

# 電漿製程技術

(100min, close book)

November 27, 2012

1. (a) For a typical dc plasma, please qualitatively plot the relation between the voltage across and the current through the plasma and identify:

(i) Breakdown voltage. (ii) Three different operation regions(as current increases).

(b) Describe the conditions required by the ambipolar diffusion to take place.

(c) What is the difference between “cold plasma” and “thermal plasma”? Using charged particle temperature versus pressure to illustrate.

2. (a) In a collision of an argon atom and an electron, calculate the percentage energy loss of the electron for an (i) elastic and (ii) inelastic collision.

(b) To remove the photoresistant material and also to etch the silicon, write down the plasma chemistry for each of them?

(c) Calculate (i) the wavelength of a microwave frequency 2.45 GHz and (ii) the temperature(°K) of an electron of 5 Volt.

3. (a) In a given electron oscillating in a collisionless plasma(13.56 MHz), in order to ionize the Ne atoms, what is the minimum electric field  $E_0$  would you expect?

(b) In a typical cold plasma:  $n_e = 10^{10} \text{ cm}^{-3}$ ,  $T_e = 2 \text{ V}$ , how many electrons are there in a Debye sphere?

(c) Using the data given in (b), calculate (i) the  $e^-$  thermal velocity and (ii) its plasma frequency,  $\omega_p$ .

(d) Please conduct a simple calculation of a plasma potential  $V_p$ , solely made of positive charges ( $n_i = 10^{10} \text{ cm}^{-3}$ ); the distance between the two electrodes is  $L = 10 \text{ cm}$ , and what is your conclusion?

$$e^- = 1.6 \times 10^{-19} \text{ C}, \quad m_e = 9.1 \times 10^{-31} \text{ kg}$$

$$k = 1.38 \times 10^{-23} \text{ J/K}, \quad c = 3 \times 10^8 \text{ m/s}$$

$$\epsilon_0 = 8.85 \times 10^{-12} \text{ F/m}$$

$$N_A = 6.02 \times 10^{23} \text{ molecule/mole}$$

$$N_A^{-1} = 1.66 \times 10^{-24} \text{ mole/molecule}$$

$$\text{Ar}^* = 11.5 \text{ V}, \quad \text{Ar}^+ = 15.7 \text{ V}$$

$$\text{Ne}^* = 16.6 \text{ V}, \quad \text{Ne}^+ = 21.6 \text{ V}$$

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

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

Electron energy transfer:

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

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

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

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

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

$$\text{Mean power absorbed by an } e^-: \bar{p} = \frac{e^2 E_0^2}{2m_e} \cdot \frac{v_{ea}}{v_{ea}^2 + \omega^2}$$

$$\text{Child-Langmuir eq'n: } j_i = \frac{kV^{3/2}}{m_i^{1/2} d^2}$$

$$\text{Poisson eq'n: } \nabla^2 \phi = -\frac{\rho}{\epsilon_0}$$