An Active X-Ray Spectrometer Proposed for the SELENE-2 Rover

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INTRODUCTION

- The Active X-ray Spectrometer (AXS) for the SELENE-2 rover is designed to make X-ray measurements on the hostile environment of lunar surface to determine the element concentrations of various samples: rocks, regolith samples, and breccias encountered at the landing site and along the traverse of the rover (Fig. 1-4).
- The AXS measures the major elements: Mg, Al, Si, Ca, Ti, and Fe; the minor elements, Na, K, P, S, Cl, Cr, and Mn and the trace element Ni, all depending on their concentrations.
- The samples will be compared with other lunar materials (Apollo lunar samples and lunar meteorites). These data will be used to characterize the geochemistry of the landing site and the subsequent traverse of the rover.
- Depending on the landing site, new insight into the lunar geochemistry and evolution can be obtained with detailed in-situ measurement.
- If a grinding tool is attached on the rover arm, the detailed comparison of AXS data of natural surfaces and abraded surfaces can provide profound insight in the effect of space weathering.
- Cooperation of the AXS with other instruments on the rover will greatly increase our basic geochemical knowledge of the landing site, which will be used to derive a more complete understanding of the present-day lunar surface and its formation a long time ago.

X-RAY SPECTROMETER

- The AXS is a compact low-weight instrument for elemental analysis based on the principle of X-ray fluorescence spectrometry. The anticipated X-ray detector will have an excellent energy resolution to well separate the many X-ray lines in the recorded X-ray spectrum.
- The detection system of the AXS is made of an ultra low-noise silicon drift detector (SDD) with a built-in FET (integrated on chip). A two-stage thermo electrical cooler (type Peltier) will share the detector housing with the detector chip and provide the required cooling (<-5˚C) to keep the excellent energy resolution. This space-proven apparatus is manufactured by the Max-Planck-Institute Semiconductor Laboratory (MPI HLL) in Munich, Germany.
- The collimated detector in the center of the setup is surrounded by two or more X-ray sources (Fig. 3).
- The first stage electronics tolerates operational temperatures of up to +70˚C, while the pre-amplifier prefers temperatures of ≤ +40˚C.
- Operation at higher temperatures (about +100 ˚C) for hot-day operations with an optical solar reflector (OSR) and a very low non-operational temperature below -100 ˚C for the sensor head and its electronic components for lunar night should be concerned similarly as the cases of previous missions: NASA MER and ESA ROSETTA.

SELENE-2 ROVER ACTIVE X-RAY SPECTROMETER

Fig. 1. SELENE-2 Mission consists of an orbiter, a lander, and a rover.

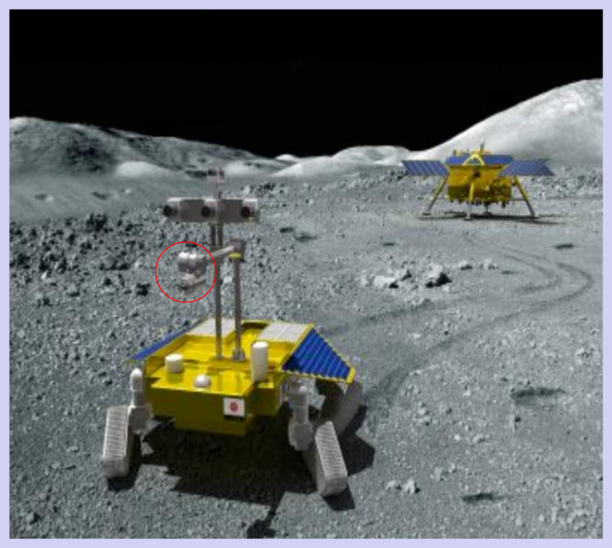

Fig. 2. Suggested location of AXS.

