Modeling of Plasma Chemistry of Hand Plasma Sterilization Device

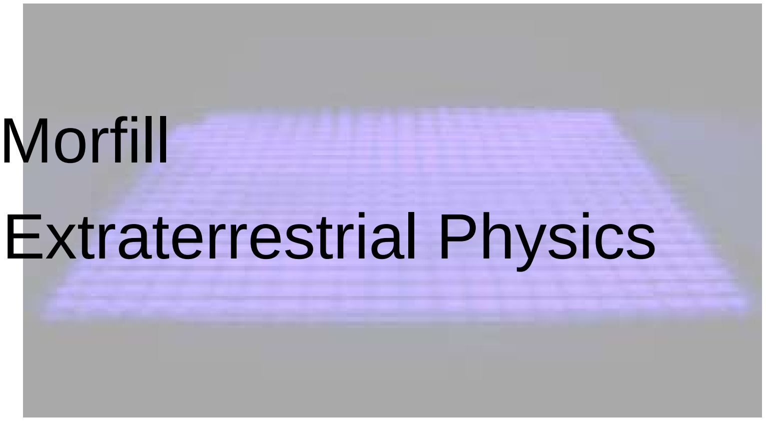
Yuki Sakiyama and David B. Graves,

Department of Chemical Engineering,

University of California, Berkeley

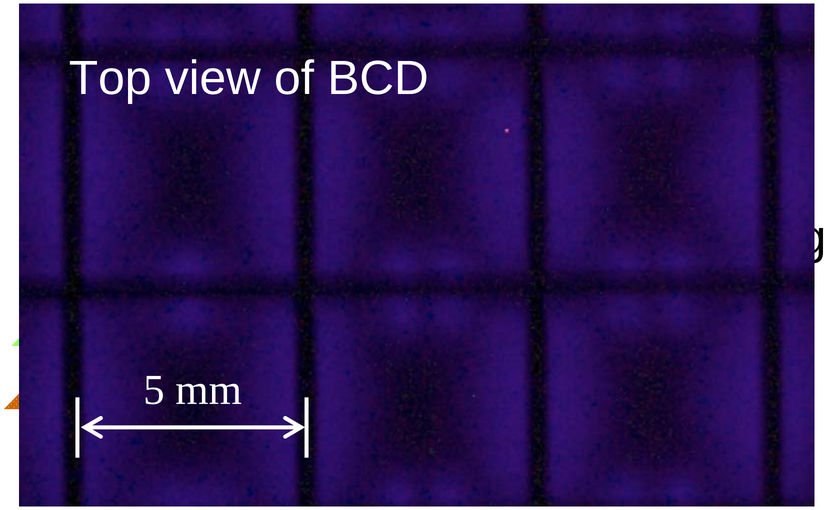
Tetsuji Shimizu and Gregor E. Morfill

Max Planck Institute for Extraterrestrial Physics



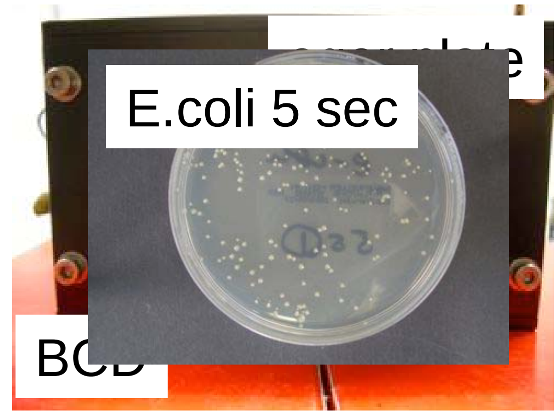
Introduction: hand sterilization dispenser

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

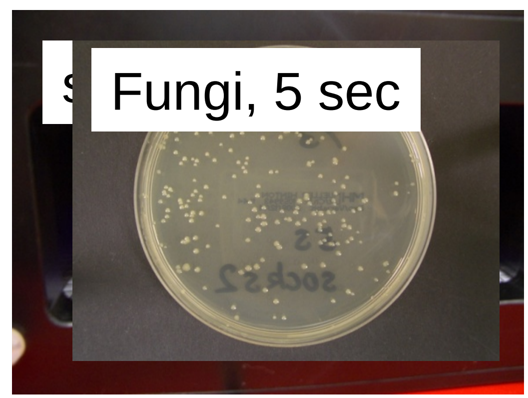


- Power: 50 Watts/100 cm^2
- Voltage: 5-10 kV_{pkpk}
- Frequency: 1-10 kHz
- Mesh size: 5 mm
- Wire diameter: 0.5 mm
- Insulator: 1.0 mm (Teflon)

