

Control of Gas- and Aqueous-phase ROS/RNS by Air Surface Micro-discharge for Radical Therapeutic Approach

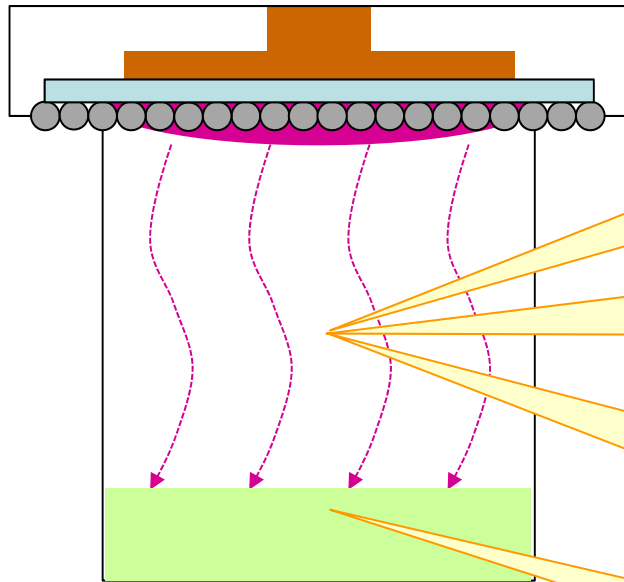
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Outline



1. gas-phase diffusion and reaction in humid air (modeling)

2. Gas-phase RONS modulation by power density (UV absorbance at 254 nm)

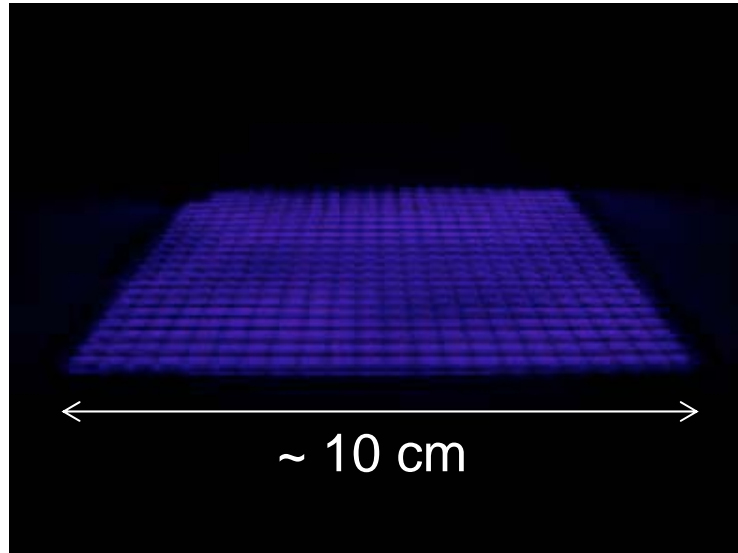
4. Gas-phase RONS modulation by water (FTIR measurement)

3. *E.coli* inactivation on agar plate for different power density (viability assay)

Device configuration

SMD = surface micro-discharge

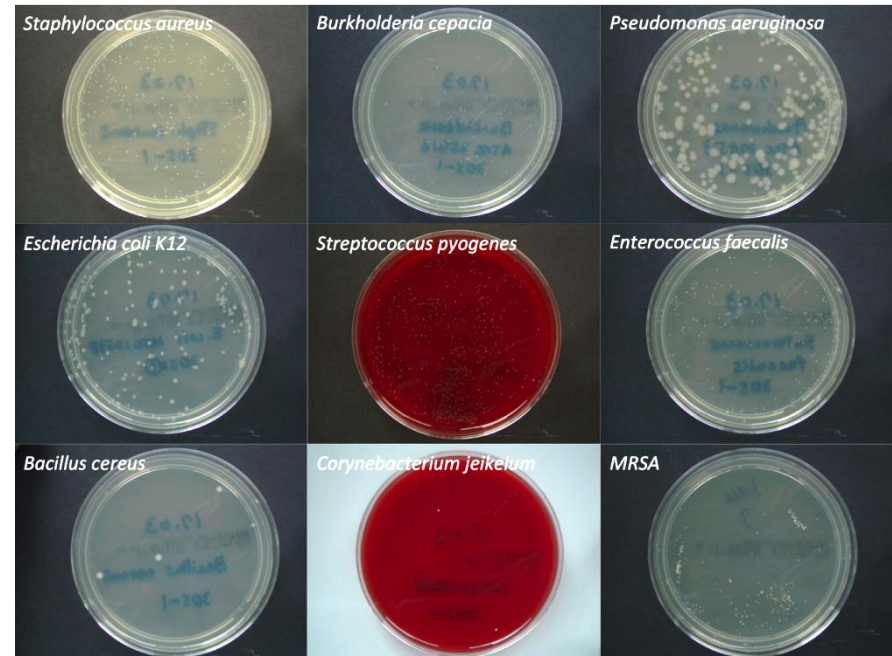
(G. Morfill et al., New J. Phys. **11** (2009) 115019)



