EPSC Abstracts
Vol. 6, EPSC-DPS2011-1864, 2011
EPSC-DPS Joint Meeting 2011

Investigating in laboratory on the impact-induced chemistry and the fate of tholins in Titan surface

D. Nna-Mvondo (1), B. N. Khare (2, 3) and C. P. McKay (2), L. Juha (4), R. Navarro-González (5) and M. Ruiz-Bermejo (1)

(1) Centro de Astrobiología (CSIC-INTA), Madrid, Spain (nnamvondod@cab.inta-csic.es / Fax: +34-915-201074), (2) NASA Ames Research Center, Moffett Field, CA, USA, (3) SETI Institute, NASA Ames Research Center, Moffett Field, CA USA, (4) Institute of Physics, Academy of Science of the Czech Republic, Prague, Czech Republic, (5) Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, Mexico D.F., Mexico

Abstract

We present results of laboratory experiments carried out to examine the impact-induced chemistry on Titan and to study the reactivity and a possible fate of tholins on Titan surface. We have used a high-energy pulsed laser to recreate the energetic processes during meteoritic impacts shocks. The experiments have consisted in ablating pure water ices and ices of 15% NH_4OH in water containing Titan tholins at 77 K under vacuum. We have examined optically the chemical changes of impacted tholins and studied the formation of complex organic compounds in the impacted ices.

1. Introduction

On Titan, theoretical studies consider that meteoritic impacts should occur on its surface [1, 2]. Research on impacts on Titan are stimulated by the goal of defining the fate of organics condensing on Titan surface but also, more generally, of assessing better the nature, evolution, and potential habitability of icy worlds. The presence of frozen water and organics like hydrocarbons, nitriles, and high-molecular-weight organic solids (tholins) on Titan surface suggests that the moon could harbor physical and chemical conditions necessary for life. An essential consideration is the supply of more complex organics onto its surface. High-energy cosmic rays reaching the surface may induce new organic processes involving the main and minor condensed atmospheric constituents [3]. It is also proposed that the deposited organics, simpler precursors, could be chemically processed under meteoritic bombardment on Titan surface [1]. Products relevant to life [1] such as amino acids [4], carboxylic acids, purines and pyrimidines [2] could be formed on Titan's surface when impact events exposed sediments of ices and Titan tholins, transiently, to aqueous conditions [2], leading to the hydrolysis of tholins [4].

2. Experimental method

A solid-state Nd-YAG pulsed laser has been used to simulate meteoritic impacts shocks [5]. Pure water ices and ices containing 15% NH_4OH in water with Titan tholins deposited above have been prepared under vacuum at 77K. Then the ices have been ablated with the IR pulsed laser at 100 mJ, (pulse duration = 10 ns, pulse repetition rate = 10 Hz) during 60 min at 77K. The focused spot size was determined to be 700 µm in diameter which leads to an energy deposition rate of about 3.5×10^{9} Wcm^{-2}. After the laser impact simulation, the gases vaporized from the impacted ices have been analyzed by FTIR measurements in the transmission mode and also by GC-MS (HP-PLOT Q column). Ices with tholins have then melt at ambient temperature and the solutions have been extracted and centrifuged to separate the insoluble impacted tholins from the liquid phase. The dry residue of the liquid phase has been derivatized and injected in a capillary column HP-5MS to detect complex organic compounds. The dried insoluble impacted tholins have been optically analyzed by FTIR diffuse reflectance spectroscopy from 50 to 23000 cm^{-1}.

3. Results and discussion

3.1 Analysis of high molecular weight compounds

Amino acids, dicarboxylic acids, α hydroxy acids, nitrogen-bearing aromatic heterocycles, nucleotides bases and urea have been detected and identified in both types of ices after impacting them but also without impacting (control samples) (Fig. 1). Those chemical products are the same in both cases, after impacting and in the control, except for 1 new organic detected after impacting ices with tholins but it is not yet identified. In the presence of NH_4OH, beta-alanine, adipic acid, 2,4-diaminopyrimidine and 2,6-diaminopurine are newly formed. The results also show that urea appears to be the most abundant product from tholins reaction when in presence of water or of 15% of NH_4OH in any case after impact and in the control, like this is the case after hydrolysis with HCl [4].

