Low-temperature microwave microplasma for bio-decontamination

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Motivation

The growing interest in the atmospheric pressure low-temperature microplasmas ready to use in the biomedical applications, such as: sterilization of medical instruments, high-precision surgery, cells treatment and deactivation of bacteria and viruses

Microwave Microplasma Source (MmPS)

Technology

Coaxial line system

Tungsten inner conductor

Microwaves

Frequency: 2.45 GHz

Absorbed power:

5-50 W (Argon)

50 - 300 W (Nitrogen)

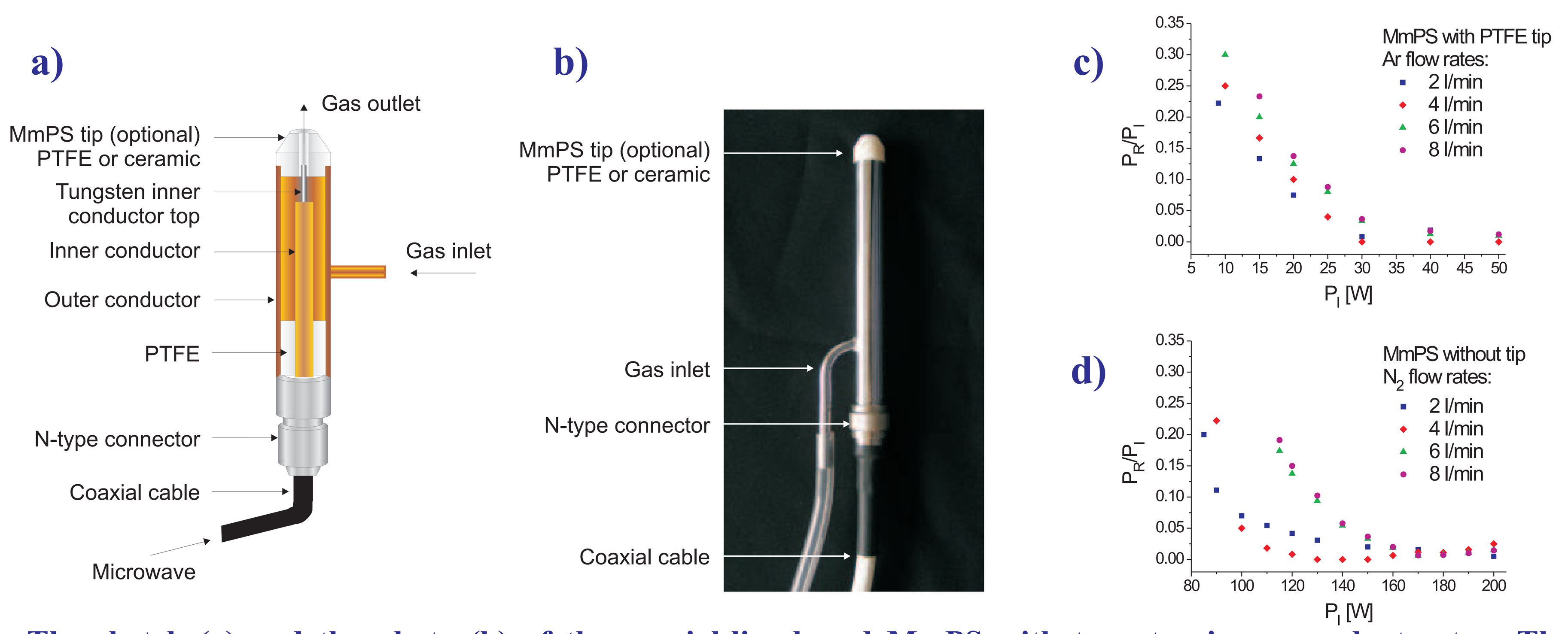
Working gases

Ar, Ar / O_2 (up to 5%),

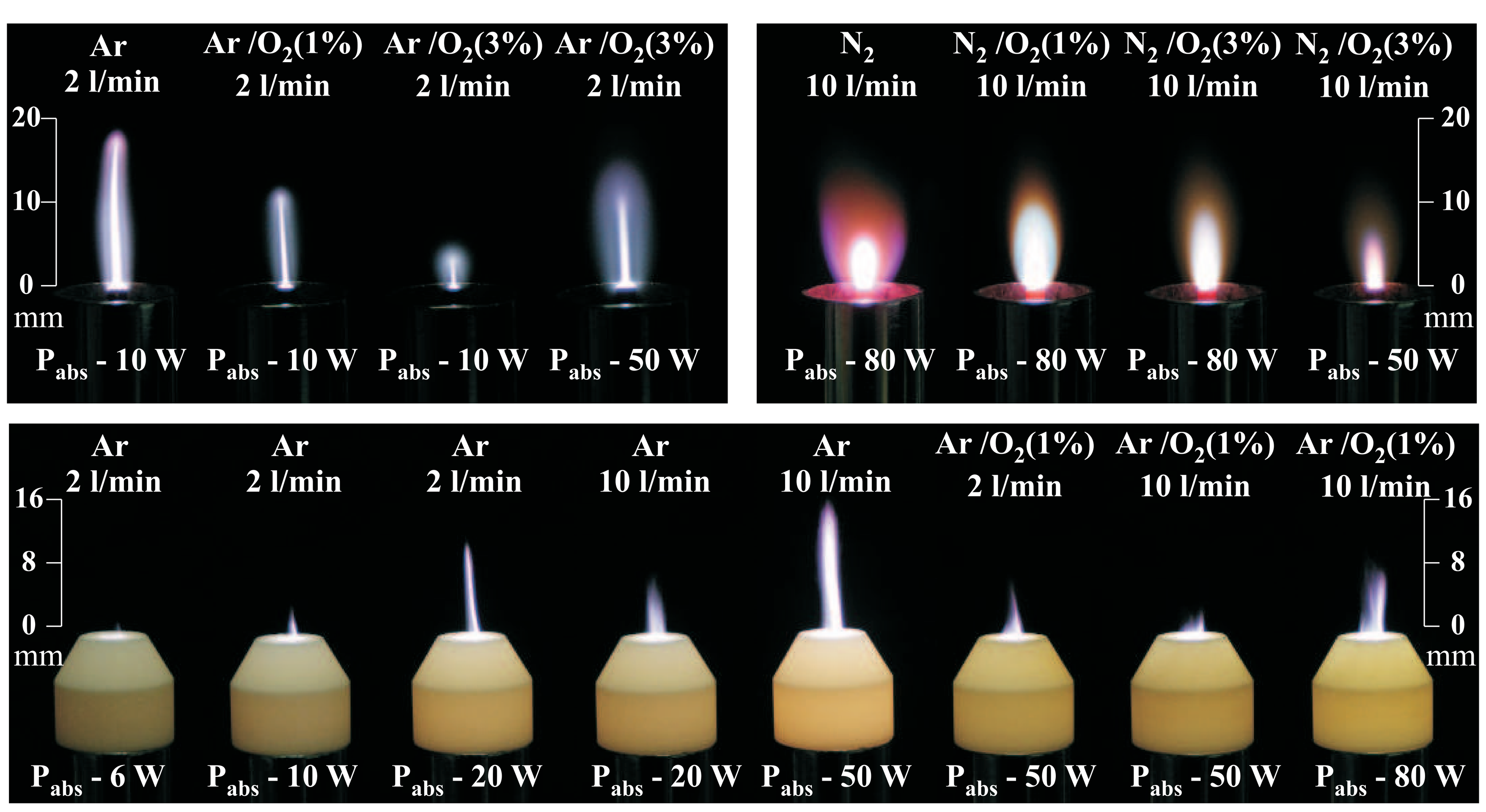
N_2, N_2 / O_2 (up to 5%)

Gas flow rate: 1-10 l/min

Gas pressure: atmospheric



The sketch (a) and the photo (b) of the coaxial-line-based MmPS with tungsten inner conductor top. The reflection coefficient P_R/P_I (P_R - reflected microwave power) as a function of the incident microwave power P_I for the different argon (c) and nitrogen (d) flow rate.



The photos of the microwave microplasma for various operating gases. MmPS without a tip and with the MACOR ceramic tip.

