EVOLUTION OF AEROSOLS IN TITAN'S IONOSPHERIC PLASMA

An Experimental Simulation

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INTRODUCTION: EVOLUTION OF ORGANIC AEROSOLS IN PLASMA ENVIRONMENT

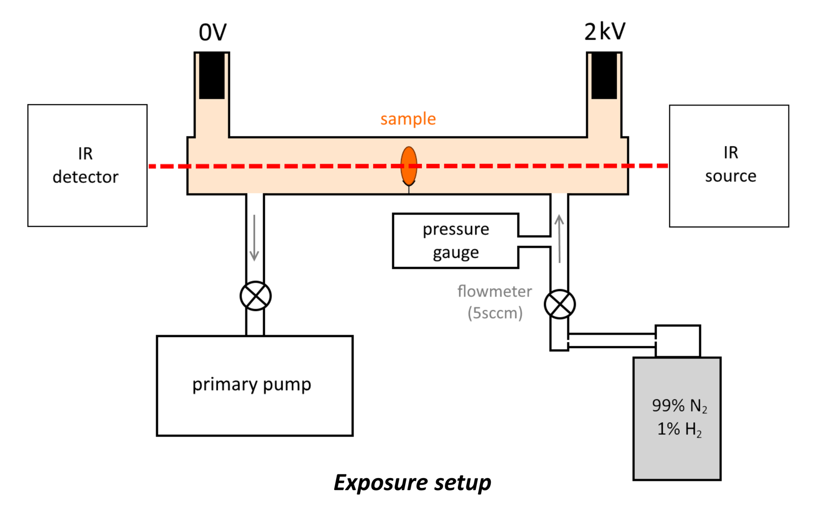
Titan is a moon of Saturn where climate and surface phenomena are governed by the presence of **organic aerosols**. Cassini spacecraft, which observed Titan from 2004 to 2017, discovered that such aerosols start forming above 1200km, in the ionosphere [1]. At this altitude the atmosphere is a **N_2-CH_4-H_2 dusty plasma** (in respective proportions 98.4%-1.4%-0.2%).

Aerosols cross the entire ionosphere when falling down to the surface of Titan. In such a **reactive environment**, these organic grains are **likely to evolve**, physically and/or chemically, through interactions with electrons, ions, radicals and excited species. Here we **experimentally simulate** the exposure of Titan's aerosols to plasma and characterize the evolutions of the sample by *in situ* **IR transmission spectroscopy**.

SAMPLE: TITAN THOLINS

PAMPRE: Analogs of Titan's aerosols ("tholins") are formed in the reactor PAMPRE at LATMOS under conditions described in [2].

Pellet: Tholin grains are then pressed with KBr under 5 tons pressure to obtain thin pellets not totally opaque in IR.



Exposure setup

EXPOSURE: N_2-H_2 DC DISCHARGE

Gas flow: we used N_2 and N_2 with 1% H_2 to see the influence of H_2. Even if present in Titan's ionosphere, CH_4 is not injected here to prevent the formation of new particles during the exposure. The pressure is 1 to 4mbar.

Discharge: a DC glow discharge is ignited in a tube of 2cm in inner diameter. The current is kept constant to 20mA.

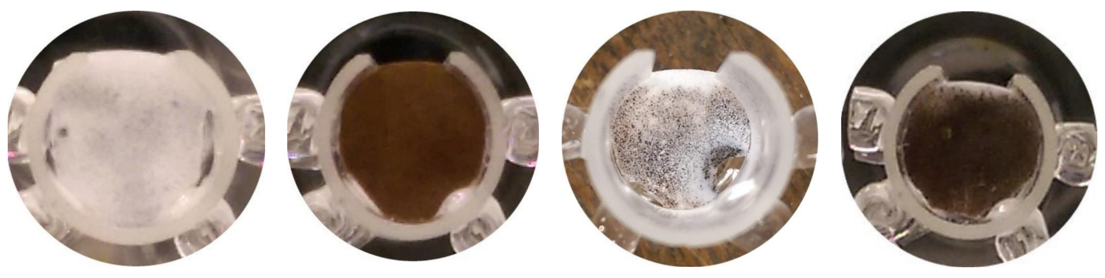
FTIR: the reactor fit inside the sample compartment of a FTIR (Bruker V70). IR transmission spectroscopy is realized *in situ* through the pellet under plasma exposure.

