ICP Fluid Equation - Organized

Tuesday, September 1, 2020 12:01 PM

Continuity Eq.

$$\frac{\partial n_e}{\partial t} = -\nabla \cdot \vec{\Gamma_e} + S_e$$

Two terms unknown

Source Term

1. $S_e = 0$, no source term (no ionization), plasma will decay
2. $S_e = k_e(T_e)n_g n_e$, simple ionization term, is determined by T_e and n_e , n_g can be seen as constant unless n_g is updated through flow caculation
3. $S_e = k_e(f(\varepsilon))n_g n_e$, ionization term is determined by EEDF (Electron Energy Distribution Function), which is computed from EEDF module

Flux Term

1. $\vec{\Gamma_e} = -D_e \nabla n_e - e\mu_e n_e \nabla \phi$, Drift-Diffusion Approximation, electron flux is assumed to be diffusion term + drift term
2. $\vec{\Gamma_e}$, uses Schaffeter–Gummel fluxes which is essentially an auto-selecting upwind differentiation technique, still under Drift-Diffusion Approximation
3. $\frac{\partial \vec{\Gamma}_e}{\partial t} = \frac{e n_e \nabla \phi}{m_e} - \frac{\nabla p}{m_e} - v_{coll}\vec{\Gamma}_e$, momentum equation
4. Momentum equation + Energy equation

$\frac{\partial n_e}{\partial t} = \nabla \cdot (D_e \nabla n_e + e\mu_e n_e \nabla \phi)$, $n_e(t+\Delta t)$ is determined by $n_e(t)$, electrostatic potential $\phi(t)$.

Diffusion Coefficient, $D_e = \frac{k_B T_e}{m_e v_{coll}}$; Mobility, $\mu_e = \frac{e}{m_e v_{coll}}$;

Unknown term is $\phi(t)$, which is determined by the Poisson's Equation:

$\nabla(\epsilon \nabla \phi) = -(\Sigma n_i - n_e)$,

Poisson's Equation is determined by all charged species including ions, so ion densities need to be solved simultaneously.

Ion densities can be solved following the same routine as electrons

$\frac{\partial n_i}{\partial t} = \nabla \cdot (D_i \nabla n_i + e\mu_i n_i \nabla \phi)$, $n_i(t+\Delta t)$ is determined by $n_i(t)$, electrostatic potential $\phi(t)$.

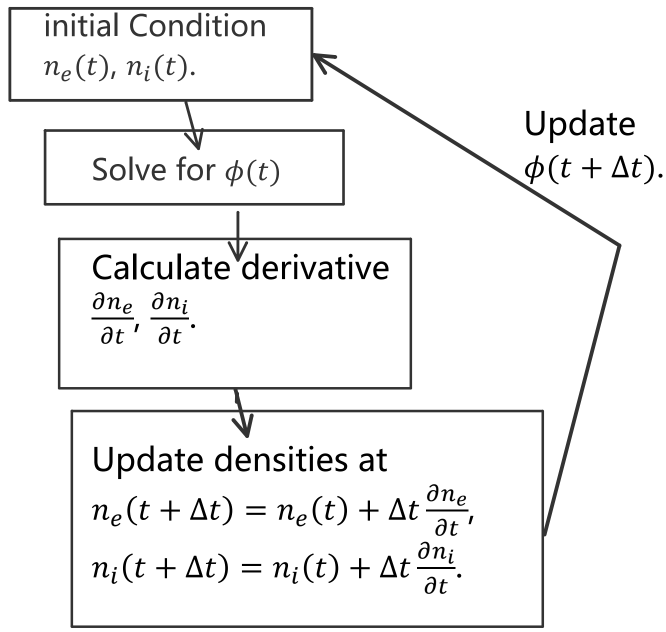
Diffusion Coefficient, $D_i = \frac{k_B T_i}{m_i v_{coll,i}}$; Mobility, $\mu_i = \frac{e q_i}{m_i v_{coll,i}}$;

Now we have,

$\frac{\partial n_e}{\partial t} = f_1(n_e(t), \phi(t))$,

$\frac{\partial n_i}{\partial t} = f_1(n_i(t), \phi(t))$,

$\nabla(\epsilon \nabla \phi(t)) = -(\Sigma n_i(t) - n_e(t))$,



Since at the surface/b.c., time step Δt, is limited by the dielectric relaxation time for explicit method.

$$\Delta t < \frac{\epsilon_0}{\sigma_m}.$$

σ_m is the conductivity of the materials.
An implicit coupling method is needed.

Boundary Condition

Cartesian	Cylindrical
$n_{e,i} = 0$, at non-plasma b.c.	$\vec{\Gamma}_{e,i}\ in\ \vec{r}$, at $r = 0$
$\phi = \phi_0\|_{b.c.}$, at domain b.c.	$\nabla\phi = 0\ in\ \vec{r}$, at $r = 0$