Frequency	1-10 kHz
Voltage	1-10 kV _{pp}
Power	0.01-1 W/cm ²
Distance to sample	1-10 mm
Exposure time	1-1000 s

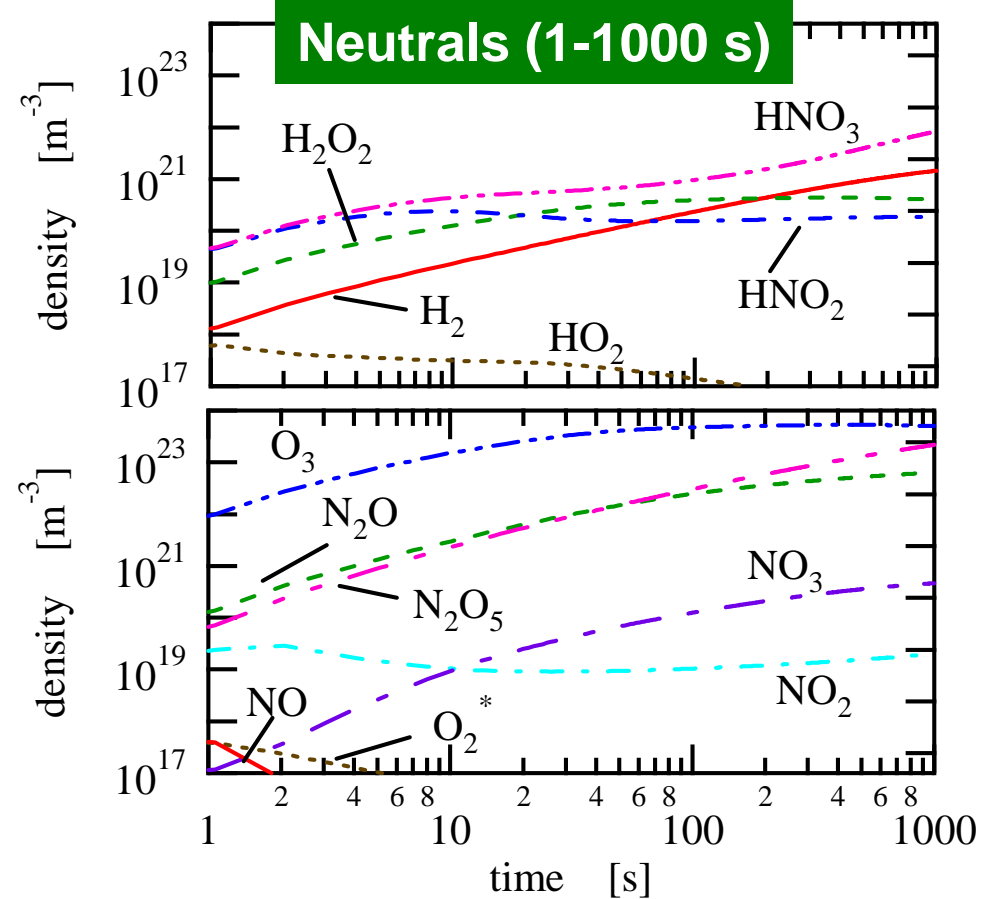
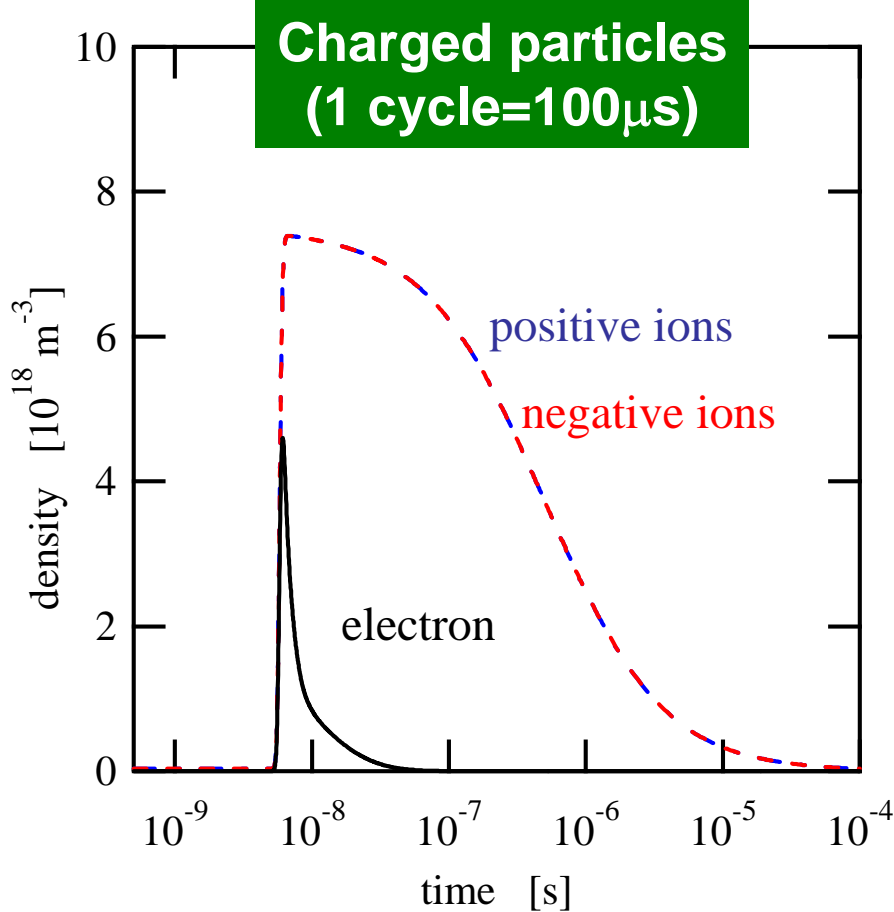
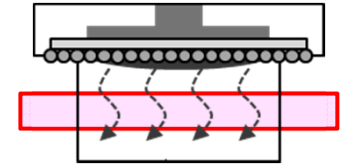
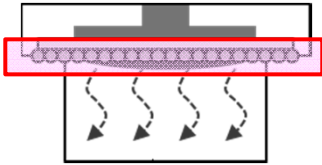
Anti-microbial effect

