

Aerosols-plasma interaction in the ionosphere of Titan. A. Chatain^{1,2,3}, N. Carrasco¹, L. Vettier¹ and O. Guaitella², ¹Université Paris-Saclay, UVSQ, CNRS, LATMOS/IPSL, Guyancourt, France (audrey.chatain@latmos.ipsl.fr). ²Ecole polytechnique, Sorbonne Université, CNRS, LPP, Palaiseau, France. ³Sorbonne Université, CNRS, LMD/IPSL, Paris, France.

Introduction: The Cassini mission discovered that Titan’s famous orange aerosols start forming around 900-1200 km, in the ionosphere [1]. The ionosphere is the upper part of the atmosphere, ionized by UV solar photons and energetic particles from Saturn’s magnetosphere. It therefore hosts reactive plasma species (electrons, ions, radicals, excited species) that are likely to interact with the newly formed aerosols.

We know that carbon-bearing species trigger the carbon growth of the aerosols. Nevertheless, the interaction of Titan’s aerosols with the other ‘carbon-free’ plasma species has never been studied before. For this work, we designed a new experimental setup to study this interaction, observed the evolutions induced on the aerosols and the gas phase, and proposed evolution mechanisms at the surface of the grains.

The THETIS experiment: THolins Evolution in Titan’s Ionosphere Simulation. The ionosphere of Titan ‘free of carbon species’ is simulated by a DC glow plasma discharge in N₂-H₂ (with up to 5% H₂). Analogues of Titan’s aerosols (tholins) are previously formed in suspension in the plasma experiment PAMPRE [2]. They are then spread on a thin metallic grid, which is exposed to the N₂-H₂ plasma.

Evolution of the aerosols is monitored by *in situ* infrared spectroscopy and *ex situ* scanning electron microscopy. The gas phase (neutrals and positive ions) is continuously probed by a mass spectrometer whose transmittance has previously been finely determined [3] to enable a quantitative comparison between all the mass intensities.

Experimental results: Morphological and chemical evolution of the tholin grains. Tholins are physically eroded by the exposure to the plasma, showing erosive structures of 20 nm on the 300 nm-grains. Chemical functions of the material evolve, with the disappearance of isonitriles and unsaturated structures, and the formation of a new nitrile band [4].

Changes in the gas phase composition. The aerosols erosion has a feedback effect on the composition of the gas phase. Ammonia (NH₃), which is formed in the N₂-H₂ plasma, decreases with the insertion of tholins. This suggests that ammonia or its precursors are consumed by tholins. On the opposite, we observed the production of HCN and other carbon-containing molecules, such as acetonitrile (CH₃-CN) and cyanogen (C₂N₂). Observations of positive ions give similar results, with the decrease of ammonia-related ions

(NH_x⁺), and the formation of new carbon-containing ions (related to HCN, acetonitrile and cyanogen, plus highly-unsaturated hydrocarbons).

Heterogeneous processes at the surface of the grains: From these results and previous heterogeneous chemistry modelling work in microelectronics [5], we suggest in Figure 1 some surface processes. Radicals are likely to chemically react with the tholins. In particular, an interaction of tholins carbon atoms with the radicals N, NH and H leads to the formation of HCN_(s) (adsorbed at the surface). In parallel, ion sputtering ejects fragments of tholins into the gas phase (like HCN). In addition, NH – which is fundamental in the production of NH₃ – is used at the surface of tholins to form HCN_(s), and can then explain the decrease of NH₃.

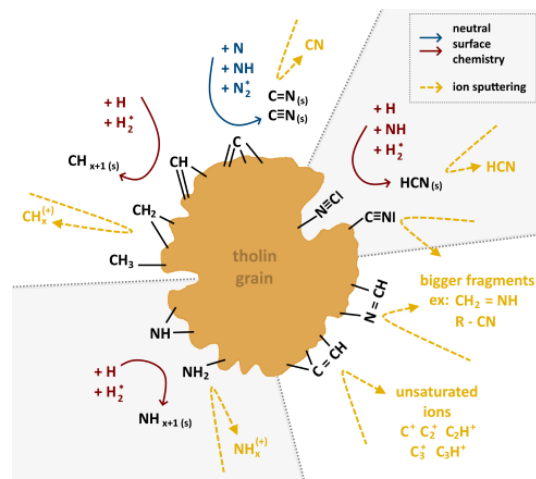


Fig 1. Suggestion of surface processes, as interactions between a tholin grain and N₂-H₂ plasma species.

Conclusion related to Titan: Though radicals are hard to detect in Titan ionosphere, models [6,7] predict that they are present in great quantity, and therefore could lead to the above mentioned processes. Actual chemical models in the ionosphere do not take heterogeneous chemical reactions into account, which will certainly be an interesting next step to try to explain the remaining discrepancies with Cassini observations.

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