

EXPERIMENTAL DETERMINATION OF OPTICAL CONSTANTS FROM MARTIAN ANALOG MATERIALS USING A SPECTRO-POLARIMETRIC APPROACH G. Alemanno¹, E. Garcia-Caurel², J. Carter¹, R. Brunetto¹, F. Poulet¹, A. Alèon-Toppiani¹, R. Urso¹, O. Mivumbi¹, Boukari C.³, Godard V.³ ¹Institut d'Astrophysique Spatiale, CNRS, UMR-8617, Université Paris-Sud, bâtiment 121, F-91405 Orsay Cedex, France, (giulia.alemanno@ias.u-psud.fr), ²LPICM, Ecole polytechnique, CNRS, 91128, Palaiseau, France, ³CNRS GEOPS UMR 8148 Bassin et Ressources, Bâtiment 504, Orsay, Cedex, France

Introduction: Thanks to high-resolution mapping of the Martian surface using visible and near-infrared imaging spectrometers in orbit around the planet, it has been possible to reveal the presence of several and diverse hydrated minerals [e.g. 1, 2, 3, 4]. Quantitative analyses of the mineralogy of the hydrated deposits could help deciphering the geochemical processes that occurred during their deposition/formation (allowing for instance to distinguish between authigenic and diagenetic mechanism) and in the case of aqueous minerals to constrain the amount of H₂O store in (near) surface rocks. This information will be also essential to constrain the nature of global and local-scale mineralogical transitions on the planet [e.g. 5]. These quantitative estimates of the mineralogical composition on a planet's surface require the application of appropriate radiative transfer models to the orbital spectroscopic data. These models take into account the combined influence of the atmospheric components (both aerosol and gas), use assumptions on the surface texture and require a good knowledge of the optical constants for each mineral phase that may be present on the surface [6, 7]. Applying radiative transfer models to the orbital data is however limited in the NIR due to the absence of optical constants for many minerals in the monoclinic and triclinic crystal systems identified on the surface of Mars. We here present our experimental approach to derive the optical constants of some Martian analogue materials based on the infrared ellipsometry technique. The technique of Spectroscopic Ellipsometry is a powerful tool for the optical analysis of the dielectric properties of materials [8]. This technique has been developed and so far, widely applied to the optical characterization of thin films but it has not been widely applied to the determination of optical constants of planetary analog materials. In this work, we used a spectro-polarimetric approach for the optical characterization of materials of Martian interest with particular attention to hydrated minerals (such as phyllosilicates, hydrated silica) and evaporites (such as carbonates, sulfates and chlorides) with two objectives 1) to support a global evaluation of the water content on Mars [9] and 2) to provide the scientific community with missing data on optical constants on these kinds of materials. This technique represents a significant refinement over the semi-empirical approach to optical constant determination using BRDF (Bidirectional Reflectance Distribution Function) measurements of a

finite set of grain sizes for each mineral. It also allows to obtain, not only the real values of the optical constants, but also important information about the crystal structure of the sample and its optical response depending on the sample orientation.

Experimental setup: The experimental setup used for the optical measurements, consists in a new broadband Mueller ellipsometer designed to work in the mid-infrared range, from 3 to 14 μm [8]. The Mueller Ellipsometer is installed at the SOLEIL Synchrotron laboratory and it is composed by: a light source, an input arm, an exit arm and an acquisition system. The illumination source is a commercial FTIR spectrometer providing an infrared beam in a continuous spectral range from 1.5 to 14 μm . In **Figure 1**, a schematic representation of the experimental set-up and a picture of it, are shown.

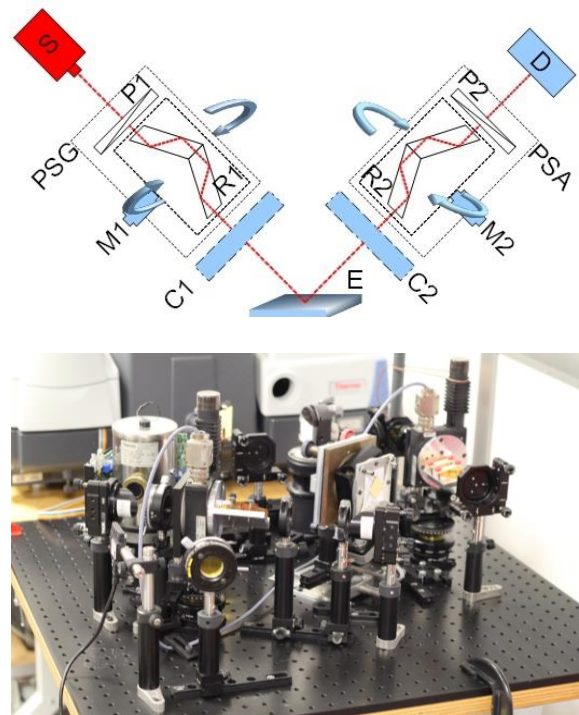


Figure 1. Up: Schematic representation of a Mueller ellipsometer [8]. Bottom: picture of the Mueller infrared ellipsometer installed at the SOLEIL laboratories and used for the measurements performed in this project.

