

Adsorption, Formation and Transport of Molecular Water on Lunar Regolith. T. M. Orlando¹, B. A. Jones¹, A. B. Aleksandrov¹, C. A. Hibbitts², M. D. Dyar³, ¹Center for Space Technology and Research, Georgia Institute of Technology, Atlanta, GA, 30332, Thomas.orlando@chemistry.gatech.edu. ²Johns Hopkins University Applied Physics Laboratory, Laurel, MD, 20723. ³Mount Holyoke College, Dept. of Astronomy, South Hadley, MA, 01075.

Introduction: Understanding the adsorption, formation and transport of molecular water on the Moon is of both fundamental and applied interest. This is particularly true given the current intense interest in “going forward” to the Moon. Spectroscopic studies in the 2-3 micron region imply up to 10-1000 ppm molecular water and hydroxyl (OH) may exist on lunar surface [1-3]. However, the presence and persistence of molecular water in the sunlit regions is doubtful since the water desorption rate is rather high above 180K. However, permanently shadowed craters, such as parts of Cabeus, are cold enough to capture migrating water molecules for geologic timescales. Indeed, the LCROSS impact experiment at Cabeus crater showed the presence of up to 6% concentration (by mass) of water and ice in the ejecta plume [4]. This was consistent with previous modeling efforts by Watson et al. in 1961 [5].

Understanding the sources of water and how strongly it interacts with the regolith and how it can be extracted for utilization requires knowledge of the binding energies, diffusion constants and transport coefficients. All of these quantities will depend on the regolith composition, temperature and space weathering history. Most of the diffusion and transport coefficients necessary to model migration and motion of water on and within regolith are not in the literature. Some existing models use the water-ice sublimation energy for the water interaction with the lunar surface though this is known to be less than the interaction energy of the adsorbed layer [6].

We have completed a series of temperature program desorption (TPD) measurements of water adsorbed on lunar materials (mare vs. highland) under high-vacuum conditions. The results can be used to support or contradict the likelihood of significant quantities of adsorbed water persisting in sunlit and/or relatively warm (> 150 K) locations on the Moon. TPD measurements also provide estimates for water adsorption lifetimes and can be used to enhance the existing water migration models.

Experimental Methods: TPD experiments were performed under Ultra-High Vacuum (UHV) conditions. TPD is a well-known technique for obtaining desorption activation energies. This is typically done by measuring the rate of desorption versus temperature with at a constant temperature ramp using a calibrated mass spectrometer.

Samples: The lunar samples we have obtained are low and high-Ti mare soils, KREEPy soil, highland soil, and a mixed lot. This allows for a good sampling of the varied mineralogy from different Apollo landing sites on the Moon. Details about the sample material mineralogy can be found in the Lunar Sourcebook [7], and references cited therein.

Results: For water adsorption at low temperatures (< 100K), the TPD spectra contain evidence for both bulk-water ice formation and a broad distribution of molecularly chemisorbed water. A numerical analysis method was used to obtain the distribution function of the molecular binding energies. In this case, where the coverage dependence and diffusion between and around grains has been taken into account. Using this approach the distribution functions for the mare and highland were similar, however, the total amount of water on the highland samples was considerably higher. The distribution function was then used as an initial condition to numerically simulate the diffusion and transport of water from hot-to-cold regions on and between grains. The simulation now includes migration, re-adsorption, and non-thermal water losses and demonstrates that transport involves multiple adsorption and desorption “steps”. The sum of these yields an effective water removal and transport energy which is useful for modeling the actual lunar surface. However, but this should not be referred to as the “binding energy”.

In addition, water formation is shown to occur via a process known as recombinative desorption (RD) for temperatures over 350K for both mare and highland samples. The yield of water from RD is considerably higher from the highland vs. the mare samples. This is related to the chemical composition and the relative amounts of Ti, Fe and Mg.

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