PLASMATOR NUMERICAL THEORY

KINEMA

PLASMATOR NUMERICAL THEORY: Neutral Model

- Well mixed reactor

$$\partial n_i / \partial t = C_0 (F/V)(N_i^0 - N_i N_{total})$$

- Diffusion Approximation

$$\partial n_i / \partial t = -\vec{\nabla} \cdot D_{ij} \vec{\nabla} n_i + R_i$$

- Finite Rate Chemistry
  - Volume Chemistry
    - electron impact ionization
    - metastable excitation
    - dissociation
    - dissociative attachment
    - detachment
  - Surface Chemistry
    - neutralization
    - recombination
    - metastable quenching

PLASMATOR NUMERICAL THEORY: Electron Model

- Assumed to be dominated by drift/diffusion
- Solved using continuity and energy conservation

$$\partial n_e / \partial t = -\vec{\nabla} \cdot \vec{\Gamma}_e + R_e,$$

$$\frac{\partial}{\partial t}(\frac{3}{2} n_e k T_e) = -\vec{\nabla} \cdot \vec{Q}_e - e n_e \vec{\Gamma}_e \cdot \vec{E} + P_{in} - n_e n_N k_i \in_i,$$

$$\vec{\Gamma}_e = -n_e m_e \vec{E} - \frac{1}{m_e v_N} \vec{\nabla} n_e k T_e$$

$$\vec{Q} = \frac{5}{2} \Gamma_e k T_e - \frac{5 n_e k T_e}{2 m_e v_N} \cdot \nabla(k T_e)$$

- Solved implicitly using a time-split, first order upwind ADI scheme

PLASMATOR NUMERICAL THEORY: Ion Model

- Assumed to be isothemal
- Solved using continuity and momentum conservation

$$\partial n_i / \partial t = -\vec{\nabla} \cdot n_i \vec{v}_i + R_i,$$

$$\partial n_i \vec{v}_i / \partial t = -\vec{\nabla} \cdot \left(n_i \vec{v}_i \vec{v}_i \right) + \frac{e n_i \vec{E}}{m_i} - \frac{1}{m_i} \vec{\nabla} n_i k T_i - n_i \nu_{iN} \vec{v}_i.$$

- Solved explicitly

PLASMATOR NUMERICAL THEORY: Poisson's Equation

- The electrostatic potential is solved for independently of the rf fields
- Solved sing a time-advanced form

$$\nabla^2 \phi = -e\left(n_+ - n_e - \Delta t \cdot \frac{\partial n_e}{\partial t} \right) / \in_o$$

  - avoids the dielectric relaxation instability
  - enforces strong implicit coupling between the electric field and electron density

PLASMATOR NUMERICAL THEORY: EM Model

Azimuthal symmetry reduce Maxwell's Eqns to:

- Helmholtz wafe eqation for Etheta

$$\nabla^2 \varepsilon_\theta + \frac{\omega^2}{c^2} K \varepsilon_\theta = -i\omega\mu_0 J_{\theta ext}$$

- Lapace Eqn (n_{eext}=0) for other directions

$$\vec{\nabla} \cdot (K \vec{\nabla} \phi) = -n_{e_{ext}} / \in_0 \qquad \vec{\nabla}\phi = (\varepsilon_r, \varepsilon_z)$$

Cold plasma dielectric tensor

$$K = 1 + \frac{i}{\omega \in_0} \sigma_p$$

Plasma conductivity

$$\sigma_p = \frac{\in_0 \omega_{pe}^2}{\nu_{en} - i\omega}$$