Low-temperature microwave microplasma for bio-sterilization

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Résumé

We present results of the investigations of an atmospheric pressure argon microwave (2.45 GHz) microplasma which can be used in the biomedical applications. The microplasma in the form of a column was generated using a simple coaxial microwave microplasma source (MMS). The performance of MMS was tested at argon flow rate from 1 to 10 l/min and absorbed microwave power from 5 to 50 W. The length and diameter of microplasma ranged from 0.5 - 25 mm and 0.5 - 2 mm, respectively, depending on the operating parameters. The microwave power reflection coefficient (P_R/P_I) in the MMS was about 5% without any tuning elements. The spectroscopic investigations of the microwave microplasma were carried out to determine the electron density and the rotational temperature of heavy spices in the microplasma. The measured electron density varied from 10^{14} to 10^{15} cm^{-3}, depending on operating parameters and location within the microplasma column. The rotational temperatures were determined to be about 700 K for OH radicals and 800 K for N_2 molecules which were present in the microplasma due to the absorption of gases, including water vapour, from the ambient air. The gas temperature at the microplasma tip was as low as about 300 K. This makes the microwave microplasma suitable for many applications, also biomedical.

Introduction

The interest in the atmospheric pressure low-temperature microplasmas is growing because of many merits of such a microplasma: small size (from µm to several mm), portability of the source, easy to use, low investment and operation costs. The microplasmas can be used for gas cleaning, in microwelding and surface modification, as light sources, and atomic spectroscopy systems. Also there is interest in using the microplasmas in the biomedical applications such as sterilization of medical instruments, high-precision surgery, cells treatment and deactivation of bacteria and viruses [1-4]. Here we report results of the experimental investigation of a simple coaxial MMS [5] operated in argon. The presented MMS is a more advanced version of previous MMSs developed by us and described in [6-9]. The main advantages of the presented MMS are simplicity and low cost.

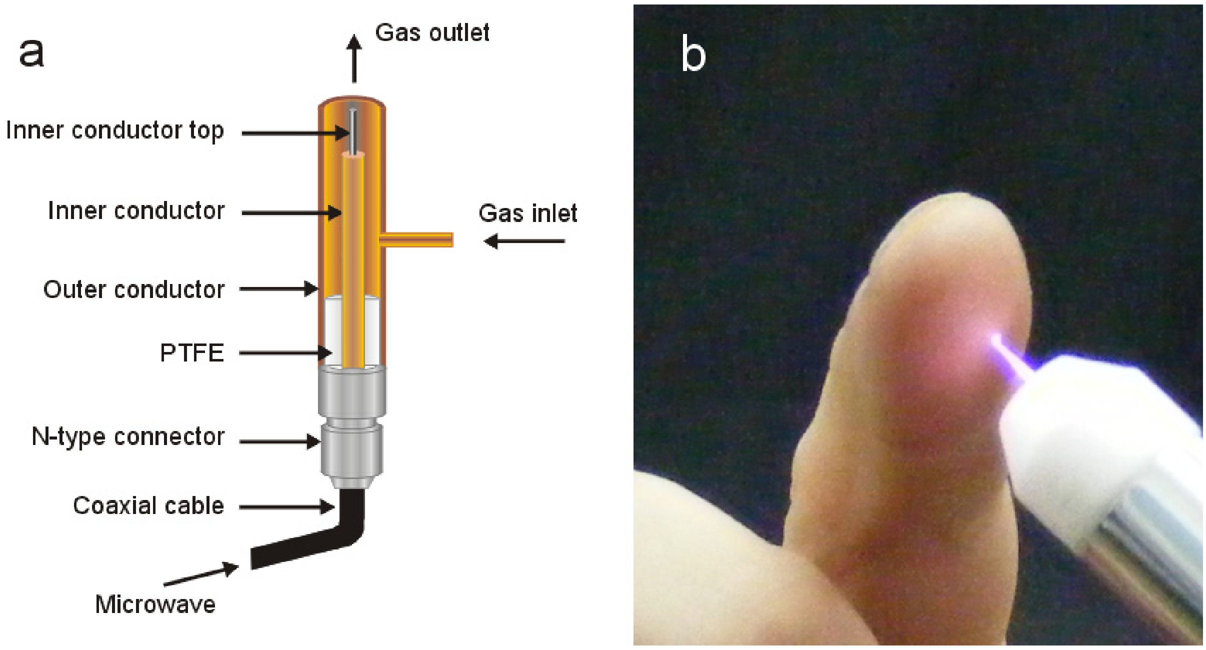

Fig. 1: The sketch of the MMS (a) and photo of low-temperature argon microwave microplasma (b).

The structure of the MMS is based on a coaxial line, formed by the inner (a brass rod ended with a thinner rod top) and outer (a brass cylinder) conductors (Fig. 1a). The top of inner conductor can be made of various materials (e.g. tungsten or graphite). The inner conductor is fixed inside the outer conductor tightly with a PTFE centering disc. The operating gas (in this case argon) was supplied through a void duct between the inner and outer conductors. The MMS was connected to the coaxial cable using N-type connector. The microwave power was supplied through a 50 Ω coaxial cable from a 2.45 GHz microwave magnetron generator. The argon microplasma generated by the MMS had the form of a tiny candle-like flame above the inner conductor top. Optionally the MMS could be operated with a PTFE tip, as seen in Fig. 1b. This tip played three functions: it formed a kind of nozzle that increased the velocity of argon in plasma forming zone, it prevented breakdowns between the inner and outer conductors, and it covered the hotter part of the microplasma column, thus exposing only the lowest temperature microplasma (i.e. its tip). The MMS was not equipped with any tuning element.

Experiments

To assess the usefulness of the argon microwave plasma for the biomedical applications, e.g. for sterilization, we performed spectroscopic measurements (Optical Emission Spectroscopy) of the electron density and microplasma temperatures. The main parts of the experimental setup used in these measurements were the magnetron generator (2.45 GHz), microwave power measuring system, the MMS, gas supplying and flow control system, and spectrometer (CVI DK-480 with 1200 gr/mm and 3600 gr/mm grating), equipped with a CCD camera and a PC computer, for emission spectra analysis. The microwave power P_{abs} absorbed by the microplasma was determined from the difference (P_I - P_R), where P_I and P_R are the incident and reflected microwave powers, respectively. The incident P_I and reflected P_R microwave powers were directly measured using directional coupler and dual-channel power meter. The measured power reflection coefficient (P_R/P_I) was about 5%.

The electron density in the argon microplasma was determined from the Stark broadening of H_β spectral line of the hydrogen Balmer series which was observed in the emission spectrum due to the presence of water vapour in the microplasma (from the ambient air). The rotational spectra of OH radicals ($A^2\Sigma^+ \rightarrow X^2\Pi$) and N_2 molecules second positive system ($C^3\Pi \rightarrow B^3\Pi$) were employed for the determination of rotational temperatures of OH and N_2 species. The measured spectra were compared with those simulated in SPECAIR program [10] in order to determine rotational temperatures of OH radicals and N_2 molecules. The rotational temperatures were determined to be about 700 K for OH radicals and 800 K for N_2 molecules at the microplasma column base. Using a thermocouple we found that the microplasma gas temperature at the microplasma tip could be as low as 300 K. These values were measured at an absorbed microwave power of 10 W. The obtained allows us to estimate the microplasma gas temperature.

Conclusions

The simplicity of the source, stability of the microplasma and wide range of its parameters allow the conclusion that the MMS can find practical applications in various fields. The usefulness the argon microplasma described in this paper for bio-sterilization is under tests.

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