Japan Geoscience Union Meeting 2013
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PPS22-P01 Room:Convention Hall Time:May 22 18:15-19:30

Development of an in-situ K-Ar dating instrument

Yuichiro Cho[1*], Yayoi N. Miura[2], Tomokatsu Morota[3], Shingo Kameda[4], Kazuo Yoshioka[5], Ryuji Okazaki[6], Noriyuki Namiki[7], Ko Ishibashi[7], Sohsuke Ohno[7], Masanori Kobayashi[7], Tomoko Arai[7], Hiroki Senshu[7], Koji Wada[7], Seiji Sugita[8]

[1]Dept. Earth & Planetary Science, Univ. Tokyo, [2]Earthquake Research Institute, Univ. Tokyo, [3]Nagoya University, [4]Rikkyo University, [5]ISAS/JAXA, [6]Kyushu University, [7]PERC, Chiba Institute of Technology, [8]Dept. Complexity Science and Engineering, Univ. Tokyo

We have been developing an in-situ dating method based on the K-Ar system for future planetary landing missions. The K-Ar dating method employs radiometric decay of 40K into 40Ar with half-life of 1.25 Gyr [Steiger & Jager, 1977]. Our system measures K and Ar with two techniques at the same laser irradiation spot on a sample: laser-induced breakdown spectroscopy (LIBS) and quadrupole mass spectrometry (QMS), respectively (LIBS-QMS system). Potassium and argon are extracted from a sample simultaneously by the laser ablation, in which the sample is vaporized by a series of intense (> 1GW/cm2) laser pulses. We used a Nd:YAG laser with 6 ns of pulse width and 1064 nm of wavelength (Surelite I, Continuum). The laser energy was set at 100 mJ and the spot diameter was ˜500 micron. The pulse repetition rate was 2 Hz. We used a small spectrometer with a charge couple device (CCD) (HR 2000+, Ocean Photonics Inc.), to simulate a small and simple spectrometer for the spacecraft missions. The light emission from plasma was collected by a lens and transmitted through an optical fiber to the entrance slit of the spectrometer. The spectral acquisition time was 1 ms and the shutter was opened before the laser pulses reached the sample; time-integrated plasma emission was observed to simulate a non-gated operations on the planetary missions. The intensity of the K line at 769 nm was normalized by that of the O emission line at 777 nm in order to reduce signal fluctuations.

The gas extracted from the sample was purified with a Ti-Zr getter. The purified Ar gas was trapped on the charcoal trap cooled by liquid nitrogen. The Ar isotopes, 36Ar, 38Ar and 40Ar, are measured with the quadrupole mass spectrometer. Blank mass spectra were also acquired and subtracted from the main data. Finally, the volume of laser ablation pit was measured with a laser microscope to obtain the concentration of 40Ar within the pit.

In order to construct a calibration curve for K2O, 24 geologic samples with known K2O concentration were measured with our LIBS system. The calibration line can be fitted by a power law: I=0.11$C^{0.55}$-0.00686, where I and C are the signal intensity and K2O concentration (wt%). The detection limit and the quantification limit of our LIBS system were 300 ppm and 1 wt%, respectively. Also the detection limits of 36Ar and 40Ar were measured to be 2x10^{-12} and 2x10^{-11} [cm3 STP], respectively, in this study. As a result, if a rover encounters a rock with K2O=1 wt%, as Mars Exploration Rover found at Gusev crater, our instrument is expected to measure K and Ar from a rock sample; i.e., the error in LIBS measurement would be <20% and the S/N for QMS signals would be sufficient (=200).

Using our instrument, we measured three samples whose K concentrations and ages have been measured previously with flame photometry and a sector mass spectrometer: a hornblende (K2O=1.12 wt%, 1.75 Ga), a biotite (K2O=8.44 wt%, 1.79 Ga), and a plagioclase (K2O=1.42 wt%, 1.77 Ga) [Nagao, unpublished data]. We obtained the model ages of 2.1+/-0.3, 1.8+/-0.2, and 2.0+/-0.3 Ga, respectively.

Since the three samples have similar ages and different K concentrations, we should be able to construct a "virtual" isochron by plotting the concentrations of K and $40Ar_{rad}$. The slope of the isochron simulated with our experimental data yields 1.34 Ga of age. The data with known values yields 1.79 Ga. Such underestimation probably results from both overestimation for K and underestimation for 40Ar in the biotite data, which have large weight for the regression. Nevertheless, a positive correlation between [K] and [$40Ar_{rad}$] is obvious. Although further improvement in the accuracy of our measurements is necessary, the data obtained in this study demonstrate that our LIBS-QMS method can reproduce the trend essential for quantitative isochron-based age measurements.