The input arm includes a Polarization State Generator (PSG) composed by one fixed grid type linear polarizer and an achromatic retarder mounted in a rotatable holder. The retarder consists of a bi-prism made of two

identical Fresnel rhombs disposed symmetrically and joined by optical contact in a 'V' shape. A sequential rotation of the retarder with respect to the fixed position of the polarizer allows generating four optimal polarization states. The retardation is induced by the four total internal reflections of the beam during its propagation through the bi-prim. The exit arm is a Polarization State Analyzer (PSA) with the same optical components of the PSG but mounted in reverse order [8, 10]. The results of an ellipsometric measurement is a set of sixteen independent values that allows calculating the Mueller matrix of the sample [8], that is correlated to the optical properties of the sample itself.

Data and methods: A library of Mars relevant samples (prominently clays, salts and micas), based on our spectroscopic observations of Mars has been chosen. We focused on a subset of them to optimize the sample preparation and the measurement protocol. We measured different types of samples: natural crystals, pellets, some are double face polished and some not. So far, we obtained promising optical constants measurements in the MIR (>2 μm) for the samples in **Table 1**.

Table 1 – List of some samples analyzed in this work. For each sample are reported: sample ID, mineral, type and crystalline structure.

ID	Mineral	Type	Structure
M10	Olivine	Silicate (pyroxene)	Rombic
M11	Siderite	Carbonate	Trigonal
M12	Muscovite	Mica (Al-rich)	Monoclinic
M13	Biotite	Mica (Fe-rich)	Monoclinic
M14	Gypsum	Sulfate	Monoclinic
M15	Hedenbergite	Silicate (pyroxene)	Monoclinic
M16	Copiapite	Sulfate	Triclinic
M17	Montmorillonite	Phyllosilicate (Al-rich)	Monoclinic
M18	Pyrophyllite	Phyllosilicate (Al-rich)	Monoclinic

Samples have been prepared embedding them in a mixture of resin + hardener and then polishing their surface at different steps down to $\lambda/4$.

All the samples have been measured in the MIR range between 2 – 13 μm with a MIR Global Source, a KBr beamsplitter and a McT detector.

We performed ellipsometric experiments following always the same procedure: 1) evaluation of the Mueller matrix and of the ellipsometric angles Δ and Ψ ; 2) creation of a model of the sample to determine its optical constants; 3) Once the model is built, calculated data are fitted to the experimental data; 4) Evalu-

ation of the best-fit model that provide the best match between the two sets of data.

In parallel, reflectance measurements using a FTIR Microspectrometer installed at the SOLEIL laboratory have been performed, to better characterize the samples studied and to have a comparison for the ellipsometric measurements.

Preliminary results: The work done in this project so far leads to building a facility for optical constants measurements on planetary analog materials. We worked to define a measurement protocol and a data modelling procedure that has the potential to be extended and applied to the study of materials and planetary surfaces, other than Mars.

We optimized the sample preparation and the measurement protocol for the MIR infrared range considering the anisotropic behavior of the samples and their response to the ellipsometric measurements. We obtained promising optical constants measurements for the samples listed in **Table 1**. **Figure 2** shows preliminary results obtained for the sample M14, in comparison with those obtained by Long et al. (1993) [11].

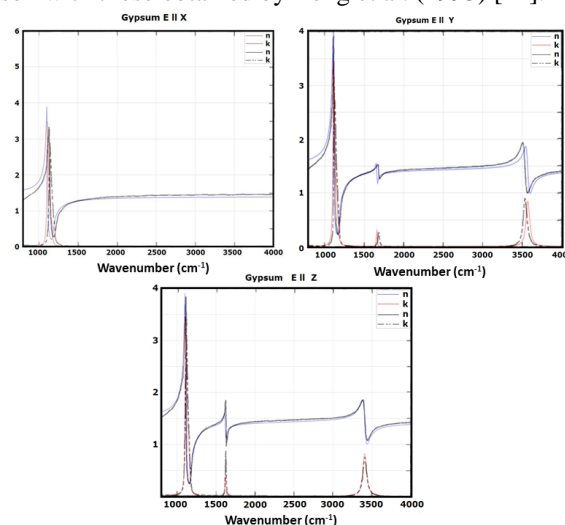


Figure 2. Comparison between the optical constants obtained for the gypsum sample (M14) in the different three configurations: Ellx, Elly and Ellz in this work and those obtained by Long et al. (1993).

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