

Simulations of low-temperature plasmas

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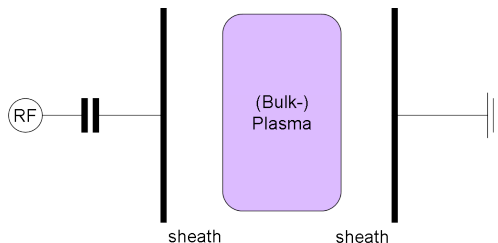
Project B5 in SFB Transregio 24

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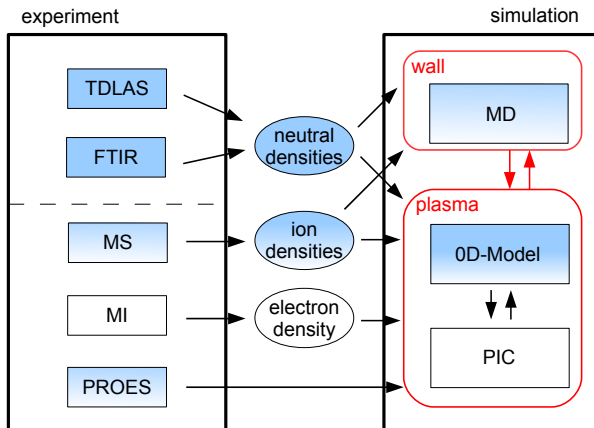
System of choice

capacitively coupled radio frequency CF_4/H_2 -discharge



- low-temperature plasma $\Rightarrow T_e \gg T_i, T_{neutrals}$

Overview



Particle Balance Simulation

Species:

- CF_4, H_2
- CF_3, CF_2, CF, H, \dots
- $CF_3^+, CF_2^+, CF^+, H^+, F^+, \dots$
- F^-, e, CF_3^-, \dots
- $C_xF_y, CH_xF_y, HF, \dots$

Reactions:

- dissociation
- charge transfer
- neutralization
- three-body recombination
- ...

- >200 reactions, >40 species (neutrals, ions, electrons)

System of differential equations

Neutrals:

$$\frac{\partial N_i}{\partial t} = - \sum_{i,j} k_{ij} N_i N_j + \sum_{k,l} k_{kl} N_k N_l - Q_{i,pump} (+ Q_{i,feedgas})$$

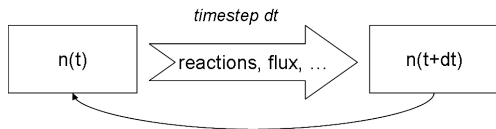
Positive Ions & electrons:

$$\frac{\partial N_i}{\partial t} = - \sum_{i,j} k_{ij} N_i N_j + \sum_{k,l} k_{kl} N_k N_l - Q_{i,cs}$$

Negative Ions:

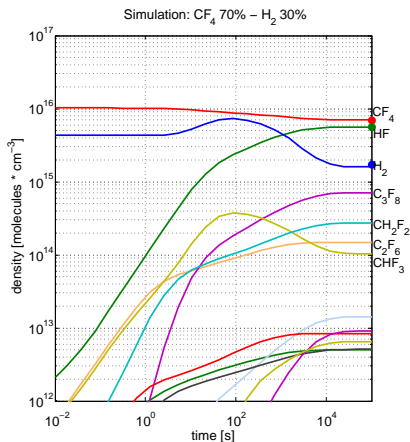
$$\frac{\partial N_i}{\partial t} = - \sum_{i,j} k_{ij} N_i N_j + \sum_{k,l} k_{kl} N_k N_l$$

0D-scheme



- implementation in MATLAB with ode15s (variable order solver based on computation of Jacobian Matrices)
- speed up in comparison with standard ode (Runge-Kutta) in order of magnitude of 1000

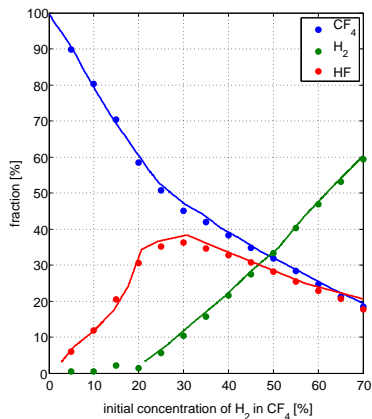
Standard Run



- feed gas: CF₄ / H₂
- pressure: 66.6 Pa
- flux: 25 sccm
- electron temperature: 1.5 eV
- initial electron density: $4 \cdot 10^9$ cm⁻³

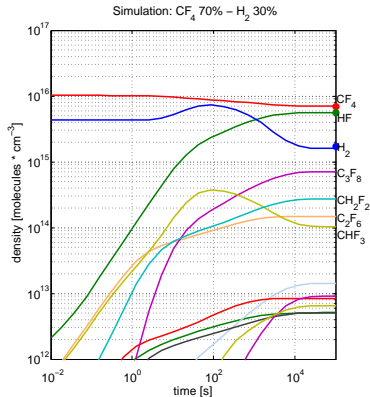
*data: Truesdale & Smolinsky, *J. Appl. Phys.* 50 (1979)

Comparison with flowtube experiment



- variation of initial H₂ concentration
- feed gas: CF₄ / H₂
- pressure: 66.6 Pa
- flux: 25 sccm
- solid lines: data of Truesdale et al.
- markers: 0D simulation

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CF₄ plasma - small vs. larger molecules