PHYSICAL EROSION

WITH NAKED EYES

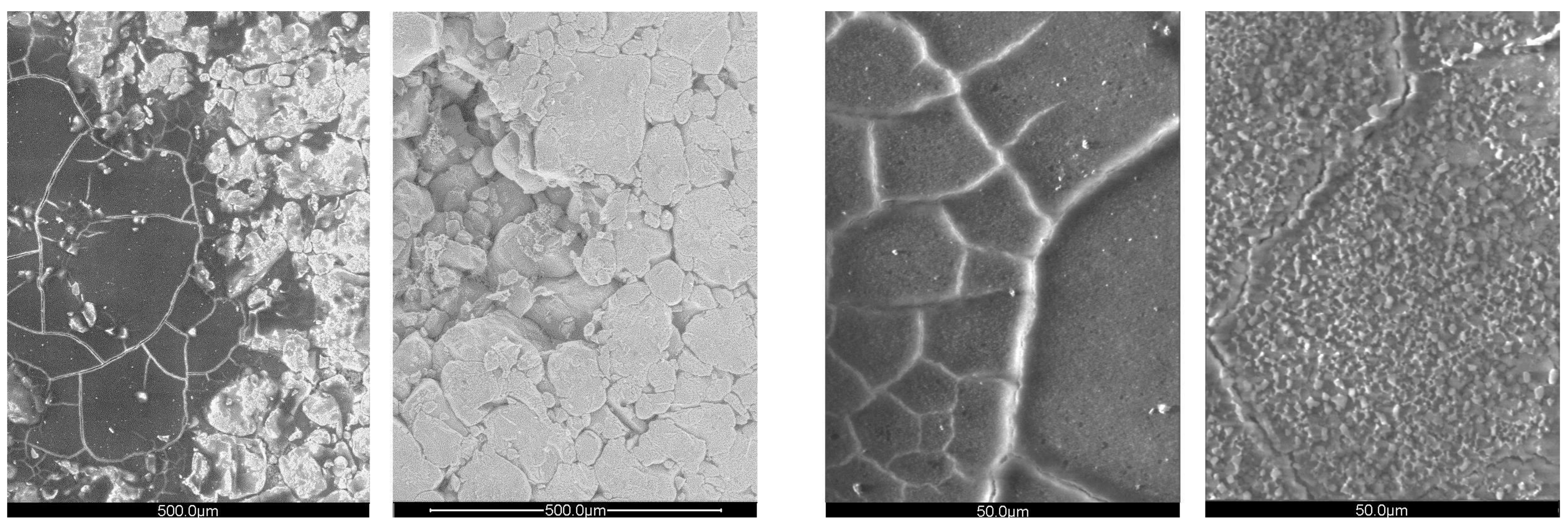
Pellets become whiter and rougher:

- **preferential erosion** of the brown organic material
- stronger erosion with H_2



Pure KBr — *KBr + tholins* — *KBr + tholins after 5h – N_2-H_2* — *KBr + tholins after 5h – N_2*

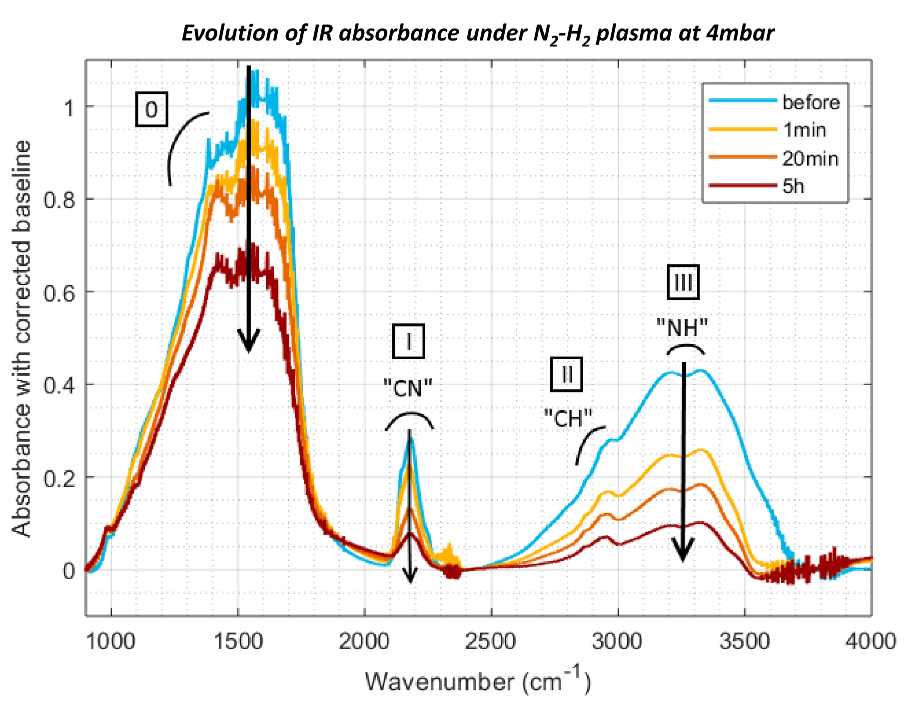
WITH SCANNING ELECTRON MICROSCOPY (SEM)

