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► **To cite this version:**

Ahmed Mahjoub, Nathalie Carrasco, Pierre-Richard Dahoo, Thomas Gautier, Cyril Szopa, et al.. Optical properties of organic material produced in a dusty plasma. ESCAMPIG 2012 (Europhysics Conference on the Atomic and Molecular Physics of Ionized Gases), Jul 2012, Viana do Castelo, Portugal. 2 p. hal-00741827

HAL Id: hal-00741827

<https://hal.science/hal-00741827v1>

Submitted on 15 Oct 2012

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Optical properties of organic material produced in a dusty plasma

A. Mahjoub^{1*}, N. Carrasco¹, P.-R. Dahoo¹, T. Gautier¹, C. Szopa¹, and G. Cernogora¹

¹ *LATMOS UVSQ UPMC CNRS 11 Bd D'Alembert 78280 Guyancourt France*

(*) ahmed.mahjoub@latmos.ipsl.fr

Thin films of organic material produced in a dusty plasma in N₂-CH₄ mixtures are deposited on silicon substrates. The real (n) and imaginary (k) parts of the complex refractive index are determined using the spectroscopic ellipsometry technique in the 370-1000 nm wavelength range. The optical index depend strongly on the methane concentrations: k values decreases with initial CH₄ concentration, while the real optical index (n) increases. Thanks to Mid-infrared spectra recorded for thin films, the larger absorption in the visible range is explained by an increase of the secondary and primary amines signatures.

1- Introduction

Titan the biggest Saturn's satellite, presents a dense atmosphere mainly constituted of N₂ and CH₄. The energetic particles coming from Saturn's magnetosphere and the solar UV radiation dissociate both N₂ and CH₄, allowing a complex chemistry leading to the formation of solid aerosols as a permanent haze around the satellite. These aerosols play an important role in the climate, the composition and the properties of Titan's atmosphere. Models developed to explain the optical properties of Titan's atmosphere require knowledge of optical indices of Titan's haze. As no return sample is planned from Titan's atmosphere at short term, the use of laboratory experiments is of primary importance to produce analogues of Titan's aerosols. In the present work we report optical properties of Titan's aerosols analogues (tholins) produced in CCP RF dusty plasma.

2- Experiment

The CCP RF discharge is described in details in [1]. The plasma is produced between a shower shape electrode and a grounded confining cylindrical metallic grid. Gas mixture from 0 to 10% of CH₄ in N₂ is injected through the polarized electrode. Si substrates (0.5 mm thick and 13mm diameter) are deposited on the grounded electrode. Discharge is running at a pressure of 0.9 mbar during 2 hours in order to obtain a less than 1µm thin film. After tholins film deposition, samples are studied by spectroscopic ellipsometry at atmospheric pressure in order to determine n and k, the real and imaginary parts of their refractive in the 370 - 1000 nm wavelengths range. Spectroscopic Ellipsometry (SE) is an optical technique based on the measurement of the change in polarized light upon light reflection on a sample [2-3]. The ES measured parameters are fitted using the Complete EASETM Woollam software in order to determine: the thickness d, the non-uniformity, the roughness and the complex refractive index of the organic thin film.

3- Results

Figure 1 shows the values of n and k obtained for films produced at different percentages of injected methane. We observe that k values decrease of one order of magnitude when the concentration of CH₄ increases from 1% to 10%., in agreement with the anti-correlated evolution of the n values.

To strengthen our discussion on the relationship between the composition of tholins and its optical constants, Mid-infrared spectra were recorded on the DESIRS (Spectroscopy and Microscopy in the Infrared using Synchrotron) beam line of SOLEIL synchrotron radiation facility (France) using a NicPlan microscope coupled to a Nicolet Magna System 560 Fourier Transformed Infra-Red (FTIR) spectrometer with a spectral resolution of 4 cm⁻¹ (Fig.2).

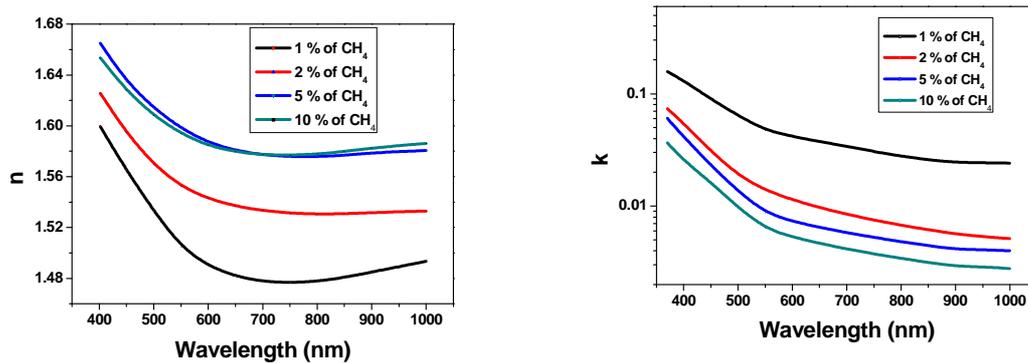


Figure. 1: real (left) and imaginary (right) index of the tholins thin films refractive indices produced with different initial methane concentration.

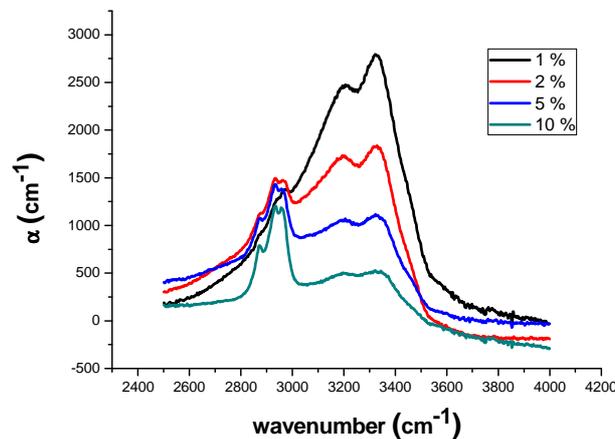


Figure 2: Absorption spectra of organic thin film in the Mid-Infrared for different CH₄ concentrations

Figure 2 shows in all spectra a broad doublet centered at 3205 and 3325 cm⁻¹ respectively [4]. These bands are attributed to primary and secondary amines increase. The increase of amount of amines in the organic film when the CH₄ percentage decreases, could explain the observed increase of k values [5].

Acknowledgments

This work was financially supported by the ANR-09-JCJC-0038 contract.

We thank Dr. Dumas for given us the opportunity to use SMIS facility of the French synchrotron Soleil.

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