Spectroscopic characterization of nitrogen plasma generated by waveguide-supplied coaxial-line-based nozzleless microwave source

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INTRODUCTION

SUBJECT :

Spectroscopic study of rotational and vibrational temperatures of selected heavy species in high flow rate atmospheric pressure microwave nitrogen plasma

MOTIVATION :

Development of microwave plasma technology at atmospheric pressure and high gas flow rates
Determination of the plasma gas temperature from the rotational temperature of the heavy species [1-3]

APPLICATIONS :

Gas processing:
production of hydrogen via hydrocarbons decomposition [4]
hazardous gas treatment [5]

MICROWAVE PLASMA SOURCE (MPS)

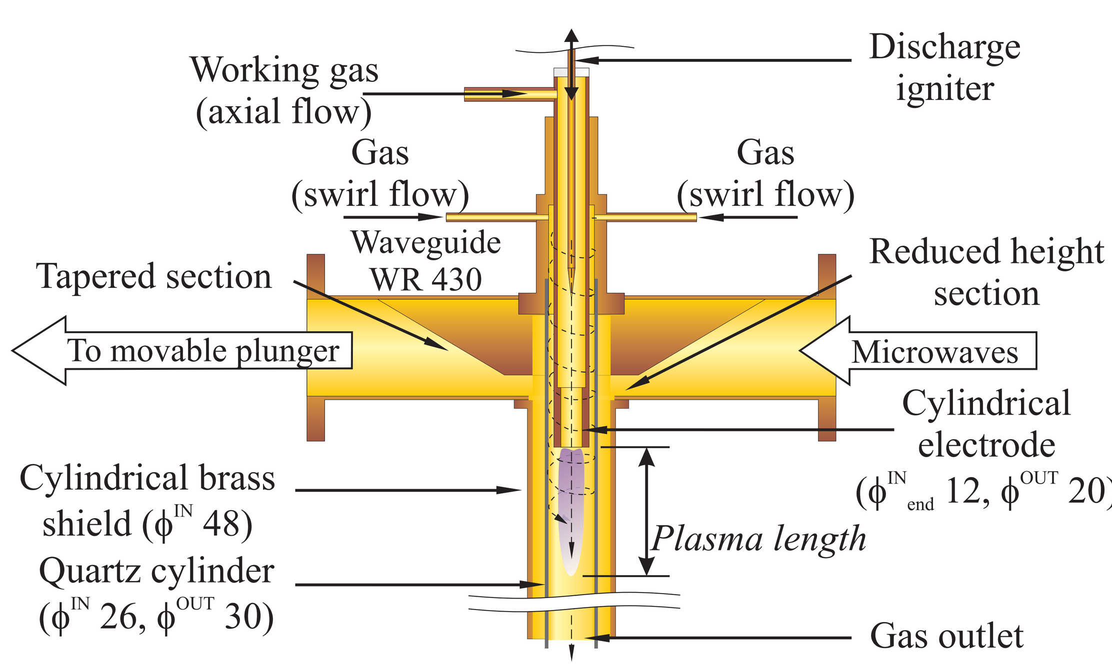
MICROWAVES

Frequency: 2.45 GHz
Powers: 600 - 5500 W

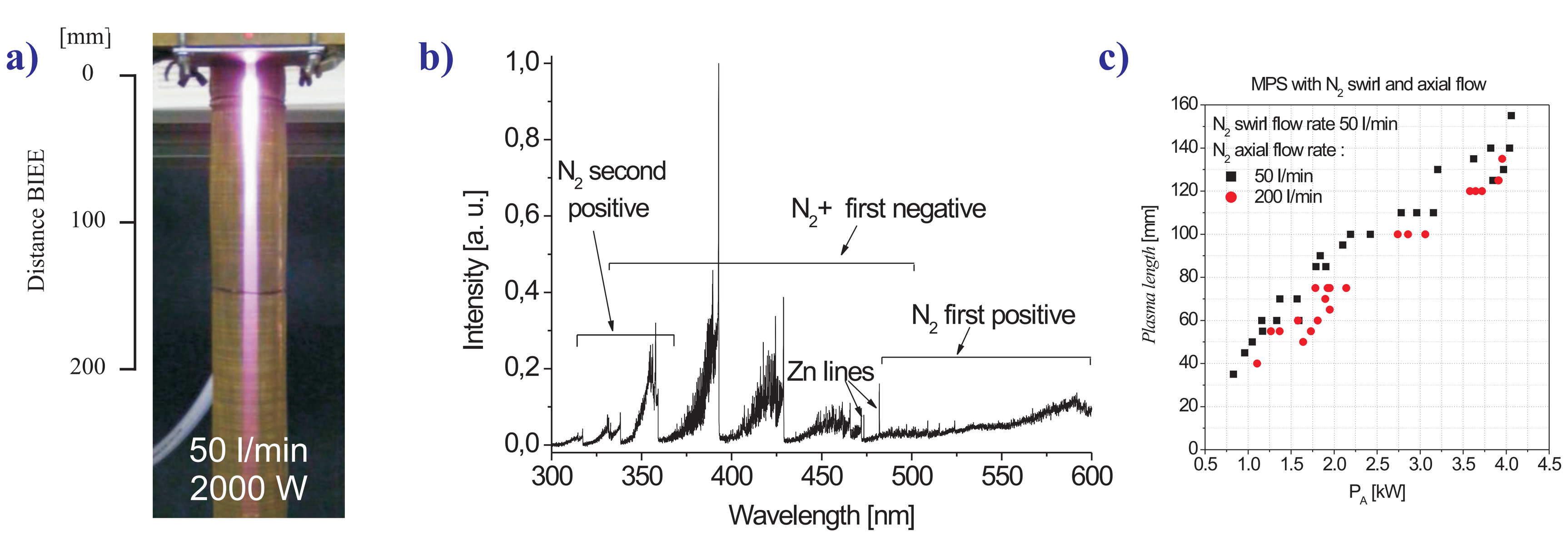
GAS FLOW

Swirl flow: N_2
Flow rate: 50 l/min
(small amount of water vapour optionally added)