Keywords: Decadal Survey, In-situ age measurements, Planetary landing missions, K-Ar dating

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Elemental analyzer for landed lunar and planetary explorations: Laser-induced breakdown spectrometer (LIBS)

Ko Ishibashi[1*], Shingo Kameda[2], Masanori Kobayashi[1], Noriyuki Namiki[1], Tomoko Arai[1], Koji Wada[1], Hiroki Senshu[1], Sohsuke Ohno[1], Yuichiro Cho[3], Seiji Sugita[4]

[1]Planetary Exploration Research Center, Chiba Institute of Technology, [2]School of Science, Rikkyo University, [3]Graduate School of Science, The University of Tokyo, [4]Graduate School of Frontier Science, The University of Tokyo

A laser-induced breakdown spectrometer is one of the elemental analyzers, which is composed of a laser, a spectrometer, and an optical system. The measuring principle of LIBS is as follows: Samples are irradiated with pulsed laser beams in order to generate plasma plumes of a small amount of the sample. When atomic and ionic species excited in the plumes are deexcited, the emission of lights occurs according to the difference in energy levels before and after the deexcitation. These lights are measured with a spectrometer as emission lines on spectra. The wavelength of emission lines is unique to each element, and the intensity of emission lines is correlated with the elemental abundance. Both qualitative and quantitative analyses, such as elemental abundance determination and mineral classification, are carried out by analyzing the acquired spectra.

LIBS has several advantages such as (i) capability of remote analysis (up to ten meters or more depending on laser intensity), (ii) rapid data acquisition (a few second to a few minutes), (iii) ability to analyze almost all elements including light elements, (iv) high spatial resolution (several tens to several hundred of micrometers), and (v) unnecessity of sample preprocessing. LIBS has potential for being a powerful elemental analyzer in landed lunar and planetary explorations. Actually, LIBS is loaded on Mars Science Laboratory, which is the first use of LIBS in space. LIBS would be a standard elemental analyzer in landed missions.

Now we are developing a LIBS for landed lunar explorations. We have had decided basic design of the LIBS and finished detailed designing of the measurement distance variable optical system. We have had also done the improvement of spectral analysis method for determining elemental composition with high accuracy. Then, last year we carried out two types of field tests with LIBS test models. One is an elemental composition measurement test, and the other is an onboard LIBS test on a rover. These tests were conducted at Mount Mihara on Izu-Oshima island.

We made a small portable LIBS, and carried out the field elemental composition measurement test with it. The LIBS we made is for a short range measurement and has a fifty-millimeter fixed focal length. Standard igneous rock samples have been measured with the LIBS in the laboratory in advance to make regression models for spectral analysis to determine elemental compositions. In the field we measured many samples such as bounding stones and lava flows under the Sun and obtained spectra with high signal-to-noise ratio. The elemental compositions determined with those spectra shows reasonable values for basalt. The determined values had, however, large error bars, which may be due to a small number of standard igneous rock samples used for making the regression models. We are going to prepare more standard samples to improve the determination precision.

We also carried out the LIBS onboard test on a rover (Micro 6 rover, JAXA). A test model of the measurement-distance adjustable optical system was made, and autofocus test and laser irradiation test through the optical system were carried out on the rover.

We plan to carry out field test with a test model of the measurement-distance adjustable LIBS. We are going to perform a sequence of measurement with it on a rover: Selecting a measurement point, autofocusing, laser irradiation, spectra acquisition, elemental composition determination. Through this we will confirm the operational procedure and quantitative measurement under onboard and natural terrain conditions.

Keywords: landed exploration, elemental analyzer

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Investigation of Martian surface and internal structure by multiple penetrator probes

Hiroaki Shiraishi[1*], Ryuhei Yamada[2], Yoshiaki Ishihara[3], Naoki Kobayashi[1], Masahiko Hayakawa[1], Satoshi Tanaka[1], Kojiro Suzuki[4]

[1]Japan Aerospace Exploration Agency, Institute of Space and Astronautical Science, [2]National Astronomical Observatory of Japan, RISE project, [3]INational Institute of Advanced Industrial Science and Technology, [4]Graduate School of Frontier Sciences, The University of Tokyo

