Micro-XRF for In Situ Geological Exploration of Other Planets

X-ray fluorescence instruments are used for non-destructive testing, sorting of recycled materials, and hazardous waste detection.

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In situ analysis of rock chemistry is a fundamental tool for exploration of planets. To meet this need, a high-spatial-resolution micro x-ray fluorescence (Micro-XRF) instrument was developed that is capable of determining the elemental composition of rocks (elements Na–U) with 100 µm spatial resolution, thus providing insight to the composition of features as small as sand grains and individual laminae. The resulting excitation beam is of sufficient intensity that high signal-to-noise punctual spectra are acquired in seconds to a few minutes using an Amptek Silicon Drift Detector (SDD).

The instrument features a tightly focused x-ray tube and HVPS developed by Moxtek that provides up to 200 µA at 10 to 50 keV, with a custom polycapillary optic developed by XOS Inc. and integrated into a breadboard Micro-XRF (see figure). The total mass of the complete breadboard instrument is 2.76 kg, including mounting hardware, mounting plate, camera, laser, etc. A flight version of this instrument would require less than 5W nominal power and 1.5 kg mass.

The instrument includes an Amptek SDD that draws 2.5 W and has a resolution of 135 to 155 eV FWHM at 5.9 keV. It weighs 180 g, including the preamplifier, digital pulse processor, multichannel analyzer, detector and preamp power supplies, and packaging. Rock samples are positioned relative to the instrument by a three-axis arm whose position is controlled by closed-loop translators (mimicking the robotic arm of a rover). The distance from the source to the detector is calculated from the position of a focused laser beam on the sample as imaged by the camera. The instrument enables quick scans of major elements in only 1 second, and rapid acquisition (30 s) of data with excellent signal-to-noise and energy resolution for trace element analysis.

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Oxygen-generating concept can be developed in an efficient system with low specific mass.

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The innovation consists of a thermodynamic system for extracting in situ oxygen vapor from lunar regolith using a solar photovoltaic power source in a reactor, a method for thermally insulating the reactor, a method for protecting the reactor internal components from oxidation by the extracted oxygen, a method for removing unwanted chemical species produced in the reactor from the oxygen vapor, a method for passively storing the oxygen, and a method for releasing high-purity oxygen from storage for lunar use.

Lunar oxygen exists in various types of minerals, mostly silicates. The energy required to extract the oxygen from the minerals is 30 to 60 MJ/kg O. Using simple heating, the extraction rate depends on temperature. The minimum temperature is approximately 2,500 K, which is at the upper end of available oven temperatures. The oxygen is released from storage in a purified state, as needed, especially if for human consumption.

This method extracts oxygen from regolith by treating the problem as a closed batch cycle system. The innovation works equally well in Earth or Lunar