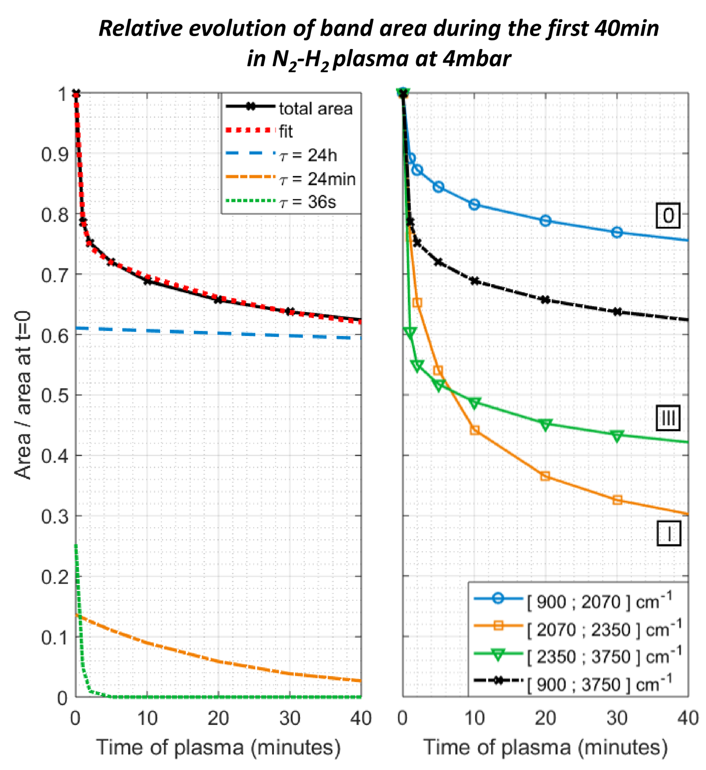


Before exposure — *After 4h exposure (N_2-H_2 ; 4mbar)* — *Before exposure* — *After 4h exposure (N_2-H_2 ; 1.3mbar)*

- black organic material is **removed** from the surface contrarily to bigger KBr grains.
- at **low pressure**: some tholins are left and appear **rougher**.

WITH IR TRANSMISSION SPECTROSCOPY

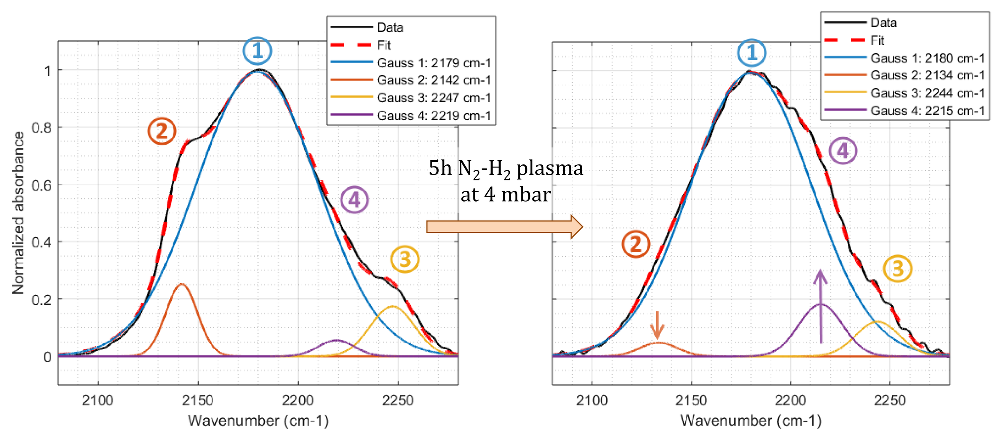




- **absorption decreases** with exposure time
 ⟹ organic absorbent material is removed from the pellet
- **3 timescales**: 1min, 20min and <10h ⟹ quick and slow erosion processes
- bands proportionally **evolve at different speeds** : [III] ↘ quickly, [I] ↘ more at the 20min timescale, whereas [0] mainly ↘ with a longer characteristic time.