Sterilization on agar plate

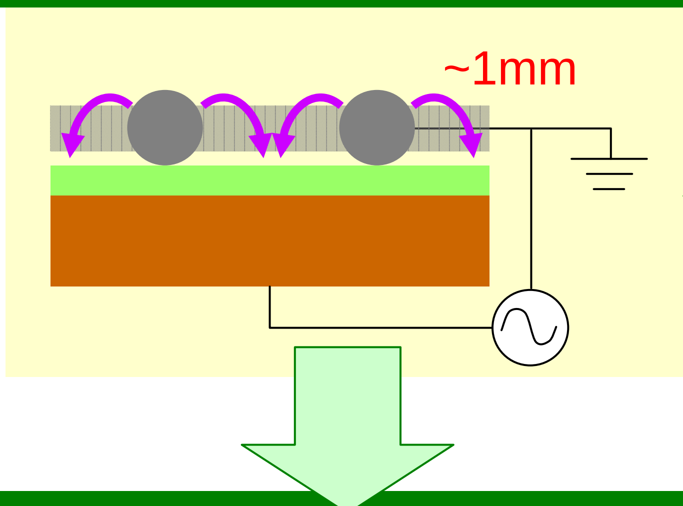


Sterilization through socks

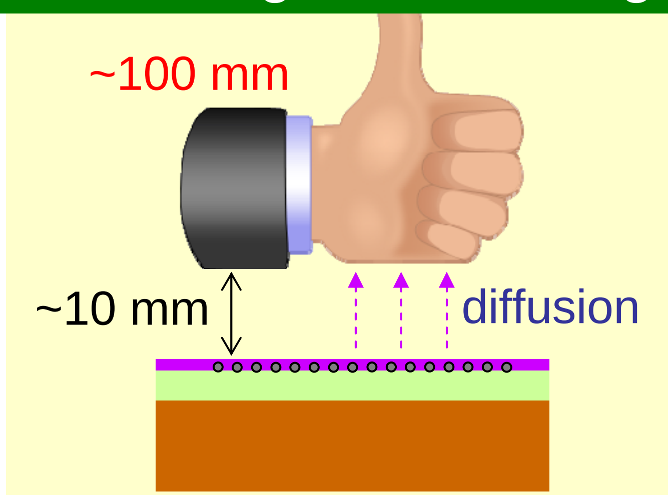


Model: strategy

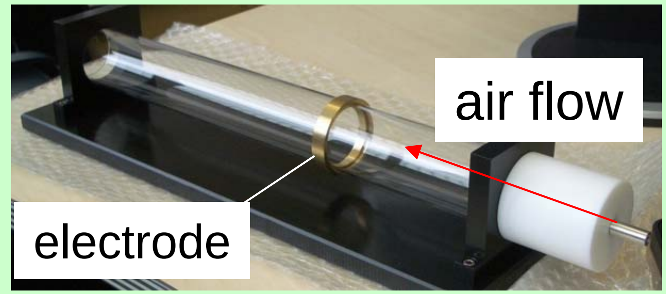
Plasma region: plasma chemistry

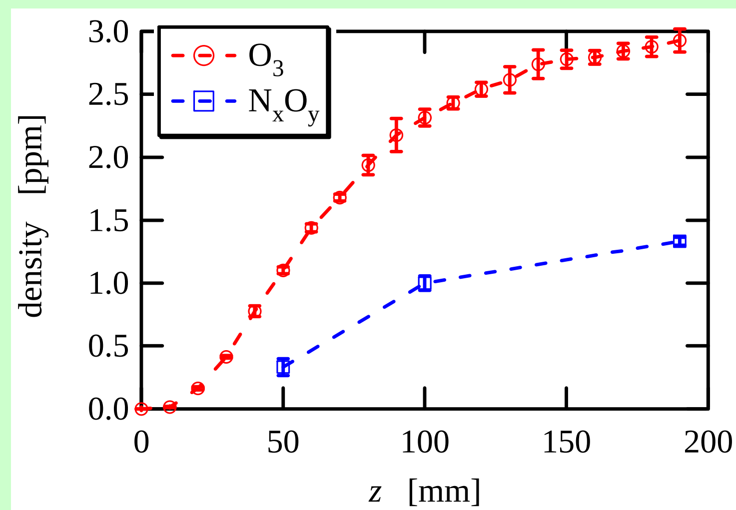


Treatment region: reactive gas flow



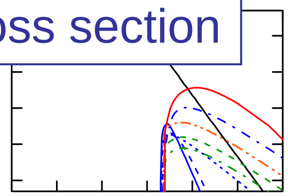
reactor tube experiment





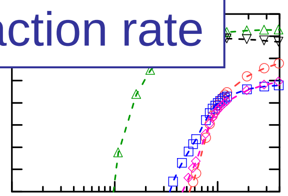
Model: governing equation

