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Sublimation of ice/dust mixtures

Antoine Pommerol (1), Olivier Poch (2), Bernhard Jost (3), Clément Feller (1), Holly Capelo (1), Stefano Spadaccia (1), Jessica Sunshine (4), and Nicolas Thomas

(1) Physikalisches Institute, University of Bern, Switzerland, (antoine.pommerol@space.unibe.ch), (2) IPAG, University of Grenoble-Alpes, France, (3) Jet Propulsion Laboratory, California Institute of Technology, CA, USA. (4) University of Maryland, College Park, MD, United States.

1. Introduction

The Planetary Ice Laboratory has been in constant development at the University of Bern since 2010. The main objective of this facility is to characterize experimentally the reflectance of icy planetary and cometary analogues to better interpret quantitatively the remote-sensing and in-situ data returned by various missions.

Ice sublimation is a dominant mechanism for the surface evolution of many solar system objects, with or without an atmosphere. While the physics of the phase change for a pure compound such as water is reasonably well understood, the case of complex mixtures of ices and dust is complicated. Modeling such mixtures is challenging and requires experiments with complex but well-controlled samples to better understand the processes.

Between 2014 and 2017, we have performed a series of sublimation experiments with various ice/dust samples using the SCITEAS (Simulation Chamber for Imaging the Temporal Evolution of Analogue Samples) setup described in [1]. In this presentation, we will review these past experiments and summarize what we have learned and describe our plans for future work on this topic based on these previous results.

2. Ice-dust mixtures

Preparing well-characterized and reproducible icy analogue samples is crucial for our project. Working with water ice in the lab is very challenging as the material continuously evolves affecting all physical properties of the samples. In order to produce samples suitable for the type of experiments foreseen, we have developed a series of protocols and portable setups called Setups for the Preparation of Icy Planetary Analogues (SPIPA) that allow us to prepare fresh samples where and when we need them. The dust and the ice can be associated in various ways including intimate mixtures at the level of the individual grains, inclusion of small dust grains in the matrix of a large ice grain, a mantle of ice around a dust grain, a coating of dust grains around an ice grain, etc. Often, these different types of associations will result in very distinct optical properties. It is therefore crucial to be able to prepare the mixtures in these different ways and compare results for a given bulk composition but different mixing modes.

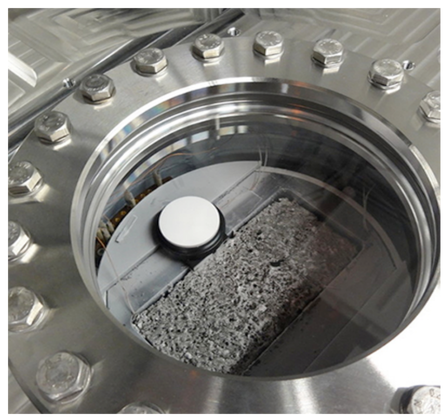

Figure 1: Picture of a sample made of micrometer-sized particles of water ice intimately mixed with lunar regolith simulant (JSC1-AF) and carbon black particles sublimating in vacuum seen through the window of the SCITEAS experiment. The diameter of the window is 16 centimeters. The white round object is a standard reflectance target.

3. Sublimation experiments

Most of our past sublimation experiments shared this series of common steps: 1) The sample is prepared at low temperature (boiling liquid nitrogen, 77K) from the ice and the dust components. 2) The sample is introduced in the SCITEAS chamber. The chamber is rapidly closed, cooled and evacuated. 3) The evolution of the surface of the sample is recorded during a few tens of hours through a large window on top of the chamber (Fig. 1) using a hyperspectral imaging system. 4) The sublimated samples are extracted from the chamber and examined with different techniques.

Steps 3) and 4) were occasionally repeated a couple of times in order to acquire measurements of the bidirectional reflectance with the PHIRE-2 [2] instruments at different steps of the sublimation [5].

The heat is either provided to the sublimating samples by infrared radiation from the window and upper lid of the chamber or by visible radiation using a Sun simulator.

4. Notable results

Sublimation experiments performed during these four years have provided large amounts of data and many interesting results reported in [1,3,4,5]. We will provide a summary of the most notable results in the presentation. This includes:

- The preservation of the structure of the samples as the ice sublimated. Remnants of the initial spherical ice particles are still visible in the organisation of the dust particles as agglomerates.

- As a result of the preservation of microstructure upon sublimation, the Bidirectional Reflectance Distribution Function of the sublimated samples remains very similar to the one of the icy samples.

- We see evidence for high cohesiveness of the sublimation mantle obtained with some of the dust materials (organics, phylosilicates) and some of the mixing modes (dust grains embedded into the ice grains) that resulted in the ejection of cm-sized “flakes” of dust agglomerates.

- The VIS-NIR reflectance spectra of the high-porosity sublimation residues are remarkably featureless, showing only very shallow absorption bands and occasionally blue slopes in the infrared.

5. Future experiments

We have recently completed the construction of SCITEAS-2, the successor of the SCITEAS facility. The new chamber offers a series of significant improvements, in particular a base plate with controlled temperature, a large door to easily access the interior of the chamber and clean it after the experiments and additional windows to monitor the sample and its surroundings from various directions.

We are now resuming sublimation experiments with this new facility and will explore some aspects of the initial experiments left unexplained.

In addition, the configuration of the new chamber will make the comparison of experimental results with physical models much simpler and we expect to gain many additional insights into the physics of the evolution processes from this comparison.

New sublimation experiments dedicated to cometary physics will be performed in the framework of the CoPhyLab project [6].

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