Microwave plasma for hydrogen production from liquids

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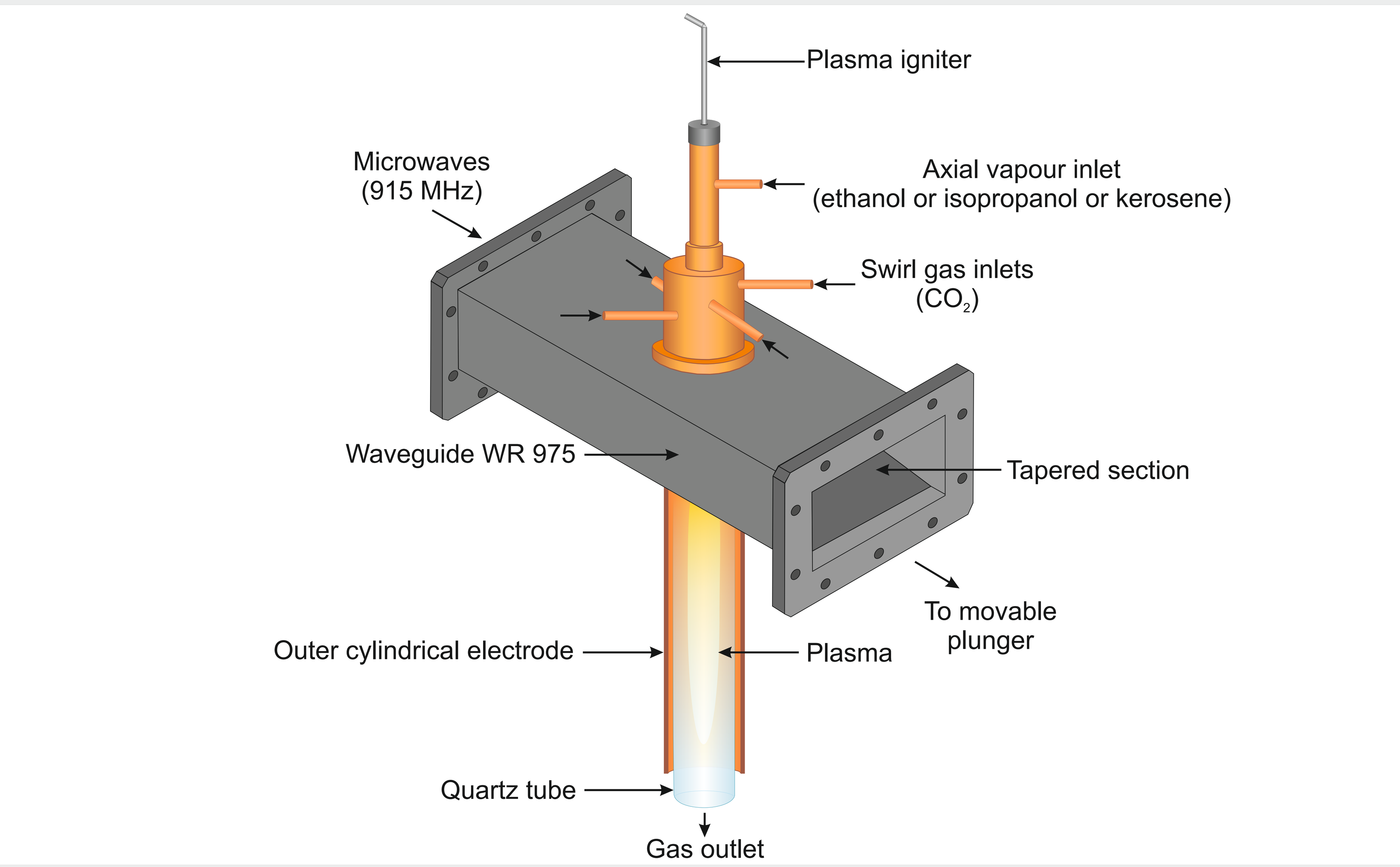
Introduction

An atmospheric pressure plasma-based method for production of hydrogen from liquids (ethanol, isopropanol, kerosene) is presented. A waveguide-supplied metal cylinder-based microwave plasma source (MPS) was used. The method is described in respect to hydrogen production efficiency defined by such parameters as the hydrogen production rate [NL(H_2)/h] and the energy yield [NL(H_2)/kWh]. The operating parameters were: an absorbed microwave power, a working gas flow rate, a kind of a liquid, and a liquid flow rate.