A new mission to investigate the Martian surface and interior structures using multiple penetrator probes is proposed. As a decelerator and a heat shield during the Martian atmospheric entry, a flare-type thin membrane aeroshell sustained by an inflatable torus frame will be applied to attain a compact and low-weight space vehicle. The most significant advantage of the aeroshell is to reduce the aerodynamic heating during the atmospheric entry due to its low ballistic coefficient. In addition, even though dependent on the spacecraft configuration (in most cases), there is no need to equip with the conventional thermal protection system like an ablator or a heat-resistance material. Concerning to the aeroshell system, a flight validation test was successfully concluded using a sounding rocket in the summer of 2012. The Martian penetrator is a missile-shaped instrument carrier and is planned to have about 80 cm in length, 15cm in diameter, and 14 kg in weight, which would be almost identical with the lunar penetrator. Its development was completed in 2010 through several times impact penetration and thermal cycle tests at the ground test facilities after cancellation of the former LUNAR-A project. A 3-axis stabilized satellite with four identical penetrator modules, which should play roles of the carrier of penetrator modules and of data-relay orbiter, is assumed to revolve in a circular orbit of 300 km altitude around Mars. After separation from the carrier spacecraft, four penetrators will be deployed at intervals of a few hundred kilometers from each other, due to the limited number of probes and ability to detect of seismometer on-board. Each penetrator installed seismometer and heat-flow probe will operate on the potential active regions in volcanism or seismic fault zones, associated with magmatic tectonics, crustal structure and current thermal state of Mars. An optical camera onboard the spacecraft will search for impact craters and landslides around the network, which occurred during the observation period of penetrator seismometer. These detected landmarks will be available for seismological study as known earthquake foci. A meteorological sensor package embedded in a backside of aeroshell will observe the atmospheric structure and possibly monitor the environment on the surface. These monitoring data would be useful for data reduction of seismic and heat-flow data. This paper describes the martian penetrator design, the sequence of its deployment phase, onboard instruments, and their operational strategy.

Keywords: Mars Exploration, surface Environment, internal Structure, penetrator, seismometer, heat flow probe

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A proposal of a small scientific satellite mission to validate penetrator systems

Hideki Murakami[1*], Hiroaki Shiraishi[2], Naoki Kobayashi[2], Ryuhei Yamada[3], Satoshi Tanaka[2], Masahiko Hayakawa[2], Hajime Hayakawa[2], Nozomu Takeuchi[4], Taro Okamoto[5], Keiko Kuge[6], Yasushi Ishihara[7], Dapeng Zhao[8]

[1]Faculty of Science, Kochi University, [2]Department of Planetary Science, Institute of Space and Astronautical Science, Japan Aerospace Explo, [3]National Astronomical Observatory of Japan, RISE project, [4]Earthquake Research Institute, The University of Tokyo, [5]Department of Earth and Planetary Sciences,Graduate School of Science and Engineering,Tokyo Institut, [6]Department of Geophysics, Graduate School of Science, Kyoto University, [7]IFREE, JAMSTEC, [8]Department of Geophysics, Tohoku University

We propose a new mission to validate the penetrator technology and to investigate the surface and subsurface structures on the far side of the Moon, using a miniaturized penetrator probe. The miniaturized penetrator is a missile-shaped instrument carrier and is planned to have a shape of about 60 cm in length and 10 cm in diameter, and a weight of 8 kg, which would be two thirds scale model of the lunar penetrator developed for the former LUNAR-A project. The major objective of this mission is to demonstrate the technical issues in penetrator system; (1) holding and separation mechanisms, (2) a sequence of de-orbit, attitude control and subsurface deployment, (3) data-relay and remote operation by way of an orbital spacecraft, and (4) simultaneous long-term geophysical observations. Furthermore, the developed miniaturized penetrator system can be applied to a future mission for a more distant planetary body than the moon.

A tri-axial stabilized satellite with two identical penetrator modules, which should be play roles of the carrier of them and of data-relay orbiter, is assumed to revolve in a near-circular orbit of 100 km by 25 km altitude around the Moon. After the separation from the spacecraft, the two penetrators will be deployed at an interval of a few hundred meters or a few kilometers from each other on the far side equatorial regions. The penetrator will hit on the lunar surface with a velocity of 250 to 300 m/sec and penetrate into the regolith up to a depth of 2 or 3 meters. Each penetrator can carry some of a short-period seismometer, heat-flow probe, magnetometer, and gamma-ray spectrometer and observe the sub-surface and internal structure on the most ancient geological unit, in which the initial product from a differentiated magma ocean might be still remain.

The magnetometer will monitor the time-series of magnetic field as a stationary point, and the gamma-ray spectrometer buried in the lunar regolith will be able to observe the abundance of heat-producing elements, under a condition of the significant low-level cosmic ray background. These data would be also useful for data reduction of seismic and heat-flow data. An optical camera onboard the spacecraft will search for impact craters and landslides around the network, which occurred during the observation period of penetrator seismometer. These detected landmarks will be available for seismological study as known earthquake foci. This paper describes the miniaturized penetrator design, the sequence of its deployment phase, potential onboard instruments, and their operational scenario.

