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Plasmas and Titan's atmosphere

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Abstract

This work is dedicated to provide a general overview about plasma experiments carried out in atmospheric pressure CH_4-N_2 discharges in our laboratories. Such electrical discharges are believed to be a good analogue to conditions in Titan's atmosphere, since they are sources of electrons, radicals, charged and excited particles and UV radiation. Our research showed that CH_4-N_2 plasmas provide similar gas constituents as it was observed in Titan's lower atmosphere.

1. Introduction

Since the first flyby of Cassini the knowledge about constituents of Titan's lower atmosphere has been successfully enhanced. Many theoretical models [1-2] and laboratory experiments [3-6] were performed in order to mimic Titan's organic chemistry that is believed to be induced by UV-radiation, charged particles and electrons. In our case, experiments have been made in corona, dielectric barrier (DBD) and gliding arc discharges.

2. Description of the experiments

A detailed description of experimental set ups for different discharge configurations used in our experiments can be found in our recently published papers [3-6]. However, a simple schematic diagram of the experimental apparatus is shown in Figure 1. The gaseous mixture of CH_4 and N_2 in the discharge reactor was prepared and regulated using MKS mass flow controllers. The reactor was connected to the long path IR gas cell equipped with KCl windows and placed in Nicolet Nexus FTIR spectrometer. Optical Emission Spectrometry (OES) using a Jobin Yvon TRIAX 550 spectrometer with a CCD detector was used to monitor the optical emission from the N_2-CH_4 plasma. The most of experiments were made at laboratory temperature, few of them at 230 K.

In case of gliding arc discharge a GC-MS analysis has also been carried out to identify organic products with lower concentration.

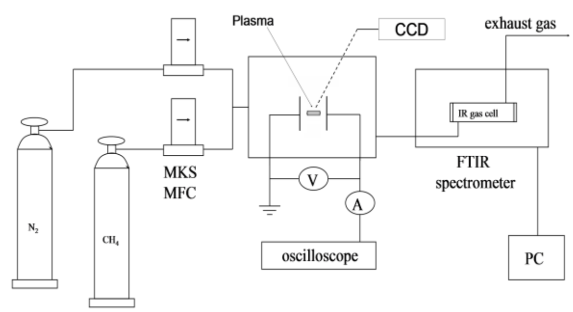

Figure 1: Simple schematic diagram of experimental set-ups used in our experiments.

3. Main results – plasmas as mimic of planetary atmosphere

Use of different plasma source provides different plasma composition, however, FTIR spectra recorded in each discharges showed a similarity (Figure 2). Corona discharge in CH_4-N_2 mixture was rich in C_2H_2, C_2H_6 and HCN [3]. High sensitivity mass spectrometry measurements also confirmed the dominancy of CN^- anion that is believed to be the precursor of heavier negative ions such as C_3N^- and C_5N^- [4], which have also been detected in corona (Figure 3). Such plasmas may provide information of the relative ion yields in planetary ionospheres and in the case of Titan have provided clues as to the nature of the anions observed by the Cassini instrument.

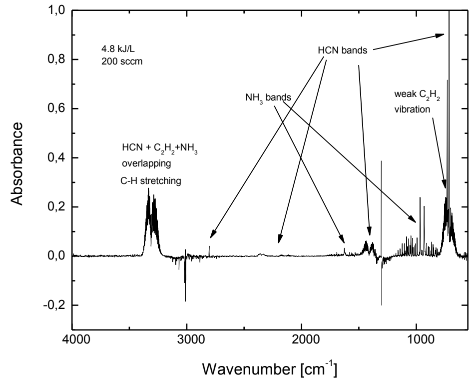

Figure 2: A typical FTIR spectrum recorded in a gas cell filled with products formed in the discharge reactor.

Gliding arc and DBD discharge experiments can be characterized by more intensive heterogeneous reactions, i.e. formation of NH_3 through catalytic reactions (large surface of dielectric pellets and electrodes) [5-6].

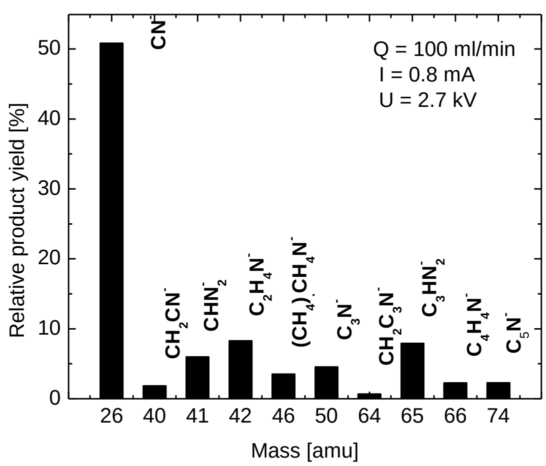

Figure 3: A Relative abundances of the most dominant anions formed in negative corona discharge.

GC-MS analysis made in gliding arc discharge provided a detailed information about the minor constituents formed in the CH_4-N_2 plasma which could not been detected by FTIR spectroscopy such ethene, cyanogens, propene, propane, propyne, propadiene, butenyene, butadiene, butadiyne, acetonitrile 2-propenenitrileand 2-propennitril, benzene and toluene.

6. Summary and Conclusions

Plasma discharges may provide valuable information on the chemistry prevalent in planetary atmospheres. Although there are limitations is to use plasmas for such mimic studies, in particular the effects of heterogeneous chemistry inherent in any plasma reactor, these disadvantages are outweighed by the insights and advances made by the conduct of such studies. Plasmas produce a similar gas composition as it was observed in Titan's atmosphere.

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