Control of Gas and Aqueous Phase Reactive Chemical Species by Air Surface Micro-Discharge

Y. Sakiyama¹, T. Shimizu², H.-W. Chang¹,³, M. J. Pavlovich, D. S. Clark¹, D. B. Graves¹, and G. E. Morfill²
¹ Department of Chemical and Biomolecular Engineering, University of California, Berkeley, USA
² Max Planck Institute for Extraterrestrial Physics, Garching, Germany
³ Department of Chemical Engineering, National Taiwan University, Taipei, Taiwan

BACKGROUND

Reactive oxygen and nitrogen species (RONS) play different roles in the regulation of multiple cellular-level processes. Our previous numerical simulation [1] showed the major RONS generated by surface micro-discharge (SMD) [2] includes O₂, N₂O, N₂O₅, and HNO₂. A challenge is to control the plasma chemistry in the gas phase in such a way that the therapeutic potential can be realized. Also, aqueous-phase chemical reactions are thought to play crucial roles because cells and tissues to be treated are mostly immersed in or contact with water or other solutions. We demonstrate that distributions of SMD-generated chemical species can show surprising complexities through UV/FTIR absorption spectroscopy. In addition, we discuss the inactivation mechanisms of E. coli cells on agar plate and in liquid medium.

REACTIVE OXYGEN AND NITROGEN SPECIES IN GAS PHASE

A simplified fitting model

2 unknown variables
• n(NO) and n(NO₂)
3 fitting parameters
• n(NO) T max
• t max

RONS distributions in PBS

Inactivation of E. coli

CONCLUDING REMARKS

✓ SMD shows surprisingly dynamic and transient behavior of RONS.
✓ Power density is a key parameter to control the distributions of RONS.
✓ We observed positive correlation between ozone density and inactivation rate of E. coli in gas phase.
✓ The short-term bactericidal effect in liquid phase can be explained by ozone, whereas nitrites and nitrates appears to be important for long-term sterilization efficacy.

REFERENCES


ACKNOWLEDGEMENT

SMD-generated RONS

simulation results

Bacterialicidal effect

Positive correlation between ozone density and inactivation rate of E. coli cells

REACTIVE OXYGEN AND NITROGEN SPECIES IN AQUEOUS PHASE

Short-term effect

Long-term effect

RONS distributions in PBS

Inactivation of E. coli