CHEMICAL ENGINEERING DEPARTMENT
ChE 234, Spring, 2002

Homework Assignment No. 5

PROF. F.F. CHEN

Assigned May 18, 2004 Due May 25, 2004

1. Consider a plane-parallel argon discharge of radius R and plate separation d, with $d << R$ so that loss of plasma out the sides can be neglected. Let the plasma density n be uniform, so that ions escape to the plates at the Bohm rate. In steady state, the ionization rate has to balance the loss rate. This condition results in a relation between the neutral pressure p_o, in mTorr, and the electron temperature T_{eV}.

a) [*15*] Equating the total ion loss rate to the total ion creation rate in the discharge, derive a relation between p_0 nad T_{eV} in terms of the quantities c_s and $<\sigma v>_{ion}$ and the discharge dimensions.

b) [*15*] Using the approximate formula for $<\sigma v>_{ion}$ given in HW #1, calculate p_0 as a function of T_e for $d = 5$ cm, and plot T_{eV} vs. p_0 on a log-log scale between 0.1 and 100 mTorr.

2. An RIE reactor (shown below) is cylindrically symmetric around the axis shown. The top electrode has radius a and is driven to the RF voltage $V_a = \hat{V}_a \sin(\omega_a t)$ through a blocking capacitor. Similarly, the bottom electrode has radius b and is driven by a bias oscillator to the voltage $V_b = \hat{V}_b \sin(\omega_b t)$. The blocking capacitors prevent dc from being applied. The plates are separated by a distance d. The other walls of the vacuum chamber are ceramic. Assume that the plasma is a perfect conductor, and neglect the displacement current through the sheaths.

a) [*20*] Following the method shown in class, you are to find an expression for the RF variation of space potential V_s as a function of time. You may use the following abbreviations:

$$A_{a,b} = \text{area of electrode } a \text{ or } b$$

$$A_c = \text{area of ceramic wall}$$

$$\delta_{a,b} = A_{a,b} / A_c$$

$$\varepsilon = (\pi m / 2M)^{1/2}$$

$$\eta = eV / KT_e$$

First, set the ion and electron fluxes to the insulating wall equal to each other and derive a condition for the sheath drop $\eta_s - \eta_c$ on the walls. Then set the total electron losses to all surfaces equal to the total ion losses. (All the voltages are oscillating.) Solve to obtain an analytic expression (no numbers) for η_s.

b) [*40*] Plot η_s vs. $\omega_\beta t$ from 0 to 360° for the case a = 10 cm, b = 5 cm, d = 4 cm, V_a = 100V peak at 13.56 MHz, V_b = 200V peak at 2 MHz, KT_e = 2.5 eV, and argon gas.

c) [*5*] Plot the fractional electron current to plate b together with the voltage applied to b and the sheath drop on b.

d) [*5*] Calculate the time average $< V_s - V_b >$ and compare it with the normal sheath drop when no voltages are applied.

e) [e*xtra credit*] What is the dc value of V_s? If you cannot determine the answer, tell why.