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Influence of chemical and morphological properties on the mid-infrared refractive indices of Titan aerosol analogs

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Introduction:

In the atmosphere of Saturn's largest satellite, Titan, the solid particles in suspension (photochemistry organic aerosols) play an important role notably to the attenuation of the solar spectrum by absorption and scattering. To constrain these interactions, the optical properties of Titan's atmospheric aerosols, refractive index n and extinction coefficient k were recovered from observations [1, 2, 3, 4]. The refractive indices database has been expanded using solid analogs of Titan's aerosols produced and analyzed in laboratory [5, 6, 7]. The experimental data are generally consistent with the optical properties derived from Titan's aerosols, including the contribution to the extinction and albedo of Saturn's moon [5, 7, 8]. However, comparisons of vibrational modes in the mid-infrared (MIR) suggest a difference in composition between laboratory analogs and Titan's aerosols [9, 10]. These discrepancies in the refractive indices of solids can originate from their morphological and chemical properties. Indeed, numerous experimental studies have revealed the variability in the morphology and chemical composition of solid analogs formed in simulations of Titan's atmospheric chemistry.

Aim and Methods:

The PAMPRE dusty radio-frequency (RF) plasma experiment is used to simulate Titan's atmospheric chemistry up to the formation of solid analogs to Titan aerosols [11]. This reactor enables to produce two morphologies of solid analogs: films deposited on substrates commonly used for optical studies, and quasi-spherical powders. For fixed experimental conditions, the analysis of the chemical composition between analog films and analog powders shows variations, particularly in the N/C ratio of the solid compounds detected [12]. Here, with well-known experimental conditions of PAMPRE reactor, we produced film and powder analogs and recovered their optical properties in the MIR spectral range, to observe the potential effects of their morphological and chemical differences.

For optical analysis, powder analogs are compressed (pellets). Compared to films deposited on substrates, pellets potentially have other morphological aspects such as porosity, that may impact

optical measurements. These morphological aspects are constrained and taken into account in the optical processing of the pellets. To recover refractive index n and extinction coefficient k of solid analogs, two types of optical analyses were performed: reflectance measurements from 2 to 12.5 μm by Mueller ellipsometry, and transmittance measurements from 2.5 to 20 μm by spectroscopy. From the reflectance and transmittance measurements, the refractive indices n - k were derived using Lorentz formalism and the single-subtraction Kramers-Kronig iterative model (SSKK), respectively.

Results:

On the MIR spectral range, we observe the difference in optical properties between compressed powders (pellets) and films, both analogs to Titan's atmospheric aerosols. A significant increase in the MIR absorption properties of the pellets compared to the films are observed, in particular the signatures of (hetero-)aromatic and amine features. This more intense absorption of nitrogen chemical groups in analog powders (pellets) correlates with chemical analyses of similar analogs in [12], which observed a higher N/C ratio in the solid compounds of the powders than in the films. We also observe that the reflective power of the pellet analogs is not only affected by the refractive index n but also significantly by the porosity. These new results provide further constraints on the influence of physico-chemical properties on the optical characteristics of solid aerosol analogs.

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