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An RF plasma experiment to simulate the production of Titan's atmospheric aerosols

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Abstract

Several experimental setups have been developed in order to reproduce and study the laboratory Titan's atmospheric chemistry. Among them the plasma device PAMPRE provided significant clues on the understanding of the polymeric chemical structure of the aerosols [1-2]. The influence of the methane initial concentration on the aerosol production efficiency was studied, highlighting a surprising decrease of the aerosol production yield with the methane concentration [3]. In order to find some clues on this inhibition process, we quantified the atomic hydrogen content by *in-situ* optical emission spectroscopy.

1. Introduction

Over the past 25 years, several photochemical models of Titan's atmosphere have been developed independently to reproduce the observations to the best extent possible and to unveil the processes explaining their origin. Despite their quality, the Cassini's mission has also highlighted their incompleteness, showing in the upper atmosphere numerous unexplained species and *a fortiori* unknown processes coupling nitrogen and hydrocarbon chemistry, and involving neutrals, and positive and negative ions. The complex mechanisms leading to the production of the organic aerosols surrounding Titan remain thus mostly unknown. One way to study what is mostly unknown is to reproduce in the lab the whole chain of reactions occurring in Titan's atmosphere simultaneously, with all the possible couplings between the reactive species (and not independent reactions) and to identify and analyze globally the processes occurring in a Titan-like global experiment.

Several experimental set-ups have already been used in a few laboratories to simulate globally Titan's atmospheric reactivity. Some of them use UV radiation as the energy source, others use various plasma discharges. We will present the advantage and limitations of an RF plasma setup, named PAMPRE [4], and an example of a recent result obtained on the understanding of the aerosol production process.

2. Experimental method

RF-CCP reactors (Radio-Frequency Capacitively Coupled Plasma) are well-known for initiating the creation of solid particles [5] in a reactive gas mixture. These aerosols are electrically charged and can thus grow in levitation in the plasma (see Fig.1). They remain in suspension in the plasma, i.e. with no interaction with the reactor wall, until the electrostatic force, responsible for the levitation is no longer stronger than other forces, (particle weight, neutral and ion drag forces), at which point the solid aerosols are ejected out of the plasma.

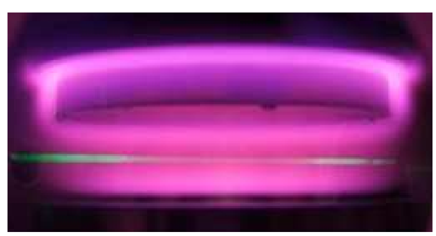

Figure 1: Photo of a N_2-CH_4 plasma in the PAMPRE setup; the green line is due to the light scattering of a laser beam at 532 nm by the aerosols in suspension.

The plasma is produced by an RF CCP discharge. Gases are injected continuously through the polarized electrode. Results presented here are obtained for a pressure of 1 mbar and 30W of absorbed RF power.

Stable neutrals in the gas phase are directly analyzed in situ by a Pfeiffer QME 200 quadrupole mass spectrometer. Radiative species are studied by Optical Emission Spectroscopy [6]. Atomic hydrogen abundance is quantified by actinometry, i.e. by measuring the ratio between emission lines intensities I(H) and I(Ar) populated by electron collisions, [Ar] being known:

$$[H] = A\frac{I(H)}{I(Ar)}\frac{k_{e-Ar}(T_e)}{k_{e-H}(T_e)}[Ar],$$

The two selected lines correspond to the emission of two close radiative levels of H and Ar.

3. Example of Results: the role of atomic hydrogen on Titan's aerosol production

Various initial N_2-CH_4 gas mixtures (methane varying between 1 and 10 %) are studied. Aerosols are quantified by their mass weighing and analyzed by elemental analysis. These data, combined with the measurement of the methane consumption by *in situ* mass spectrometry enable to calculate the carbon gas to solid production yield (fig. 2). This efficiency surprisingly decreases with the initial amount of methane in the gas mixture.

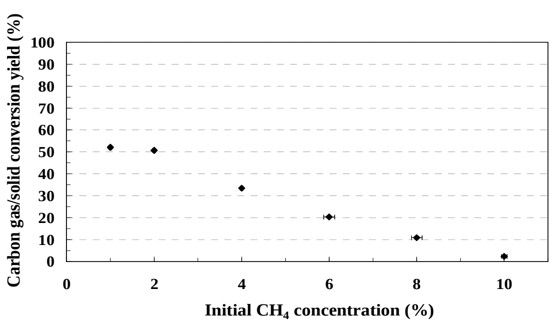

Figure 2: Evolution of the carbon gas to solid production yield as a function of % CH_4.

A negative correlation is found between the carbon gas to solid production yield and the atomic hydrogen abundance determined by *in situ* actinometry (fig. 3), confirming the suspected role of hydrogen on inhibiting heterogeneous organic growth processes. This new result is also in agreement with the linear global H-enrichment of the aerosols with the methane concentration measured by elemental analysis in [3].

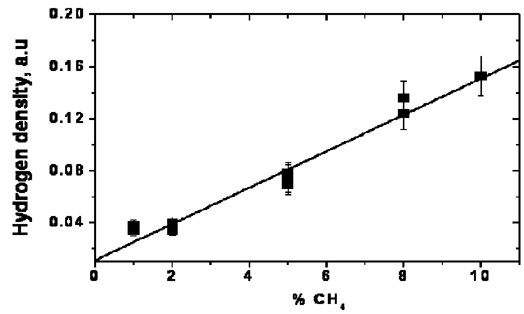

Figure 3: Evolution of hydrogen atom densities as a function of % CH_4.

Acknowledgements

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