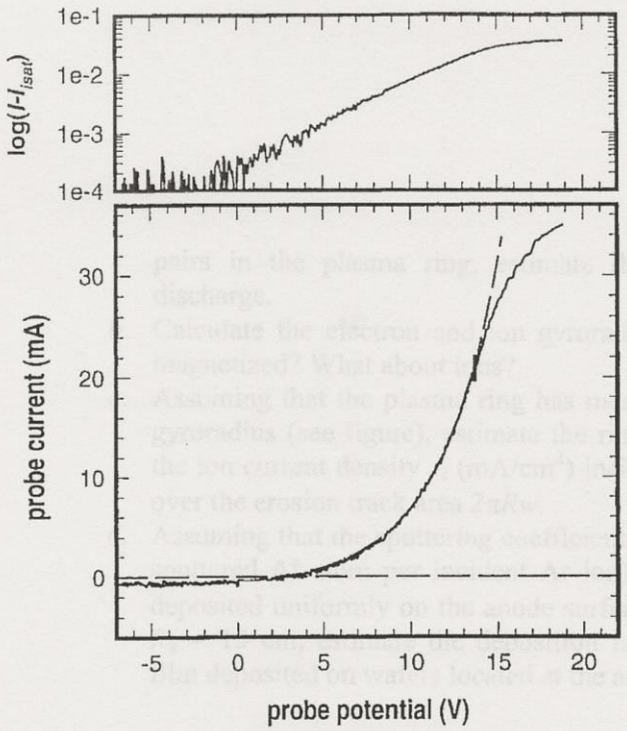
EE507 – Plasma Physics and Applications

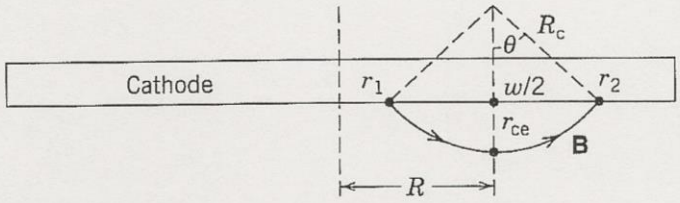
Homework #6

1. The figure below shows a Langmuir probe trace for an inductively coupled 10-mTorr-argon discharge.
   a. What happens on the left part of the graph? Why is the probe current saturated for negative probe potential?
   b. Estimate the value of the ion saturation current.
   c. Explain what happens as the potential of the probe is increased.
   d. The potential at which $I_{probe} = 0$ mA is called floating potential. Why? Estimate the value of the floating potential in this case.
   e. The region where the probe current shows a logarithmic behavior is sometimes called transition region. What happens to ions and electrons on this region? Are attracted or repelled?
   f. Beyond this region the current saturates. The value of the voltage that marks this transition is called plasma voltage. Estimate the value of the plasma voltage for this case. What happens to ions and electrons for voltages beyond this value? Are attracted or repelled?
   g. The simple model we discussed in class fits relatively well the experimental values in the transition region (dashed, exponential-type curve on the lower figure). The expression for the current on this region is $I = -e\, n_s\, u_B\, A + I_{sat} \exp[(V-V_p)/kT_e]$. Use this expression to calculate T_e from the logarithmic plot.
   h. If the probe has an area of 0.137 cm^2, estimate the plasma density far away from the probe.



2. A glow discharge in argon with $R = 2$ cm, $l = 25$ cm is operated at $p = 100$ mTorr. This gives $T_e \approx 4$ V, $\varepsilon_T \approx 40$ V, $\lambda_e \approx 0.4$ cm, and $D_a p \approx 104$ cm2-Torr/s. Find the electric field strength E. Assuming that most of the discharge is positive column, what is the voltage drop in the positive column? If the discharge current is 10 mA, what is the plasma density?

3. An axially symmetric planar magnetron discharge in argon with an aluminum cathode has a magnetic field strength $B_o = 200$ G at a radius $R = 10$ cm, where the field line is tangent to the cathode surface. The field line radius of curvature is $R_c = 3$ cm (See figure below). The discharge current is $I_{dc} = 2$ A, and the pressure is $p = 2$ mTorr.



a. Assuming that the effective secondary emission coefficient is about 0.05 for Ar^+ ions on Al and that 20% of the secondary electrons are lost by diffusive transport to the anode before creating electron-ion

pairs in the plasma ring, estimate the dc voltage V_{dc} across the discharge.

b. Calculate the electron and ion gyroradii (r_{ce} and r_{ci}). Are electrons magnetized? What about ions?

c. Assuming that the plasma ring has mean height equal to the electron gyroradius (see figure), estimate the ring width w (erosion track) and the ion current density J_i (mA/cm^2) incident on the aluminum cathode over the erosion track area $2\pi Rw$.

d. Assuming that the sputtering coefficient at the erosion track is unity (1 sputtered Al atom per incident Ar ion) and that sputtered atoms are deposited uniformly on the anode surface over an area of πR_a^2, where R_a = 15 cm, estimate the deposition rate (Å/min) for the aluminum film deposited on wafers located at the anode surface.