Kinetic Simulation of Dual Frequency Capacitive Discharges
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Workshop
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Motivation

- Single Frequency Standard for Etching
  - Cannot independently vary ion flux and ion bombarding energy
- Dual Frequency Discharge
  - High frequency controls plasma density (ion flux)
  - Low frequencies control ion energy distribution
- Three Frequency Discharge
  - High frequency controls plasma density (ion flux)
  - Two low frequencies control ion energy distribution

Milestones

Year 1:
- Develop one-dimensional asymmetric particle-in-cell simulation of dual frequency discharge.
- Develop model of dual frequency rf biasing to control ion energy distribution

Simulation Codes

- XPDC1 and XPDP1
- PIC-MCC Codes
- 1-D Bounded Electrostatic Code with External Circuit (Used for Blocking Capacitor)
- Ion and Electron Motions Using Newton’s Laws/Poisson’s Equation.
- Ion and Electron Collisions Using Monte Carlo Collisions

Cylindrical (XPDC1) Input Parameters

- \( f_H = 27.1 \text{ MHz} \)
- \( T_H = 37 \text{ ns} \)
- \( f_L = 2 \text{ MHz} \)
- \( T_L = 0.5 \text{ ms} \)
- \( p = 190 \text{ mTorr Ar gas} \)
- \( \Delta t = 10 \text{ ps} \)
- \( \Delta R = \frac{\lambda_d}{\Delta R} = 6 \)
- \( C_b = 1 \times 10^{-9} \text{ F} \)
- \( N_{\text{init}} = 1 \times 10^{15} \text{ m}^{-3} \)
- \( V_H = 100 \text{ V} \)
- \( V_L = 900 \text{ V} \)

Effective Collision Frequency for Heating vs. Pressure

- \( P_{\text{eff}} = \frac{1}{2} \left( \frac{1}{P_{\text{bulk}}} \right) \left( \frac{1}{\alpha} \right) \)

Numerical Issues with XPDP1 – (Planar) Parameters Used

- \( p = 50 \text{ mTorr} \)
- \( T = 300 \text{ K} \)
- \( I = 3 \text{ cm} \)
- \( f = 27.12 \text{ MHz} \)
- \# cells = 800
- \( N_{\text{bulk}} = 1 \times 10^{12} \text{ m}^{-3} \)
- \( d_t = 18 \text{ ps} \sim 1/5 \nu_{\text{bulk}} \)
- \( d_x = 3.75 \times 10^{-4} \text{ m} \)
- \( A = 0.544124 \text{ m}^2 \)
- \( C_b = 18 \text{ nF} \)

Acknowledgment