Effects of a He/O_2 atmospheric pressure plasma effluent and its components on bacteria and bio-macromolecules

Jan-Wilm Lackmann[1], Simon Schneider[2], Eugen Edengeiser[3], Steffen Brinckmann[4], Fabian Jarzina[1], Andreas Nabers[1], Lars I. Leichert[5], Jan Benedikt[2], Julia E. Bandow[1]

[1] *Microbial Biology, Ruhr University Bochum, Bochum, 44801, Germany*
[2] *Reactive Plasmas, Ruhr University Bochum, Bochum, 44801, Germany*
[3] *Institute for Physical Chemistry, Ruhr University Bochum, Bochum, 44801, Germany*
[4] *Department of Micromechanical and Macroscopic Modelling, Ruhr University Bochum, Bochum, 44801, Germany*
[5] *Medical Proteome Center, Ruhr University Bochum, Bochum, 44801, Germany*

E-mail: julia.bandow@rub.de

Using the X-Jet introduced by J. Benedikt *et al*. [1] we investigated the effects of a He/O_2 plasma effluent and its components separated into (V)UV radiation and particles on live bacteria and bio-macromolecules. We employed Environmental Scanning Electron Microscopy (ESEM) to investigate the microscopically visible effects of the plasma effluent as well as the emitted (V)UV radiation or particles on vegetative bacteria. The observed ablation of bacterial cell layers was time-dependent and strongest after treatment with the total effluent. Treatment with the particle channel led to intermediate ablation, ablation caused by the (V)UV channel was weakest but significant.
Effects of the plasma effluent and its components on DNA and proteins, two important classes of bio-macromolecules, were studied *in vivo* and *in vitro*. Evidence of plasma-mediated damage to DNA and proteins in living cells was provided by the induction of DNA and protein damage-specific reporter genes upon plasma exposure. To characterize the effects on DNA on a molecular level single-stranded and double-stranded DNA oligomers were dried on glass slides and exposed to the plasma effluent as well as to the emitted (V)UV radiation or particles separately. Raman spectroscopy revealed (V)UV-specific and particle-specific modifications of nucleobases. pUC18 plasmid DNA encoding part of the β-galactosidase enzyme for blue/white selection in *E. coli* DH5α was used as model to study the impact of plasma on DNA integrity and functionality [2]. Transformation efficiencies and mutation frequencies of dried, plasma-exposed pUC18 indicate both significant introduction of mutations and dose-dependent loss of intact plasmid DNA. Two model proteins were chosen to study plasma-related inactivation mechanisms. Glyceraldehyde 3-phosphate dehydrogenase (GapDH) enzyme activity decreased rapidly after exposure to the plasma effluent. Exposure to (V)UV radiation alone had little effect on GapDH activity, while the emitted particles alone efficiently inactivated the enzyme, though much less rapidly than the total effluent. mCherry protein was efficiently inactivated by (V)UV radiation with inactivation being reversible for exposure times up to 5 min. In contrast a 5 min exposure to the particle channel or the total plasma effluent lead to permanent mCherry inactivation.

References

[1] Schneider S., Lackmann J.-W., Narberhaus F., Bandow J., Benedikt J., Journal of Physics D: Applied Physics (2011)**, 44,** 295201–295210.
[2] Lackmann J.-W., Schneider S., Narberhaus F., Benedikt J., Bandow J. E., *In* Plasma in bio-decontamination, medicine and food security (Springer) (2012), 17–29.