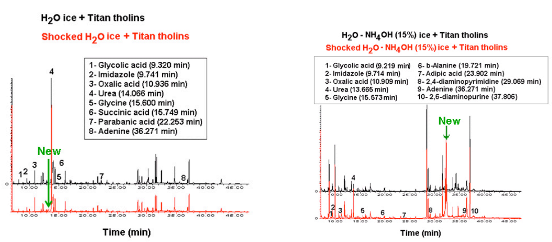

Figure 1: Chromatograms of complex organics identified in impacted ices and in the control.

3.2 Reflectance spectroscopy of impacted Titan tholins

The structural changes of impacted tholins with water ice or with 15% NH4OH ice and non-impacted tholins have been first examined by measuring their reflectance properties from the far-IR to the visible (Fig. 2). The overall spectrum of Titan tholins is not drastically affected when tholins are shocked by simulated impacts. The spectrum of the impacted tholins shows identical absorption bands as the initial tholins.

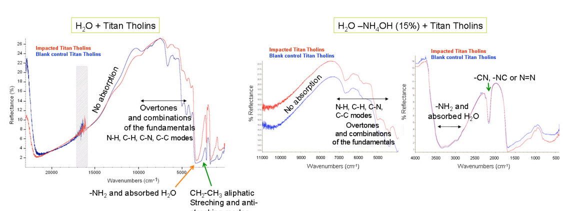

Figure 2: Diffuse reflectance spectra in impacted ices and in the control.

3.3 Comparison with DISR spectrum

The laboratory spectra of Titan tholins have been compared with the reflectance spectra of 16 standard amino acids and of urea formed by the hydrolysis of Titan Tholins [4], the mixture of these amino acids with urea and the Huygens Probe's DISR reflectivity spectrum of Titan surface [6] in the specific spectral range of DISR instrument (500 - 1600 nm) (Fig. 3).

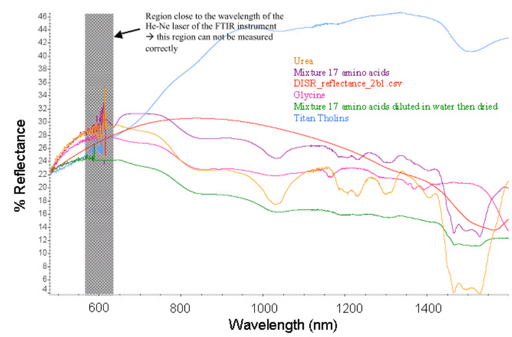

Figure 3: Comparison of reflectance properties of Titan tholins, amino acids and DISR Titan surface.

We confirm that the red slope in the visible of DISR could be explained by a complex organic material such as tholins. However the blue slope in the near-IR and the single absorption band at 1500 nm do not fit neither tholins nor amino acids nor urea spectral features.

References

[1] Artemieva, N. and Lunine, J.: Cratering on Titan: impact melt, ejecta, and the fate of surface organics, Icarus, Vol. 164, pp. 471-480, 2003.

[2] Thompson, W.R. and Sagan C.: Organic chemistry on Titan - Surface interactions. Proceedings of Symposium on Titan, ESA SP-338, pp 167-176, 1992.

[3] Raulin, F. and Owen, T.: Organic chemistry and exobiology on Titan, Space Sci. Rev., Vol. 104, pp. 379-395, 2002.

[4] Khare, B.N., Sagan, C., Ogino, H., Nagy, B., Er, C., Schram, K.H. and Arakawa, E.: Amino acids derived from Titan tholins, Icarus, Vol. 68, pp. 176-184, 1986.

[5] Nna-Mvondo, D., Khare, B., Ishihara, T., McKay, C.P.: Experimental impact shock chemistry on planetary icy satellites, Icarus, Vol. 194, pp. 822-835, 2008.

[6] Schröder, S.E. and Keller, H.U.: The reflectance spectrum of Titan's surface at the Huygens landing site determined by the descent imager/spectral radiometer, Planet. Space Sci., Vol. 56, pp. 753-769, 2008.