Spectroscopic study of an atmospheric pressure microwave plasma with addition of alcohol vapours

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Introduction

SUBJECT :

Spectroscopic study of rotational temperatures in atmospheric pressure microwave plasma with alcohols vapours addition

MOTIVATION :

Development of microwave plasma technology of hydrogen production via liquide hydrocarbon decomposition

The gas temperature can often be inferred from the rotational temperature of the heavy species of the gas [1-4]

APPLICATIONS :

Production of hydrogen via liquid hydrocarbons decomposition [5-7]

Microwave Plasma Source (MPS)

MICROWAVES
Frequency: 2.45 GHz or 915 MHz
Powers: 3000 - 6000 W

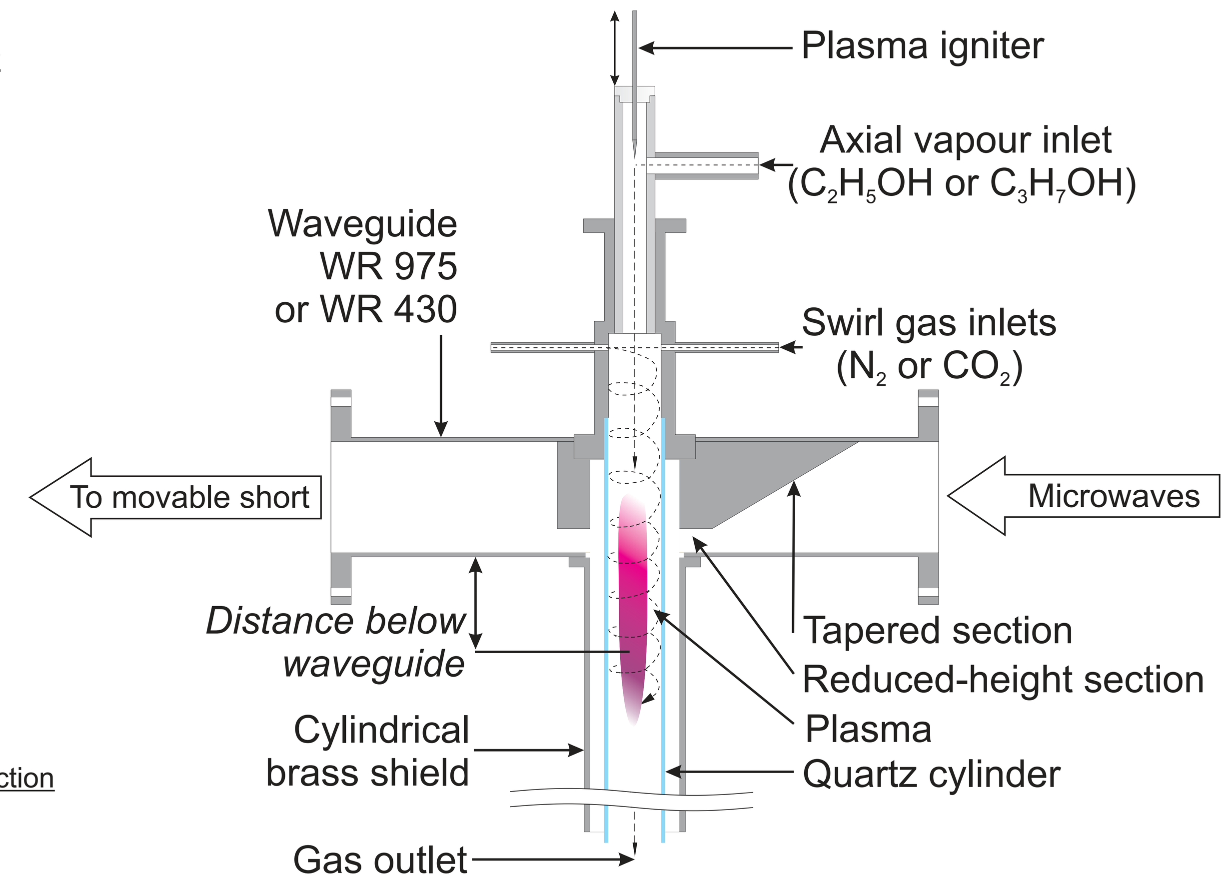
TECHNOLOGY
Waveguide-supplied
Nozzleless
Cylindrical