Experimental Setup

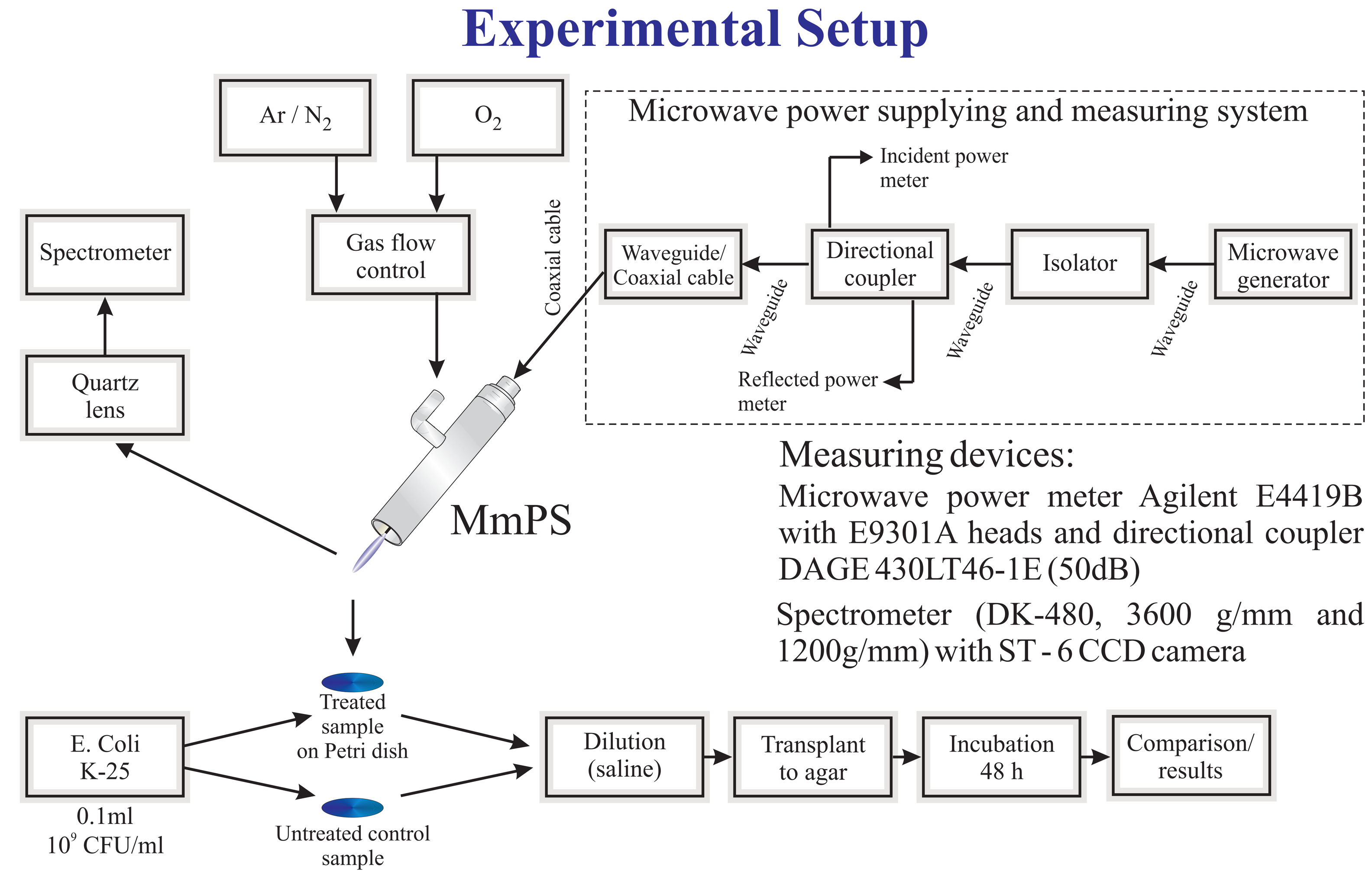
