Low Temperature Non-Thermal Plasmas at Atmospheric Pressure: Diagnostics and Medical Applications

Oleg Petrov[1], Svetlana Ermolaeva[2], Mikhail Vasiliev[1], Elena Sysolyatina[2], Igor Samoilov[1], Ravil Amirov[1], Andrei Mukhachev[2], Tetsuji Shimizu[3], Boris Naroditsky[2], Gregor Morfill[3], Anatoly Grigoriev[4], Vladimir Fortov[1], Alexander Gintsburg[2]

[1] *Joint Institute of High Temperatures RAS, Moscow, 125412, Russia*
[2] *Gamaleya Institute of Epidemiology and Microbiology, Moscow, Russia*
[3] *Max Planck Institute for Extraterrestrial Physics, Munich, Germany*
[4] *Institute of Biomedical Problems RAS, Moscow, Russia*
E-mail: ofpetrov@ihed.ras.ru

This study was devoted to diagnostics of low temperature plasma non-thermal plasmas at atmospheric pressure and investigation of its bactericidal effect against bacteria in biofilms and within eukaryotic cells.

In our studies the low temperature plasmas were 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) and by the ferroelectric bed reactor (ferroelectric packed-bed technology) that employs a high-voltage DC and AC power supplies in conjunction with a tubular reactor packed with high-dielectric ceramic pellets. Usually the pellets are held within the tube arrangement by two metal mesh electrodes. When external voltage is applied across the high dielectric layer, the pellets are polarised, and an intense electric field is formed around each pellet contact point. Many pulsed discharges take place around each contact point of the ferroelectric pellets, and the discharge energy can be controlled by changing the dielectric constant of the pellet, and by the voltage waveform.

Complex plasma diagnostic measurements under various regimes of work were carried out. It was performed with the use of method of optical imaging, optical emission spectroscopy, chemical gas analysis of plasma stream, and probe diagnostics of SHF radiation of the plasma torch (for microwave discharge). In the experiments the high resolution spectra of the OH around 308 nm, Ar and N_2 in the spectral range 320-850 nm were obtained. Calibration of the spectrometer was carried out by deuterium and halogen lamps. A gas composition of plasma flow was analyzed: the concentrations of nitric oxide NO, nitric dioxide NO_2 and ozone O_3 were measured. The results of the probe measurements of SHF radiation for plasma torch were also presented. At some regimes of microwave plasma torch the SHF radiation can exceed 10 mW. Estimations and measurements concerned with the use of below-cutoff waveguide for elimination of SHF radiation were obtained.

The model of immersed surface-associated biofilms was used to assess bactericidal effects of plasma treatment. Reduction in the concentration of live bacteria in biofilms treated with plasma for 5 min was demonstrated. The intracellular infection model with the pathogenic bacterium, Chlamydia trachomatis, was used to study the efficacy of microwave argon plasma against intracellular parasites. A 2 min plasma treatment of mouse cells infected with C. trachomatis reduced infectious bacteria by a factor of $2x10^6$. Plasma treatment diminished the number of viable host cells by about 20 %. When the samples were covered with MgF_2 glass to obstruct active particles and UV alone was applied, the bactericidal effect was reduced by $5x10^4$ fold compared to whole plasma.