

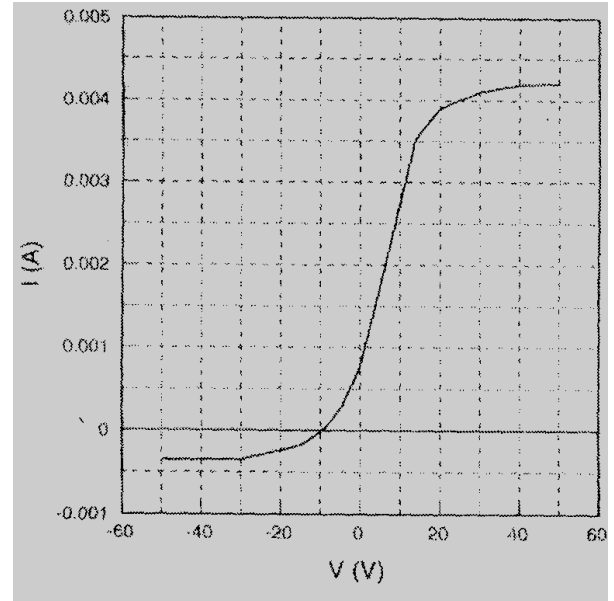
# Plasma Processing Technology

Final(100min, close book)

January 7, 2014

- Calculate the distance in cm between the electrodes at the minimum breakdown potential ( $V_b$ ) for a dc discharge in neon ( $C_2 = 2.61$ ) at  $p = 20$  mtorr.
  - What are the conditions required by the Penning ionization to take place?
    - Take argon and neon for instance to write down the plasma chemistry for the Penning reaction.
  - Find out (i) the critical ion velocity for entering a plasma sheath by considering the energy conservation of the ions and the exponential distribution of the electrons in the sheath, (ii) the potential existing in the Bohm presheath, and (iii) the ionic current density in the sheath.

- 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.
  - The following figure shows the result of IV trace obtained from a single Langmuir probe; 1 mm in diameter and 4 mm long. (i) Calculate the  $T_e$  and (ii) extract the values for  $V_p$ ,  $V_f$  and the  $I$  at the ground potential.
  - Use drawing to illustrate the principle and construction of a multipolar ECR plasma reactor.



- What is the benefit of using a remote plasma reactor, such as a helical resonator for deposition of  $\text{Si}_3\text{N}_4$ ?
  - Why a matching unit is necessary in a RF discharge?
    - Give the necessary condition for the maximum work.
  - Suggest an efficient way for the synthesis of hydrogenated amorphous silicon (a-Si:H) including precursors using PECVD.
  - What type of material 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  $-425\text{V}$ ?

$e^- = 1.6 \times 10^{-19} \text{ C}$   
 $k = 1.38 \times 10^{-23} \text{ J/K}$   
 $h = 6.63 \times 10^{-34} \text{ J}\cdot\text{s}$   
 $c = 3 \times 10^8 \text{ m/s}$   
 $m_e = 9.1 \times 10^{-31} \text{ kg}$   
 $\epsilon_0 = 8.854 \times 10^{-12} \text{ F/m}$   
 $\text{Ar}^* = 11.5 \text{ V}$   
 $\text{Ne}^* = 16.6 \text{ V}$   
 $\text{Ar}^+ = 15.7 \text{ V}$   
 $\text{Ne}^+ = 21.6 \text{ V}$   
 $\text{Ar atom weight} = 39.9 \text{ g}$   
 $\text{Ne atom weight} = 20.2 \text{ g}$   
 $N_A = 6.02 \times 10^{23} \text{ molecules/mol}$

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

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

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

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

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

$$V_b = \frac{C_1(pd)}{C_2 + \ln(pd)}$$