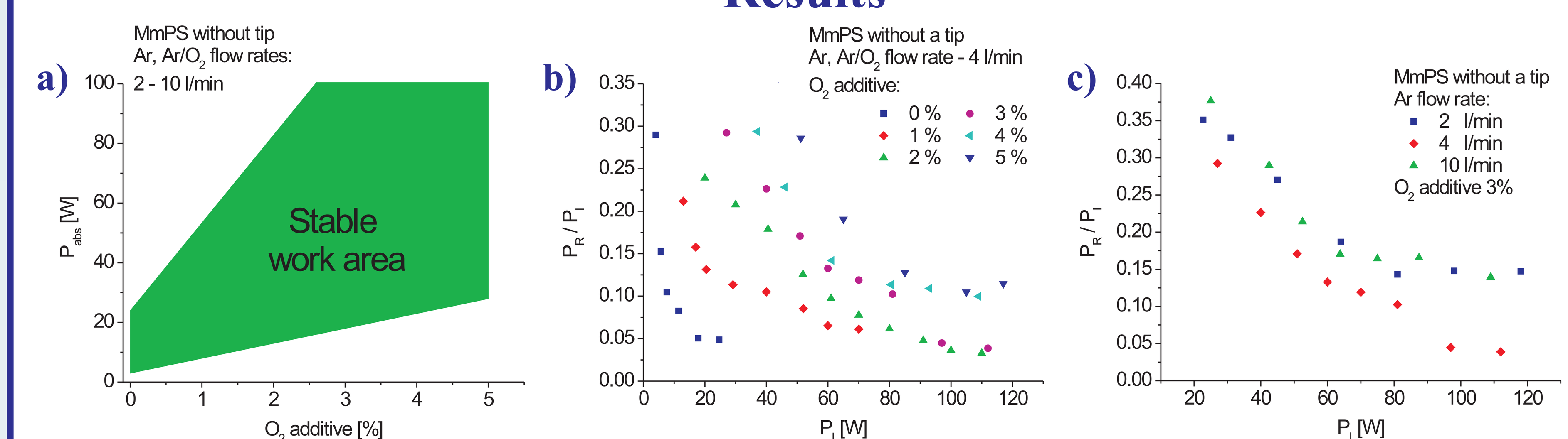
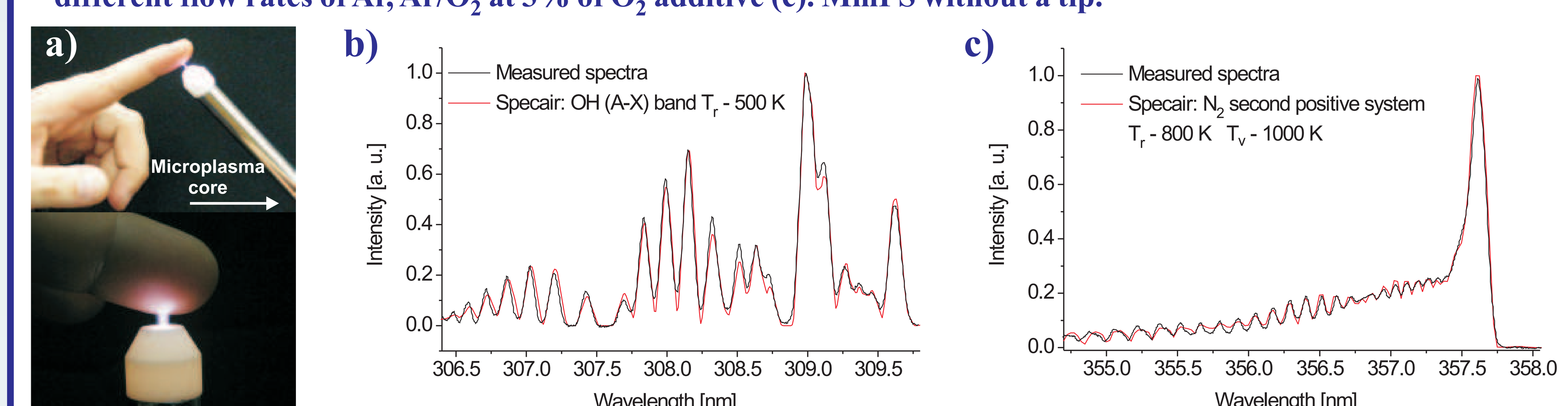