Keywords: penetrator system, lunar interior exploration, small scientific satellite

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Fluorescent microscopy for searching extraterrestrial life

Yoshitaka Yoshimura[1*], AOKI, Kohei[1], Hajime Honda[2], SUGAI, Ayaka[2], ICHINOSE, Yu[2], Akihiko Yamagishi[3]

[1]College of Agriculture, Tamagawa University, [2]Department of Bioengineering, Nagaoka Univ. Tech., [3]Department of Molecular Biology, Tokyo University of Pharmacy and Life Science

Fluorescent microscopy is a method to detect localized biosignatures *in situ* and a potentially powerful tool to detect extraterrestrial life. It is highly sensitive and will provide clear evidence for extraterrestrial life as images. Stained objects are observed with an epifluorescence microscope with a resolution of 1 micrometer. Many types of fluorescent dyes are commercially available and used in various biological studies. In this study, fluorescent dyes were selected based on the basic characteristics of life: genetic information, metabolism, and discrimination of self from non-self. Each characteristic was detected using a different type of fluorescent dye that was specific for nucleic acids, enzymes, or cytoplasmic membranes. The range of detectable molecules of the selected dyes was investigated with various samples: cultured bacteria, miniature cells which were deficient in DNA, proteins, protenoids, PAH, and Martian soil simulants. The optimum combination of dyes that had the potential to distinguish biological objects from non-biological compounds and useful to search extraterrestrial life especially on Mars will be discussed.

Keywords: fluorescence, microscope, Mars, astrobiology

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Astrobiology Exploration Research Institute

Seiji Sugita[1*], Hisayoshi Yurimoto[2], Shogo Tachibana[2], Yasuhito Sekine[1]

[1]University of Tokyo, [2]Hokkaido University

In this paper, we discuss our proposed Astrobiology Exploration Research Institute. The primary role of this institute is to lead research in "soft material" analysis research for remote-sensing observation from an orbit, in-situ analysis on planetary surfaces, and returned-sample analyses in laboratories. "Soft material" analyses hold the key for the upcoming era of astrobiology planetary missions.

Keywords: planetary exploration, astrobiology, center of exellence, industry-academia collaboration, Onboard instrument development, soft material

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Lunar and planetary explorations in a coming decade: Current status and ongoing schedule

Noriyuki Namiki[1*], Naoki Kobayashi[2], Hirohide Demura[3], Keiji Ohtsuki[4]

[1]PERC/Chitech, [2]Department of Planetary Science, ISAS, [3]The University of Aizu, [4]Kobe University

Future Planetary Exploration Working Group of Japanese Planetary Science Society is discussing planetary explorations that will be strongly supported by this community. Then we started "Planetary Exploration in a Coming Decade" activity in 2010 aiming to organize a new mission to be launched between 2017 and 2027. The first stage of the activity is ending in March, 2011. A summary of the first stage will be reported by 5 panels; (1) terrestrial solid planets, (2) terrestrial atmosphere and magnetosphere, (3) minor body, (4) Jovian planets, icy satellites, and exoplanets, and (5) astrobiology. Each panel received proposals regarding "top sciences" of each category from the community in the summer of 2010. On September 10 in 2010, an open meeting was held at Kobe University to discuss top sciences among the community of planetary scientists. From the summer of 2011, the second stage began. Proposals for new mission and instruments were submitted by 13 groups and were adivsed by the second-stage committee not only to improve the proposal, but also to raise and develop exploration groups. In 2012 May, the thrid stage started. The main purpose of the third stage is to polish up the proposls in the view of feasibility. In September 14 and 15, 2012, we held a workshop to integrate individual proposals into a few comprehensive mission plans, such as in-situ chronology and interior exploration of the moons and planets, primitive small body exploration, and sercha of life on Mars. The mission concepts of these comprehensive mission plans will be discussed for later evaluation by the third stage committee.

Keywords: Planetary exploration

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Scientific goals for sample-return mission from 107P/Wilson-Harrington

Shogo Tachibana[1*], Seitaro URAKAWA[2], Makoto Yoshikawa[3], Ryosuke Nakamura[4], Masateru Ishiguro[5]

[1]Hokkaido Univ., [2]JSGA, [3]JAXA, [4]AIST, [5]Seoul National University

We propose Sample Return mission from 107P/Wilson-Harrington. The target object is a near-Earth dormant comet that potentially preserve pristine minerals, ice, and organics in the early solar system, which may not be intact in target asteroids for Hayabusa-2, Osiris-REx, and MarcoPolo-R. Samples from 107P/Wilson-Harrington will contribute significantly to our understanding of the evolution of the early solar system.

Keywords: sample return, comet, asteroid