- $\sim 10^7$ cfu/ml
- 4-5 log-reduction in 30 s

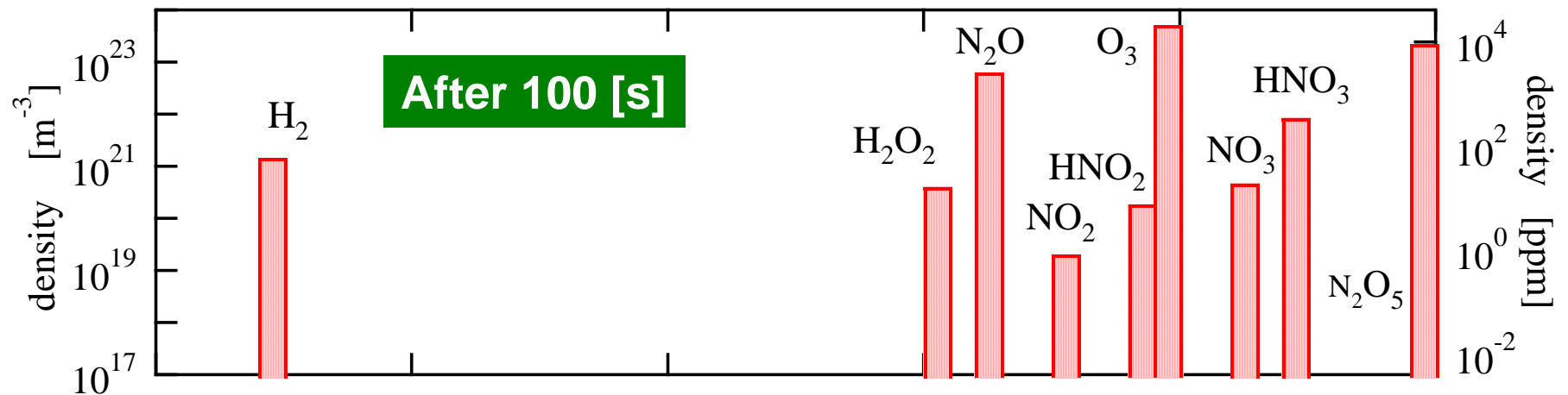


Modeling: multiple-timescale reactions

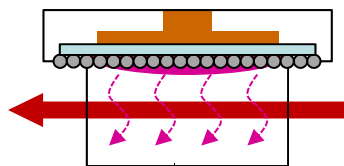
- Power density: 0.1 W/cm^2 (low power mode)
- 56 species/626 reactions with multiple-time steps
- SMD region and gas gap
- Input parameter: pulse-like electric field for 1 ns



Modeling: verification of model (low power mode)

