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Surface elemental analysis with 1 mm spatial resolution for samples in ambient atmosphere using the AEXS instrument

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The progress in the development of the Atmospheric Electron X-ray Spectrometer (AEXS) instrument is described. The AEXS is a miniature instrument[1−5] based on the excitation of characteristic luminescence spectra (such as X-Ray Fluorescence (XRF)) from samples in planetary atmospheres *in situ* using a focused electron beam. Unlike in the Scanning Electron Microscope (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 the vacuum within the AEXS electron column from the outside atmosphere. 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, enabling to assess sample heterogeneity. By correlating XRF with XUV and optical luminescence spectra, information could be obtained also about the bonding structure and past biological activities in the mineral.

The proof-of-principle AEXS has been demonstrated in several stages, consisting of constructing increasingly integrated setups that simulate operation of a portable instrument. After the characterization of the effect of the electron-transmissive membranes on the collected spectra, the setups included an actively pumped vacuum chamber from within which the electrons were transmitted, a sealed 10keV electron tube, and a stand-alone miniature 20keV microprobe vacuum-sealed with a 500nm thick SiN membrane. The latter microprobe requires no active pumping - a big step towards the development of a portable instrument. The microprobe has been used for performing elemental analysis of NIST and USGS traceable metal and mineral standards, with a good agreement with the certified composition for samples in up to about 90 Torr-cm thick external atmospheres. The spatial resolution for the microprobe has been tested by performing XRF measurements using a Gabbro (Norite) sample from the Stillwater Complex, Montana that contained mineral grains of 1 to 3 mm in size: The grains' surface elemental composition was resolved with about 1 mm spatial resolution, a big improvement in instrument capabilities for NASA missions. XRF instruments flown so far were essentially bulk analysis instruments. Resolving the XRF spectra both spatially and spectrally may give clues about sample's geological or biotic origin.

The AEXS development includes integration of the instrument head with a high voltage power supply for the tube's electrodes. The power supply is being developed in several stages, including electronic boards, dielectric housing (necessitated by low electrical strength at Mars atmosphere pressure), and low temperature operation. 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. The use of electrons as the excitation particles enables a new approach for *in situ* observations. Though widely used in the laboratory SEM, it has not been previously used in ambient atmospheres due to the difficulty of generating electron beams in thick atmospheres - it has been considered only within the context of a miniature SEM requiring placing the samples into the SEM's vacuum. To date, all *in situ* missions have carried some form of an XRF instrument, and a XRD/XRF instrument is scheduled for MSL'09. To decrease power consumption and mass, the thermionic emitters in the present microprobe should be replaced with Carbon-nanotube-based field-emitters,greatly simplifying the power supply architecture. Intense electron beam probes could find application for surface microbial reduction.

1 References

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