

Basic Nanotechnology Processes

E SC 212

Unit 2

An Introduction to Uses of Plasma in Processing

Lecture 1

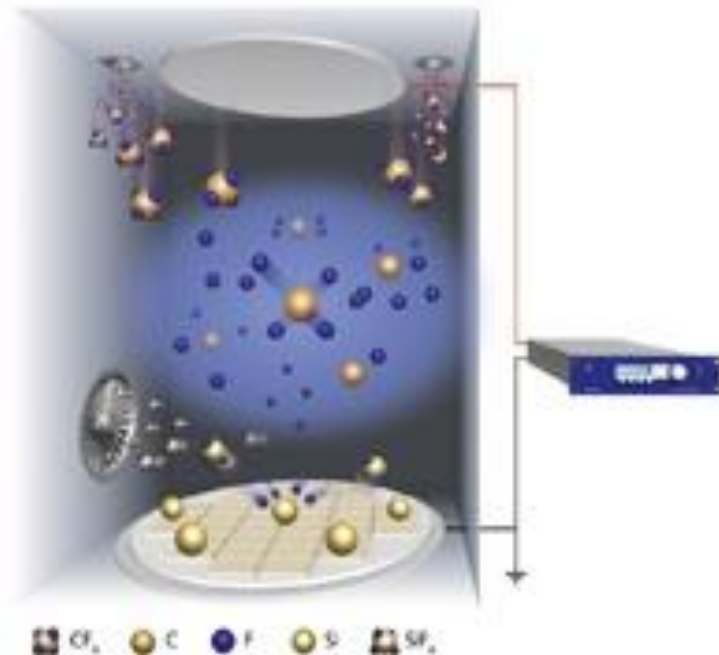
Plasma Basics

Outline

- What is a plasma?
- How are they made?
- Why are they useful in processing?
- Additive Plasma Processes
- Subtractive Plasma Processes

Basic Definition of a Plasma

- An (almost) neutral “soup” of electrons and positively charged ions



How is it made?

- By using some energy source to tear the electrons off of atoms (ionize the atoms) resulting in energetic electrons and ions
- Examples: lighting discharge, fluorescent light, sodium vapor lamps, flames
- Each plasma has a specific color determined by its composition (the gas(es) used) due to quantum mechanical energy levels