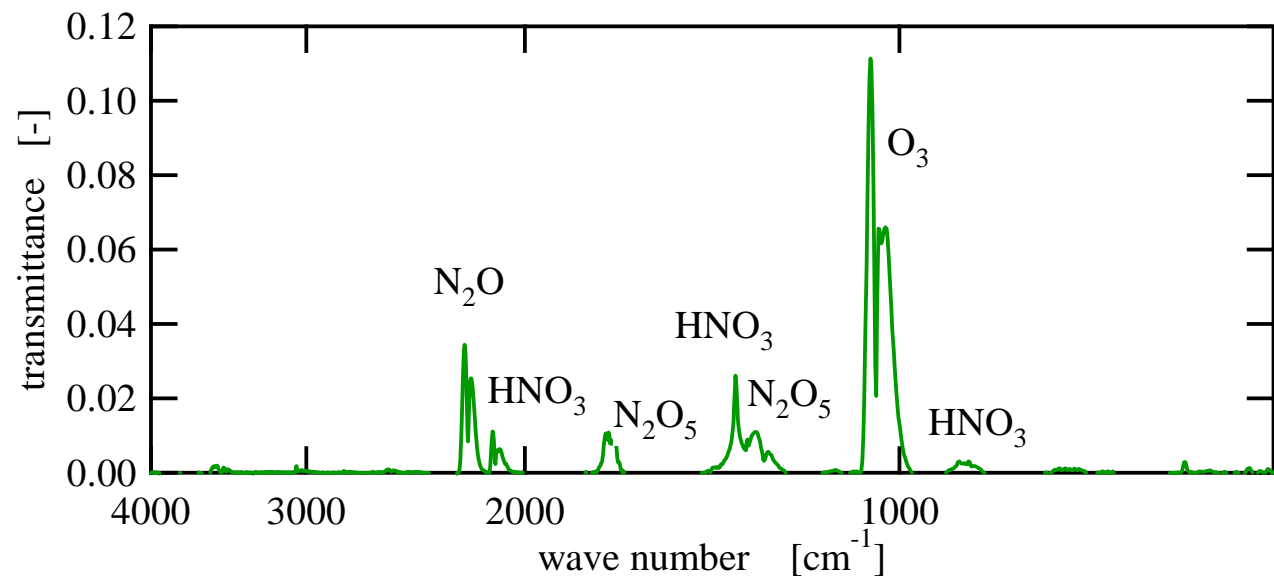


FTIR measurement (qualitative comparison)