Axial flow: N_2
Flow rate: 50 - 200 l/min

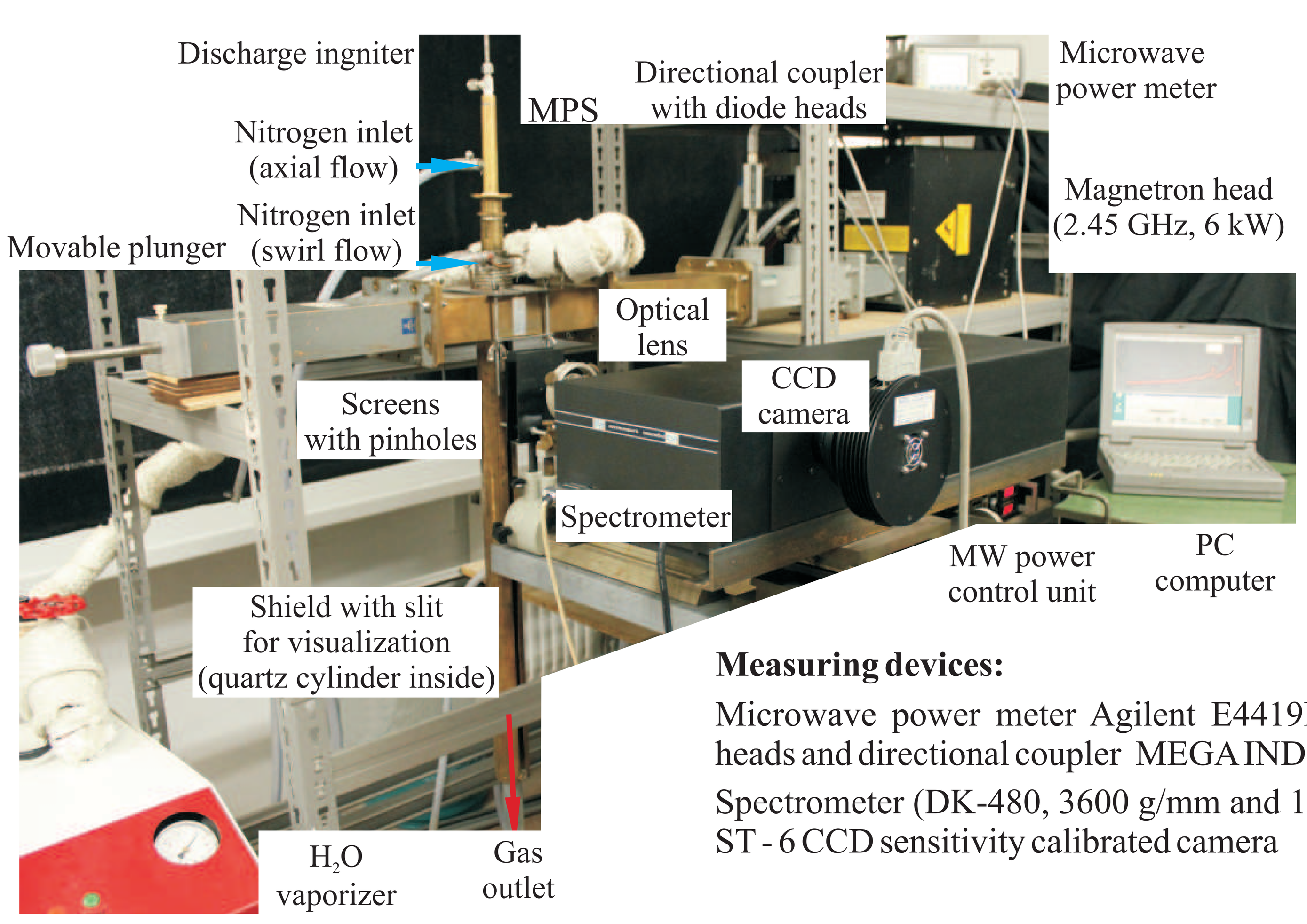


The sketch of MPS



a) Nitrogen microwave plasma, b) Measured emission spectrum of nitrogen plasma (P_A – 2 kW, nitrogen flow rate - 50 l/min, 25 mm below the electrode end) c) the length of nitrogen plasma (measured from electrode) as a function of microwave absorbed power P_A ($P_A = P_I$(incident) - P_R(reflected)) for different axial flow rates

EXPERIMENTAL SETUP



Measuring devices:

Microwave power meter Agilent E4419B with E9301A heads and directional coupler MEGA IND. 069Y7 (70dB)

Spectrometer (DK-480, 3600 g/mm and 1200 g/mm) with ST - 6 CCD sensitivity calibrated camera

The experimental setup for spectroscopic study of nitrogen microwave atmospheric pressure plasma at high flow rates

REFERENCES:

[1] E. Pawelec, M. Simek, H. Nassar, et al.: Acta Physica Polonica A **89** (1996), 503
[2] Ch. Izarra: J. Phys. D: Appl. Phys. **33** (2000), 1697
[3] J. Raud, M. Laan, I. Jogi: J. Phys. D: Appl. Phys. **44** (2011), 345201
[4] M. Jasinski, M. Dors, J. Mizeraczyk: J. Power Sources **181** (2008), 41
[5] M. Jasinski, M. Dors, J. Mizeraczyk: Plasma Chem. Plasma Process. **29** (2009), 363
[6] http://www.sri.com/psd/lifbase/
[7] http://www.specair-radiation.net