GAS FLOW
Ar, CO_2, N_2
Swirl flow
Flow rate: 2100 - 4500 NL/h

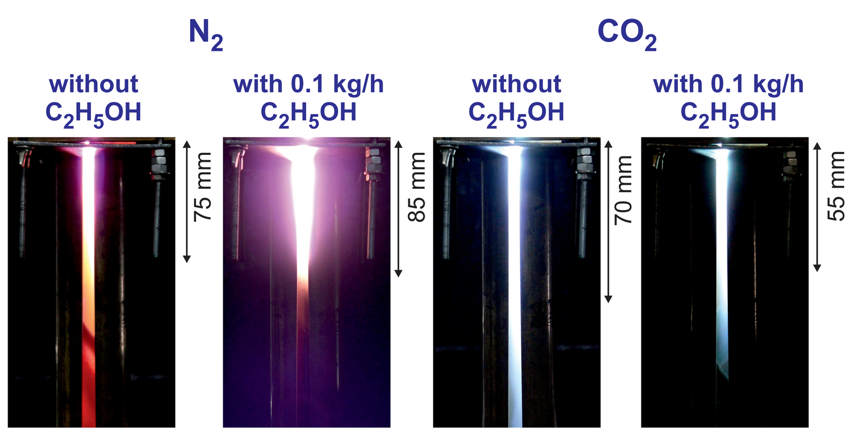
ALCOHOL VAPOUR FLOW
C_2H_5OH, C_3H_7OH
Axial flow
Flow rate: 0.1 - 2.4 kg/h

PROCESSES
Pyrolysis:
$C_2H_5OH \rightarrow 3H_2 + CO + C$
C_3H_7OH - problems with intense soot production

Dry reformig:
$C_2H_5OH + CO_2 \rightarrow 3H_2 + 3CO$
$C_3H_7OH + 2CO_2 \rightarrow 4H_2 + 5CO$