cross section



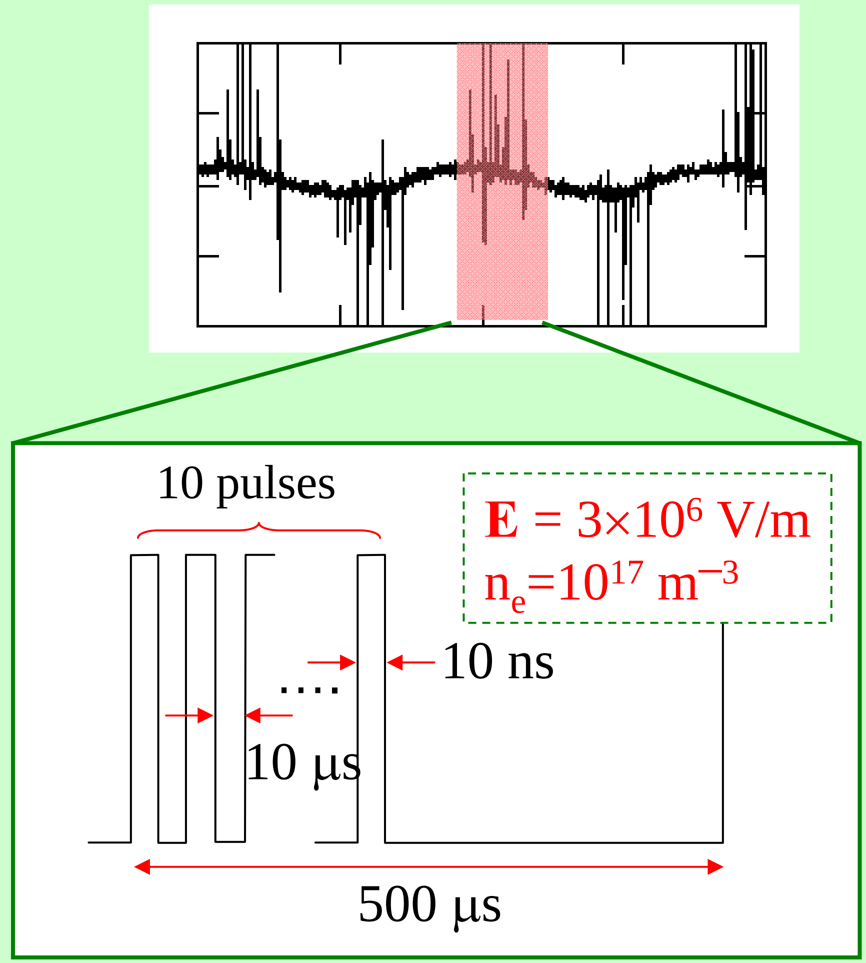
Boltzmann equation

reaction rate



Global model (solver: Matlab)

$$\frac{\partial n_i}{\partial t} = \sum_j k_{ij} n_j n_{j'} n_{j''}$$



Model: plasma chemistry

48 species

11 negative particles: e, O^-, O_2^-, O_3^-, O_4^-, H^-, OH^-, NO^-, N_2O^-, NO_2^-, NO_3^-

16 positive particles: N^+, N_2^+, N_3^+, N_4^+, O^+, O_2^+, O_4^+, NO^+, N_2O^+, NO_2^+, H^+, H_2^+, H_3^+, OH^+, H_2O^+, H_3O^+