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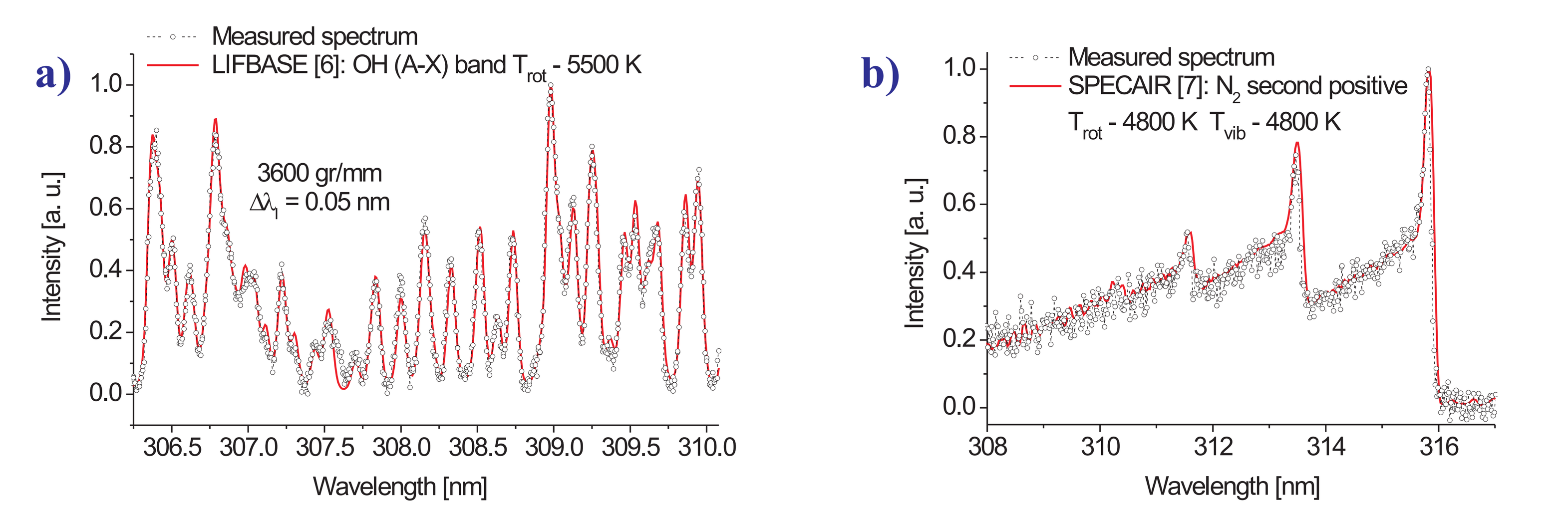
