Low temperature atmospheric argon plasma: Diagnostics and medical applications

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Résumé

We present here the methods of optical and probe diagnostics of low temperature plasma produced by microwave generator with frequency of 2.45 GHz at low power (~ 150 W) and at low temperatures of a gas (argon) flow (< 40°C). The spatial distribution of a brightness temperature in plasma was obtained. The profile of gas temperature near the torch outlet was measured. High-resolution vibrational-rotational spectrum in a wide range of wavelengths was derived by the method of optical emission spectroscopy. Probe measurements of the floating potential of plasma were carried out. The estimation and adaptation of parameters of a plasma flow (temperature, velocity, ion number density) according to medico-technical requirements were obtained.

Introduction

Use of plasma in medicine was connected with its thermal effect on a processed surface until nowadays. However, non-isothermal plasma influence has been of great interest recently because of a possibility of its application for obtaining of various effects: sterilizations, healing of wounds, cell detachment, etc. Presented are the methods of optical and probe diagnostics of low temperature plasma produced by microwave generator with frequency of 2.45 GHz at low power (~ 150 W) and at low temperatures of a gas (argon) flow (< 40ºC).

Fig. 1: The generator of low temperature argon plasma

Diagnostics and experiments

The generator of low temperature argon plasma (fig. 1) is the electrode of complicated configuration placed in the grounded metal cylinder with connecting pipe for delivery of buffer gas of argon. When pumping argon through a discharge gap with speed of 4-8 l/min and providing magnetron power 120-150W a flow of microwave discharge plasma is obtained and small plasma channels between the end of the electrode and an internal surface of the grounded cylinder are formed. Diameter of a plasma stream in such conditions is not less than 30 mm. Inert gas consumption controls is carried out by system of monitored inflow. Speed of argon flow defines a length of plasma torch which was about 35-45 mm in our experiments. To derive such parameters of a plasma torch as temperatures, floating potential, plasma components, we chose typical parameters of biological experiments with microorganisms, mammal tissue and person (power of the discharge - 120W, speed of argon flow - 5 l/min, orifice gas - argon with purity of 99.998 %). The plasma torch was fastened on an optical table with possibility of its exact positioning in space by means of micrometric screws (fig. 2). The room temperature was 19ºC. Optical diagnostics was used for obtaining of spatial distribution of a brightness temperature in plasma torch behind a discharge outlet (fig. 3). Survey of plasma was made by a digital

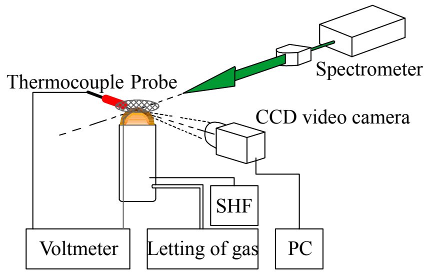

Fig. 2: The generator of low temperature argon plasma

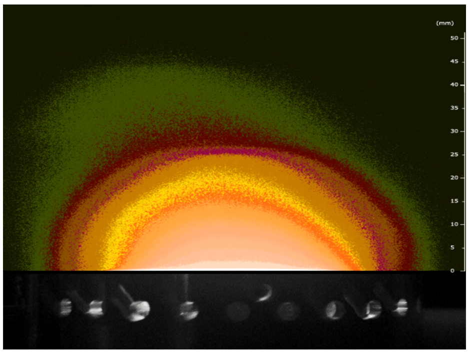

Fig. 3: The distribution of a brightness temperature in plasma torch behind a discharge outlet

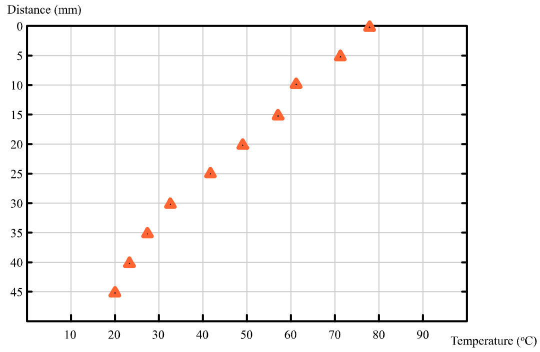

Fig. 4: Gas temperature distribution in plasma behind a torch outlet

CCD-camera. We optimized the location of the camera during the experiment, its time resolution varied in a range of 10-40 μs. The image of plasma of a torch received by specified way was processed then on the computer by means of specially developed software. We measured gas temperature in plasma behind a torch outlet by the shielded thermocouple to exclude distortions of measurement results owing to plasma influence on a thermocouple current (fig. 4). We used chromel-alumel type of the thermocouple that is suitable for temperature measurements in a range up to 1100°C.

Spectrometer Avesta ASP 150TF was used for realization of a method of optical emission spectroscopy of a torch to obtain high-resolution vibrational-rotational spectrum in a wide range of wave lengths. The width of the spectrometer entrance slit was 100 μs. The information about emission was gathered by series of CCD-detectors connected with the computer. Monochromator resolution with 2400 dashes of a lattice per 1 mm was 0.016 nm. Exposition time of CCD was generally 0.02 s, signal was amassed during 10 expositions. The area of a covering of a spectrometer was 185-1105 nm. Plasma emission was focused on the end of the optical fiber that was connected with spectrometer.

We designed special, so-called net probe to measure a floating potential of plasma. With the help of it we obtained longitudinal profiles of a plasma field along the torch. The net probe was kept by a molybdenum holder and covered a plasma torch completely. When measuring we regulated a position of a torch to a net probe from 0 to 45 mm. the profile of a floating potential of a grid in plasma torch along an axis z is presented on fig. 5. Plasma density in this area is estimated in a range of 10^5-10^6 cm^{-3} that is sufficient for an effective charging of small biological objects. In this case charging time is defined by the 100-th and tenth fractions of a second that is much less than time of processing of working surfaces. Further, measurements had shown that in an interval of 5-35 mm behind torch outlet the potential of an electrode decreased to 5V.

During biomedical experiments we investigated an influence of low temperature argon plasma on microbal biofilms and on animal (rats) while modeling an infection. Quantitative estimations of a survival of bacterial cells in vitro after an irradiation were derived. The obtained results let us assert that the considerable percent of bacteria in a biofilm perishes after plasma effect. We also estimated an efficiency of healing of a wound by reduction of the area of its surface.

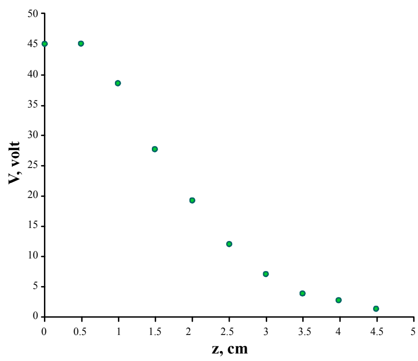

Fig. 5: Profile of a floating potential of a grid in plasma torch along an axis z.

Conclusion

The estimation and adaptation of parameters of a plasma flow (temperature, velocity, ion number density) according to medico-technical requirements were obtained. Research results had shown an efficiency of low temperature argon plasma effect on biological objects in vitro and in vivo for disinfecting and healing of the festering wounds.

Acknowledgments

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