

## PRODUCTION OF OH/OD IN LUNAR SAMPLES: PROTON/DEUTERON BOMBARDMENT

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**Introduction:** The Moon Mineralogy Mapper (M<sup>3</sup>) on Chandrayaan-1 recently detected IR absorption features in the 2.8 to 3.0 micron range on the surface of the Moon [1]. Corroborating evidence of the spectral absorptions [2,3] and independent identification of polar ice [4] has confirmed that a population of OH, and possibly H<sub>2</sub>O, is present in or on particle grains at the lunar surface. In this laboratory study, we sought to test the hypothesis that the ~3 μm signal observed by spectral reflectance remote sensing has its origins in the solar wind [5]. Infrared spectra were acquired from lunar specimens exposed to hydrogen and deuterium ion beams. In particular, the 2.5 - 5.4 μm region corresponding to hydroxyl and deuterioxyl bands was investigated. Although a number of studies have used terrestrial minerals [6] and glasses [5] to carry out ion-implantation experiments and subsequent IR measurements, none have used Apollo lunar soils. The use of lunar soils as targets for implantation provides spectroscopic evidence for the viability of the solar wind hypothesis and enables qualitative comparisons to spectra acquired by remote sensing.

**Experimental:** Two lunar specimens were used in this study, a mare soil, Apollo 17 (70051), and a plagioclase-rich highland soil, Apollo 16 (62241). Ilmenite powder was also used for implantation experiments. Dehydroxylation/dehydration of the specimens was accomplished by heating them to 500°C at a pressure of 2x10<sup>-4</sup> Pa for two hours. Ion implantation was accomplished using the etching gun of a Gatan PECS 682 coater-etcher system. In separate experiments, lunar soils were exposed to <sup>1</sup>H<sub>2</sub><sup>+</sup> and D<sub>2</sub><sup>+</sup> ion beams with an energy of 2.3 keV, 80-109 μA, and a pressure of 0.03-0.05 Pa for up to three hours. After each hour of exposure, the specimen was removed from the instrument, shaken to expose fresh surface, and the implantation resumed. Samples were immediately transferred to the dry environment of the FTIR for measurement. Spectra were acquired using a Nicolet 4700 FTIR with 4 cm<sup>-1</sup> resolution and 256 scans.

**Results:** Figure 1 shows reflectance spectra for the Apollo 16 highland soil reported as the ratio of R/R<sub>0</sub>. The specimen heated under vacuum served as the reference, R<sub>0</sub>. The effect of high temperature is to dehydroxylate the lunar soil as shown by the broad band at 2.94 μm (3404 cm<sup>-1</sup>) (Fig. 1, black) of the specimen

before any treatment. Exposure of a heated sample to hydrogen or deuterium ion beams produces absorptions at 2.96 (Fig. 1, blue) and 3.92 μm (Fig. 1, red), respectively. The isotope shift of the OH fundamental vibrational stretching frequency from 3520 cm<sup>-1</sup> to 2600 cm<sup>-1</sup> during D<sup>+</sup> exposure shows that ion implantation was successful and not due to reaction of the highland soil surface with water vapor during sample transfer between instruments. The IR signals are attributed to hydroxyl and deuterioxyl groups that formed during reaction of H<sup>+</sup> and D<sup>+</sup> with silicates in vapor deposited rims [7]. Comparison of the OH band position and shape in Figure 1 to data acquired by EPOXI [2] are similar suggesting that the bands detected by remote sensing have their origin in the solar wind.

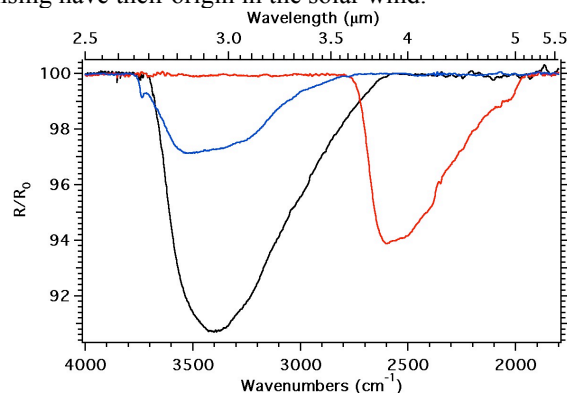


Figure 1. Diffuse reflectance spectra of the Apollo 16 sample before (black), after 500°C and exposure to the D<sub>2</sub><sup>+</sup> (red) and H<sub>2</sub><sup>+</sup> ion beams (blue).

After initial measurements, the Apollo 16, 17, and ilmenite specimens were stored under ambient conditions for several months. During this period, a OH signal grew in and the OD signal decreased. IR spectra acquired as a function of storage time will be presented and discussed. IR data acquired in this study will be compared to spectral libraries.

**References:** [1] Pieters C. M. *et al.* (2009) *Science*, **326**, 568 -572. [2] Sunshine, J. M. (2009) *Science*, **326**, 565 - 568. [3] Clark, R. N., (2009) *Science*, **326**, 562 - 564. [4] Colaprete, A. (2010) *Science*, **330**, 463-468. [5] Zeller, E. B., *et al.* (1966) *J. Geophys. Res.* **71**(20), 4855-4860. [6] Siskind, B., *et al.* (1977) *J. Vac. Sci. Technol.* **14**(1), 537-542. [7] McCord, T. M., *et al.* (2011), *J. Geophys. Res.*, *in press*.