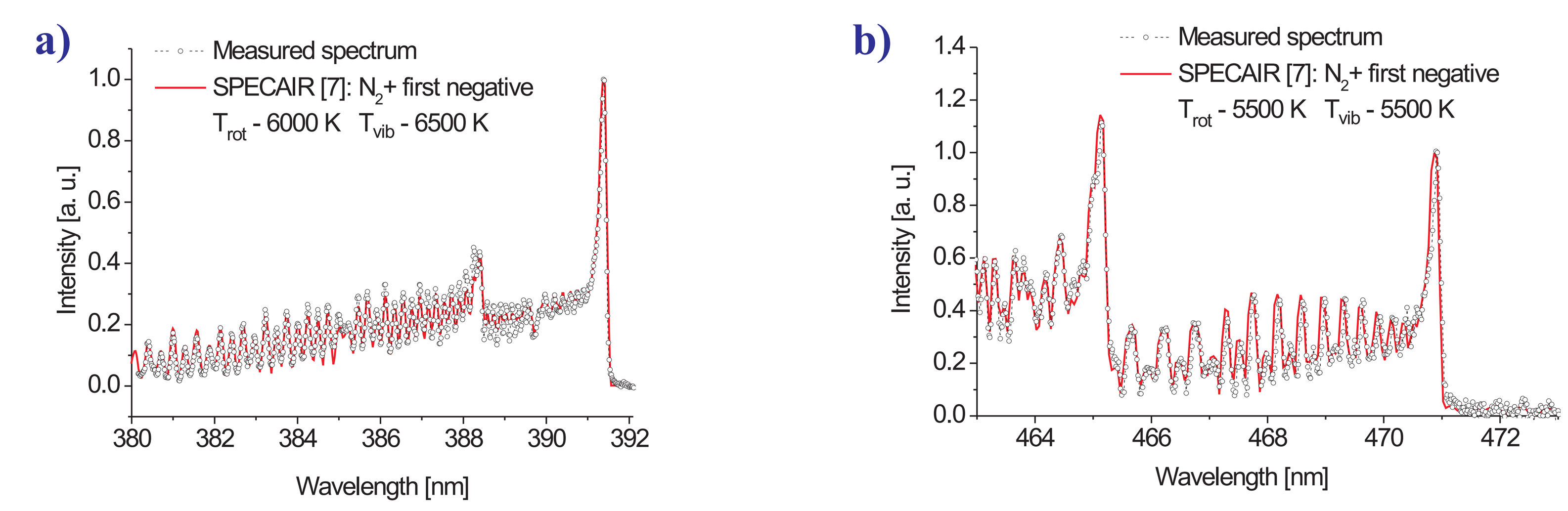
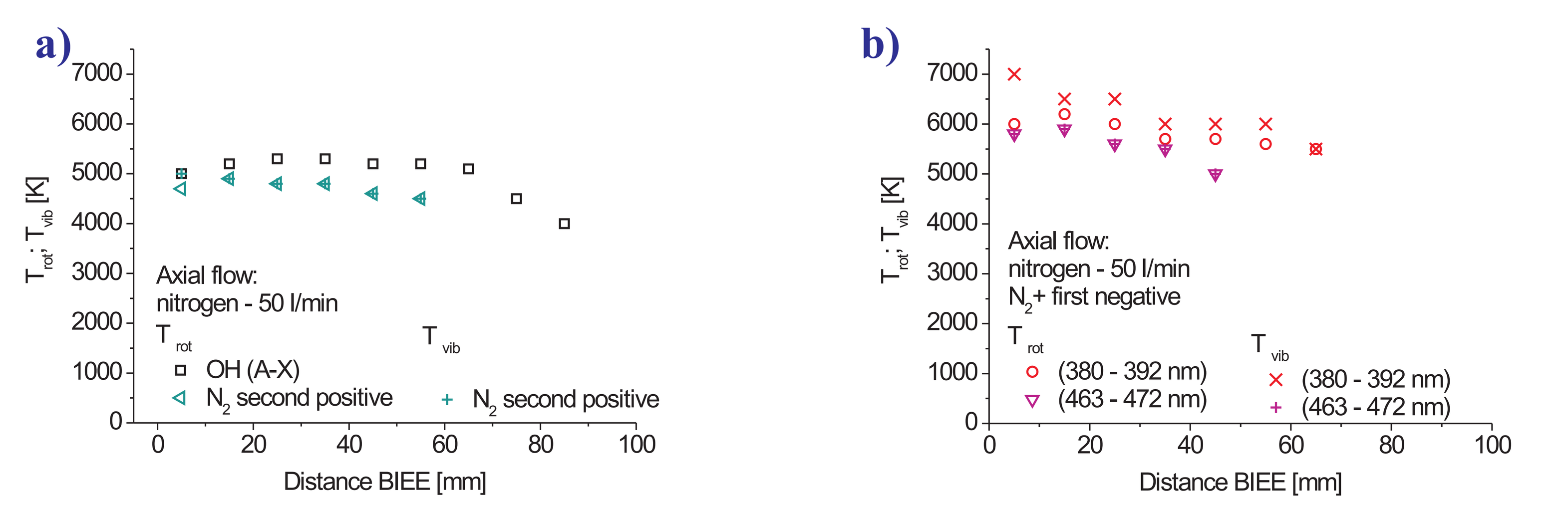
RESULTS