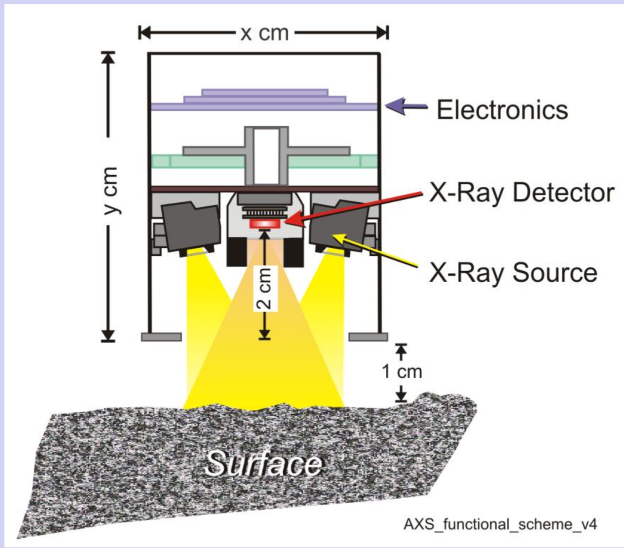

Fig. 3. Planned X-ray analysis on the Moon.

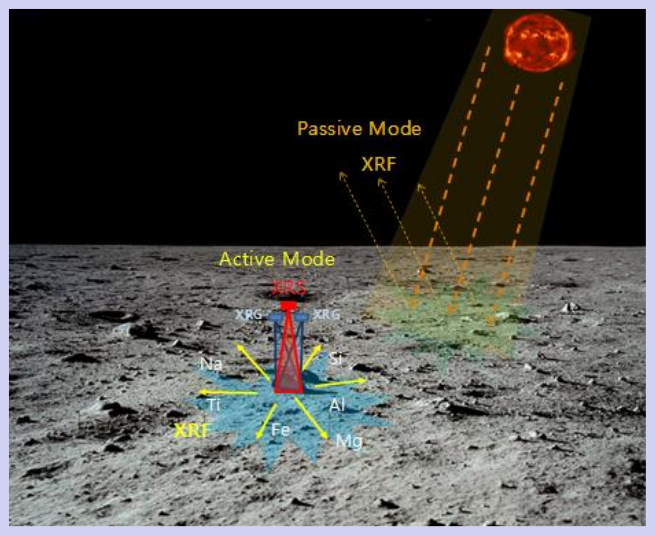

Fig. 4. Proposed Active X-ray Spectrometer for the SELNE-2 Rover.

CURRENT STATUS

- During the phase A of the AXS pre-project, feasibility study on the stability of X-ray flux of XRG, required surface roughness for XRS measurement on the Moon, camera image resolution, an expected experimental uncertainty of the AXS system, thermal design as well as feasibility of rock abrasion tool on lunar condition have been investigated (Fig. 5-7).

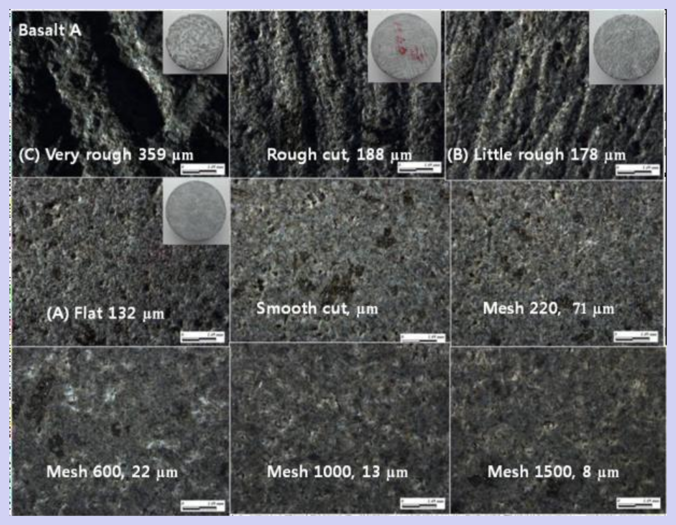

Fig. 5. Nine different surface roughnesses taken at a resolution of 27.5 μm/pixel by an Olympus microscope.