Diagram of the experimental setup for diagnostics of low-temperature microplasma for bio-sterilization.

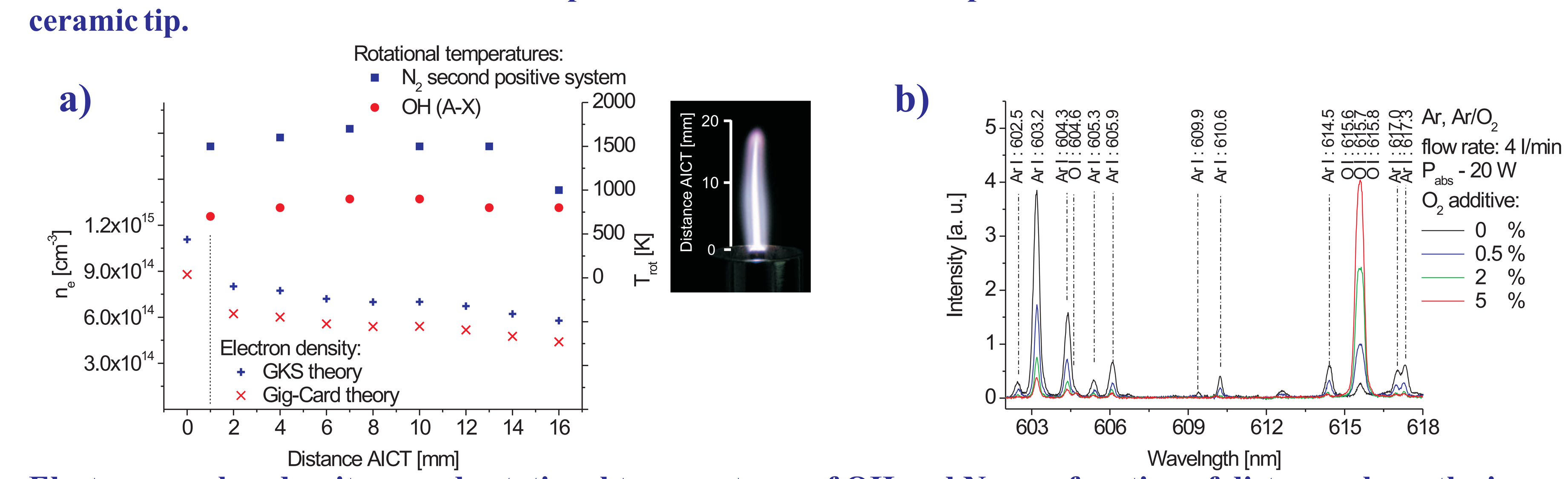
Results



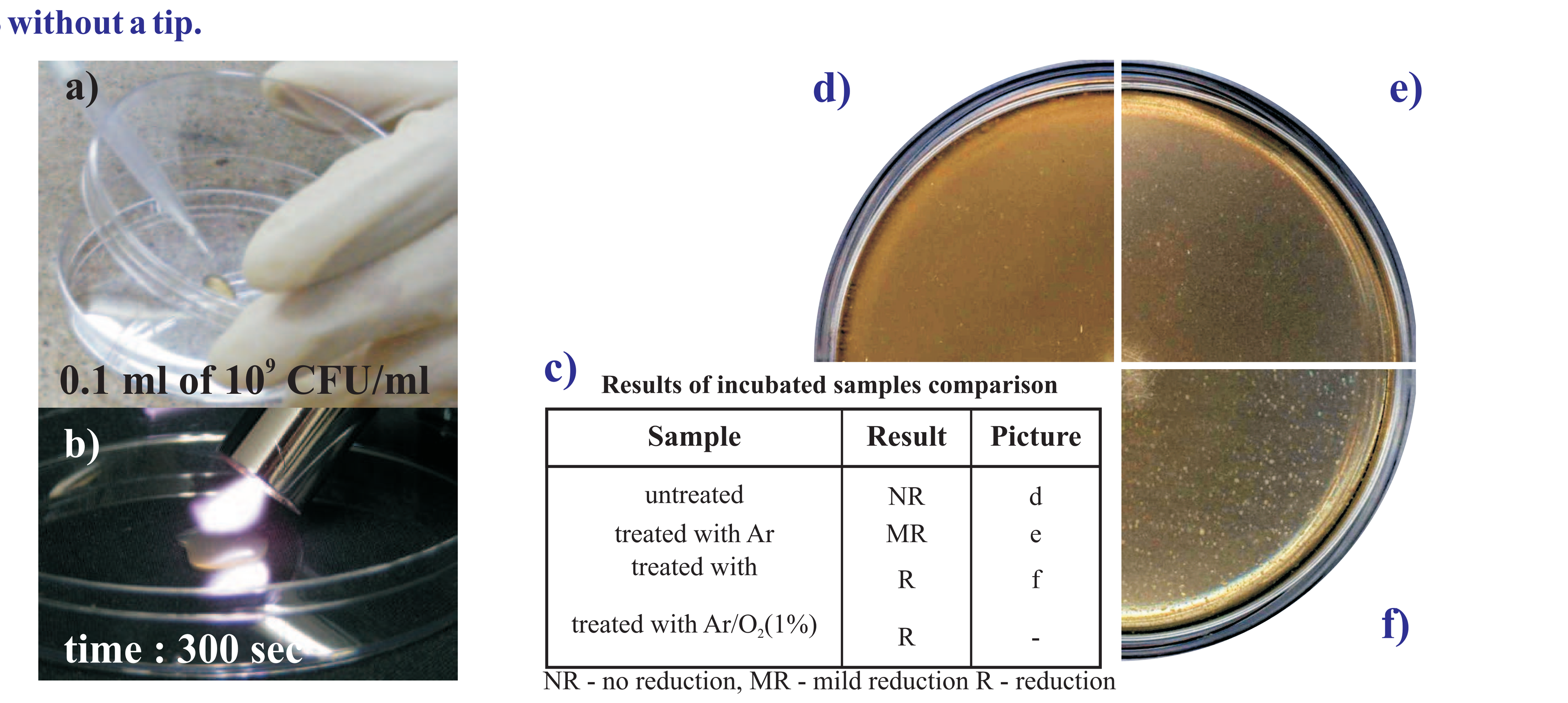
Required absorbed microwave powers for stable microplasma generation for different O_2 additive (a). Ar, Ar/O_2 flow rate from 2 l/min to 10 l/min. The reflection coefficient P_R/P_I (P_R - reflected microwave power) as a function of the incident microwave power P_I for the different O_2 additive at Ar, Ar/O_2 flow rate of 4 l/min (b) and for different flow rates of Ar, Ar/O_2 at 3% of O_2 additive (c). MmPS without a tip.



Photos of Ar microplasma (a), comparison of the measured and simulated in Specair program emission spectra of OH (A-X) band (b) and N_2 second positive system (c). 3600 g/mm grating, P_{abs} - 10 W, Ar flow rate - 10 l/min. The observation area within Ar microplasma: core of the visible part of column. MmPS with the MACOR ceramic tip.



Electron number density n_e and rotational temperatures of OH and N_2 as a function of distance above the inner conductor top (AICT) in Ar microplasma column. P_{abs} -10 W, Ar flow rate - 2 l/min (a). Influence of O_2 additive on emission spectra at 602-618 nm (4 mm above inner conductor top). P_{abs} -20 W, Ar, Ar/O_2 flow rate 4 l/min (b). MmPS without a tip.



c) Results of incubated samples comparison

Sample	Result	Picture