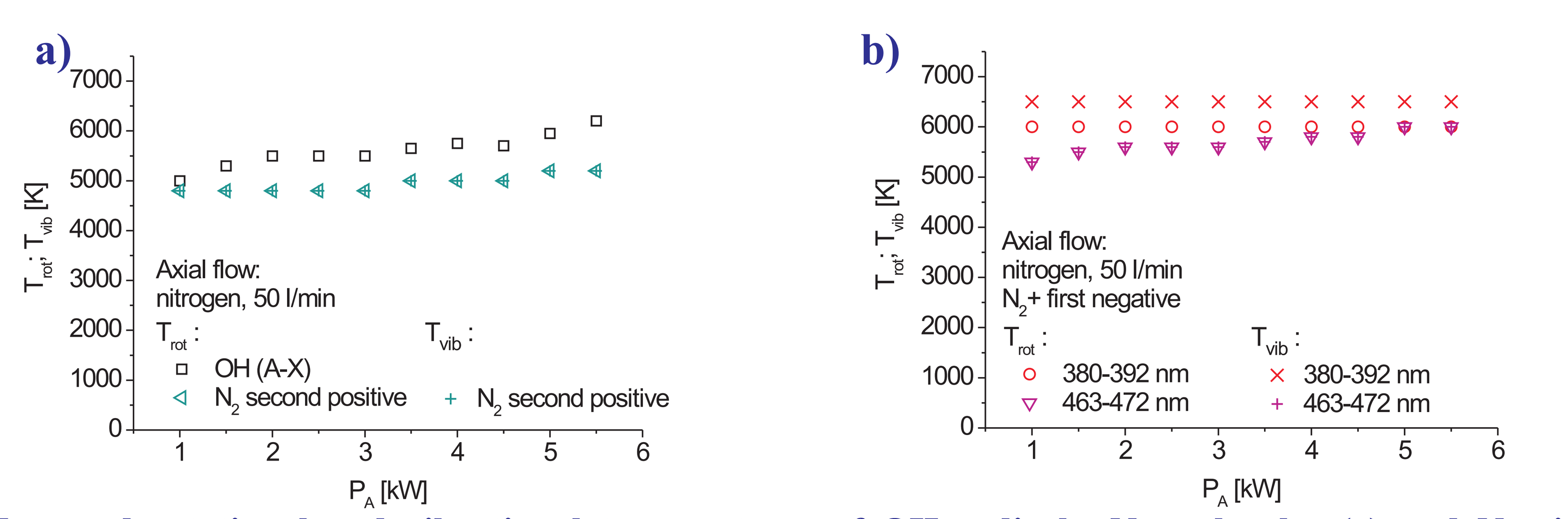
Comparison of the measured and simulated emission spectra of OH(A-X) rotational band and N_2 second positive system in nitrogen plasma (P_A – 2 kW, nitrogen flow rate - 50 l/min, 25 mm below the electrode end)