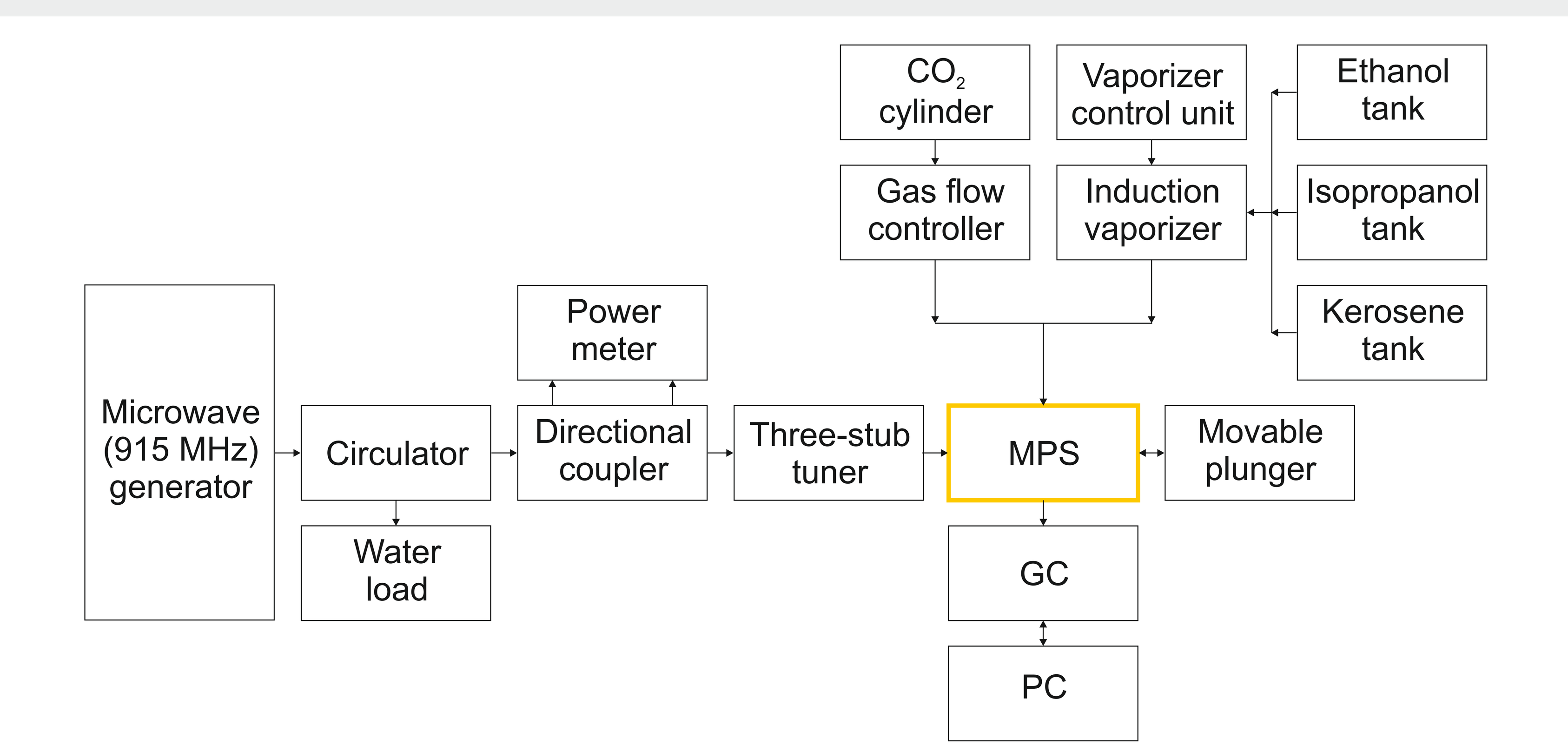
Microwave plasma source (MPS)

In the waveguide-supplied metal cylinder-based MPS the plasma is generated inside a quartz cylinder passing perpendicularly through the centre of wide walls of the waveguide. A working gas is injected into the plasma region by four inlets, which form a swirl flow inside the quartz cylinder. The gas swirl stabilizes the plasma and also protects the quartz cylinder wall from the heat. The quartz cylinder is enveloped by an outer cylindrical metal electrode which is a part of the waveguiding structure of the MPS.

