Electron Spin Resonance (ESR) Measurements of Free Radicals Produced by Atmospheric Nonthermal Plasmas

S. Reed Plimpton[1], Mark Gołkowski[2], Sandra Eaton[3], Gareth Eaton[3], Czesław Gołkowski[4]

[1]*University of Colorado Denver, Department of Bioengineering, Denver, 80045, USA*
[2]*University of Colorado Denver, Department of Electrical Engineering, Denver, 80217, USA*
[3]*University of Denver, Department of Chemistry & Biochemistry, Denver, 80208, USA*
[4]*Super Pulse, Ithaca, 14850, USA*
E-mail: Steven.Plimpton@UCDenver.edu

The use of nonthermal gas discharge plasmas for biomedical applications has been validated in multiple studies over the last two decades. Although both so called 'direct' or 'indirect' methods of plasma application have been shown to be effective in pathogen inactivation, the actual mechanism of sterilization is still poorly understood. Recent inquiry regarding these processes has shown the significance of the interaction of reactive oxygen species with the cellular lipid bilayer which results in the radical mediated lipid peroxidation cascade [1]. However, the specific manner in which this process of cellular destabilization is accomplished depends strongly on the reactive species present. Although, various spectroscopy techniques have recently provided quantification of chemical species produced in a wide range of plasma discharges, knowledge of the gas phase concentrations is insufficient since subsequent chemical reactions on the surface can produce new active species. For example, peroxone chemistry [2] can create OH radicals from ozone and hydrogen peroxide. Direct measurement of free radicals such as OH is difficult because of the short lifetimes. An effective technique for quantification of short lived free radicals is ESR which utilizes a technique known as spin trapping. The resulting spin adduct (for example, but not limited to, DMPO-$OH^{\cdot}$) is spectroscopically analyzed to yield concentration measurements of reactive species as well as information regarding the chemical environment [3]. We perform ESR tests on a novel plasma device that utilizes the indirect delivery approach coupled with hydrogen peroxide additives which has demonstrated strong clinical potential [4].

The efficacy of inactivation is coupled to the engineering parameters (e.g. distance to surface, flow rate, application volume, and so on) of the design. Therefore, in order to optimize such a device for clinical application, correlation between treatment protocol and active chemical species is of upmost importance. This work demonstrates the direct investigation of free radical chemistry using electron spin resonance measurements.

References

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