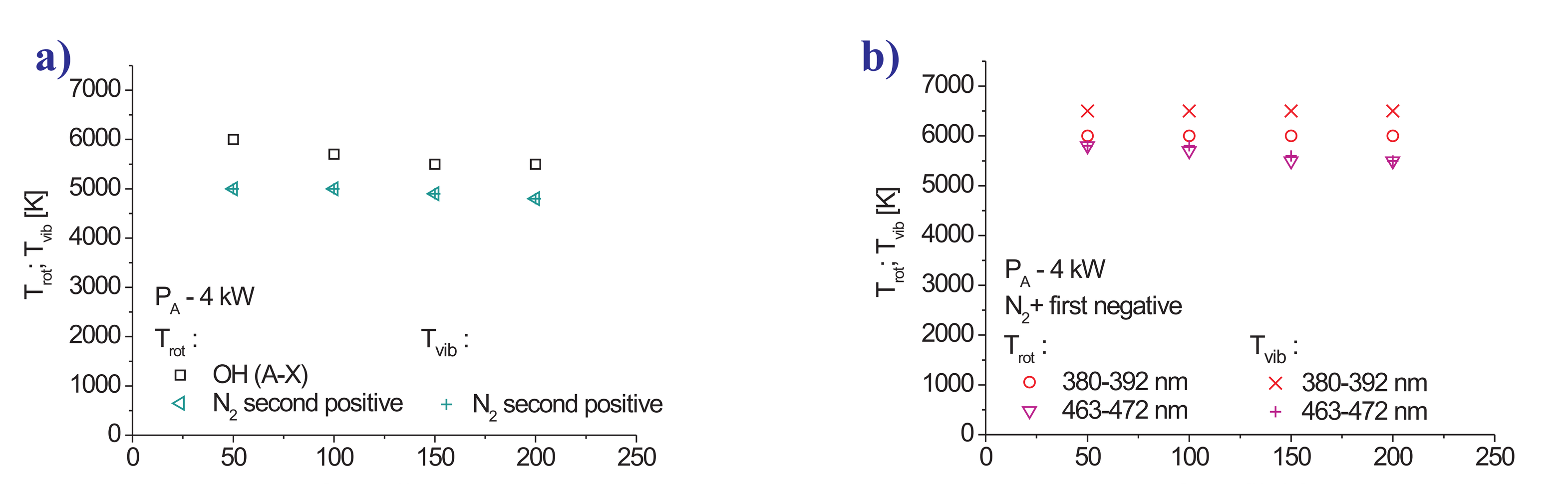
Comparisons of the measured and simulated emission spectra of N_2 + first negative system (for two different bands) in nitrogen plasma (P_A – 2 kW, nitrogen flow rate - 50 l/min, 25 mm below the electrode end)