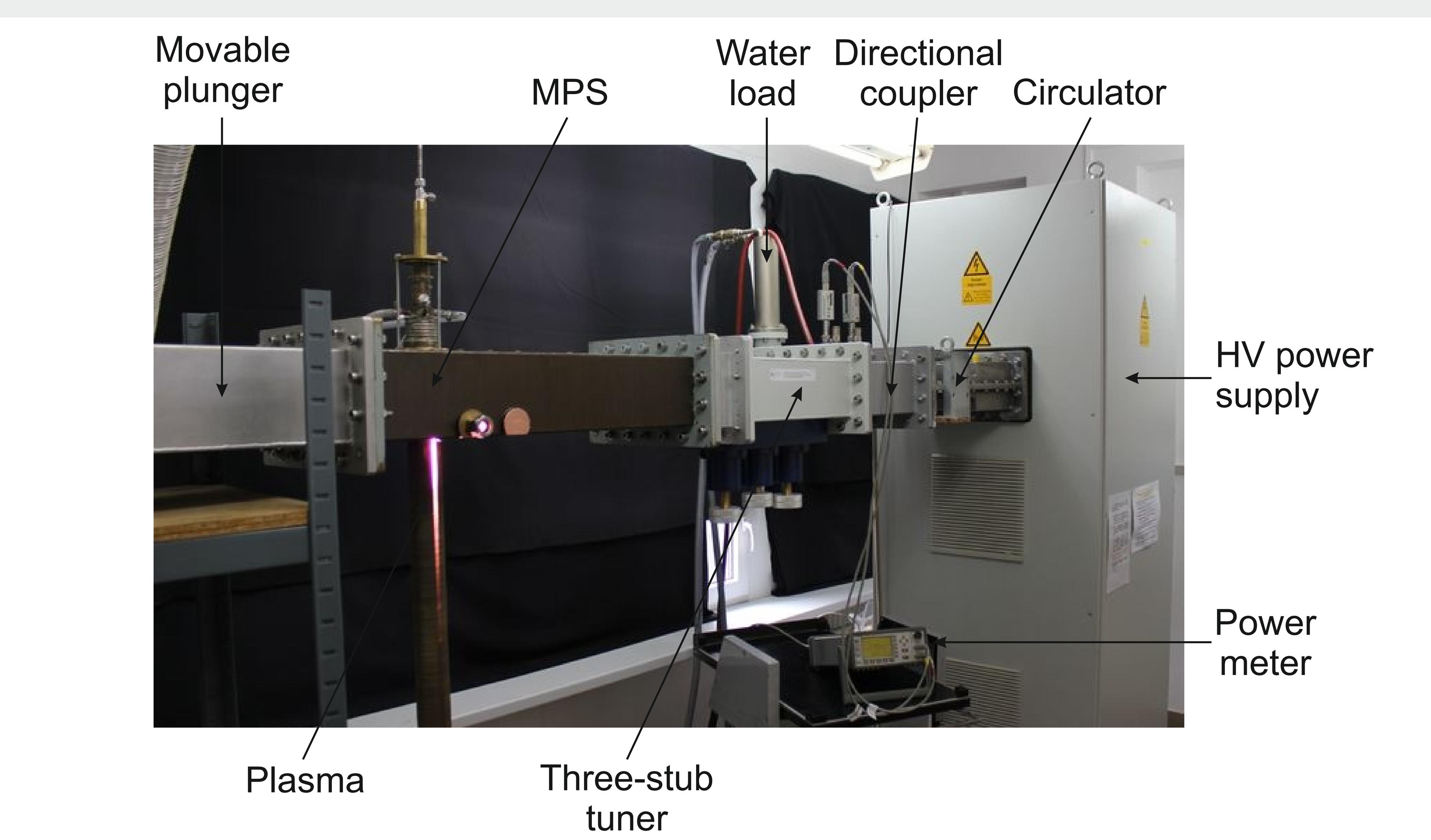


Sketch of the waveguide-supplied metal cylinder-based MPS