The sketch of MPS

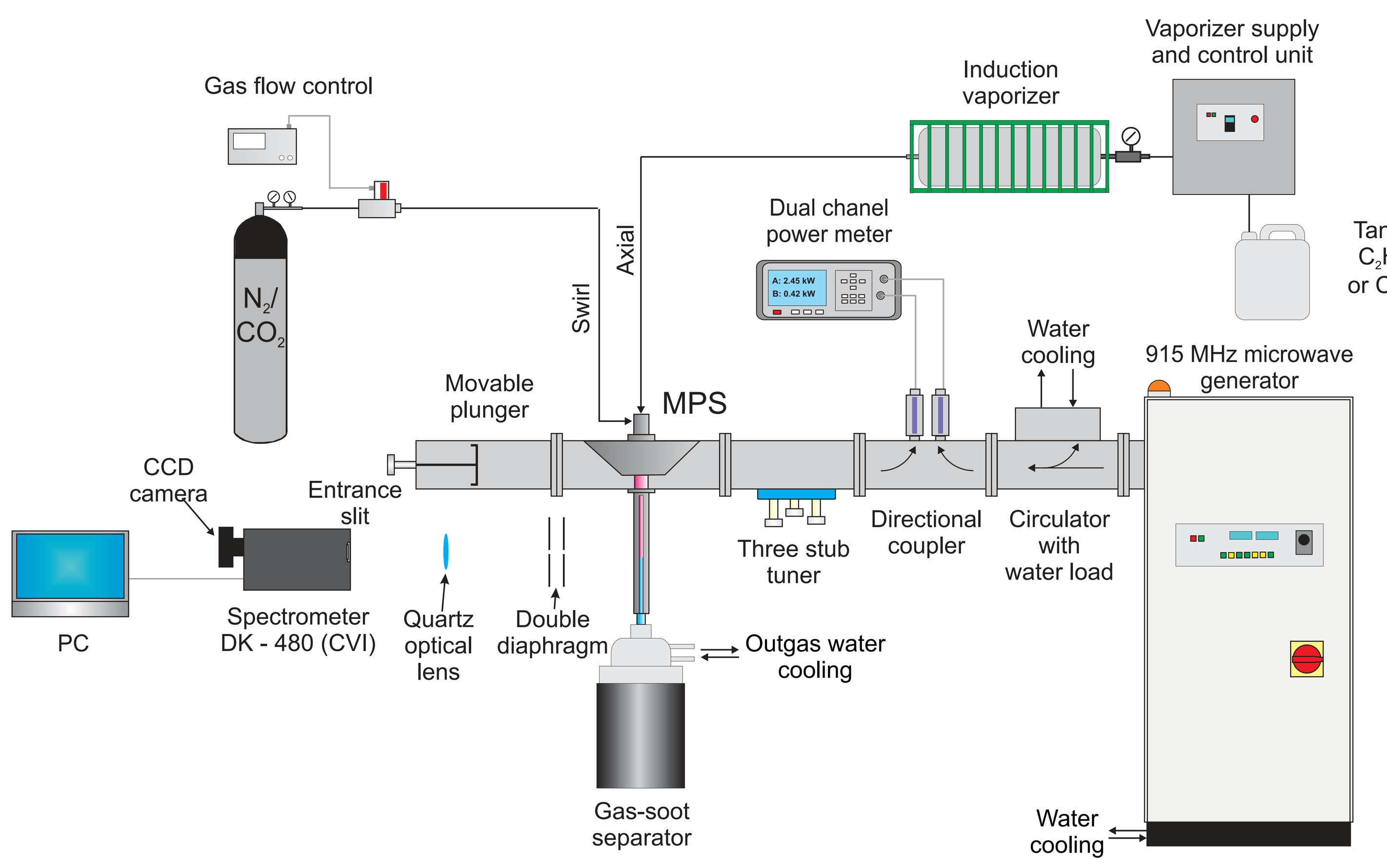


Side view of plasmas without and with ethanol vapor addition (2.45 GHz plasma system, absorbed microwave power P_A - 2 kW, working gas (N_2, CO_2) flow rate - 2700 NL/h)

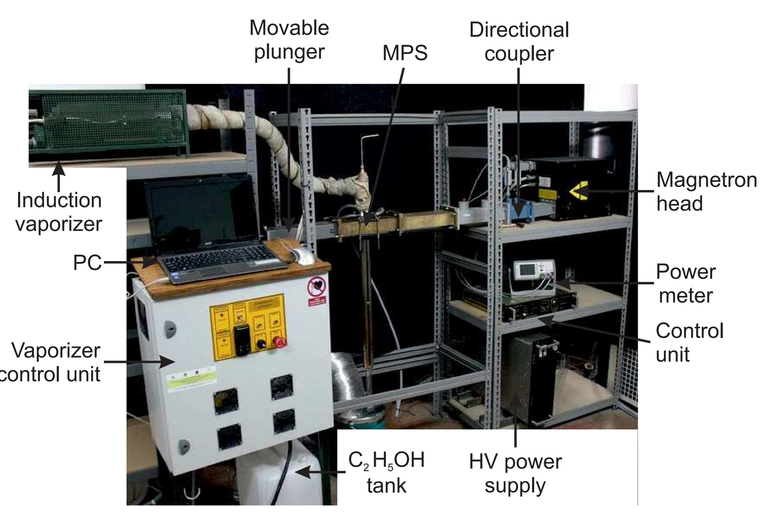
	Plasma gas composition	Absorbed microwave power [kW]	Hydrogen production rate [g(H_2)/h]	Energy yield [g(H_2)/kWh]	Hydrogen selectivity [%]
Pyrolysis	N_2 – 3900 NL/h C_2H_5OH – 0.8 kg/h	3 (915 MHz system)	66.7	**22.2**	64
	N_2 – 2700 NL/h C_2H_5OH – 1.2 kg/h	5 (915 MHz system)	**95.7**	19.1	61
Dry reforming	CO_2 – 2700 NL/h C_2H_5OH – 1.6 kg/h	5 (915 MHz system)	**59.5**	**11.9**	29.8
	CO_2 – 2700 NL/h C_3H_7OH – 2.4 kg/h	5 (915 MHz system)	**92.9**	**18.6**	29.6

