Solar Wind Proton Induced Hydroxylation on Lunar Soil 78421. J. L. McLain[1], M. J. Loeffler[2], W. M. Farrell[3], J. W. Keller[3], and R. Hudson[3]. [1]University of Maryland, College Park/CRESST2, [2]Northern Arizona University. [3]NASA Goddard Space Flight Center

Introduction: In this work, we present a new laboratory study comparing the effects of proton implantation on two different mineralogical species. We perform a comparative study of crushed fused silica and lunar soil 78421 that have been prepared, irradiated, and analyzed under the same conditions. We are especially targeting a greater understanding of the broadening of the 2.8 μm OH absorption feature described by Ichimura et al. (2012). This comparative study is further validation of the altered nature of the H trapping potential between unweathered silica and mature space weathered lunar soils.

Experiment: Proton irradiations were performed in a UHV end-chamber at NASA Goddard Space Flight Center's Radiation Effects Facility. The proton source is a lower energy 0.5-5 keV OCI Vacuum Microengineering IG70 gas fed ion gun. We optimize the proton flux by adjusting the electron emission on the ion gun power supply, and increasing H_2 gas pressure typically up to 2×10^{-5} Torr on a standard Bayard-Albert ion gauge located on the opposite side of the chamber. During optimal ion gun operation, the proton irradiation flux was normally in the range of $5.5\pm1.5\times10^{14}$ 1 keV protons/cm^{2}s, while the samples were at ambient room temperature. After irradiation, the samples were removed from the chamber and placed into the sample compartment of a Nicolet iS50 Fourier Transform Infrared (FTIR) spectrophotometer. The iS50 sample compartment houses a diffuse reflectance accessory, Pike Technologies EasiDiff®, to perform Diffuse Reflectance Infrared Fourier Transform Spectroscopy (DRIFTS). We fabricated a new sample slide mount out of aluminum in order to heat the samples up from room temperature to 400 K with a 100 W cartridge heater.

Discussion: The proton-induced hydroxylation experiments on the fused silica and 78421 soil show that 1 keV protons can react to produce an OH signature as shown by an increase of the band near 3 μm. This new IR signature can only be seen once most of the surface and interstitial hydroxyls are removed by heating the samples to very high temperatures under vacuum. A dehydroxlation/rehydroxylation model is described for silica by Zhuravlev, and verified with these experiments (Zhuravlev 2000). Interestingly, a silica sample undergoes 6 Stages of dehydroxylation depending on temperature range. After Stage 5, T = 900-1200°C, rehydroxylation is a slow, strongly activated process. The silica surface becomes very hydrophobic and drops of water will "bead up" on the surface. Even after the baked silica sample was boiled in water for 5 minutes, and then dried, the IR spectrum did not show an increase of the OH or H_2O bands. This is definitive proof that long times and very warm/wet conditions are required to affect the 3 μm band after intense baking. Details of this dehydroxlation/rehydroxylation process will be discussed.

The changes in the OH stretching band near 3 μm due to proton implantation was monitored after each subsequent proton irradiation with DRIFTS. The equilibrium concentrations of solar wind proton induced hydroxylation has been determined to be $2.3 \pm 0.7\times10^{-6}$ OH(s)/1 keV H^+ for fused silica and $2.4 \pm 0.8 \times10^{-6}$ OH(s)/1 keV H^+ for 78421. Qualitatively, the OH band for the fused silica and 78421 is very different. The OH band for fused silica is centered at 2.74 μm and is relatively sharp ranging from 2.67 - 3.1 μm FWHM, while the OH band for 78421 is centered at 3.0 μm and ranges from 2.74-3.37 μm FWHM. The downshift in frequency and broadened nature of the OH band in 78421 may be associated with the hindered steric freedom of the OH stretch caused by nearby defects or vacancies. This broadening makes it difficult to distinguish between the OH (hydroxyl) band and the nearby OH stretching mode of adsorbed H_2O on the lunar surface.

Conclusions: These laboratory results show that only when the crushed fused silica is baked can we observe an increase in the proton induced hydroxylation band at 2.74 μm using DRIFTS. Subsequent proton induced hydroxylation experiments on 78421 show that its OH band is downshifted and much broader than the fused silica sample. The extent of the shift can be explained by the behavior of the interatomic interaction Morse potential model of an inhomogeneous solid that contains many vacancies and defects. A remarkable observation of these results is the proton induced OH band is qualitatively similar to very different lunar soils types, e.g., 78421, and 70051 and 62241 from Ichimura et al 2012. The increase in the proton induced hydroxyl IR band represents only the "high energy" tail of the distribution of proton induced hydroxyl formation, and any metastable OH or trapped H would likely have already diffused out before the DRIFTS measurement.

The observed OH increase due to proton implantation is not completely thermally/chemically stable. A temperature excursion up to 400 K showed that ~20% of the 3 μm band area was depleted. Details of the thermal cycling will be discussed.