21 neutrals: N, N*, N_2, N_2*, N_2**, O, O*, O_2, O_2*, O_3, NO, N_2O, NO_2, NO_3, N_2O_5, H, H_2, OH, H_2O, HO_2, H_2O_2

630 reactions

21 electron impact excitation/ionization/dissociation

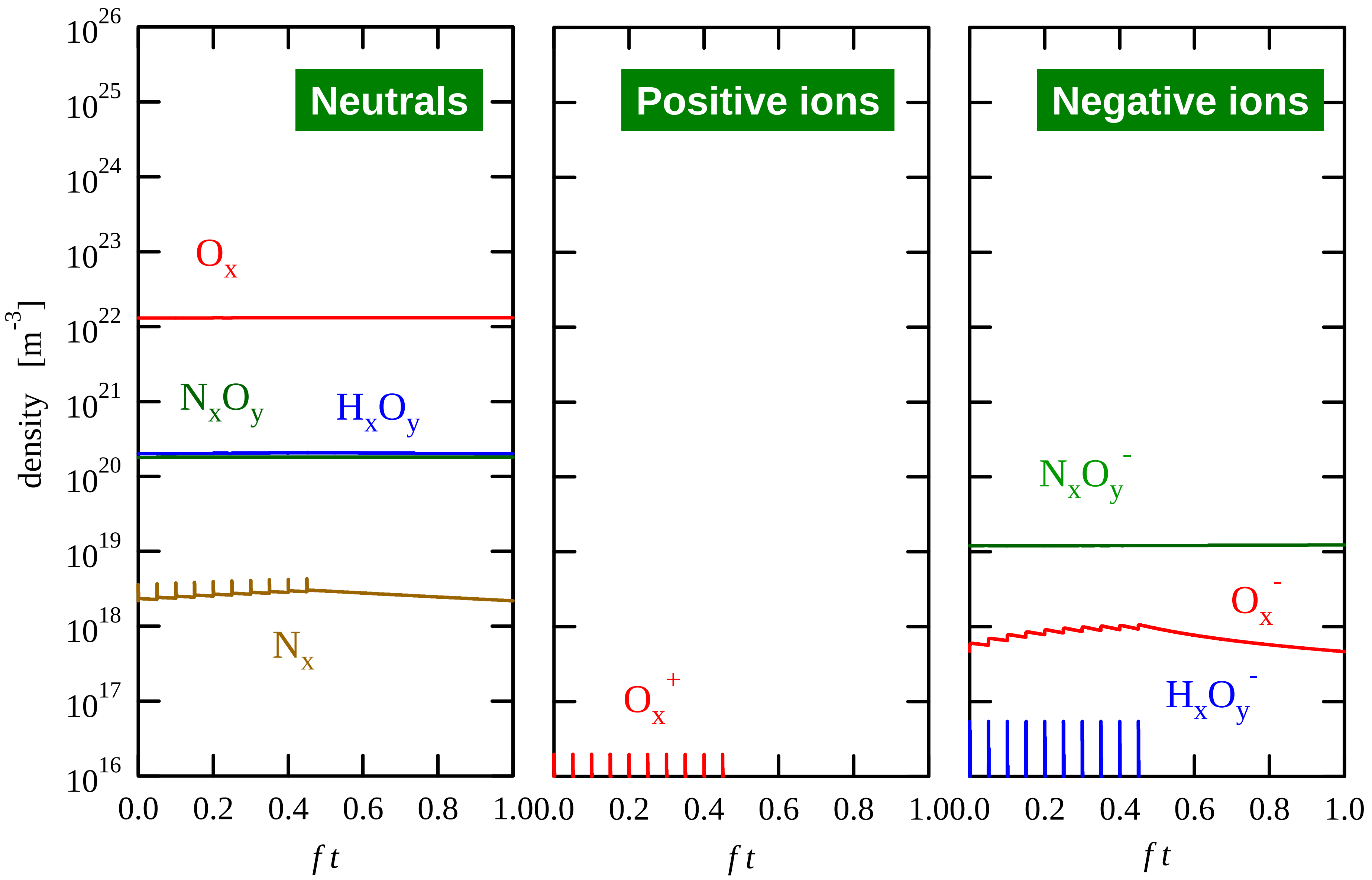
76 electron recombination/attachment

159 charge transfer