Hydrogen production from alcohols - the best results

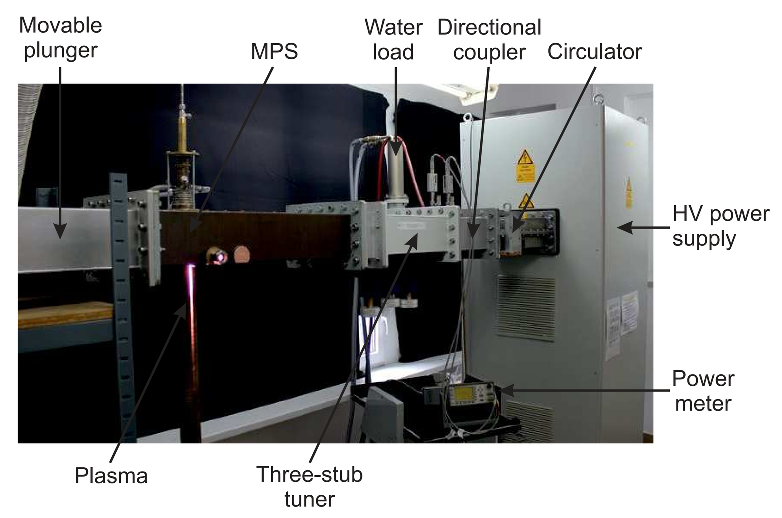
Experimental setup



The diagram of experimental setup for spectroscopic study of microwave plasma with alcohols vapour additionr

