EIPAM scientific report

Visiting Fellow: Gabriel Horvath, Department of Experimental Physics, Comenius University, Mlynska dolina F-2, 84248, Slovakia, horeszka@gmail.com
Host Institute: Prof. Nigel J. Mason, Department of Physics and Astronomy, The Open University,Walton Hall, Milton Keynes, MK7 6AA United Kingdom.
Reference number: 1790
Dates of Visit: 8th January 2008 – 2nd March 2008 and 5th May 2008 – 7th July 2008
The title of project: Simulation of processes in Titan's atmosphere via electrical discharges

Purpose of visit

The experimental studies of Titan's atmosphere and its surface conducted few years ago within the cooperative NASA/ESA Cassini/Huygens [*Bernard et al.*, 2006] and Voyager mission provided us reach information about its major and minor constituents. The dense atmosphere of Titan is mostly composed of N2 and few percent of methane. The most important minor compounds are hydrocarbons (C2H2, C_2H_4, C_2H_6, C_3H_8, C_3H_4), nitrils (HCN, HC_3N, C_2N_2) and CO [*Ferri et al.*, 1997]. Titan's atmosphere may exhibit electrification processes that would produce significant static electric fields and thunderstorm conditions. For this reason electrical activity was chosen to be simulated in our experiments in the form of positive coaxial corona discharge.

The main aim of the visit was the UV- and FTIR-study of compounds produced in positive coaxial corona discharge fed by mixture of nitrogen and methane in stationary regime. Moreover, measurements of current-voltage characteristics at different flow rates and SEM-EDX analysis of deposited films on discharge electrode also were carried out. These measurements will be used to extend the systematic studies of electron-molecule and ion-molecule reactions and to design a more suitable reactor for simulating the real Titan's conditions. Every experimental was repeated (at least 3 times) to achieve maximum reliability of measured data.

Description of the work carried out during the visit

In our study, we have focused on the analysis of major products produced in the reactor volume and on the electrode surface for different CH_4 concentrations in nitrogen at constant voltages. Three methods have been used for experimental approach – UV and FTIR analysis of gaseous products, SEM-EDX analysis of deposited film on electrode. The measurements have been carried out for various methane-nitrogen mixtures in range from 2-10% of methane. The experiments were conducted at ambient pressure and temperature in flow-stopped regime. A time evolution of concentrations of main hydrocarbons and nitriles produced in reactor volume were studied too. Every experiment was repeated (at least 3 times) to achieve maximum reliability of measured data.

Description of the main results obtained

Our experimental setup simulated the occurrence of positive coronas originating from the tropospheric methane clouds of Titan. Because of the poor occurrence of absorption of hydrocarbons above mentioned in UV region we focused on C_2H_2. Absorption cross-sections of these gas phase products were taken from [*Cooper et al.*, 1995]. The time evolutions of concentrations of mentioned hydrocarbon for different contents of CH_4 were measured at constant voltage of 6.6 kV in stationary regime (Figure 1). C_2H_2 was measured at 191 nm. As it is shown the concentrations reach saturated values in both cases after 4-5 minutes and there are slightly decreasing. By increasing content of methane in the mixture the C_2H_2 concentration is increasing. The saturated concentration of C_2H_2 in case of 10 % methane in nitrogen is 1.85x higher than for 2 % of methane.

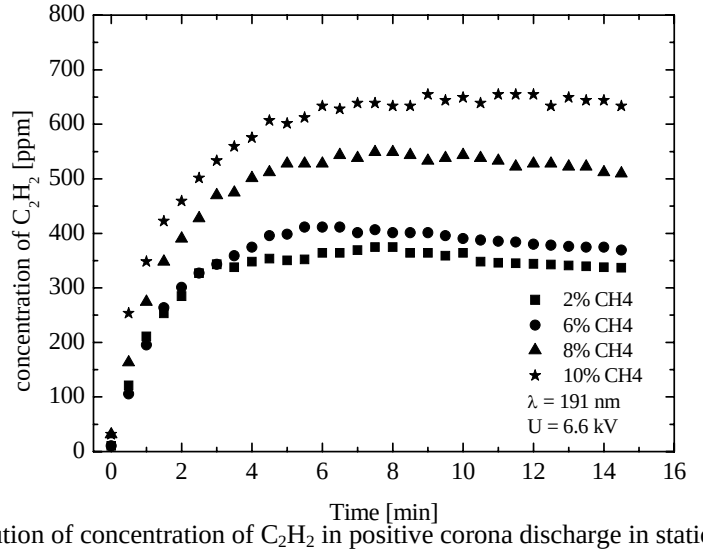

FIGURE 1. Evolution of concentration of C_2H_2 in positive corona discharge in stationary regime obtained by UV-analysis.

