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Atmospheric Electron-Induced X-Ray Spectrometer (AEXS) Development

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The progress in the development of the Atmospheric Electron X-ray Spectrometer (AEXS) instrument in our laboratory at JPL is summarized. The AEXS is a miniature instrument[1−4] based on the excitation of characteristic luminescence spectra (such as the 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 to isolate the vacuum within the AEXS electron source from the outside ambient atmosphere. The spectra are excited from the irradiated spots with high-to-medium spatial resolution, enabling to assess sample heterogeneity. The XRF spectra are analyzed using an energy-dispersive detector to determine surface elemental abundance. By correlating the XRF with XUV and optical luminescence spectra, information can be obtained about the element's bonding structure and past biological activities in the mineral.

The proof-of-principle AEXS has been demonstrated through characterization of the effect of the encapsulation membrane and Martian atmosphere on the properties of the excitation beam, assembly and characterization of a prototype instrument, and simulation of AEXS observational capabilities. Our initial setup that was used for the demonstration of the ability of the transmitted electrons to excite the XRF spectra in the external atmosphere consisted of an actively pumped chamber from within which the electrons were transmitted - not a portable instrument. The instrument that has been assembled in our laboratory during the past year[4] consists of a miniature 20keV electron microprobe that is vacuum-sealed with a thin SiN membrane and requires no active pumping - a big step towards the development of a stand-alone instrument. The microprobe has been in operation for over 1 year and used for performing elemental analysis of NIST and USGS traceable metal and mineral standards, with good agreement with the certified composition for samples in up to about 90 Torr-cm thick external atmospheres. We will also describe our experiments in vacuum, which indicate correlation between elemental abundance and CL spectra in regions colonized by microorganisms.[3] XUV spectra could be used to determine ion charge state.

The use of electrons as the excitation particles enables a new approach for *in situ* observations. To date, all *in situ* missions have carried some form of an XRF instrument, and a XRD/XRF instrument is scheduled for MSL'09. Though widely used in the laboratory SEM, electron excitation has not been previously used in ambient atmospheres due to the difficulty of generating and transmitting electrons through the atmosphere - it has been considered only within the context of a miniature SEM that would have required placing the samples into the SEM's vacuum. The AEXS instrument requires no external pumping, spectra can be acquired from samples in their pristine state. The use of high-intensity beams results in rapid spectrum acquisition (several minutes), and consequently low energy consumption in comparison to other instruments. We are also planning to replace the present thermionic emitter with a Carbon-nanotube-based field-emitter,[5] greatly simplifying the power supply architecture and lowering mass and power consumption. The predicted mass and size for a future instrument are on the order of 1 kg and 10cm, respectively. We also note that intense high-energy electron probes could find application for surface microbial reduction.

1 References

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