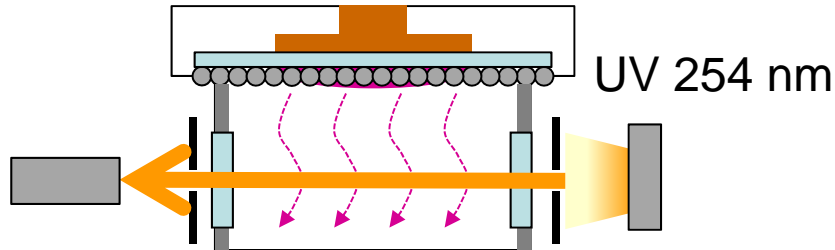


IR beam

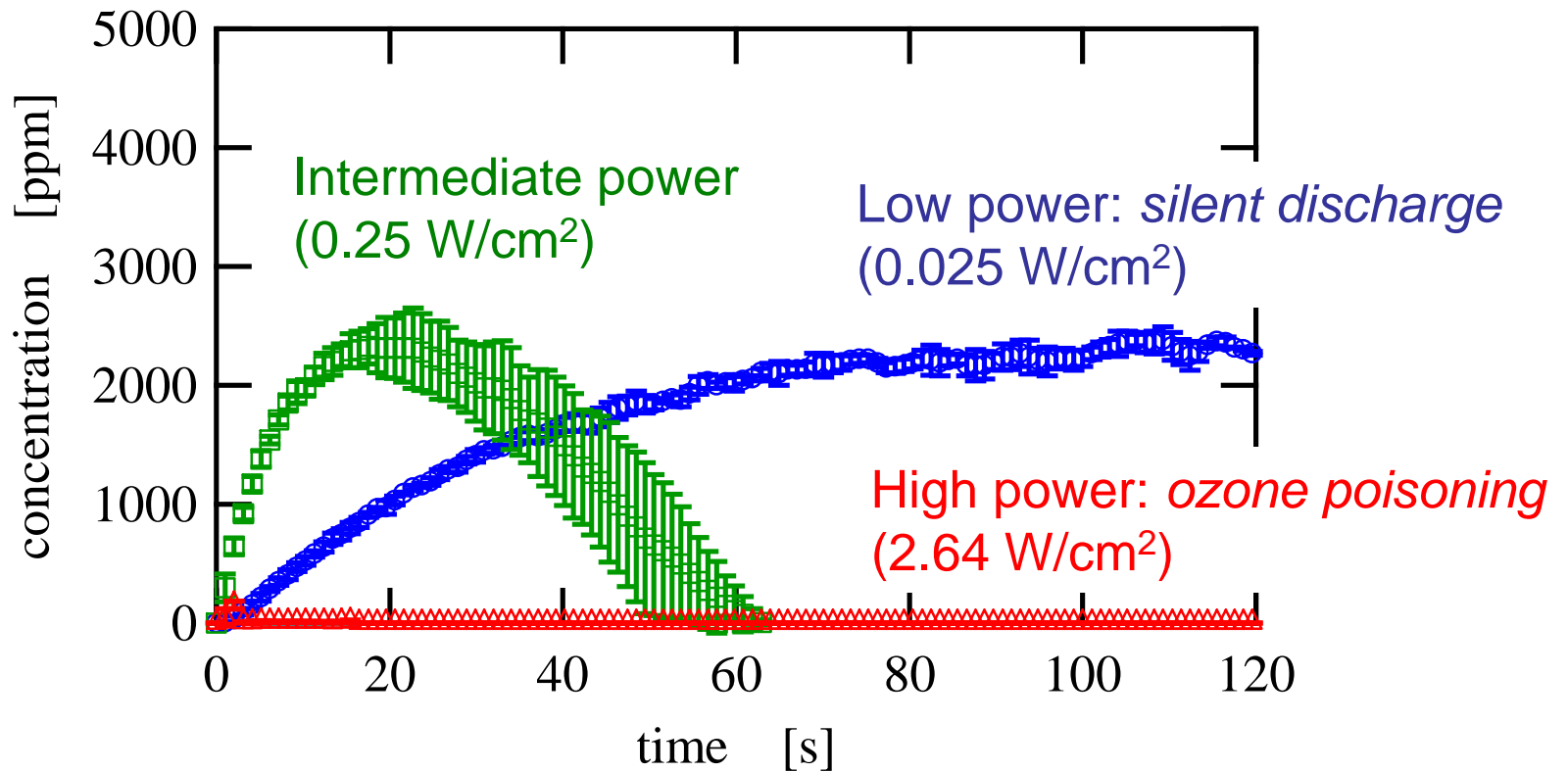
200 scans for
60-120 [s]



Gas-phase ozone: modulation by power density



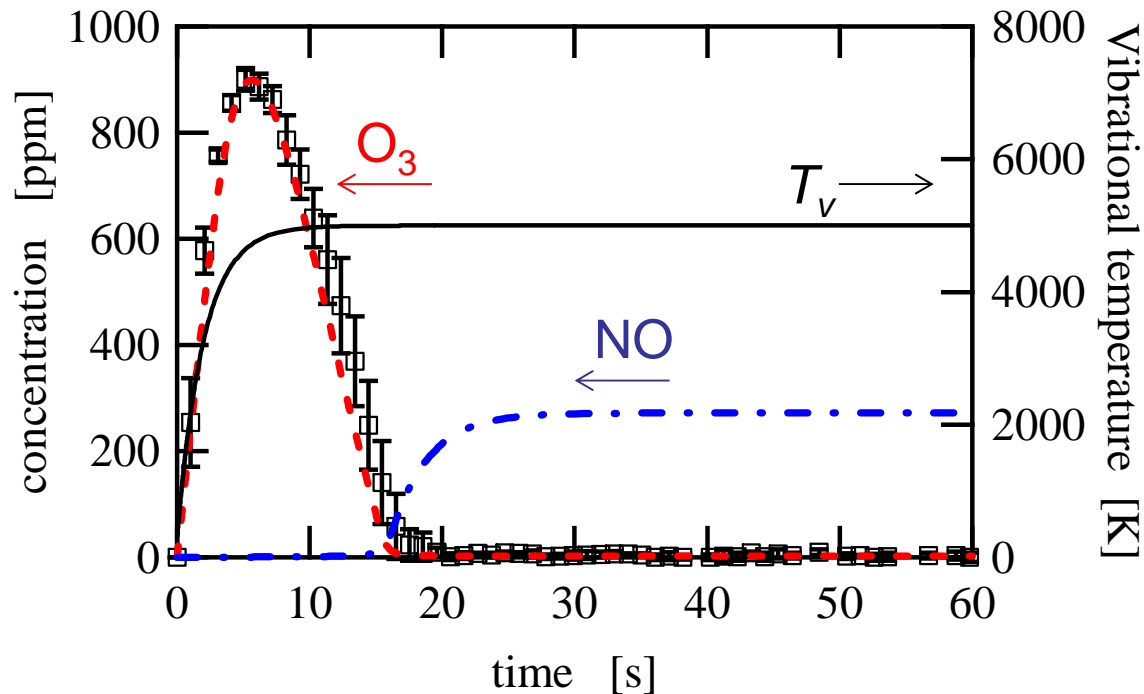
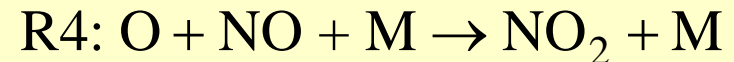
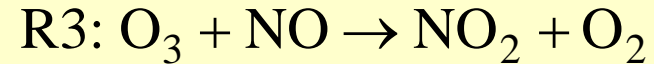
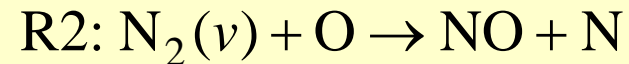
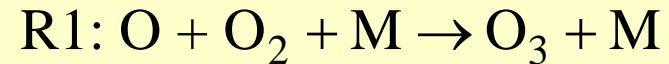
- power density: 0.03-3 W/cm²
- gas gap: ~10 mm
- temporal resolution: 1 s