untreated	NR	d
treated with Ar	MR	e
treated with	R	f
treated with Ar/O_2(1%)	R	-

NR - no reduction, MR - mild reduction R - reduction

Preliminary test with *Escherichia coli* K-25 bacteria. Placing of 0.1 ml dilution (10^9 CFU/ml) on sterile Petri dish (a). Sample treated with microplasma at microwave absorbed power of 10 W and flow rate of 4 l/min (b). Results confirmed bacteria reduction in treated samples (c): uniform bacteria colony distribution (d) in the untreated sample and spotted bacteria colony distribution in Ar (e) and Ar/O_2 (f) microplasma treated samples.

Summary

- The microplasma is high density ($6 * 10^{14}$ to $1.4 * 10^{15}$ cm^{-3}, depending on operating parameters and location within the microplasma column).
- The active spicies like: OH and O are present in microplasma.
- The rotational temperatures are about 500 K for OH radicals and 800 K for N_2 molecules in the core of microplasma column. Using a thermocouple we found that the microplasma gas temperature at the microplasma tip could be as low as 300 K.
- **Preliminary test with *Escherichia colii* K-25 indicated antibacterial effect of Ar and Ar/O_2 microplasma.**
- The simplicity of the source, stability of the microplasma and wide range of its parameters allow the conclusion that the MmPS can find practical applications in various fields.

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