Experimental setup



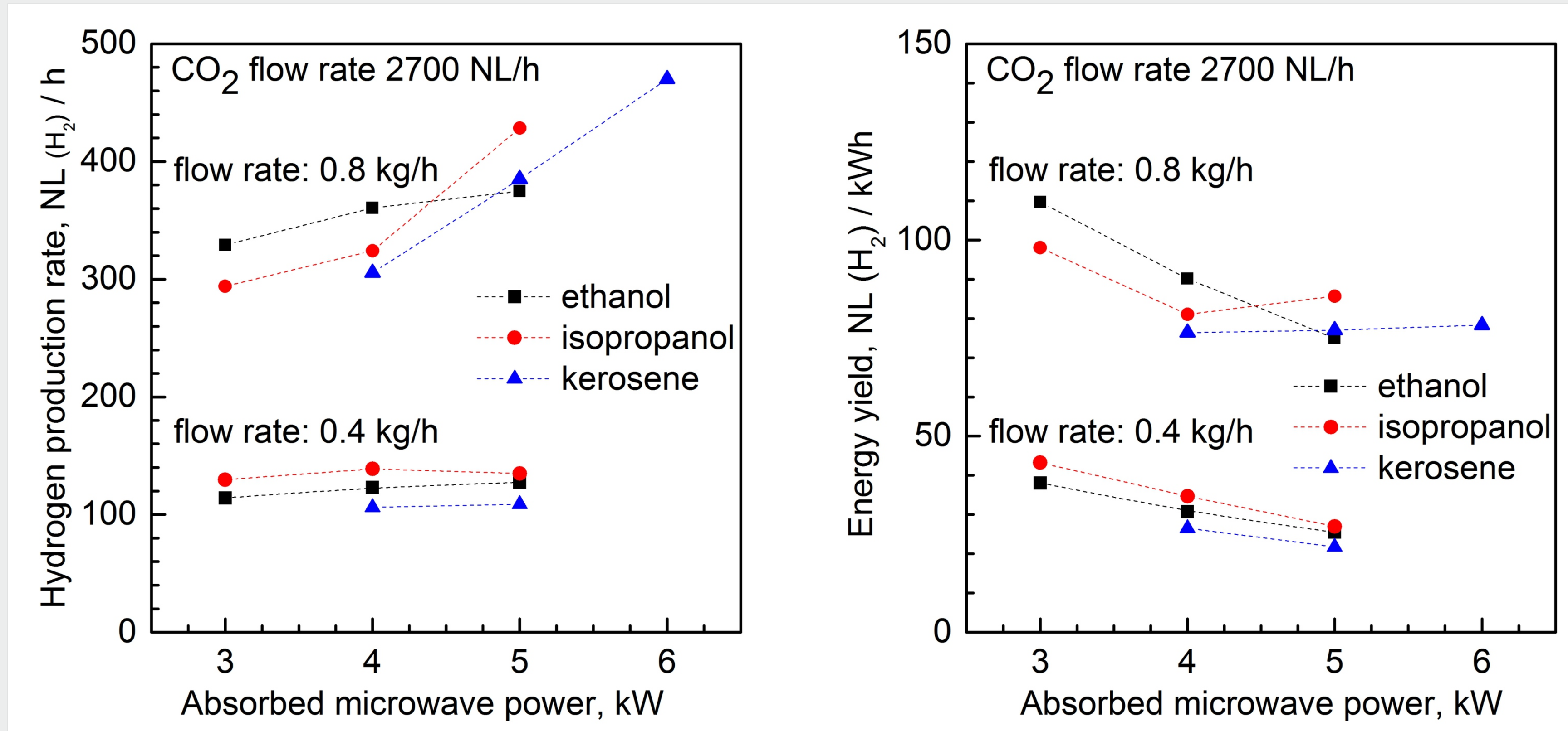
Schematic diagram of the experimental setup



