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# Cryogenic Property Measurements on Icy Compositions with Application to Solar System Ices

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Introduction and Science Motivation: We present the motivations, objectives, and preliminary experimental results for a new experimental cryo-ices initiative launched at JPL. The main motivation for this work is to fully appreciate the discoveries made by the Cassini-Huygens and Galileo missions, to prepare for the Dawn and New Horizons missions, and to look forward to potential missions to Europa, Enceladus, and Titan. This work is a joint effort among experimentalists and theorists at JPL, in collaboration with specialists in icy material properties the world over.

Experimental Approach: A range of experiments are being devised which will improve our ability to model ice-rock body internal evolution and geological processes using modern synthesis and characterization techniques under cryogenic conditions. Initial experiments will involve pure water, methanol-water, ammonia-water, and ammonia-water-methanol mixtures, relevant to a range of icy satellites and processes. Ammonia is considered to play an important role in Titan cryovolcanism, whereas methanol is chosen as an experimental analog due to its ease-of-use in the laboratory. Where beneficial, we will determine basic thermophysical properties and phase diagrams using a Differential Scanning Calorimeter.

Solids. We plan to analyze samples from terrestrial glaciers, which are relevant to both the terrestrial and planetary geology and geophysical communities. Terrestrial glaciers appear as realistic analogs for modeling processes taking place in the outer icy shells of icy satellites. These results will better enable us to predict the long-term evolution of terrestrial glaciers and ice shelves. Also, we will synthesize specimens with controlled microstructures by using equilibrium and non-equilibrium synthesis methods. Equilibrium methods, e.g., conventional (slow) freezing in a mold, will provide microstructural length scales in the range 0.2 to 1 mm (with and without preferred orientation, e.g., columnar grains). Post-synthesis microstructural characterization will be performed using Cryogenic Optical Microscopy integrating a cross-polarizer to analyze thin sections, and a Cryogenic Scanning Electron Microscope. Mechanical property measurements on solid specimens will be performed between 80 and 270 K with a cryogenically cooled Instron measurement system. Compression measurements will be conducted as a function of temperature, strain-rate, microstructural length scale and orientation. The time dependent viscous response will be measured by performing creep measurements over the same range of temperatures. Using low-frequency cyclic loading, the dissipation factor will be measured at frequencies approaching satellite orbital frequencies. We will report preliminary mechanical property measurements of Antarctic glacial specimens at cryogenic temperatures.

Fluids. In order to improve our understanding of effusive cryovolcanism, the rheological properties of liquid and mixed (slurry) materials will be measured between 80 and 300 K using a cryogenically cooled Brookfield rotational rheometer. We will report preliminary measurements of the temperature dependence of the viscous response for several compositions in the Methanol-Water System. Also, we will describe an experiment designed to measure methane wetting on water ice. These experiments will be carried out in order to explore the effects of the presence of methane lakes on Titan's surface.

We are developing the capability to investigate more complex materials relevant to surface processes on Titan, including methane-ethane phase studies, hydrocarbons such as acetylene and benzene, as well as tholins and clathrates, which should exhibit a range of rheological and mechanical properties from fast-moving fluids to glacial creep.

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