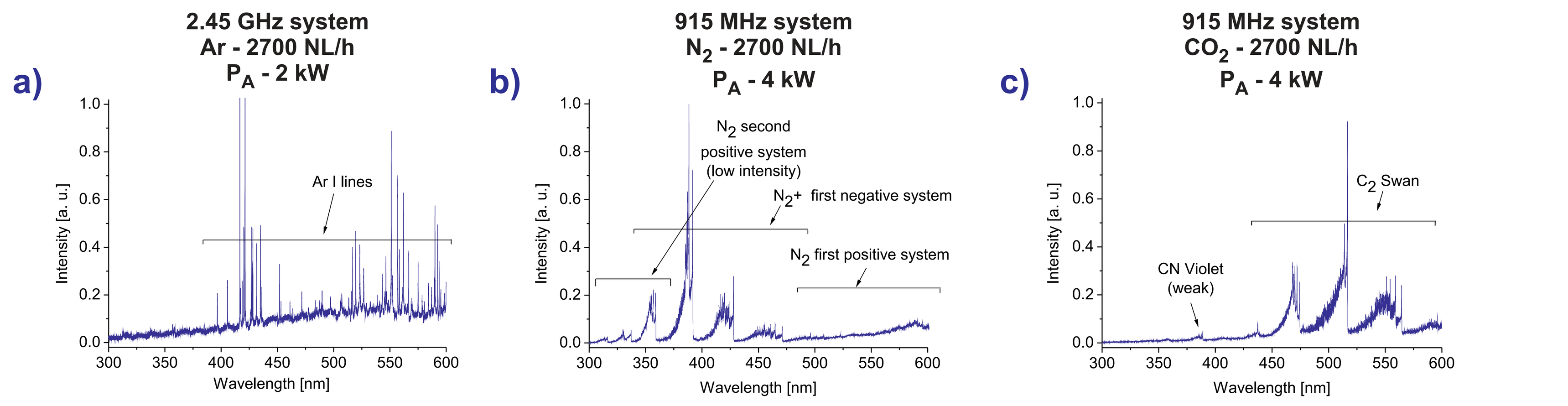


2.45 GHz microwave system
up to 6 kW

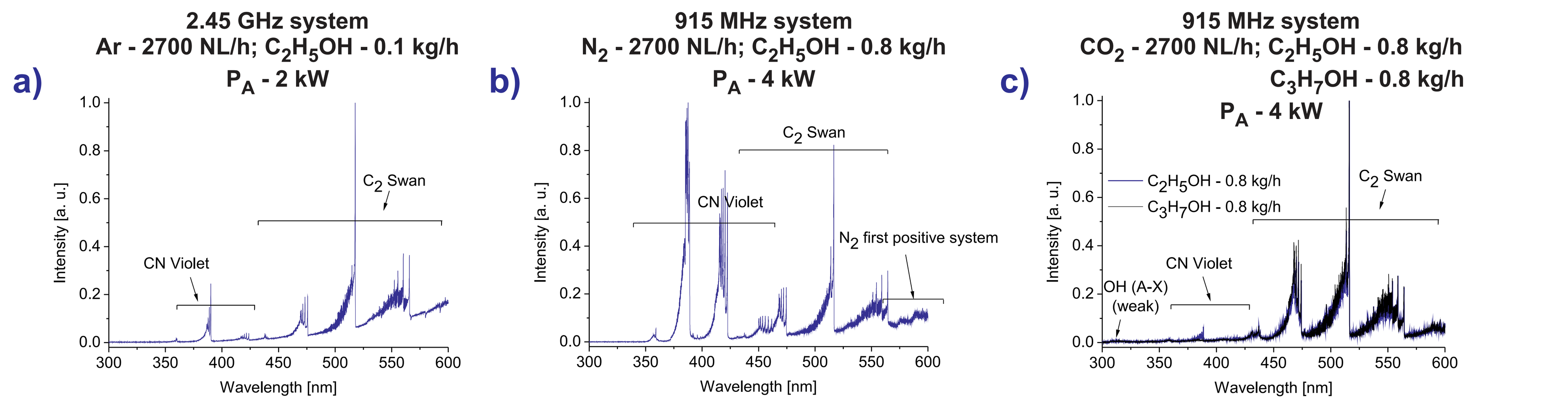


915 MHz microwave system
up to 20 kW

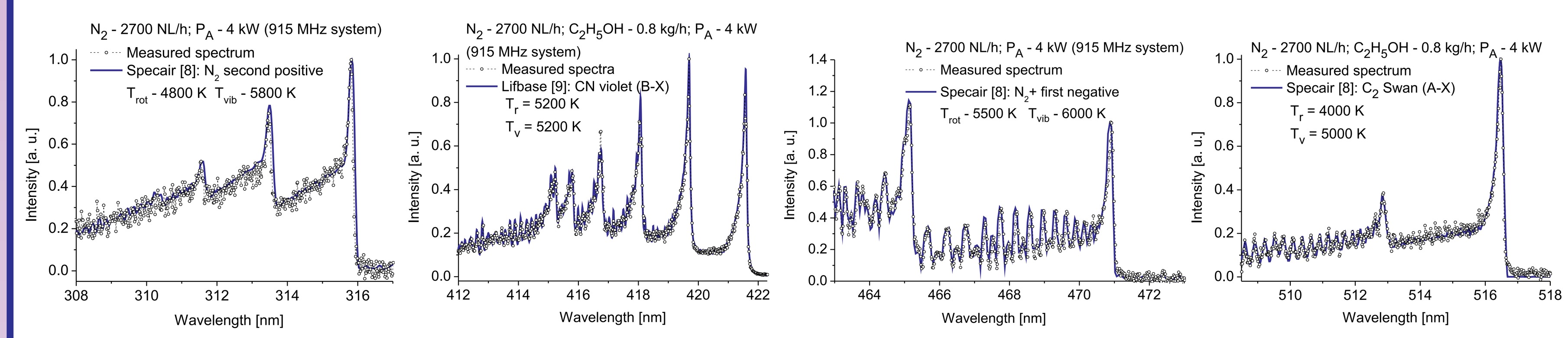
Results



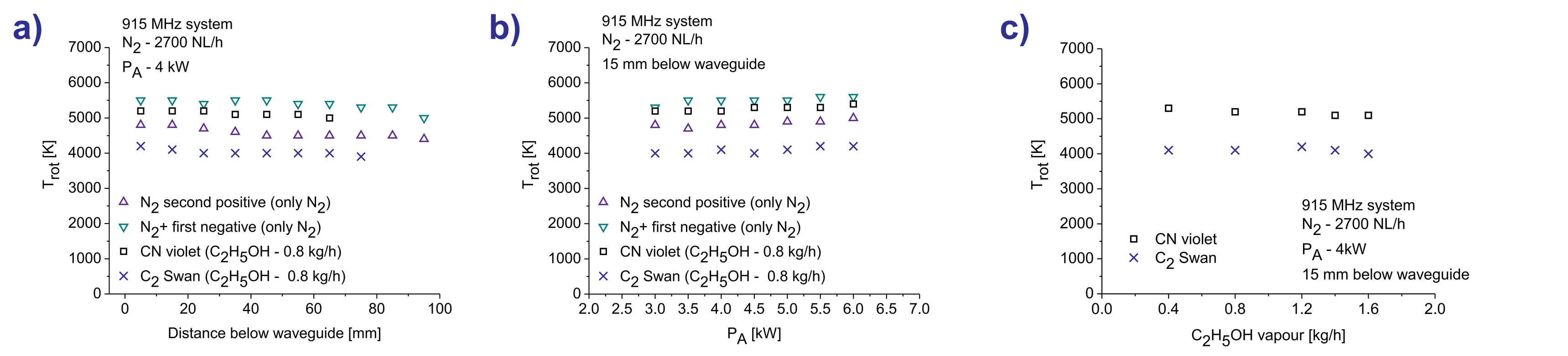
Measured emission spectra of Ar (a) N_2 (b) CO_2 (c) plasmas



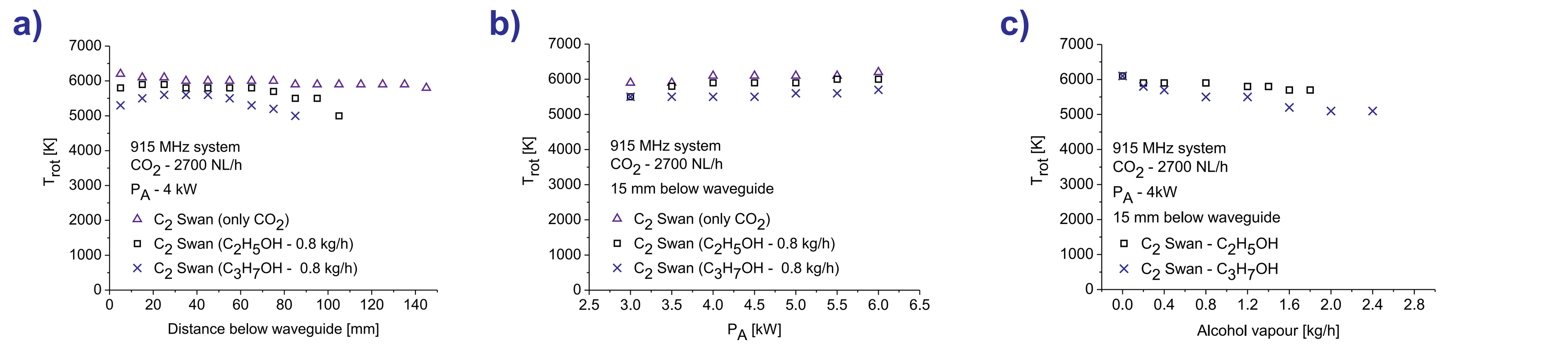
Measured emission spectra of Ar (a) N_2 (b) CO_2 (c) plasmas with alcohols vapour addition



Comparison of the measured and simulated in Specair [8] and Lifbase [9] programs emission spectra of selected systems in microwave plasmas without and with alcohols vapour addition



Rotational T_{rot} temperatures of heavy species as a function of distance below waveguide (a) microwave absorbed power (b) and C_2H_5OH vapour flow rate (c) for N_2 microwave plasma without and with C_2H_5OH vapour addition



Rotational T_{rot} temperatures of heavy species as a function of distance below waveguide (a) microwave absorbed power (b) and alcohol vapour flow rate (c) for CO_2 microwave plasma without and with alcohols vapour addition

Summary

- The study concerned the rotational temperatures of the heavy species in atmospheric pressure N_2 and CO_2 microwave plasma without and with alcochols (ethanol and isopropanol) vapour addition
- The rotational temperatures varied slightly for various discharge conditions. The variable parameters (microwave absorbed power, working gas flow rate, alcohol vapour flow rate) influenced mainly on plasma volume and less on temperature of the heavy species in the plasma core
- The temperature of plasma core is very high (4000 - 6200 K) but on account of the working gas swirl flow structure the average temperature of the gas is apparently lower (estimated to be about 1500 - 2000 K)
- Stable operation and still the high average gas temperature makes MPS attractive tool for different gas and liquid processing at atmospheric pressure

References

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