INITIAL FE 1S XANES MEASUREMENTS OF EXPERIMENTALLY SPACE-WEATHERED OLIVINE.

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Introduction: We are making synchrotron X-ray absorption spectroscopy (XAS) measurements to investigate changes in the chemical speciation of minerals due to experimental space-weathering, with particular attention to Fe speciation.

Space weathering is the cumulative effect of the processes acting upon rock surfaces in the airless environment of space. These effects include the formation of glassy agglutinates, and nanophase elemental iron spherules [1,2] that lead to substantial darkening and spectral reddening of the affected surfaces. Much of what is known about surfaces in space comes from remote sensing. Returned material is rare, and chemically fragile. By creating experimentally space-weathered materials using realistic interactions between terrestrial analogues [3] and proxies for space-weathering processes, we can create diverse weathered surfaces to enable more quantitative analysis of VNIR and MIR spectra of target bodies.

Methods: Polished thick sections of single-crystal olivines (Fo_{85}) were subjected to simulated space weathering. To simulate solar wind, samples were bombarded with protons at the Brookhaven National Laboratory (BNL) Tandem Van De Graaff at 12 keV. To simulate micrometeorite bombardment, the samples were bombarded with polypyrrole-coated olivine dust at the hypervelocity dust accelerator in the Institute for Modeling Plasmas, Atmosphere and Cosmic Dust (IMPACT) facility at the University of Colorado at Boulder.

Microprobe X-ray fluorescence maps and Fe 1s XANES spectra were collected at the Submicron Resolution X-ray Spectroscopy (SRX) beamline (5-ID) at the National Synchrotron Light Source II at Brookhaven National Laboratory. The monochromatoer was calibrated against an Fe foil with the inflection point of the XANES spectrum set to 7112 eV. X-ray fluoresence measurements were collected with a Hitachi/Vortex ME3 silicon drift detector. Fe spectra were compared with reference spectra with linear least-squares combination fitting (LCF) using mrfitty.py [4]. Four olivine reference spectra (Fo0, Fo40, Fo80 and Fo90) and a basalt glass were used as the reference spectra [5].

Results: LCF comparing olivine and basalt glass standard spectra to spectra collected from the dust-impacted sample suggest a contribution of FeII glass at the impacted surface.

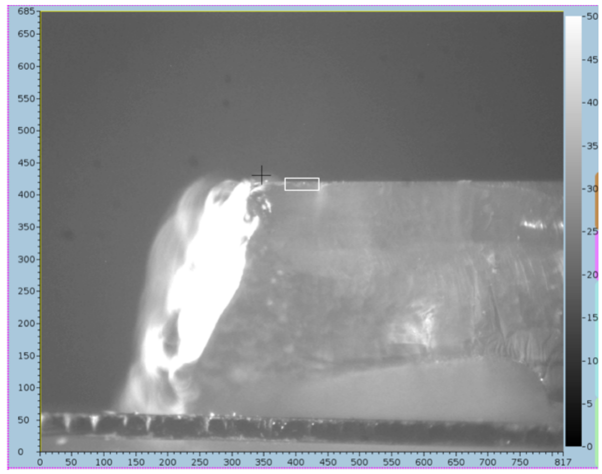

Figure 1 Light microscope image of dust-impacted olivine sample in sample stage at beamline 5-ID.

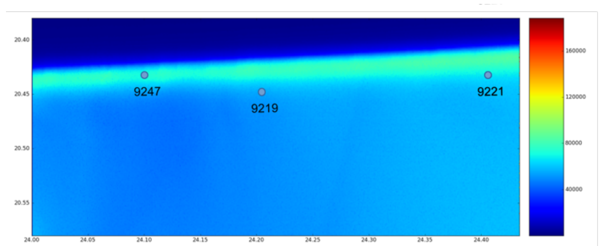

Figure 2 X-ray fluorescence map showing relative abundance of Fe with XANES spectra locations.

Discussion: LCF to basalt glass are consistent with the formation of a Fe-bearing glassy rim, which has been observed on return samples [6, 7] and other space-weathering experiments [1, 8, 9]. These preliminary results are intriguing and encouraging but call for more measurements on well-constrained sample materials, rather than immediate conclusions.

Future work: We are planning space weathering experiments using proton irradiation, dust impact and laser bombardment experiments on oriented [10, 11] thin sections of olivine, augite, diopside, anorthite, laradorite, enstatite, spinel, and ilmenite. XAS, tunneling electron microscopy (TEM), and infrared (IR) spectroscopy [12] analyses of these materials are planned.

There are two significant technical challenges for measuring Fe speciation changes associated with these space weathering features via XAS:

1) Reconciling the deep x-ray attenuation length at the iron absorption edge (10s of µm) with the much shallower depth of the predicted space-weathering features (nm to µm).

2) Reconciling the small size of the predicted space-weathering features (nm) with the available instrument spot size.

To overcome the difference between the depth of the predicted features and the attenuation length at the Fe 1s absorption edge, we can remove thin subsections of the treated samples via focused ion beam machining (FIB)[13] and collect measurements on the thinned sample. Another possible approach to this problem would be to collect XAS measurements from the surface layers via grazing incidence XAS [14, 15].

Another way to work around the deep attenuation length at the Fe Ka energy is by looking for speciation and ordering changes in lighter elements associated with Fe in these minerals. The attenuation depth at the Si 1s energy is shallow enough that ordinary thin sections coud be used to collect Si EXAFS spectra on these samples.

These methods could be employed to compare surface speciation among treated samples and untreated blanks as bulk samples. To resolve the small size of the predicted space-weathering features a nano-probe instrument [16] can be used to collect measurements on FIB thinned samples or on thin sections via grazing incidence.

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