Measured rotational and vibrational temperatures of OH radicals, N_2 molecules (a) and N_2+ ions (b) as a function of distance below inner electrode end (Distance BIEE) (P_A - 2 kW, nitrogen flow rate - 50 l/min)



Measured rotational and vibrational temperatures of OH radicals, N_2 molecules (a) and N_2+ ions (b) as a function of microwave absorbed power P_A (nitrogen flow rate - 50 l/min, 25 mm below the electrode end)



Measured rotational and vibrational temperatures of OH radicals, N_2 molecules (a) and N_2+ ions (b) as a function of axial nitrogen flow rate $Q_{axial\,N2}$ (P_A - 4kW, 25 mm below the electrode end)

SUMMARY

- Obtained rotational and vibrational temperatures ranged from 4000 to 6000 K and from 4500 to 6500 K, respectively, depending on the location in the plasma, the microwave absorbed power and axial nitrogen flow rate. OH radicals and N_2+ ions from 463-472 nm band provided comparable results. N_2 molecules in all cases provided slightly lower temperatures.
- The rotational and the vibrational temperatures of N_2 molecules as well as N_2+ ions determined from 463-472 nm band were in equilibrium in nitrogen microwave plasma. The vibrational temperature of N_2+ ions determined from 380-392 nm band was slightly higher than the rotational temperature.
- Rotational temperatures of OH radicals seem to be good estimation of the plasma gas temperature in nitrogen microwave plasma.
- Stable operation with various gases as well as wide range of parameters make MPS an attractive tool for different gas processing at atmospheric pressure and high flow rates.
- MPS was successfully used for hydrogen production via hydrocarbon conversion [4] and for Freon destruction [5] owing to high plasma gas temperature.