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

APPLICATIONS:

MICROWAVE PLASMA SOURCE (MPS)

MICROWAVES
Frequency: 2.45 GHz
Powers: 600 - 5500 W

GAS FLOW
Swirl flow: \( N_2 \)
Flow rate: 50 l/min

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

EXPERIMENTAL SETUP

Discharge ignition
Nitrogen inlet (axial flow)
Nitrogen inlet (swirl flow)
Moveable plunger
Movable plunger
Optical axis
CCD camera
Spectrometer
MPS power control unit
PC computer

Measuring devices:
Microwave power meter Agilent E4419B with E9031A heads and directional coupler MEGAIND 8097T(76dB)
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

RESULTS

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

Comparison of the measured and simulated emission spectra of \( N_2 \) first negative system in nitrogen plasma (P = 2 kW, nitrogen flow rate = 50 l/min, 25 mm below the electrode end)

Comparison of the measured and simulated emission spectra of OH radicals, \( N_2 \) molecules (a) and \( N_+ \) ions (b) as a function of distance below inner electrode end (Distance BIEE) (P = 2 kW, nitrogen flow rate = 50 l/min, 25 mm below the electrode end)

Comparison of the measured and simulated emission spectra of OH radicals, \( N_2 \) molecules (a) and \( N_+ \) ions (b) as a function of microwave absorbed power \( P \) (nitrogen flow rate = 50 l/min, 25 mm below the electrode end)

Comparison of the measured and simulated emission spectra of \( N_+ \) second positive system in nitrogen plasma (P = 2 kW, nitrogen flow rate = 50 l/min, 25 mm below the electrode end)

Comparison of the measured and simulated emission spectra of OH radicals, \( N_2 \) molecules (a) and \( N_+ \) ions (b) as a function of distance below inner electrode end (Distance BIEE) (P = 2 kW, nitrogen flow rate = 50 l/min, 25 mm below the electrode end)

Comparison of the measured and simulated emission spectra of OH radicals, \( N_2 \) molecules (a) and \( N_+ \) ions (b) as a function of axial nitrogen flow rate \( Q_{N_2} \) (nitrogen flow rate = 50 l/min, 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 \( N_+ \) 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 \( N_+ \) ions determined from 463-472 nm band were in equilibrium in nitrogen microwave plasma. The vibrational temperature of \( N_+ \) 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.

REFERENCES:

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