

Plasma Processing Technology

(100min, close book)

November 26, 2013

- The following problems are related to the dc plasma:
 - Qualitatively plot the relation between the voltage across and the current through the plasma and identify (i) breakdown voltage, and (ii) three different operation regions as current increases.
 - List the sources where the secondary electrons come from.
 - Describe the extent of the properties of the cathode fall and of the anode fall.
- Calculate the most probable speed, c_{mp} of the Ar atoms at 0°C , using the Maxwellian distribution.
 - Use charged particle temperature versus pressure to show ranges of "cold plasma" and "thermal plasma".
 - In a collision of a neon atom and an electron, compare the energy loss in fraction of the electron in an (i) elastic, and (ii) inelastic collision.
- In a given collisionless plasma(13.56 MHz), calculate the minimum electric field, E_0 required for the ionization of Ar atoms.
 - In a typical cold plasma: $n_e = 10^{10} \text{ cm}^{-3}$, $T_e = 2 \text{ V}$, calculate the (i) e^- thermal velocity, (ii) plasma frequency, and (iii) the number of electrons in the Debye sphere.
 - In an ECR plasma(2.45 GHz) in which an Ar^+ conducts gyromotion with 5eV, calculate (i) the magnetic field, and (ii) the Larmor radius.
 - Use the square wave for simplicity to illustrate the origin the negative self-bias in a parallel plate discharge.

$e^- = 1.6 \times 10^{-19} \text{ C}$, $m_e = 9.1 \times 10^{-31} \text{ kg}$
 $k = 1.38 \times 10^{-23} \text{ J/K}$, $c = 3 \times 10^8 \text{ m/s}$
 $\epsilon_0 = 8.85 \times 10^{-12} \text{ F/m}$
 $N_A = 6.02 \times 10^{23} \text{ molecule/mole}$
 $N_A^{-1} = 1.66 \times 10^{-24} \text{ mole/molecule}$
 $\text{Ar}^* = 11.5 \text{ V}$, $\text{Ar}^+ = 15.7 \text{ V}$
 $\text{Ne}^* = 16.6 \text{ V}$, $\text{Ne}^+ = 21.6 \text{ V}$
 Ar atom weight = 39.9
 Ne atom weight = 20.2

Electron energy transfer:

$$\text{elastic, } W_{tr} = \frac{2m_e}{M} W$$

$$\text{inelastic, } W_{tr} = \frac{M}{m_{in} + M} W$$

$$e^- \text{ velocity in a collisionless plasma: } \dot{x} = \frac{dx}{dt} = \frac{eE_0}{m_e \omega}$$

$$\text{Debye length: } \lambda_D = \left(\frac{\epsilon_0 k T_e}{n_e e^2} \right)^{1/2}$$

$$e^- \text{ thermal velocity: } \left(\frac{k T_e}{m_e} \right)^{1/2}$$

$$\text{Larmor radius: } r_L = \frac{m v_{\perp}}{e B}$$

$$\text{Electron cyclotron frequency: } \omega_c = \frac{e B}{m_e}$$

Maxwell distribution:

$$dn_c = 4\pi N \left(\frac{m}{2\pi k T} \right)^{3/2} c^2 e^{-mc^2/2kT} dc$$