

SPATIALLY-RESOLVED NIR SPECTRAL EFFECTS OF SPACE WEATHERING IN LUNAR PLAGIOCLASE K. L. Utt¹, R. C. Oglione¹, B. L. Jolliff², H. A. Bechtel³, J. J. Gillis-Davis¹. ¹Department of Physics, Washington University in St. Louis, St. Louis, MO 63130, USA, ²Department of Earth and Planetary Sciences, Washington University in St. Louis, St. Louis, MO 63130, USA, ³Advanced Light Source Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA (Correspondence: k.l.utt@wustl.edu)

Introduction: Space-exposed lunar soil grains are subject to micrometeoroid impacts and solar wind bombardment, a process broadly described as “space weathering.” The spectral effect of space weathering on lunar soils — darkening, reddening, and loss of spectral contrast — has been largely attributed to the formation and accumulation of nanophase iron (npFe⁰) particles in amorphous rims (<200 nm) coating mineral grains [1, 2, 3, 4]. While it is possible to study npFe⁰ within the amorphous rim via transmission electron microscopy, previous infrared (IR) spectroscopic studies have been limited to bulk, far-field measurements due to the long wavelength of IR light. The recent development of near-field IR spectroscopic techniques with a spot size of 10–20 nm, however, provides the opportunity to collect spectra with nanoscale spatial resolution [5].

Here we report near-field IR spectral measurements in two cross-sections of a space-exposed lunar plagioclase grain. Both samples were collected from the same grain but were chosen such that we could investigate the effects of micrometeoroid impact and solar wind irradiation separately. The technique used for this study provides spatial resolution on the order of space weathering effects, whereas typical laboratory spectra and remote sensing data can only measure the bulk properties of the soil. Hence, with this technique, we can assess the IR spectral features of the individual components which comprise the spectra measured by bulk methods. With a more detailed understanding of the spectral effects of charged-particle irradiation on mineral and soil grains, it may also be possible to draw parallels to silicate processing in the interstellar medium [6].

Sample Preparation: Using an FEI Quanta 3D Focused Ion Beam (FIB), we extracted two targeted liftouts from a space-exposed region of a ~250- μm grain from mature lunar soil 79221 [3]. SEM-EDS measurements collected with a Tescan Mira3 FEG-SEM (at 15 kV) indicate that the grain’s composition is consistent with anorthite-rich plagioclase, consisting primarily of Si (16 at.%), Al (16 at.%), Ca (8 at.%), and O (60 at.%). A ~3 μm protective Pt cap was deposited on the surface of the regions of interest before FIB sectioning.

One liftout (sample 1) was taken from a hypervelocity micrometeoroid impact crater (Fig. 1a). A second liftout (sample 2) was taken from a region of the space-exposed surface that included vesiculated and non-vesiculated melt splash and an adhering grain (Fig. 1b). The liftouts were thinned to a width of approxi-

mately 1 μm , polished with a low-kV ion beam, and placed on a Si chip with surface roughness <0.5 nm.

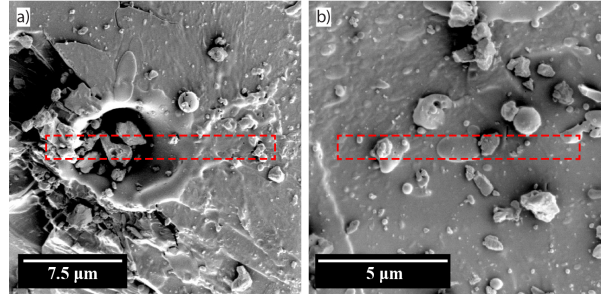


Figure 1: Secondary electron (SE) images (2 kV) showing grain surface from which a) sample 1 and b) sample 2 were extracted via FIB.

Methods: Using Synchrotron Infrared Nano Spectroscopy (SINS) at Beamline 5.4 at the Advanced Light Source [5], we collected spatially-resolved (spot size ~20 nm) near-field IR (2–14 μm) attenuated total reflectance (ATR) spectra at various distances from the space-exposed surface of the samples. In total, we obtained five line scans (three from sample 1 and two from sample 2) comprised of 32 points, each separated by 60–120 nm, beginning below the surface of the sample and ending on the protective Pt cap. Background spectra were collected from the Pt cap periodically. All spectra shown in Fig. 2 and Fig. 3 are normalized to these Pt background scans.

Results: For sample 1 (Fig. 2a), we collected spectra with 4 cm^{-1} spectral resolution from points separated by 70 nm. A representative subset of the 18 spectra obtained from sample 1 is shown in Fig. 2c. Spectra from sample 2 (Fig. 3a) were collected with 8 cm^{-1} spectral resolution from points separated by 90 nm. A representative subset of the 22 spectra obtained from sample 1, with particular attention paid to points near the surface, is shown in Fig. 3c. Dots of the corresponding color in Fig. 3b and Fig. 2b indicate the points from which we collected the spectra.

Discussion: The spectra obtained from both samples were found to change with depth from the space-exposed grain surface in a manner consistent with space weathering [7, 8]. Relative to those collected further below the surface of either sample, the spectra collected near the surface of the same sample are characterized by loss of spectral contrast, preferential loss of intensity in short wavelengths, and reduced overall inten-

