Characterization of an intermittent negative dc - corona discharge in argon designed for medical applications

R. Brandenburg, T. Gerling, R. Bussiahn, E. Kindel, T. Hoder, Ch. Wilke, Th. von Woedtke, K.-D. Weltmann
Leibniz Institute for Plasma Science and Technology e. V. (INP Greifswald),
Felix-Hausdorff-Str. 2, D-17489 Greifswald, Germany;
e-mail: brandenburg@inp-greifswald.de

Résumé

Beside the characterization of biological and medical effects of plasmas a profound physical understanding of such discharges is required. Consequently, plasma sources under investigation in plasma medicine and biology had been developed or adapted for the treatment of biological samples up to living objects. Such plasmas have to be investigated under realistic conditions, which is a challenging task for diagnostics as well as simulation. In this contribution the investigation and characterization of a novel plasma source developed for special medical applications by fast optical and spectroscopic methods is described.

Introduction

Plasma medical applications require non-thermal plasma sources for atmospheric pressure operation. The design and properties of such plasma sources is determined by the application itself [1]. In particular for the treatment of human skin the gas temperature of the plasma should be lower than 300K, which can be achieved by pulsed operation in the nanosecond time regime. Recently a novel device for the generation of a nanosecond pulsed cold plasma using a dc-power supply was described [2]. This so-called hairline plasma source produces a very thin plasma filament. Due to its geometrical parameters it is particularly suitable for the treatment of microscopic cavities, which might help to overcome problems in endodontic treatment in dentistry (fig. 1).

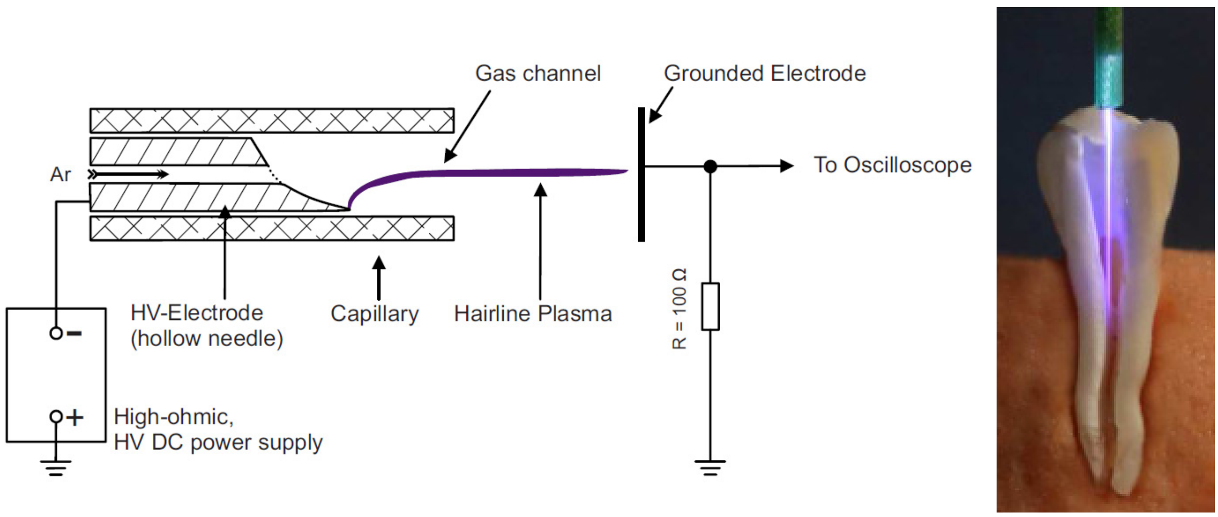

Fig. 1: Schematic of the hairline plasma device (left) and in operation on a prepared human tooth showing the plasma filament in the root canal (right) [2]

The anti-microbial efficiency has been demonstrated by exposing Escherichia coli colonized agar plates to the discharge. The path where the plasma filament was moved over the agar shows a localized antibiological effect of the plasma. Current pulses were measured and its repetition frequency was derived. Pulses between 0.4 and 1.4 A with FWHM of about 10 ns and repetition frequencies from 1 to 3 kHz were obtained Furthermore a broad characterization of the plasma filament by optical emission spectroscopy in the VUV and in UV/VIS spectral range was performed. In this contribution we will focus on the discharge development and its influence by operation parameters.