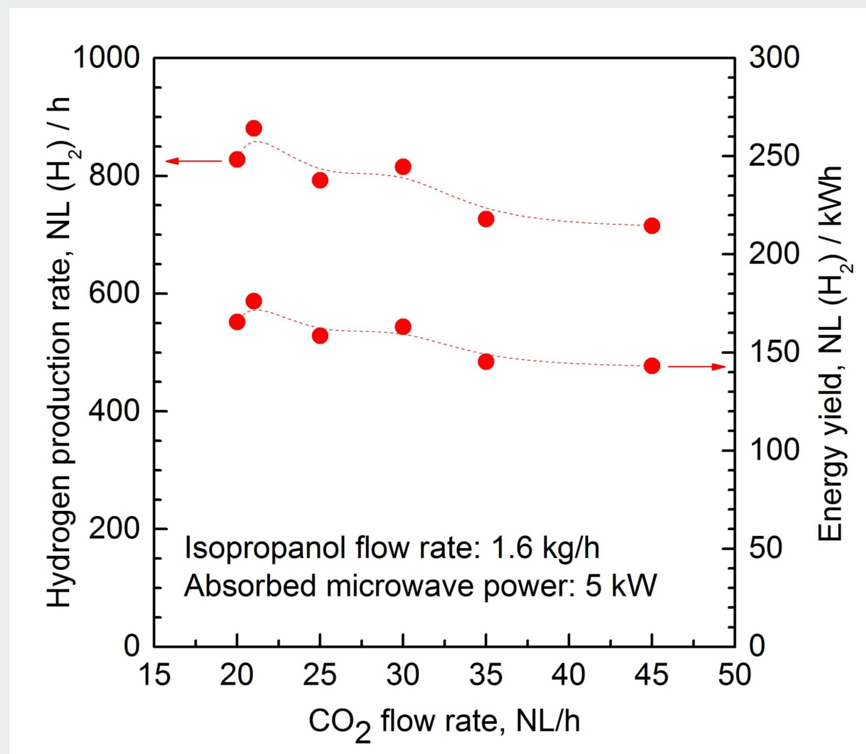
The photo of the experimental setup

Results

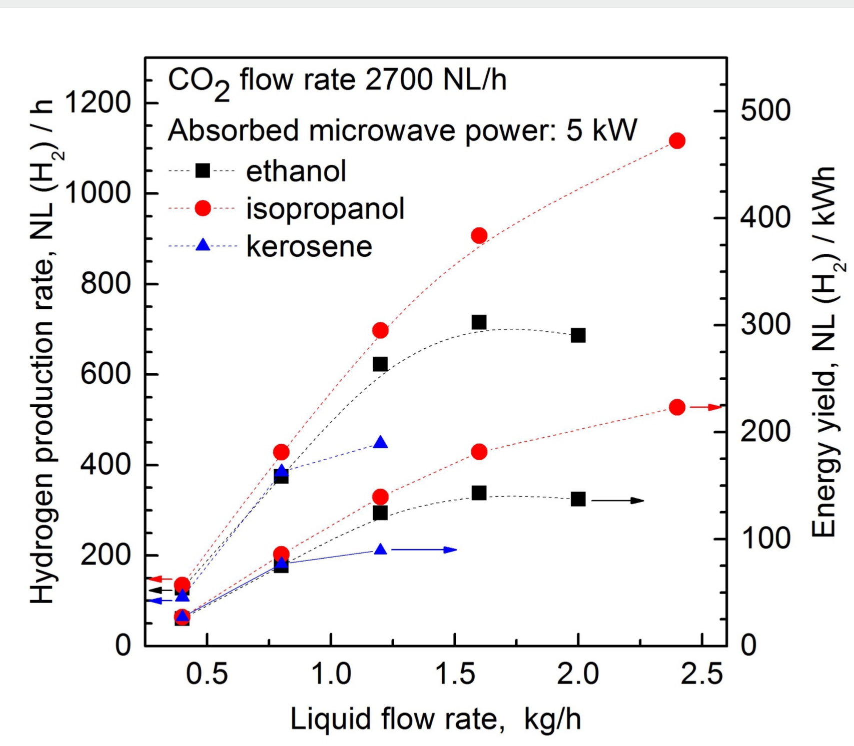
The ethanol, isopropanol and kerosene dry reforming were studied experimentally. The CO_2 swirl flow rate was up to 2700 NL/h. Liquids of flow rate up to 2.4 kg/h after vaporizing were introduced axially downwards to the plasma. The absorbed microwave (915 MHz) power ranged from 3 to 5 kW. The MPS was operated at atmospheric pressure. The hydrogen production rate in NL(H_2)/h and energy yield of hydrogen production in NL(H_2)/kW were calculated from mass balance of conversion products. Selected experimental measurements were performed few times for statistics and they show good reproducibility.



Hydrogen production rate and energy yield of hydrogen production as a function of absorbed microwave power for three liquid compounds containing hydrogen (ethanol, isopropanol, kerosene) of different flow rates (0.4 kg/h and 0.8 kg/h). CO_2 flow rate – 2700 NL/h.



Hydrogen production rate and energy yield of hydrogen production as a function of CO_2 flow rate for dry reforming of isopropanol. Absorbed microwave power – 5kW.



Hydrogen production rate and energy yield of hydrogen production as a function of liquid compounds containing hydrogen (ethanol, isopropanol, kerosene) flow rate. CO_2 flow rate – 2700 NL/h. Absorbed microwave power – 5kW.

Conclusions

Production of hydrogen by conversion of ethanol, isopropanol and kerosene using microwave (915 MHz) plasmas was studied experimentally.

As it was shown the presented method is a high potential tool for hydrogen production via plasma reforming of different liquid compounds containing hydrogen.

An advantage of the presented microwave plasma method for hydrogen production from liquids is lack of catalyst. Here, the plasma is a source of very active ions, radicals and high-energy electrons, which enhance the chemical reaction rates thus avoiding the use of expensive and impurity vulnerable catalysts.

In contrast to centralized, large scale and established commercial technology of hydrogen production, one might consider the use of the presented microwave plasma based method at distributed hydrogen production system which means the on-site production of hydrogen. It does not require a substantial transport and delivery infrastructure or large capital investments as high as those needed for large central production plants. In this case such technologies as reforming of ethanol, methanol or isopropanol (e.g. from biomass) are pursued.

Acknowledgments

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