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Electron Induced Excitation of XRF to determine Elemental Composition of Samples in Planetary Atmosphere

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One of the most powerful techniques for the characterization of mineral samples is Electron-induced Energy-Dispersive X-ray Fluorescence Spectroscopy (EDX-XRF). If used for resolving the elemental composition for samples in their natural state, high spatial resolution data will provide insight into geological processes and formation mechanisms of planets and other solar system objects. To date, all *in situ* missions have carried some form of an XRF instrument, such as the APXS instrument aboard the Mars Pathfinder and MER. The APXS determined "bulk" averaged elemental composition over areas of several cm in diameter, with the required spectrum acquisition time of several hours. However, in order to obtain spatial maps the spectrum acquisition time must be decreased and the spatial resolution increased. This is obtained by using the Atmospheric Electron X-ray Spectrometer (AEXS) instrument[1−5] based on the excitation of XRF using a focused beam of energetic electrons (>20kV) from samples in planetary atmosphere. Similar to but unlike for SEM, the samples are not drawn into the vacuum of the electron column due to the use of a thin electron transmissive membrane that isolates vacuum of the electron column from the Martian atmosphere. For samples in vacuous environments (such as Moon or Mars satellite Phobos) no isolation membrane is required. The XRF spectra are analyzed using an energy-dispersive detector to determine surface elemental abundance for the irradiated spots with high-to-medium spatial resolution (sub-millimeter to cm level) rapidly ($<$ 1min per XRF spectrum), enabling to assess sample heterogeneity from samples in their pristine state with no surface preparation.

We report on our progress in the development of the AEXS instrument. The AEXS consists of a sealed electron microprobe sealed with a 500nm thick SiN membrane, an EDX detection and analyzer system, and a high-voltage power supply. The microprobe requires no active vacuum pumping. The AEXS has been demonstrated in several stages, including simulation of operation, characterization of the effect of the membrane, assembly, and characterization of science capabilities. It has been used to analyze XRF spectra from a number of known NIST and USGS metal and mineral standards with a good agreement with the provider-certified elemental composition, for samples in up to about 90 Torr pressure atmosphere. The spatial resolution for resolved mineral grains was as high as 1mm.

NASA missions are characterized by extreme environments that put constraints on High Voltage Power Supplies (HVPS) required to power certain instruments on future landed missions. We have developed a concept for the integrated AEXS for accommodation on the instrument arm. The instrument head consists of a miniature HVPS integrated with the electron microprobe within a housing envelope, which isolates all high-voltage (HV) components from the outside atmosphere. To date, we have assembled a miniature HVPS operating in Earth environment. To produce a flight-qualifiable design, we have begun testing HV properties of test coupons (circuit boards) over an extreme temperature range, for a range of candidate encapsulation approaches, with emphasis on solid potting of surface mount components on HVM boards.

When implemented on a mobile platform, AEXS would be able to determine elemental composition of freshly exposed rock surfaces or soil grains on planetary surfaces, as a part of a payload that would also include a visual light camera capable of imaging the area being analyzed, yielding information at scale length of mineral grains. To decrease power consumption and mass, the thermionic emitters in the present microprobe should be replaced with CNT-based field-emitters,greatly simplifying electrostatic focusing and power supply architecture.

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