Common Plasma--Lightning



Common Plasma--Fluorescent Lights

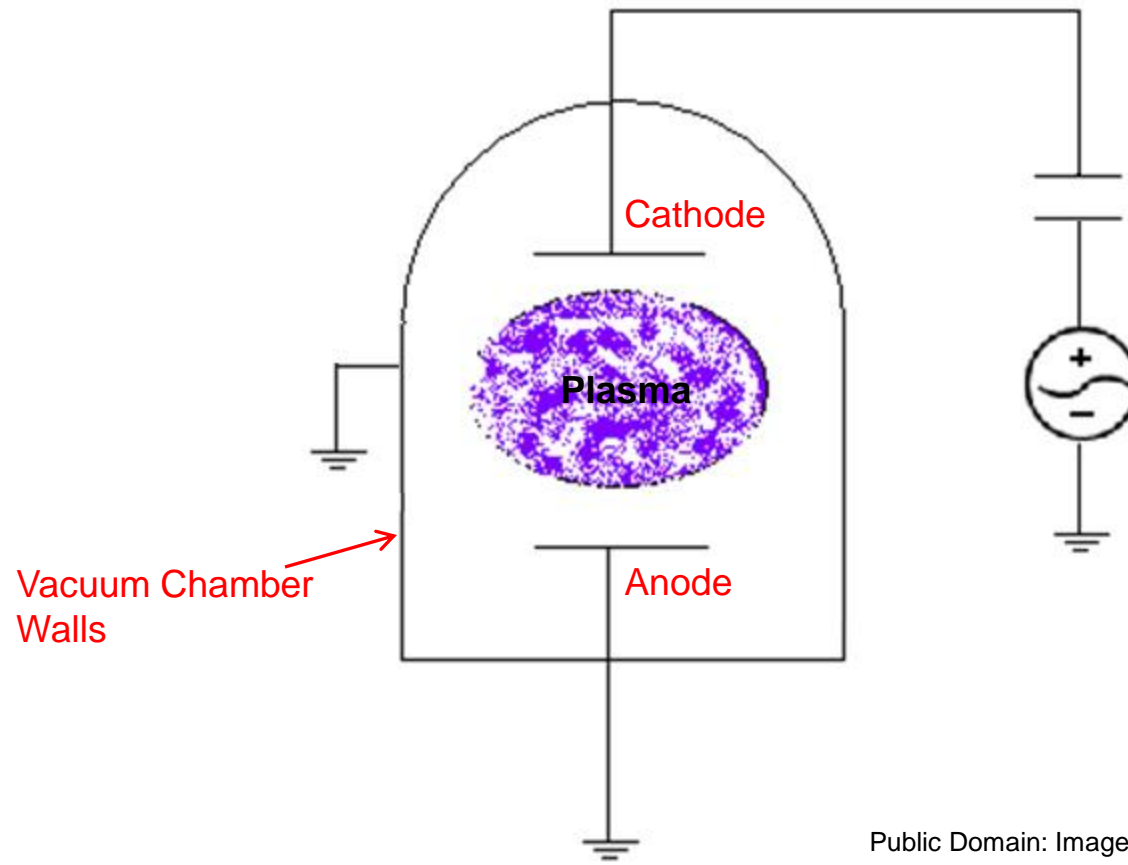
- A good example of a “plasma system” that you are familiar with is the fluorescent lights.
- What do you know about the fluorescent lights?
 - Use electrical energy to ionize atoms.
 - Under vacuum to prevent chemical reactions with air and to allow atoms and materials sufficient mean free path to allow for electron dissociation (i.e., ionization).
 - Emissions from ionized Hg gas (plasma) plus impact of coating on inside of tube plus causing fluorescence gives light at many wavelengths = (almost) white light. Different gases can change the color of the fluorescent light.

Man-made Plasmas for Processing

How are the Plasmas Used in Processing Created?

- DC bias (like a lightning storm).
- AC bias (like a fluorescent bulb).
 - There are two basic types of AC plasmas:
 - **capacitively coupled**
 - **inductively coupled plasmas**

General Set-up



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Man-made Plasmas for Processing

- **Vacuum = Clean and completely controlled**
- **Environment is completely defined by user so full control of possible chemical reactions and of collisions between molecules, atoms, etc.**
- **Control space between the gas, molecules, ions and electrons thereby controlling collisions and possibility of ionization**
- **Why is spacing important?**
 - **The space allows for collisions of the material to provide dissociation.**
 - **Spacing between the gas atoms or molecules is called Mean Free Path (MFP). Plasma glows a specific color depending on its constituents.**

Plasma Overview

- MFP allows energy to be transferred to the gas.
- Electric fields in a plasma can cause accelerated collisions, dissociation, and/or ionization.
- Dissociation is the splitting of molecules into parts of molecules. Often these parts are radicals (unpaired electrons) which are very chemically active.
- Ionization is stripping electrons from atoms or molecules.

