PROJECT OF AN ENVIRONMENTAL CELL FOR THE CONDENSATION AND METAMORPHISM OF CO_2 ICE.

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Introduction

Carbon dioxide is the major component of the Martian atmosphere, and the characterization of its atmospheric cycle is necessary to understand the past and present meteorology on Mars. Every Martian year, about one third of the atmosphere condenses into CO_2 frost within the polar regions [1]. Mars CO_2 frost presents radiative, photometric and spectral properties that appear to vary in space and time [2]. These variations can be dramatic and suggest very active microphysical phenomena of transformation (sublimation, metamorphism, phase change, segregation…). For a better understanding of the nature of the seasonal condensates and their physical, chemical and textural evolutions, near-IR spectroscopic data are now available – e.g. with OMEGA on board Mars Express and CRISM on board Mars Reconnaissance Orbiter [3,4]. However, a good understanding of these spectroscopic data requires laboratory measurements on analogue materials.

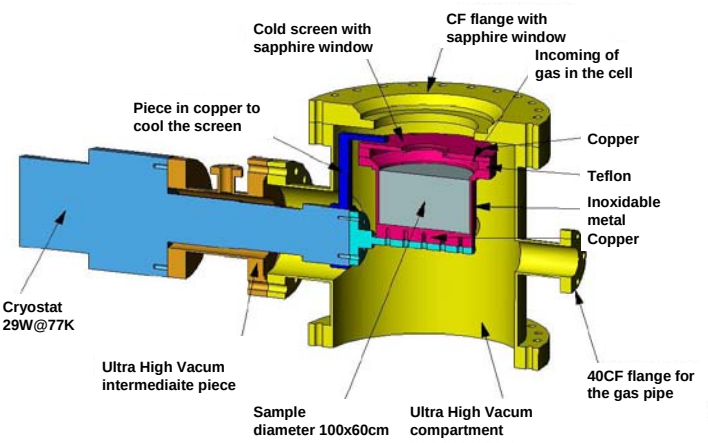

Figure 1. First schematic design of the experimental setup.

Description of the project

The objective of the CARBO-NIR project is to reproduce the observed physical and optical evolutions of the seasonal condensates [5,6,7] in order to constrain the microphysical processes at work. More precisely, we design an environmental cell that enables the study of the microphysics, the condensation, the metamorphism and the sublimation of CO_2 ice (pure or with impurities like water and dust), and the corresponding spectral evolutions in diffuse reflectance (Figure 1). This cell will reproduce the Martian low temperature and low pressure atmospheric conditions in order to condense CO_2 and to expose this ice to different evolution and metamorphism conditions. The experiment should allow the formation of a 5 cm-thick dry ice deposit by condensation under conductive or radiative cooling. Spectroscopic measurements of the ice sample will be done with the Spectro-Gonio Radiometer [8] of the Institute of Planetology and Astrophysics of Grenoble (Figure 2). Its thermodynamic (temperature, pressure…) and physical (texture, thickness…) properties will be determined too. This experimental setup needs the use of techniques in optics, cryogenics and ultra high vacuum.

Expected results

Condensation of CO_2

The experiment CARBO-NIR will bring further knowledge on the mechanisms of carbon dioxide condensation under "natural" conditions. The condensation rates will be measured for different values of incoming flux of gas. This flux will determine the overpressure – measured – in comparison to the saturation pressure corresponding to the ice temperature. The effect of the CO_2 ice temperature, and so of the total pressure, will be analysed in the Martian range (typically 3 to 11 mbar). Texture of the radiatively-condensed ice will be characterized for the first time optically and spectroscopically. Density of frost, grain size and potential preferred orientation of the grains will be estimated via a laser diagnostic together with microscopy. The Visible and NIR reflected spectral signature will be measured and directly compared to OMEGA and CRISM observations. Thus it will be possible to discriminate seasonal deposits with different origins (snow, frost) and, as a result, to interpret spatial variations in spectral signature of the Martian CO_2 ice in terms of condensation or post-depositional processes.

Metamorphism of CO_2 ice

After condensation the metamorphism of dry ice will be investigated under various conditions. We will study the influence of a vertical temperature gradient (heating from below) as well as the heating of the layer by direct lighting of the surface (illumination by a lamp that is similar to sunlight). This work will allow the observation of metamorphism mechanisms (compaction, recrystallization, reorientation of the crystals) and the determination of kinetic parameters. Notably, it may bring information about how a translucent CO_2 ice slab can form [9]. These studies will then be extended to understand in particular the segregation processes occurring between CO_2 ice, H_2O ice and dust during either CO_2 sublimation of such mixtures or during water vapour condensation conditions over CO_2 ice [7].

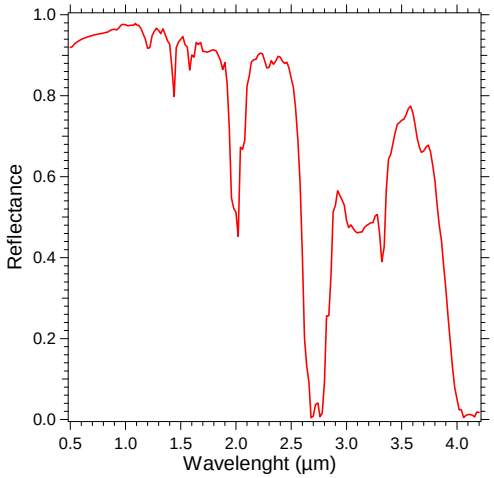

Figure 2. First test measurement of CO_2 ice with trace amount of H_2O.

Martian meteorology

The physical processes underlined by these experiments will be of great benefit for improving the physical description in the Martian general circulation models (GCM) and thus their ability of global and local simulation and prediction [10].

Conclusion

The main goal of the environmental cell CARBO-NIR is the study of CO_2 frost in Martian conditions by NIR spectroscopy. We hope to be able for the first time to measure in diffuse reflectance stable CO_2 ices at low temperature, and to describe their thermodynamic and textural evolutions.

Beyond Mars, this environmental cell will enable to study reflectance spectra under thermodynamic conditions relevant to diverse surfaces from the outer Solar System.

References:

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