NEW EXPERIMENTAL FACILITIES FOR CHARACTERIZING THE MECHANICAL, RHEOLOGICAL, THERMOPHYSICAL, AND CHEMICAL PROPERTIES OF ICY COMPOSITIONS WITH APPLICATION TO SOLAR SYSTEM ICES.

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Introduction: We present a new facility at the Jet Propulsion Laboratory in Pasadena, CA that offers the capability to experimentally determine the thermophysical, rheological, and mechanical properties of icy materials (ices and candidate cryolavas) over a cryogenic temperature range from 80-300 K, which is applicable to outer Solar system objects such as Jupiter's and Saturn's satellites as well as Mars' polar caps and terrestrial ice sheets. Facilities are also available to study the chemistry of ices at temperatures ranging from 15-300 K under the influence of ultraviolet exposure, electron irradiation and thermal cycling.

Development of these advanced experimental facilities will enable a significant body of work germane to solar system ices, including a number of first ever laboratory measurements on icy samples of interest. With our colleagues in the planetary science community, we will use these data to help interpret observations from the *Cassini-Huygens* and *Galileo* missions, missions to explore Martian polar caps such as *Phoenix*, and missions on their way to icy objects, such as *Dawn* to Ceres and *New Horizons* to Pluto and Charon. Our results will help in preparatory research for future missions to the outer solar system (*i.e.*, future flagship mission), comets and other minor bodies, and Mars. These future missions will require advanced instrumentation, and we will use our data to support this effort. One important aspect of our work is that our results will be used to help understand the effects of climate change on the Earth's terrestrial ice sheets at the polar regions.

We will present the facilities and details about the capabilities available in these new laboratories. Details about the science objectives and measurements achieved with the different systems are addressed in [1, 2]. Preliminary results obtained on simple compositions are in agreement with published literature, which shows that the different systems and the calibration procedures have been properly designed.

Experiments:

Mechanical properties of cryovolcanic slurries. In order to improve our understanding of candidate effusive cryovolcanism, we will measure rheological properties of liquid and mixed (slurry) materials between 80 and 300 K using a cryogenically cooled *Brookfield* rotational rheometer. The viscometry system is a unique system of its kind based on the experimental procedures of Kargel [3], but over a much wider range of parameters and compositions, and with a greater degree of automation. In particular, we will be focusing on non-equilibrium processes, strain-rate dependence and attempting to relate the measurements to microphysical processes, by integrating parallel modeling efforts. Control and data acquisition will be carried out using a *LabVIEW* software custom interface. Initial experiments, primarily for the sake of system calibration, involve methanol-water (CH_3OH-H_2O) [4] and eventually will include ammonia-water (NH_3-H_2O) and ammonia-water-methanol mixtures relevant to Titan, before moving on to compositions relevant to a wider range of icy satellites and processes.

Differential Scanning Calorimetry measurements are performed in order to provide information about the thermophysics of the mixtures tested with the viscometer. We use a Setaram BT 2.15 calorimeter that can span temperatures from 80 K to 300 K.

Mechanical Properties of Solid Samples. Mechanical properties of solid specimens will be performed for temperatures between 80 and 273 K with a cryogenically cooled *Instron* measurement system. The *Instron* compression system performs measurements under uniaxial compression. Measurements are controlled and automated with *LabVIEW* software. This system has achieved strain rates as low as 5×10^{8} s^{-1} and will be especially dedicated to measuring the attenuation properties of icy samples at frequencies as low as 10^{-4} Hz [1], as well as their creep properties and Young's modulus. These low frequencies approach tidal forcing frequencies associated with outer planet satellites. Compression measurements will be conducted as a function of temperature, strain-rate, microstructural length scale and orientation, applied load versus time (creep), and time-varying load in order to measure the viscous response. This system is also equipped with the capability to simultaneously measure the samples' thermal conductivity as a function of pressure.

Liquid Methane Experiments. We are currently developing a new facility that will measure the wetting properties of liquid methane on different substrate analogs to Titan's surface. This facility will also be equipped with fiber optics that will acquire the spectroscopic properties of the methane/ice substrate for comparison with the Cassini spacecraft Visible and Infrared Mapping Spectrometer Subsystems (VIMS) data.

Sample Characterization. Several methods are available for characterizing the properties of the samples before and after testing: X-ray diffractometer, Cryogenic Optical Microscopy integrating a cross-polarizer to analyse thin sections, and a Cryogenic Scanning Electron Microscope (SEM).

Physical Chemistry of Ices. The experimental facility (Fig. 1) is a multi-port vacuum chamber with a closed cycle helium refrigerated cryostat configured with a programmable, auto-tuning temperature controller that can maintain stable sample temperatures from room temperature down to 15 K. The system is also equipped with a quadrupole mass spectrometer (QMS), a Fourier transform infrared (FTIR) spectrometer, and a collection of UV lamps (both contiuum and single emission line).

Sample substrates are mounted on the cryostat such that the ice samples are located at the intersection of the chamber ports. Since the cryostat can be rotated while under vacuum, a sample can be directed at a variety of radiation sources and instruments mounted on the chamber ports without breaking vacuum. This enables a large degree of experimental flexibility.

Ice samples are prepared using vacuum vapor deposition of gas mixtures prepared in a vacuum manifold on KBr substrates which are appropriate for transmission in the infrared. This allows for direct analysis via FTIR as well as temperature programmed desorption (TPD) mass spectrometry.

Projects: We have achieved calibration and full understanding of the capabilities of the main systems (except for the liquid methane experiments). We have been using well-controlled single crystals of water ice in order to demonstrate that measurements obtained with the *Instron* compression system match existing literature data. We are developing the capability to produce polycrystalline samples of water ice, salt hydrates, clathrate hydrates, porous ices, as well as terrestrial ice sheet samples. Samples will also be shared with our JPL colleagues who are performing spectroscopic measurements. The ultimate goal of this project is to develop a database of planetary ice analog properties that will be available to the community involved in modeling terrestrial and planetary ices.

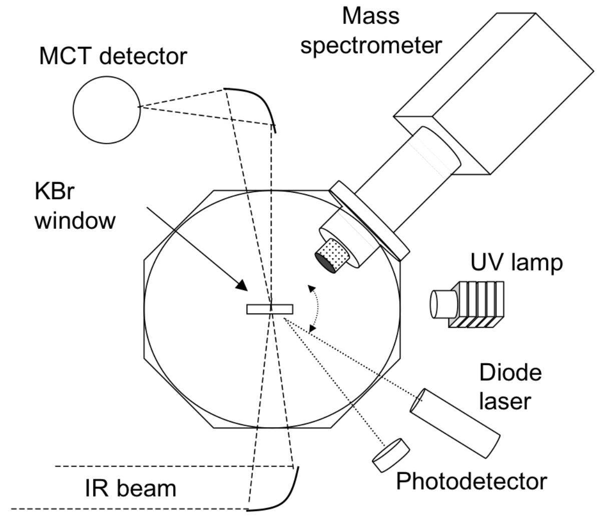

Figure 1. Schematic of the apparatus.

In terms of physical chemistry, we are performing studies on the relationship between microstructure and phase transitions in ices [5]. We are examining the temperature dependant outgassing behavior of mixed H_2O:CO_2:N_2:CH_4 ices for application to the Enceladus plume [6]. In addition, we are investigating the wavelength dependent photochemistry of doped-water ices.

The JPL Ices Group is open to external collaboration that would utilize the existing equipment in order to address scientific issues relative to terrestrial and planetary ices.

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