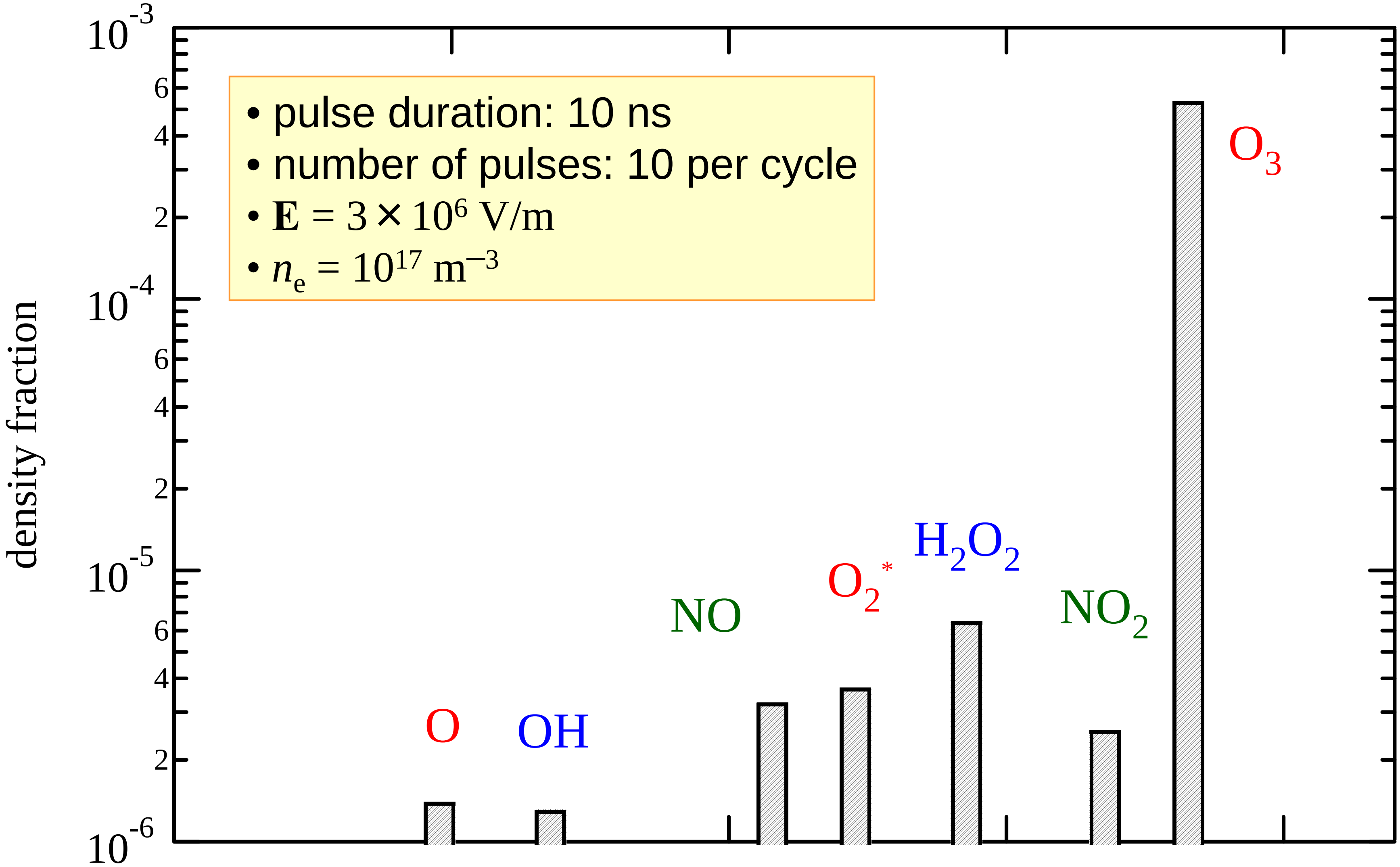
245 ion recombination

129 neutral-neutral reactions

Dynamics of reactive species



Phase-averaged density



Reaction paths of O_3 and NO

O_3

creation:

$O + O_2 + M \rightarrow O_3 + M$ (>99%)

loss:

$e + O_3 \rightarrow O + O_2 + e$ (25%)