The FTIR-analysis provided detailed information about the gaseous products. According to our measurements C_2H_2, C_2H_6 and HCN were the major products. As it is shown in Figure 2, the C_2H_2 concentration reached cca 3-4x higher values as in the case of UV-measurements. Furthermore, by FTIR measurements the C_2H_2 concentration is increasing 40 minutes (Figure 2) while by UV-analysis this effect takes only 5-6 minutes. These disagreements we explained with

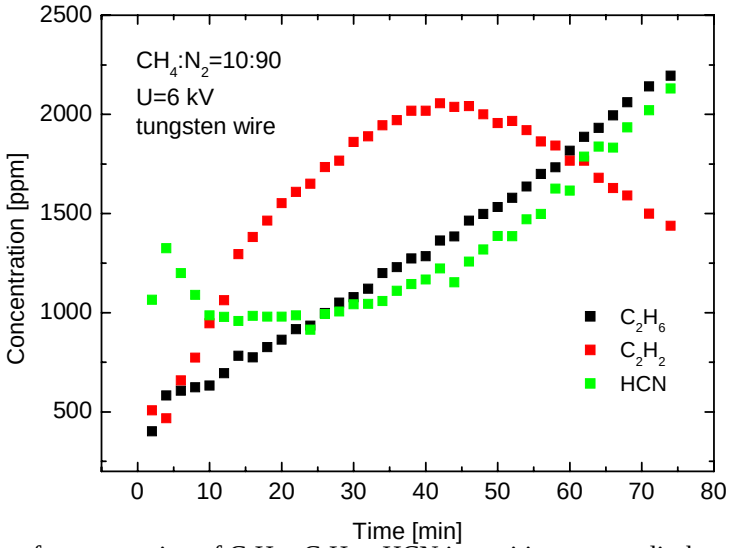

FIGURE 2. Evolution of concentration of C_2H_2 , C_2H_6 a HCN in positive corona discharge in stationary regime obtained by FTIR-analysis.

the influence of UV-radiation of the spectrometer on the methane-nitrogen mixture.

The discharge onset voltage was varying in range from 5 to 5.5 kV depending on the content of CH_4 and on the formed dust particles deposited on the electrodes. During the measurement a yellow-orange layer formed on the corona wire causing a sparks and forming rose-like spots (Figure 3A) on the covered electrode surface. The detailed EDX surface analysis about the compounds of this dielectric polymer dust is shown in the Figure 3B. In the center of the spot, where the spark is the strongest, the signal of the original wire constituents (Fe and Cr) are the highest, it is almost uncovered. From the border of the spot the signal of C and N is getting be stronger and it reaches the maximum on the non-sparking, "virgin" places. It seems that the spark channels destroy the fine layer on the wire surface thus cleaning the wire material and making a crater in the polymer. The ratio of C and N contents on the border of the spots reaches a values of C/N=9.8 while on the virgin places this ratio decreases down to 2.84.

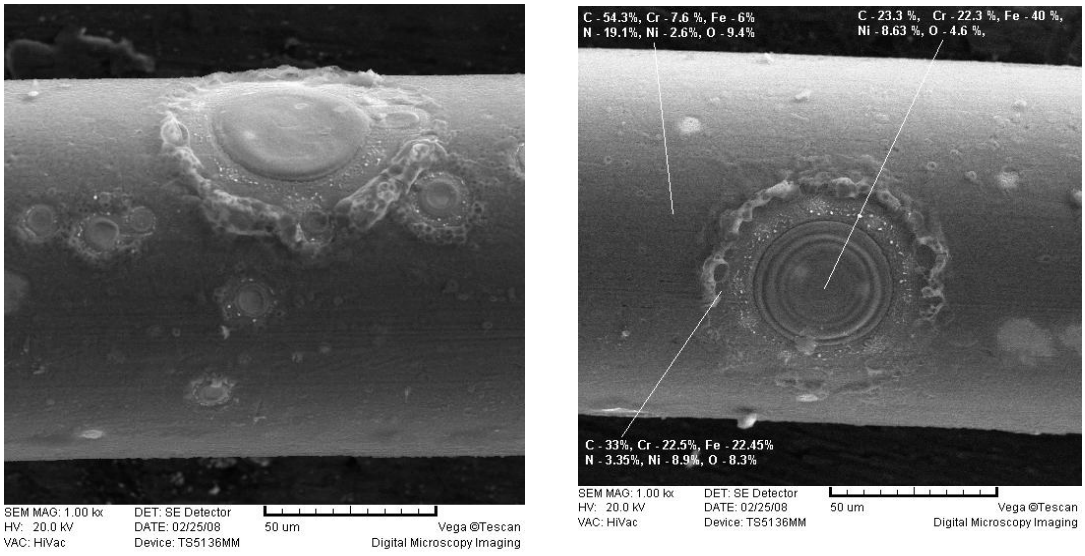

FIGURE 3A-B. SEM photos with information about EDX analysis of the covered electrode surface at 50 μm zoom.

Future collaboration with host institution

The experimental apparatus built during the visit provided new information to build a new potential reactor for further studies in collaboration with Open University. Deeper examination of chemistry is also necessary for reliable scaling and proving a direct link to real planetary atmospheres. The data obtained during visit at Open University will be analyzed and published in the near future.

References

J.-M. Bernard, E. Quirico, O. Brissaud, G. Montagnac, B. Reynard, P. McMillan, P. Coll, M.-J. Nguyen, F. Raulin, and B. Schmitt. *Icarus* **185**, 301-307, 2006.

F. Ferri, A. Rotundi, F.A. Farrelly, M. Fulchignoni, *Planet.Space Scie.* **45**, 2, 189-200, 1997.

M. Fulchignoni and 42 colleagues, *Nature* **438**, 785–791, 2005.

G. Cooper, G.R. Burton, and C.E. Brion, *J. Electron Spectrosc. Relat. Phenom.* **73**, 2, 139-148, 1995.