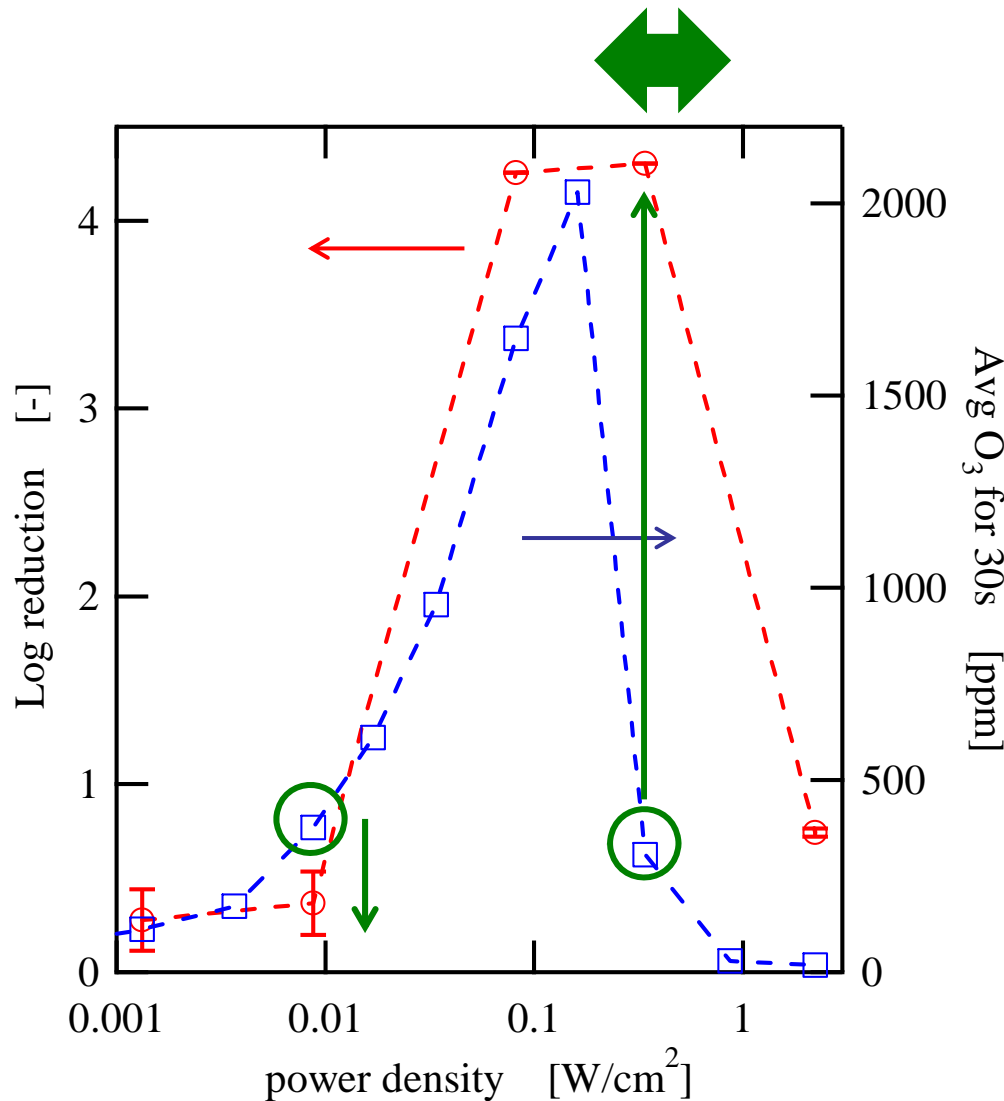
Gas-phase ozone: quenching mechanisms

Two equation model (ODE)

