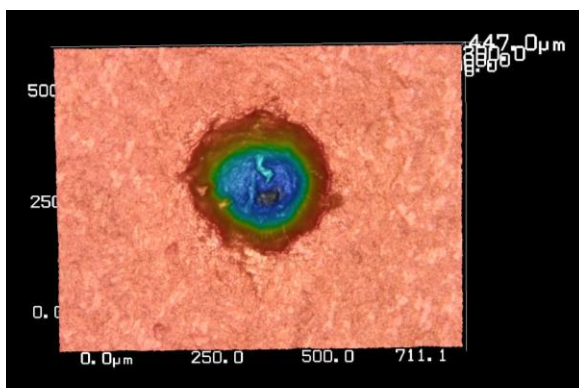

Figure 1: Ablated pit after 1000 pulses. 3D model made with Keyence microscope VK-X100.

3. Recent studies and future upgrades

Fair recently, this method has been demonstrated by several prototypes in independent laboratories [2, 3, 4 and 5]. As a very new technique, these teams explore the effects induced by the ultra-long ablation under high vacuum on the results and on the protocol [6], the performances of the K measurement by LIBS [7] and the ability to estimate the ablated volume with the LIBS spectra [8]. These works and the future studies should bring some breakthroughs to enhance the performances of the K-Ar ages.

All this new 'know-how' will help to determine opportunists upgrades for the next Technology Readiness Level (TRL) design. We will enhance the protocol by using the closest parameters as possible compared to ChemCam and SAM on MSL (e.g. laser power, laser pulse frequency…).

Summary

We present here the new technological developments of KArLE and several results depending on the future advancement. We will talk about the performances of the last upgrades and discuss about the new abilities of the prototype.

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