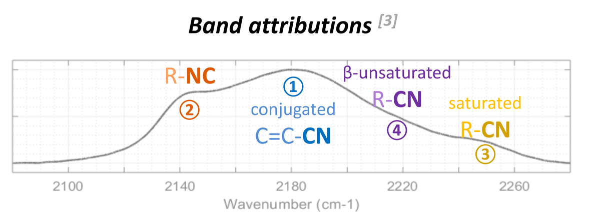
CHEMICAL EVOLUTION: BY IR TRANSMISSION SPECTROSCOPY

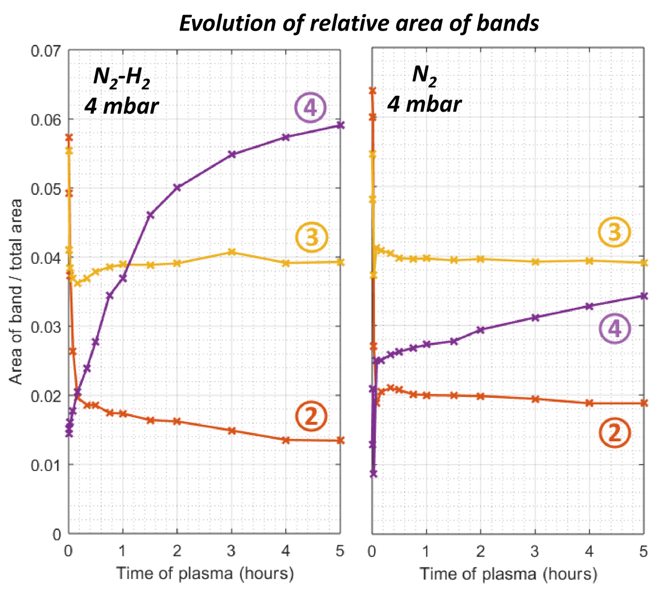
I CN BANDS (2080 – 2280 cm⁻¹)



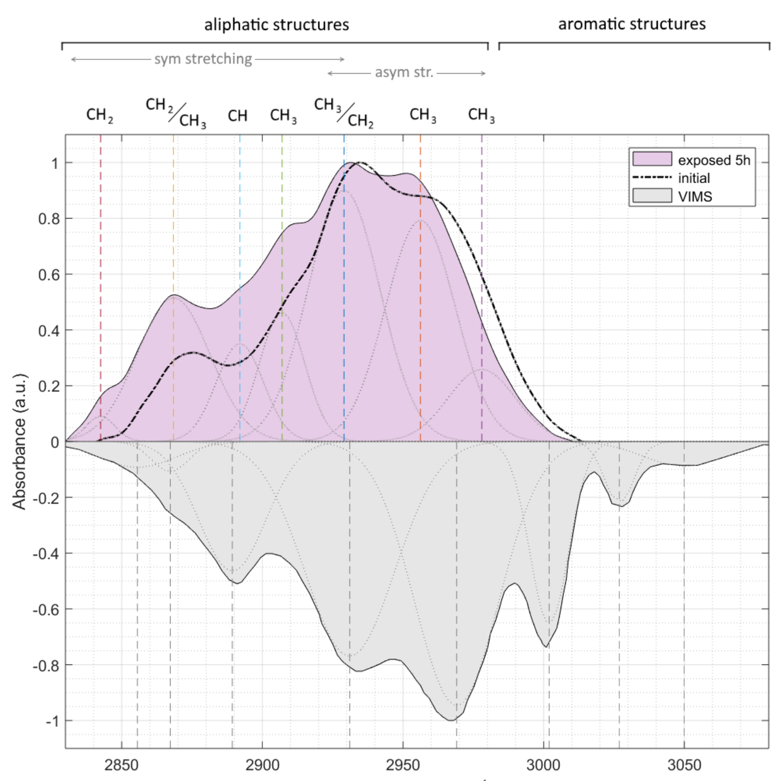
After normalization on the maximum, relatively:

- ② disappears quickly
- ④ appears progressively
- ④ is less important without H_2

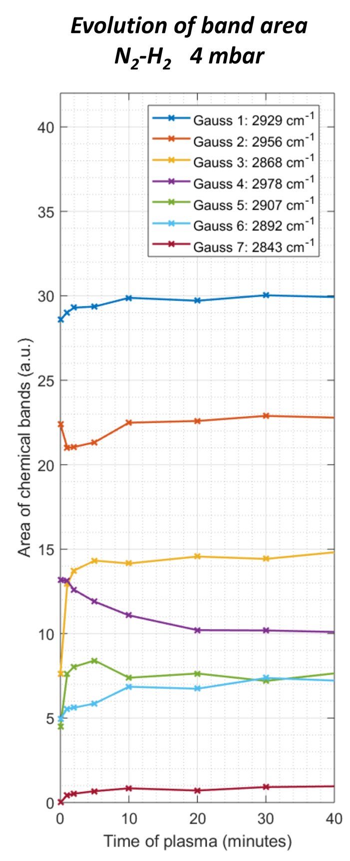




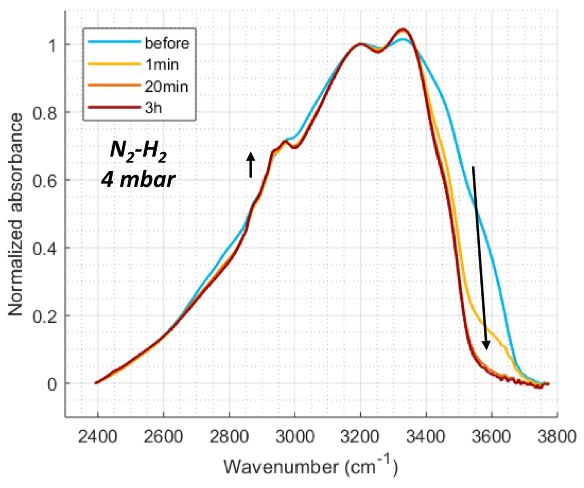
II CH BANDS (2830 – 3020 cm⁻¹)



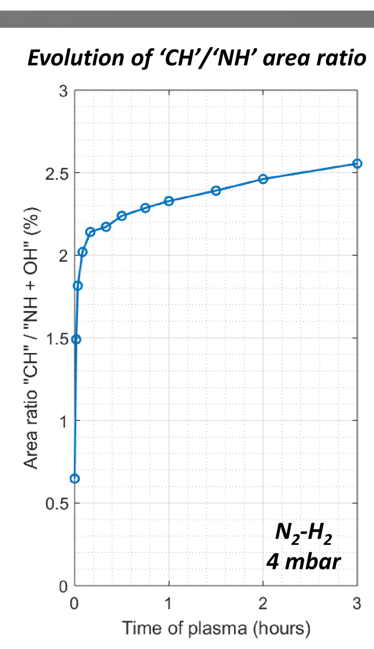
- evolution of bands
 ↦ **modifications** of chemical environment
 ↦ toward aliphatic and saturated functions
- to compare with Cassini measurements in Titan's stratosphere [3]
 ↦ similarities in the aliphatic part
 ↦ but aromatics do not seem formed by N_2-H_2 plasma processes



III NH BANDS (2400 – 3800 cm⁻¹)



- disappearance of the band at 3600cm^{-1} (-OH) in less than 5min
 ↦ quick **deoxydation** of tholins
- ratio 'CH' / 'NH + OH' bands
 ↦ first minutes: deoxydation
 ↦ but maybe also small **long-term growth** of 'CH' bands relatively to 'NH' bands



CONCLUSIONS AND PERSPECTIVES

- **physical and chemical modifications seen** ⟹ tholins are altered by plasma

(roughness, relative evolution of major bands, changes in unsaturated functions, complexification of chemical environment, deoxydation…)

- **the addition of H_2 in N_2 intensifies the evolution of tholins**

(higher erosion speed at τ=20min for CN and NH bands, β-unsaturated -CN band growth, stronger deformation of CH bands…)

↦ **what to expect on Titan**: same ionization ratio, pressure $10^{4\text{-}7}$x lower, particles 100x smaller, timescale >1000 larger [4] : compensation? ⟹ possible erosive effect + chemical modifications induced by N_2-H_2 plasma species

↦ **to go further:** evolution of gas species after interaction with the aerosols?

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