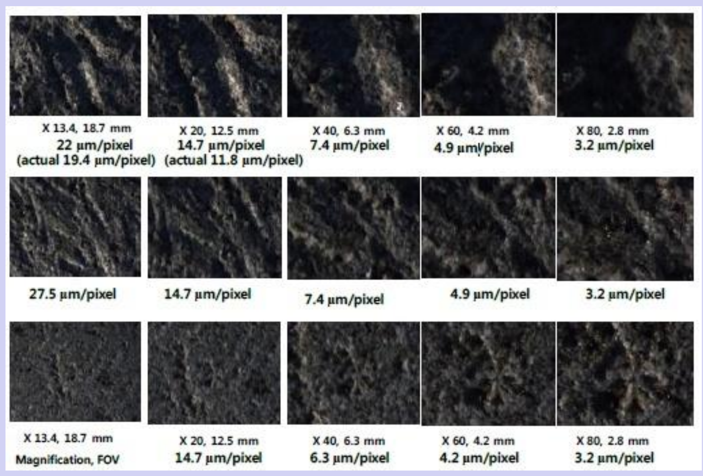

Fig. 6. Very rough, little rough, and flat surfaces shown at different resolutions. About 20 to 30 μm/pixel seems to be appropriate with respect to clarity.

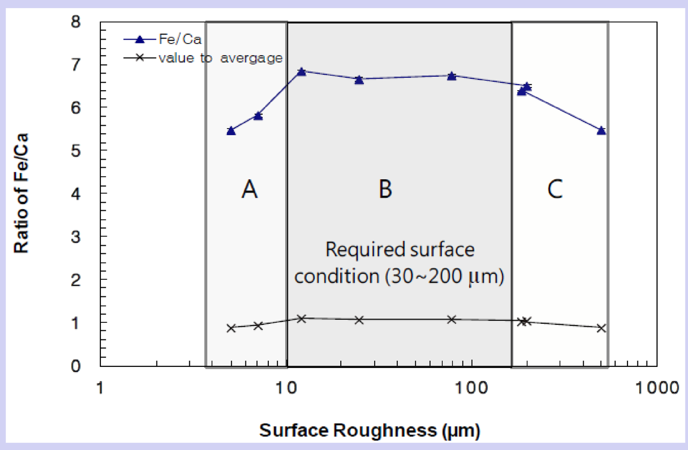

Fig. 7. Ratios of Fe/Ca (counts/counts) as a function of surface roughness. A required surface condition is determined to be a range of surface roughness of 30~200 μm.

ACKNOWLEDGEMENTS

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X-RAY GENERATOR

- A Pyroelectric crystal X-ray Generator (XRG). Pyroelectricity is the ability of certain materials to generate a temporary voltage when they are heated or cooled.
- The AXS XRG hermetically sealed in the package has a thin beryllium window, which allows the X-rays to be transmitted to the sample. The crystal to be used in the XRG is thermally cycled, typically between 20 and 100˚C.
- The XRG dominantly produces a 8 keV peak, when Ta and Cu are used, and a bremsstrahlung continuum.
- The total XRG output flux is a function of time for heating and cooling phases. Peak X-ray flux is expected to be 10^8 or more photons/s equivalent to or larger than a 2 mCi source. The outer-size is 15 mm in diameter and 10 mm high and its weight is 3.9 g. With this X-ray generator, elements from Na to Ni and up to Pb can be measured.

SCIENTIFIC GOALS

- The AXS makes use of active X-rays source, which clarify the elemental compositions of the materials ranging from major to minor elements constituting the lunar surface materials, that is, independent of three major terrains: Feldspathic Highlands Terranes (FHT), Procellarum KREEP Terrane (PKT), and South Pole-Aitken (SPA) Terrane [1-4].
- The Apollo landing sites were concentrated in the PKT, which is enriched in incompatible elements compared to the rest of the Moon.
- Thus, the data returned from the Apollo missions include a sampling bias that can lead to erroneous conclusions about the structure, composition and origin of the Moon as a whole.
- In-situ determinations of the AXS will characterize the new site geochemically, provide ground-truth for orbiting instruments, and lay the ground for a future sample return mission collecting rocks that we do not have in our terrestrial laboratories.

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