- Unknown parameters:
O₃ and NO density
- Fitting parameters:
O density, N₂ vibrational temperature, and diffusion loss

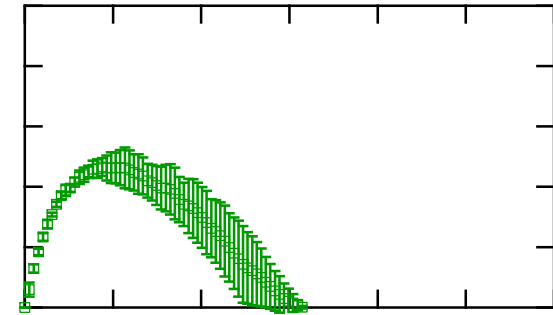


Gas-phase ozone: bactericidal activity on agar plate



Intermediate power
(0.1-1.0 Wcm²)

- O₃: quenched
- L-R: high

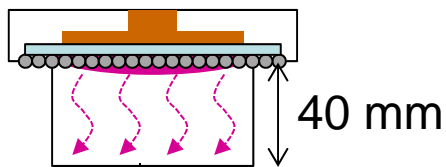


- ozone is not responsible for inactivation?
- Nonlinear reaction on lipid membrane?

Water layer: modulation of gas-phase RONS

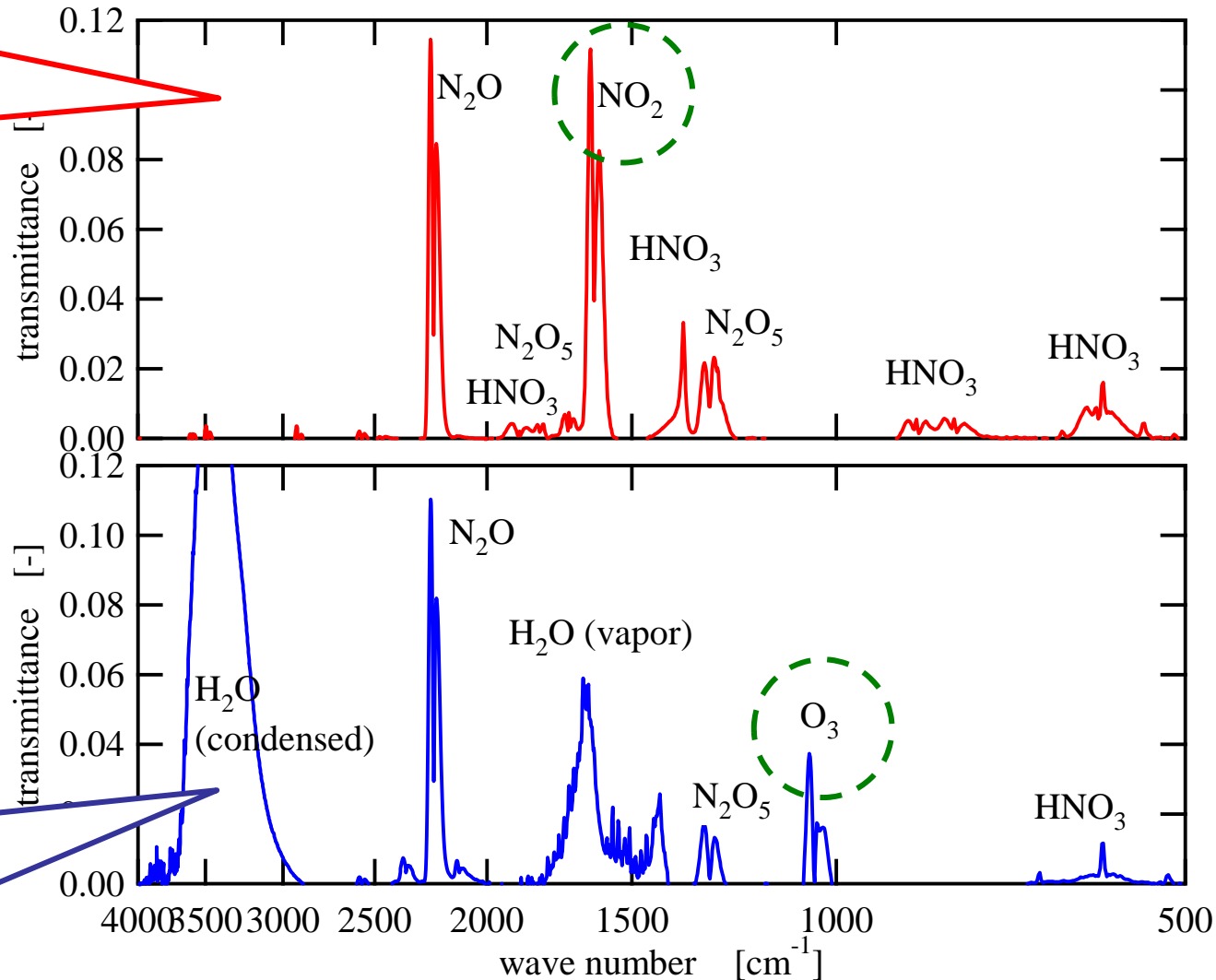
FTIR measurement

Without water

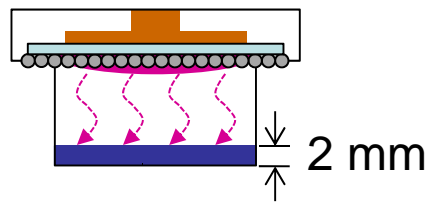


40 mm

- 0.3 W/cm²
(intermediate power)
- 2 min after plasma ignition

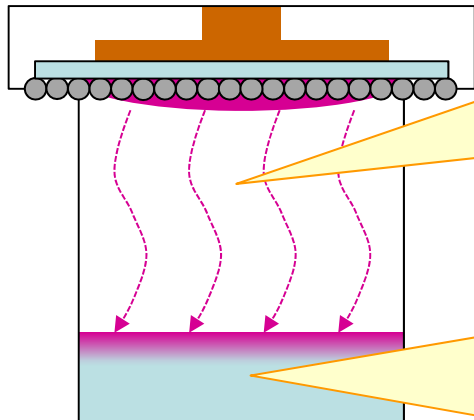
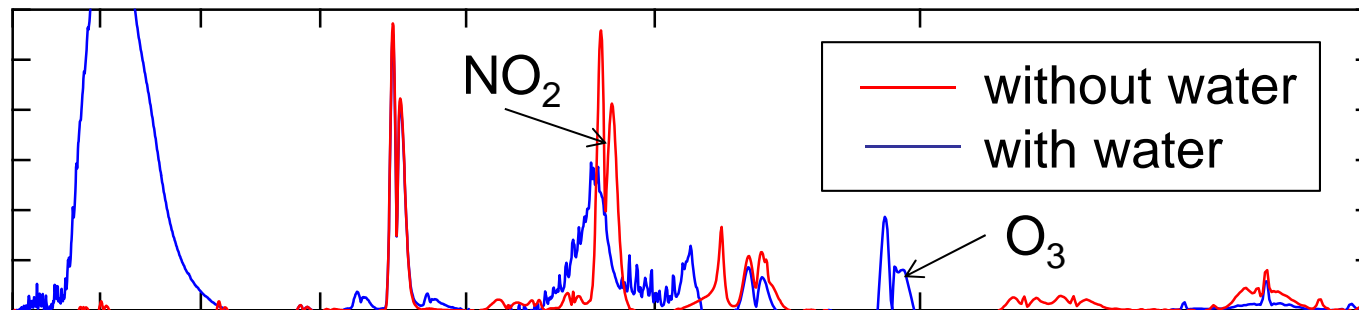


With water (2 mm)

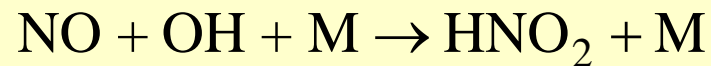


2 mm

Water layer: potential effects



1. Gas-phase water vapor (increase in humidity)



2. Selective absorption in water

Henry's law constant [M/atm]

- O₃, N₂O, NO₂: ~ 0.01
- NO₃, N₂O₅, HNO₂: ~ 1-100
- H₂O₂, HNO₃: ~ 100 000

Ref.: R. Sander, Max-Planck Institute of Chemistry (1999)

Concluding Remarks

1. Gas-phase plasma chemistry is most likely to be in transient during normal operation conditions of SMD.
2. At the intermediate power density (0.1-1.0 W/cm²), both ozone and nitrogen oxide are generated sequentially without adjusting input parameters.
3. At the intermediate power density, ozone might not be the agent responsible for the bactericidal activity.
4. Water layer has quite significant effect on gas-phase plasma chemistry.

Acknowledgements

H.-W. Chang

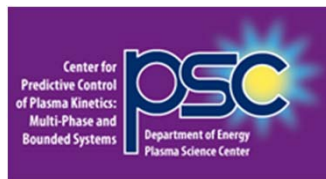
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