

10316862 Plasma Processing Technology

Final (100min, close book)

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- Calculate the length in cm between the two electrodes at the minimum breakdown potential (V_b) for a dc discharge in neon ($c_2=2.5$) at $p=20$ mtorr.
 - (i) What are the conditions required by the Penning effect? (ii) Take argon and neon for instance to write down the plasma chemistry for the Penning ionization.
 - Derive an expression of the thickness of the plasma sheath as a function of the plasma potential in terms of the Debye length (λ_D), using the Child-Langmuir equation to start with.
- Give the electrical circuit of a single Langmuir probe for measuring the current density (I) vs. the applied potential (V) in a plasma, using a sweep voltage supply and an X-Y recorder.
 - A pair of I and V was extracted from the linear portion of the I-V curve; they are (0.001A; 2V) and (0.003A; 12V), and the probe has the dimension of $L=4$ mm and $D=1$ mm. Now evaluate the electron temperature (T_e) of this plasma.
 - What is the benefit from a remote plasma reactor, using a helical resonator as the plasma source for the deposition of SiO_2 ?
- (i) Why a matching unit is necessary for the RF discharge?
(ii) Give the necessary condition for the maximum work.
 - An ECR plasma (2.45 GHz) of Ar gives the following data: $T_e=5$ V, $n_e=10^{18} \text{ m}^{-3}$, and $v=10^{10} \text{ s}^{-1}$, while Ar^+ possessing 5 eV. Calculate (i) the Larmor radius of the Ar^+ in the bulk plasma, (ii) critical velocity and its driving potential for the Ar^+ entering the plasma sheath.
 - Same conditions as given in (b), calculate (i) the ion current density in the plasma sheath, and (ii) the mean power transferred from the outside $E_0 (=30\text{V/cm})$ to the unit volume of the Ar at the resonant condition ($\omega=\omega_c$).
 - What type and depth of the radiation damage can be induced on a silicon wafer when exposed to a gas mixture of $\text{CF}_4 + 40\% \text{ H}_2$ plasma for RIE at 25 mtorr and at the bias voltage of -425V?

$$e^- = 1.6 \times 10^{-19} \text{ C}$$

$$k = 1.38 \times 10^{-23} \text{ J/K}$$

$$h = 6.63 \times 10^{-34} \text{ J}\cdot\text{s}$$

$$c = 3 \times 10^8 \text{ m/s}$$

$$m_e = 9.1 \times 10^{-31} \text{ kg}$$

$$\epsilon_0 = 8.854 \times 10^{-12} \text{ F/m}$$

$$\text{Ar}^* = 11.5 \text{ V}$$

$$\text{Ne}^* = 16.6 \text{ V}$$

$$\text{Ar}^+ = 15.7 \text{ V}$$

$$\text{Ne}^+ = 21.6 \text{ V}$$

$$\text{Ar atom weight} = 39.9 \text{ g}$$

$$\text{Ne atom weight} = 20.2 \text{ g}$$

$$N_A = 6.02 \times 10^{23} \text{ molecules/mol}$$

$$\text{Mean power absorbed by an } e^-:$$

$$\bar{p} = \frac{e^2 E_0^2}{2m_e} \frac{v}{v^2 + (\omega - \omega_c)^2}$$

$$\text{Child-Langmuir equation:}$$

$$j_i = \frac{4\epsilon_0}{9} \left(\frac{2e}{m_i} \right)^{1/2} \frac{V_s^{3/2}}{d_s^2}$$

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

$$\text{Plasma frequency: } \omega_p = \left(\frac{n_e e^2}{m_e \epsilon_0} \right)^{1/2}$$

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

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

$$\text{For } V \ll V_p, \quad I_e = \frac{en_e v_e}{4} \exp \frac{-e(V_p - V)}{kT_e}$$

$$\text{Paschen's law: } V_b = \frac{c_1 (pd)}{c_2 + \ln(pd)}$$

$$\text{Critical ion velocity: } v_c(x=0) = \left(\frac{kT_e}{m_i} \right)^{1/2}$$

$$\text{Potential at the presheath: } V(x=0) = \frac{kT_e}{2e}$$