$O_3 + OH \rightarrow HO_2 + O_2$ (25%)

$NO + O_3 \rightarrow NO_2 + O_2$ (15%)

$O_2^* + O_3 \rightarrow O + 2O_2$ (10%)

NO

creation:

$O + NO_2 \rightarrow NO + O_2$ (60%)

$N^* + O_2 \rightarrow NO + O^*$ (15%)

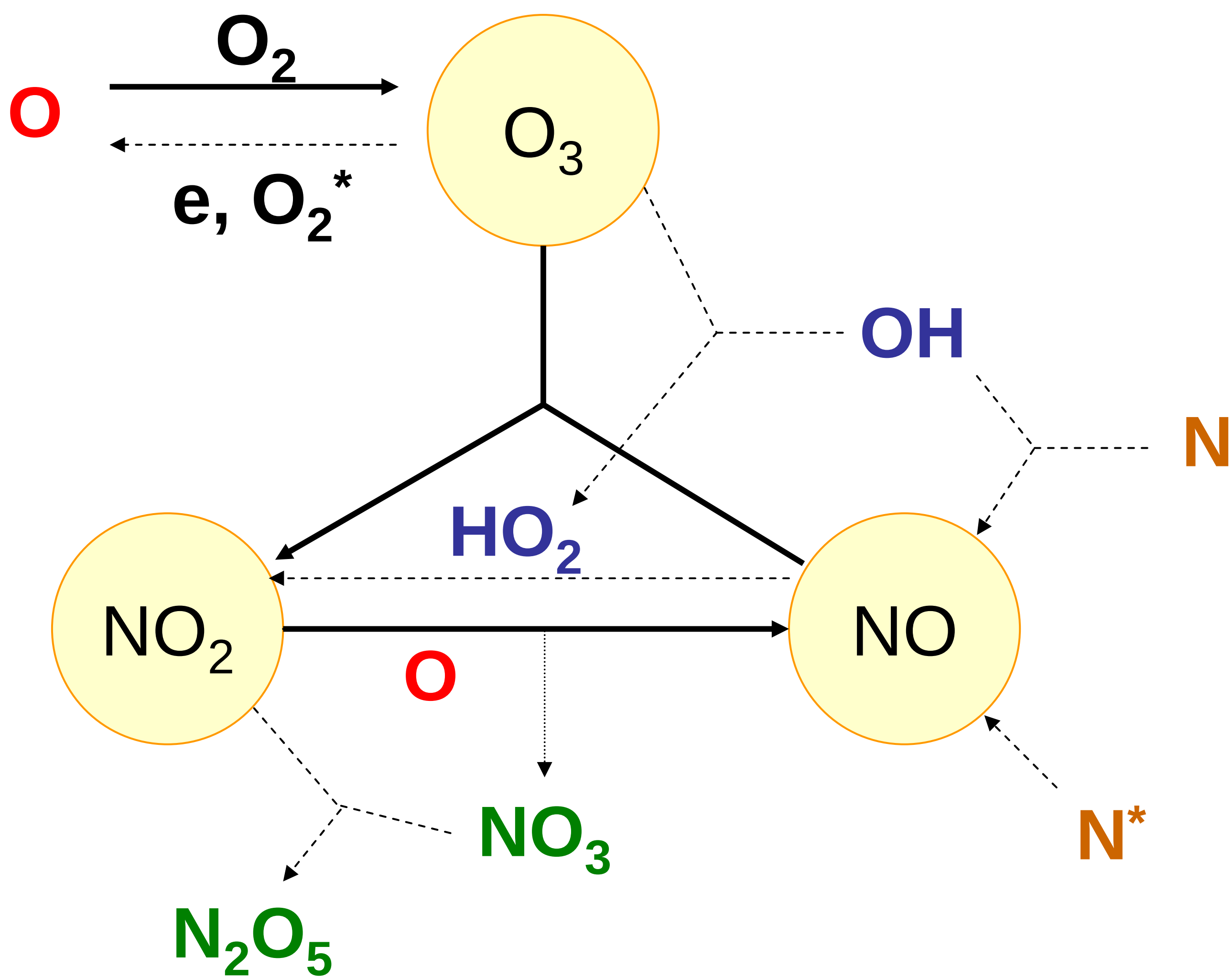
$N + OH \rightarrow NO + H$ (10%)

loss:

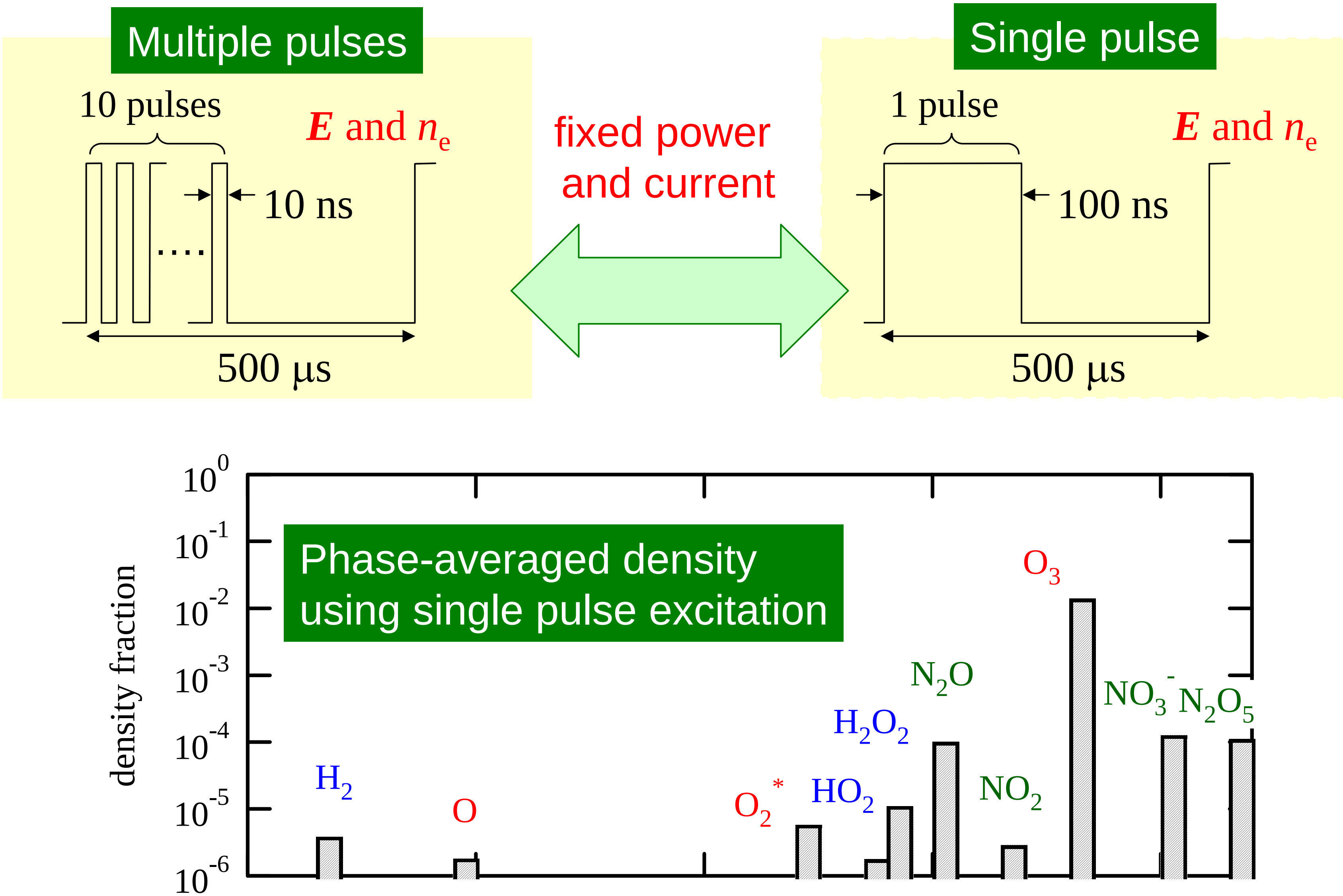
$NO + O_3 \rightarrow NO_2 + O_2$ (80%)

$NO + HO_2 \rightarrow NO_2 + OH$ (10%)

