

DIURNAL VARIATION OF THE SOLAR WIND-INDUCED OPTICAL SIGNATURE OF WATER ON THE

LUNAR SURFACE T. M. Orlando¹, B. Jones¹, A. Alexandrov¹, C. A. Hibbitts² and M. D. Dyar³, ¹School of Chemistry and Biochemistry, Georgia Institute of Technology, Atlanta, GA 30332, Thomas.Orlando@chemistry.gatech.edu, ²Applied Physics Laboratory, Johns Hopkins University, Laurel, MD 20723, ³Planetary Science Institute, 1700 E. Fort Lowell, Tucson, AZ 85719.

Introduction: Observations using infrared (IR) spectrometers on three separate missions, the *Cassini* Visual and Infrared Mapping Spectrometer (VIMS), *EPOXI* Near InfraRed Spectrometer (EPOXI-NIRS), and the *Chandrayaan-1* Moon Mineralogy Mapper (M³), have detected what is interpreted to be either OH or H₂O in the very upper surface of the lunar regolith [1-3]. Formation of hydroxyl was originally suggested to result from solar wind H⁺ implantation into silicate-rich surfaces [4] and the resultant O-H bonds were predicted to exhibit the diagnostic 2.8- μ m infrared absorption feature. The highly irregular OH sites in regolith would produce a large band-width [5] as observed [6]. The optical signature is complicated and several issues remain unresolved. These include the band position and band-width of the absorption feature, the generally low adsorption probability of molecular water onto the surfaces of lunar grains [7], and the relative amounts of molecularly adsorbed water on the illuminated Moon.

The *EPOXI* NIR [8] and M³ [2] observed variation of the the 2.8 – 3.0 μ m band dependent on time-of-day and compositional unit, with intensity inversely proportional to temperature and/or solar photon flux. The temperature- and time-dependence of the 3 μ m portion of the data could be associated with diffusion of surficial molecular water [8]. Possible thermal effects on the calibration led to a re-evaluation of the data using a more detailed thermal correction process [9,10]. These new approaches re-inforce the initial interpretation that temperature and latitude dependencies have been observed, though the reasons remain unclear.

Recent efforts to model solar wind interactions with lunar regolith have also been reported. They focus on retention of solar-implanted protons vs. transport of atomic and molecular hydrogen in the near-surface region using a Monte Carlo approach and an assumed distribution of effective activation energies [11] for neutral atomic and molecular hydrogen diffusion. Though a qualitative hydrogen cycle was proposed, the temperature dependence was not correlated with the effective mass transport of the chemically stable bonds in the OH groups. This is reasonable because OH transport within silicates and glasses requires molecular water formation via an activated recombination process that typically requires temperatures much higher than those available on the sunlit side of the Moon.

Results: It is known that implanted H in the form of OH may be affected by non-thermal processes (i.e., ultraviolet photodissociation and sputtering [12]). In addition, water formation at the surface or within the interface region occurs via recombinative desorption (RD) of OH groups and can occur at temperatures below the maximum excursion temperature on the sun-lit face, depending upon the amount of hydroxylated Ti-, Al- and Fe- oxides [13]. With these known OH loss processes in mind, an atomistic and molecular model describing the fate of solar wind-induced hydroxyl groups on and within regolith material has been developed.

Specifically, we utilize experimentally derived cross sections and rates for interfacial OH formation and destruction. The latter steps involve water and H₂ formation via RD, photodestruction, and lunar regolith interfacial OH/H₂O replenishing. The resulting solar wind “hydration” cyclic process describes the observed latitude (Figure 1) and diurnal dependencies of the 2.8 μ m optical feature well (Figure 2). The method is self-consistent and can be used to predict the concentration of solar wind induced hydroxyl groups as a function of time and spatial point (latitude) on the Moon and other

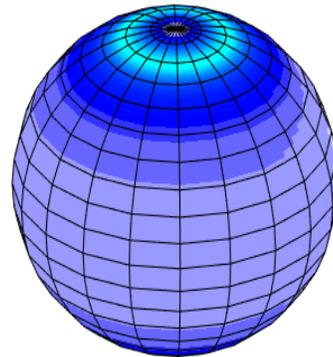


Figure 1. Simulated OH concentration using the coupled kinetic model that invokes H⁺ implantation followed by OH destruction and water formation and release via recombinative desorption. The lowest concentration is at the equator followed by a build-up near the poles.

airless bodies [14]. Because H₂ formation does not contribute to chemically bound OH formation and its subsequent optical signatures, the fate and transport of H₂ after production need not be considered.

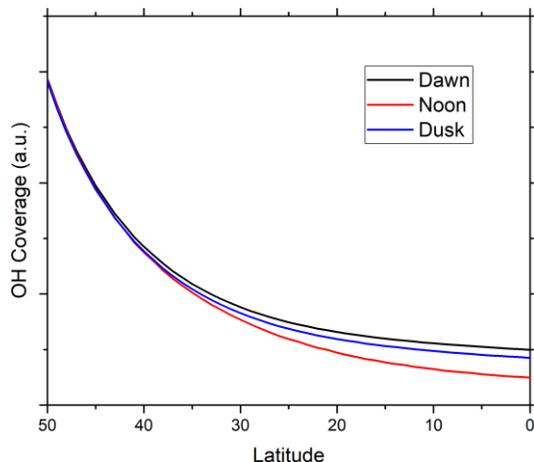


Figure 2. Diurnal variation of the chemically bound hydroxyl formed via solar wind bombardment within the lunar regolith as a function of latitude as predicted by the kinetic model presented here.

Summary: A new solar-wind initiated reaction cycle has been developed from both experiment and modeling to account for the diurnal variation of the optical signature of hydroxyl on lunar regolith [14]. Specifically, the 2.8- μm feature can be accounted for by following the formation and loss mechanisms of solar wind produced chemically bound hydroxyl (-OH) groups on and within lunar regolith grains. After saturation, hydroxyls are constantly removed and replenished by a cycle that primarily involves formation and release of H_2 and $\text{H}_2\text{O}(\text{g})$. The latter is formed via recombinative desorption resulting in a low density, low altitude tenuous atmosphere on the sun-lit side. The $\text{H}_2\text{O}(\text{g})$ undergoes photo-dissociates and dissociative or molecular re-adsorption on the lunar surface over limited recursion distances and over typical lunation period. A significant lasting $\text{H}_2\text{O}(\text{g})$ population is not expected. Overall, the cyclic process depends on substrate temperature, chemical composition, and can be generally applied to other airless bodies exposed to solar wind.

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