Possibilities of plasma conversion of CO_2 and H_2/H_2O to CH_4 at extraterrestrial conditions

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Manned mission to Mars is a promising but risky step in future space exploration. The amount of rocket fuel needed for a return of such mission back to Earth is one of many complications. It is nearly impossible to carry all needed fuel from the mission start due to an exponential nature of Tsiolkovsky equation. On-site production from the local sources (CO_2 atmosphere, surface and subsurface water ice) seems a necessity.

We investigate the possibilities of simple plasma-based conversion process as an alternative to a classical catalytic chemistry. Intended plasma chemistry is based on Sabatier reaction and water shift reaction [1]. Plasma conversion of CO_2 was already a topic of many experimental and modelling studies, e.g. [2] and [3].

Schematic drawing of the experimental set-up is shown in Fig.1. Surface wave driven (2.45 GHz surfatron) microwave discharge is operated at conditions similar to Mars surface (300 K, 600 Pa). Working gas is a mixture of CO_2 with H_2 or H_2O. Optical emission spectroscopy is used for the plasma diagnostics while MS and FTIR are used to determine chemical composition of the outflowing gas.

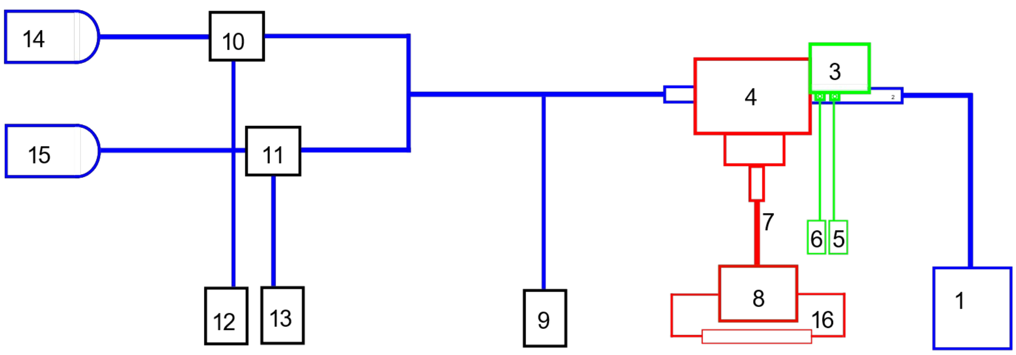

Fig. 1: Experimental setup: 1 – vacuum pump, 2 – fused silica discharge tube of 8 mm diameter, 3 – optical cable holder with micrometric screw, 4 – surfatron launcher, 5 – spectrometer JY Triax 550, 6 – low-res spectrometer Avantes, 7 – coaxial cable, 8 – Sairem solid state microwave generator, 9 – capacitive pressure gauge 10, 11 – flow controllers Bronkhorst 12, 13 – display units, 14 – CO_2 bottle, 15 – H_2 bottle, 16 – cooling water circuit

Plasma appearance in different gas mixtures is shown in Fig.2. Image analysis of such photographs can provide e.g. dependence of plasma length on gas flows, as in Fig.3.

a) b) c)

Fig. 2: Discharge appearance at P = 50 W, for several gas flows a) H_2 ~ 100 sccm, b) H_2 ~ 50 sccm, CO_2 ~ 50 sccm, c) CO_2 ~ 100 sccm.

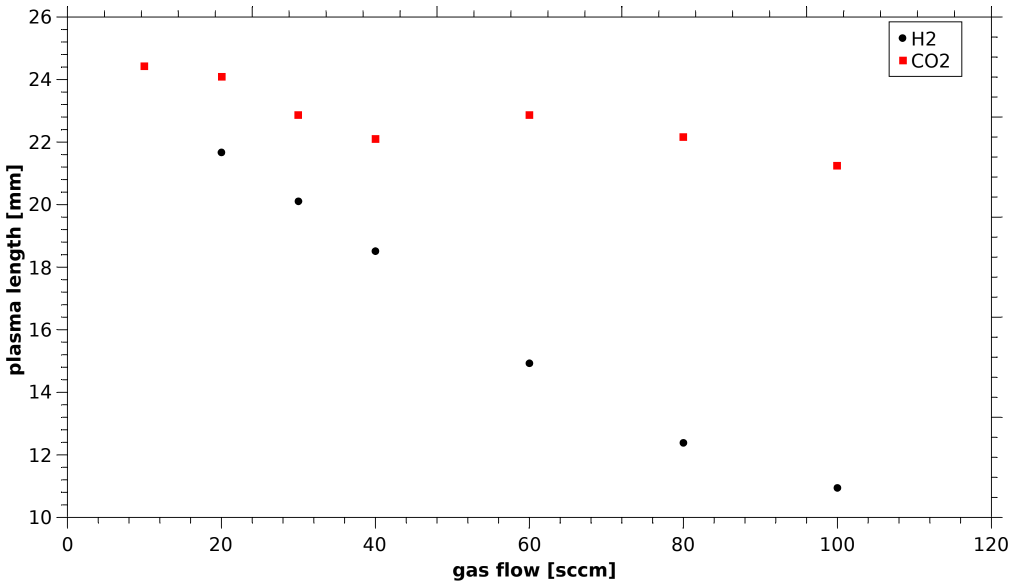

Fig. 3: Dependence of plasma length for P = 50 W in pure H_2 and pure CO_2 on the gas flowrate.

Mass spectrometry analysis of products of reactions under different CO_2:H_2 gas mixture ratios has shown a production of CO, H_2O and H_2 but only minor concentration of CH_x fragments was detected using 20:80 gas mixture ratio. PFTIR confirmed the presence of CO and H_2O molecules originating from reassociating reactions but no CH_4 was detected under studied conditions.

In conclusion, the catalyst-free plasma production of methane under Mars surface conditions was attempted using microwave plasma in various CO_2 + H_2 gas mixtures. Analysis of stable products by MS and FTIR showed presence of associating reactions products, but no definitive proof of hydrocarbon products could be obtained.

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