

# 10316862 Plasma Processing Technology

(100min, close book)

November 18, 2014

- Convert the electron speed ( $c$ ) based Maxwell distribution to the energy ( $\epsilon$ ) based Maxwell distribution, and (ii) find the most probable  $\epsilon$  from the distribution curve.
    - Explain all possible sources of secondary electrons in dc plasma, and (ii) what are the potential ranges of the cathode fall and the anode fall?
    - Describe the requirement(s) for an ambipolar diffusion to take place in terms of Debye length, and (ii) evaluate the  $D_a$  of a typical cold plasma of Hg arc with a given Hg ion diffusivity ( $D_i$ ) of  $10^{-3} \text{ cm}^2/\text{s}$ .
- In a plasma etching system of Si/CF<sub>4</sub>, show the plasma chemistry for isotropic and for anisotropic etching of the Si through the electron-neutral ionization and electron-neutral dissociation of the CF<sub>4</sub>.
  - To deposit a layer of TiN (1-10  $\mu\text{m}$ ) on a piece of high-strength steel, give the reason for your suggestions regarding the precursor chemistry as well as the deposition temperature.
  - Use the square wave to illustrate the origin of the negative self-bias in a parallel plate discharge.
- Briefly describe the conditions for a stable plasma to exist.
  - What is the physical significance of the cathode dark space as a function of the pressure and the minimum length between the two electrodes before it extinguishes.
  - 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:  $n_e = 10^{12} \text{ cm}^{-3}$ ,  $T_e = 5 \text{ V}$ , calculate the (i)  $e^-$  thermal velocity, (ii) plasma frequency, and (iii) the number of electrons in the Debye sphere.

一共 10 小題，每小題 10 分。

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

ambipolar diffusion coefficient:

$$D_a = \frac{D_e \mu_i + D_i \mu_e}{\mu_e + \mu_i}$$

Einstein relation:

$$\mu = \frac{|q|D}{kT}$$

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

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

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

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

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

Maxwell distribution:

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