Experimental

The intermitted dc-corona plasma device (see fig.1, left) consists of an inner high voltage hollow needle electrode (outer diameter 0.8 mm) connected with the negative pole of a high ohmic high voltage dc - power supply (U = 1 - 14 kV). The needle electrode is surrounded by an insulating capillary forming a gas channel in front of the electrode (length of some millimetres). The feed gas used here is argon which is supplied through the inner channel of the hollow needle. The second electrode is connected with the grounded positive pole of the power supply. The distance between the end of the capillary and the second electrode can be up to 1.5 cm. In dependence on the electrode distance and the applied voltage a plasma filament appears between both electrodes with a typical radial extension of 30 µm and a maximal length of 1.8 cm. In order to investigate the discharge development an ICCD camera equipped with a far field microscope was used. The spatially and temporally resolved development of light emissions at selected wavelengths was performed by means of Cross-Correlation Spectroscopy [3].

Results and discussion

The fig. 2 shows an example of the discharge development derived from the measurements at λ= 337 nm and 391 nm, which are the 0-0-transitions of the molecular band of the second positive system of N_2 and the first negative system of N_2^+, respectively. The argon plasma is operated at open atmosphere causing the mixture with the surrounding air. In the figures the axial coordinate is the ordinate, while the abscissa is the time scale (which is only relative due to the nature of CCS measurements). The tip of the needle electrode (cathode) is at 0 mm, while the horizontal line at 5 mm shows the end position of the quartz tube. The grounded electrode (anode) is located at 8.2 mm. The number of counted photons is colour coded in logarithmic scale.

The results demonstrate the highly complex development of the plasma filament. Five subsequent phases are investigated, namely (i) pre-phase (t < 125 ns) with maximal emission in front of the capillary, (ii) anode directed front of light (negative streamer) (t= 125 … 140 ns), (iii) cathode directed front or streamer (t= 140 … 155 ns), (iv) plasma column with high energetic species (t= 145 … 160 ns) and (v) decay phase (t> 160 ns). The contribution will discuss the discharge formation in detail with special attention to biomedical applications.

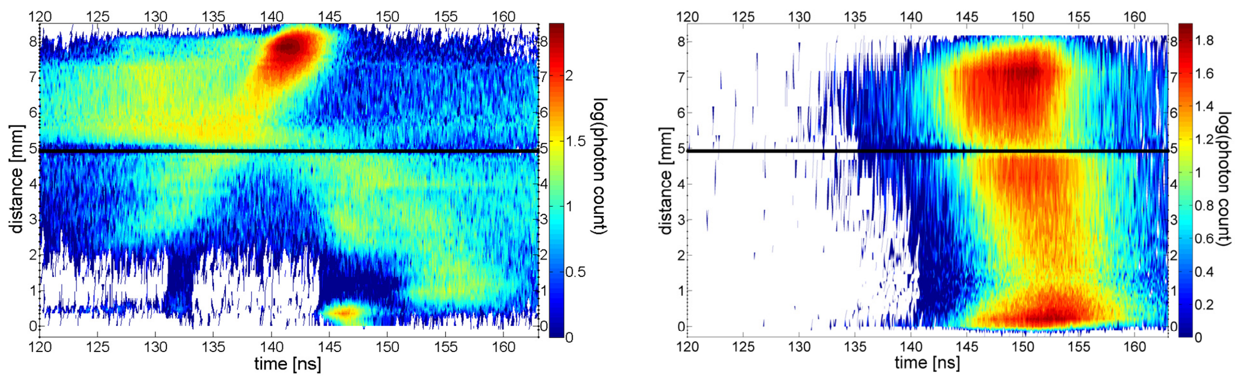

Fig. 2: Spatio-temporal development of intermittent negative dc-corona filaments in flowing argon for N_2* (left; λ= 337 nm, 11 eV excitation energy) and N_2^+* (right; λ= 391 nm, 19 eV exc. energy)

Acknowledgements

This study was realized within the joint research project "Campus PlasmaMed" supported by the *German Federal Ministry of Education and Research* (grant no. 13N9779).

References

[1] K.-D. Weltmann, E. Kindel, Th. V. Woedtke, M. Hähnel, M. Stieber, R. Brandenburg, Pure Appl. Chem. **82** (2010) 1223.
[2] R. Bussiahn, R. Brandenburg, T. Gerling, E. Kindel, H. Lange, N. Lembke, K.-D. Weltmann, Th. von Woedtke, T. Kocher, Appl. Phys. Lett. **96** (2010) 143701.
[3] K.V. Kozlov, H.E. Wagner, R. Brandenburg, P. Michel, J. Phys. D: Appl. Phys. **34** (2001) 3164.