Reaction networks between O_3, NO, and NO_2

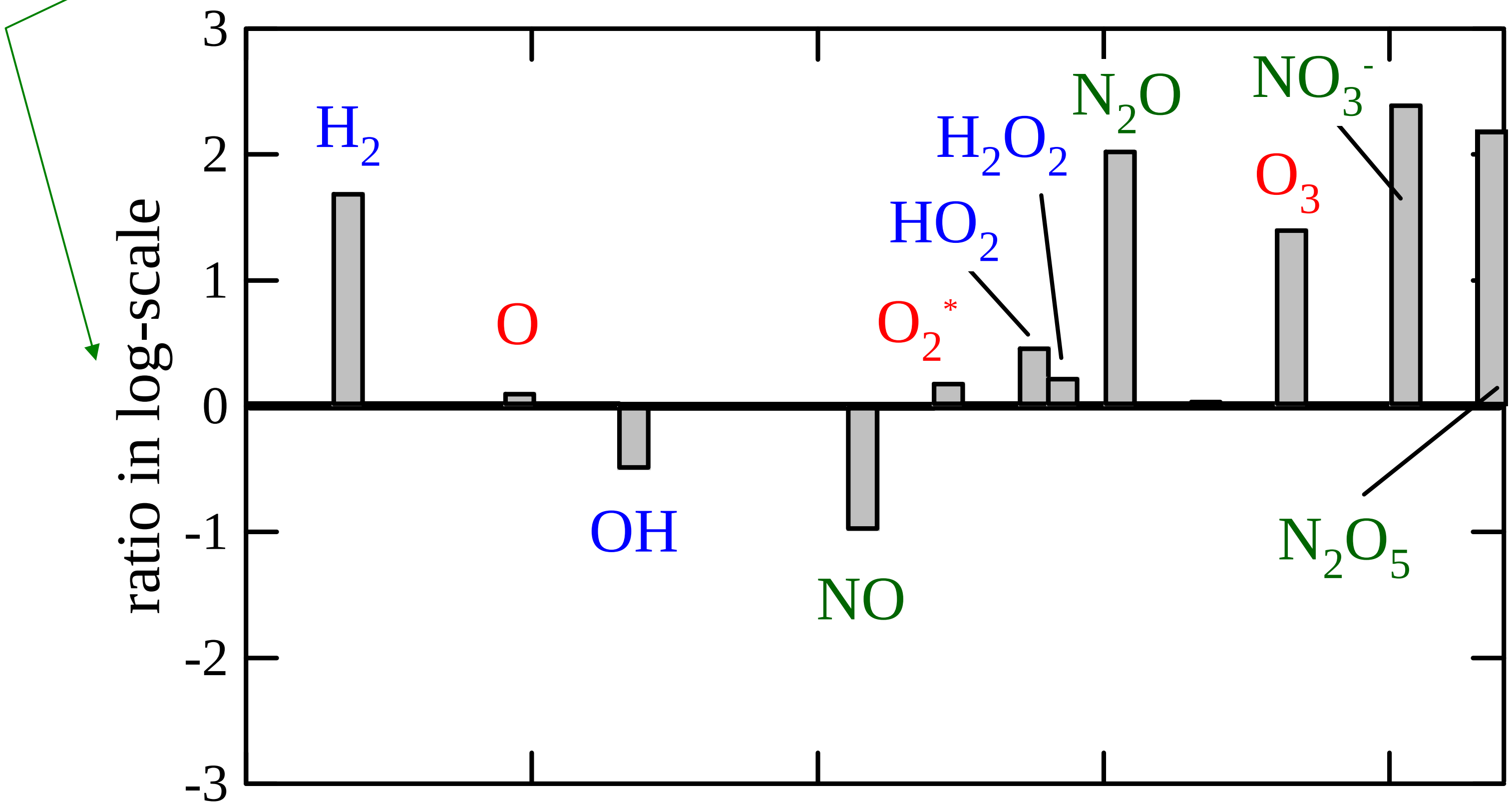


Control of plasma chemistry -1



Control of plasma chemistry -2

$$= \log\left(\frac{\text{density with single pulse}}{\text{density with multiple pulses}}\right)$$



Concluding Remarks

1. We have developed a plasma chemistry model for air barrier corona discharge. The 0D global model includes 48 species/630 reaction paths.

2. Our simulation results indicated that the most abundant species in the barrier corona discharge could be O_3, followed by H_2O_2, O_2^*,NO, NO_2, O, and OH.

3. We showed an example to control plasma chemistry by modifying the discharge current waveform.