CHEMICAL ENGINEERING DEPARTMENT
ChE 234, Spring 2004

Principles of Plasma Processing

Final Projects: Plasma Topics

Prof. F.F. Chen | Due date: June 17, 2004

Research Sources

The main journals containing articles relevant to the physics of plasma processing and their websites are the following:

Journal of Vacuum Science and Technology A (JVSTA), http://scitation.aip.org/jvsta

Plasma Sources Science and Technology (PSST), http://www.iop.org/EJ/journal/PSST

Physics of Plasmas (PoP), http://scitation.aip.org/pop

IEEE Transactions on Plasma Science (IEEE-TPS), http://ieeexplore.ieee.org/xpl/RecentIssue.jsp?puNumber=27

Physical Review Letters (PRL), http://prl.aps.org

A very useful site on which you can find all the articles by a given author or a given topic is:

ISI Web of Science, http://isi3.isiknowledge.com/portal.cgi/wos

In doing a literature search, it is often easier to find the latest paper by a certain author on a certain topic and then trace backwards to previous papers in his list of references. Once a topic is chosen, suggested papers for your initial search will be given to you. If two students pick the same topic, we can negotiate; it may be OK.

Suggested Topics

1. Performance of helicon sources in industry

This is a report reviewing how helicon sources have been used in industry so far. You will be provided with a list of publications on industrial uses of helicon sources. There have been many such reports, and you may want to specialize to a single topic, such as etching, deposition, or optical coatings. The main point is to evaluate the performance of helicon sources in relation to other plasma sources. Are they better for some applications than for others? In reviewing specific papers that you have picked out, describe the apparatus and the measurement techinques used, and give examples of results obtained.

2. Avoidance of coating effects on Langmuir probes

Since Langmuir probes measure the current from the plasma, they will fail if an insulating coating is deposited on them in the course of operation. Two methods have been invented to sidestep this problem. The Plasma Oscillation Probe, as used, for instance by H. Sugai of Japan, is based on the excitation of plasma oscillations along the probe. The capacitively coupled probe, used, for instance, by N. Braithwaite of England, puts a pulsed voltage on the probe and measures the current capacitively coupled through the coating. The theory of the method should be described, as well as the construction of the apparatus. Give examples of the results, and if possible compare the accuracy with other methods. Conclude with your evaluation of the utility of these methods.

3. Surface-wave microwave sources

A large body of work has been done by M. Moisan and J. Margot of Canada on using microwaves to ionize plasmas without cyclotron resonance. The idea is to generate a special surface wave which does the ionizing. This project involves describing the theory of these waves, the apparatus used to generate them, and the results that have been achieved. If there have been practical applications of surface wave generation, these should be emphasized. End with an opinion on the usefulness of this method to the semiconductor industry.

4. Particulates in RIE reactors

Dust is a problem in high-pressure plasma sources. Start with observations of such particles and the methods of detection. What are the sizes of the dust grains, and what do they look like? How do you determine the potential that they charge to, and how much charge is on each one? Where in the plasma do these grains accumulate, and why? Finally, how are these grains formed? There are some papers on this subject, but the final answer may not yet be known.

5. Dual-frequency CCPs

A new type of capacitive discharge is being successfully marketed by Lam Research, Inc. for oxide etch. These devices have very small gaps, so that the sheaths can occupy most of the space, leaving only a small region of quasineutral plasma. The pressure is so high that collisions occur in the sheath, and most of the ionization and heating occurs there. These sources are, therefore quite different from ones we are familiar with. However, Prof. J.K. Lee and his group in Korea have made many numerical studies which throw light on how these sources work and why they are successful. This project is to review this work and pick out the most interesting parts.

6. Ambipolar diffusion in one dimension

This project is no more than a long homework problem and will take the least time, but it requires more mathematical experience than the other topics. Up to now, we have considered weakly collisional plasmas which in which the density is almost uniform, with a slow decrease to ½*n* at the sheath edge. In high-pressure plasmas, however, when the mean free path is much shorter than the discharge dimensions, the ions must diffuse to the walls, driven by an ambipolar electric field. The project is to solve the steady-state ambipolar diffusion problem in the presence of ionization for a plane-parallel discharge.

The plasma lies between two infinitely large conduction plates at $x = \pm d$, so that the problem is one-dimensional. The equation of continuity is

$$\frac{\partial n}{\partial t} + \nabla \cdot \Gamma = Q, \quad \text{where} \quad \Gamma = -D_a \nabla n \ \text{ and}$$

Q is the source term

$$Q = Zn, \quad Z = n_n < \sigma v >_{ion} .$$

a) Show that in steady state the equation to be solved can be written

$$n'' = -qn \text{, where } q \equiv Z / D_a .$$

b) Show that a solution symmetric about $x = 0$ has the form $n = n_0 \cos(kx)$, and determine the value of k.

c) Since the density will be low near the sheath edge, assume $n(\pm d) = 0$. Show that this boundary condition imposes a condition on d if q is known.

d) Evaluate q for $KT_e = 3$ eV assuming that D_a is given by the $T_e/T_i >> 1$ approximation. For this you will need the ion-neutral charge-exchange collision frequency ν_{io}. The best way to find this is to use the measured mobility of Ar^+ in Ar, which is $\mu_{io} = 1.17 \times 10^6 / p_0$(mTorr) and calculate D_{i0} from this mobility.

e) Show that d, in cm, is specified by $d(\text{cm}) = 36 / p_0(\text{mTorr})$.

f) Figure out what would happen if this very restricting condition is not satisfied.