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In-Situ Calorimetric Measurements for Space Exploration

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IN-SITU CALORIMETRIC MEASUREMENTS FOR SPACE EXPLORATION: AN INSTRUMENT CONCEPT. C. C. Hays, S. M. Hollen, M. Barmatz, and T. Chui, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, Charles.C.Hays@jpl.nasa.gov.

Introduction: Evidence for the presence of subsurface water ice at the moon's poles was supplied by radar images from the Clementine space probe and from neutron spectrometer data returned by the Lunar Prospector spacecraft [1][2]. However, the controlled crash of the Lunar Prospector probe into a crater at the Moon's south pole did not provide direct spectroscopic evidence from either Earth-based observatories or the Hubble Space telescope. It will be necessary for NASA to determine the existence, abundance, and properties of lunar water ice and the surrounding regolith. Any lunar mission that will conduct a quantitative study of the near-surface deposits or one that seeks to utilize these deposits for resource harvesting will require an in-situ method for determining the physical properties of the icy deposits, and the surrounding lunar regolith. These studies are particularly important to determine both the abundance of water ice as well as its form, which is likely to be amorphous [3]. Amorphous water ice is readily formed in extremely cold environments through vapor deposition, making it the most common form of ice in the universe [4]. The moon's permanently shaded polar craters, with temperatures near 40 K, provide a cryogenic environment favorable for the formation of amorphous water ice. Over astrophysical time scales, vapor deposition of water could be a physical process responsible for the existence of water ice at the moon's poles. These shaded craters would also preserve the remnants of ice delivered by ancient cometary impacts. We propose developing a mini-differential-scanning-calorimeter (mini-DSC) for in-situ measurements of regolith samples on lunar and planetary surfaces to determine the existence, abundance, form, and possibly the origin of lunar water ice.

Approach: Calorimetric instruments are the method of choice for determining the thermophysical properties of solids, liquids, and gases. The method is straightforward: an unknown specimen is placed in a small, insulated chamber, and on controlled heating, the temperature of the specimen chamber is compared to another nearly identical empty reference chamber. Phase and/or state changes in the unknown specimen caused by heating will be manifest in temperature differences between the unknown and reference chambers. These quantitative measurements would provide direct knowledge of the thermophysical properties of an icy deposit, such as specific heat, glass transition temperature, heat of crystallization, melting temperature, latent heat of melting, and latent heat of vaporization. If the specimen could be weighed, the abundance of ice in the regolith could also be determined. In addition to their value to space exploration and fundamental knowledge, these data are of critical importance for managing the heat loads of any water or oxygen extraction facility, which must include a method for controlling the imposed thermal loads, e.g., via a thermal radiator.

Prototype: For the purpose of studying amorphous ice here on earth before possibly encountering it on the moon, we propose to develop a prototype mini-DSC at JPL. In order to fully interpret the data to be taken with the mini-DSC, we will study the properties of amorphous water ice synthesized under conditions relevant to the Moon, including both vapor deposition and quenching tests. Further studies will examine: 1) the effects of water vapor deposition onto surfaces of lunar regolith simulant; and 2) the effects of dispersing small particles of the simulant into liquid water, and then quenching to form amorphous ice.

Method of Characterization: Our studies will also build on the reported properties of amorphous water ice prepared via vapor deposition. The phase diagram is complicated and dependent on the synthesis method; however, the widely adopted glass transition temperature is 136 K, and the crystallization of the amorphous phase occurs over the range 155-161 K. Additionally, the heat released upon crystallization of the amorphous ice is approximately 22.6 cal/g. This heat is nearly 1/3 the normal latent heat of melting for normal (hexagonal) water ice, approximately 79.9 cal/g. These properties, and our proposed research, will allow us to characterize lunar water ice. Furthermore, the magnitude of the heat of crystallization and its implications on managing heat loads mandate a full understanding of the cryogenic properties of amorphous water ice.

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