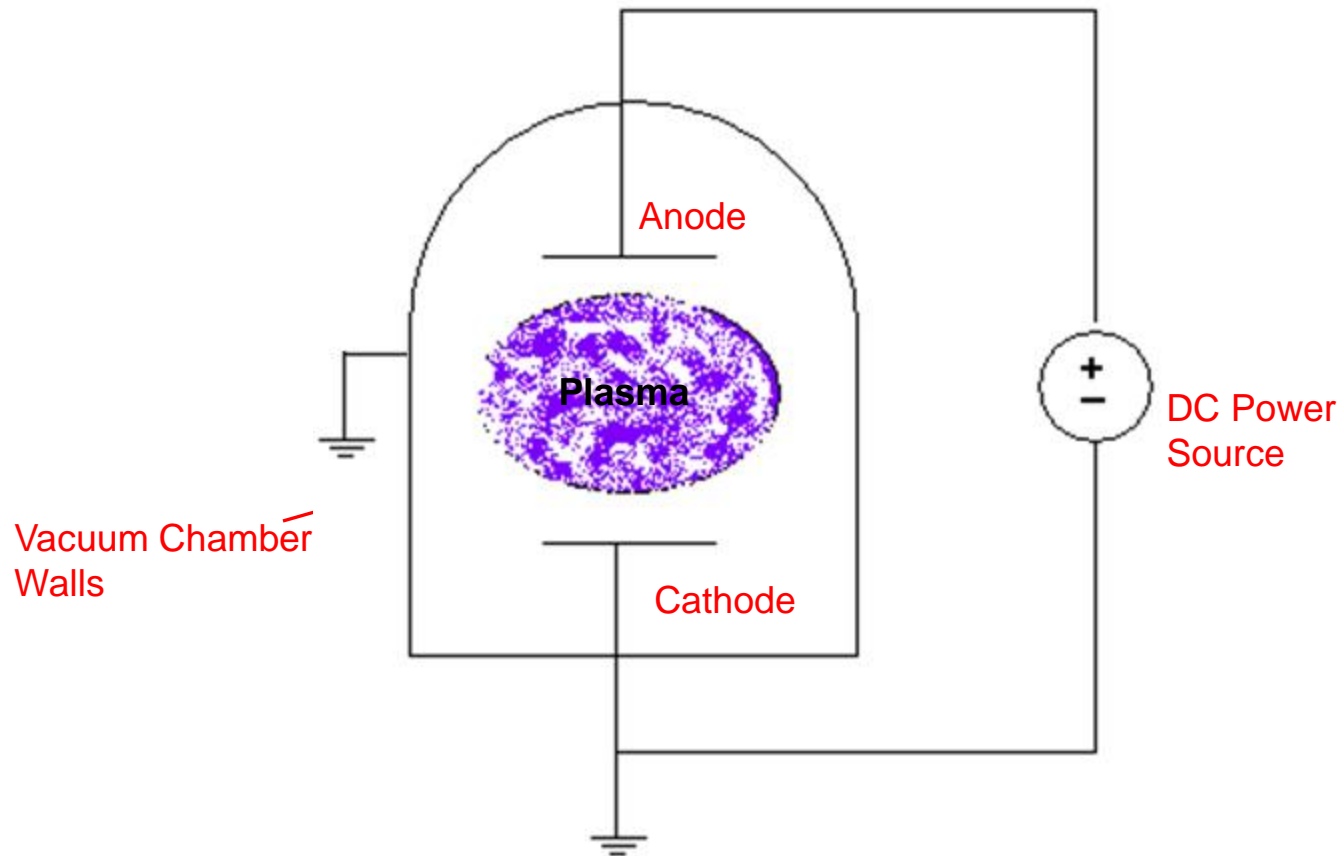
Why are Plasmas Useful in Processing?

- Energetic ions can be used to bombard surfaces thereby driving chemical reactions giving etching or deposition.
- Plasmas can be used to split apart precursor gas atoms or molecules in the plasma. The fragments can recombine to produce unique materials that deposit as films.
- **Energy is not supplied in the form of heat** but as electrical energy through current and voltage. **Generally this allows a relatively lower temperature process.**
- Plasmas have dissociated atoms, molecules, and **radicals**, and can also have chemical reactions, occurring in the plasma and/or at the surface.
- Plasmas have physical processes too: ion bombardment.

Controlling Factors in Man-made Plasmas

- Pressure
- Energy input
- Flow rate
- Voltage developed between the plasma and substrate
- Chamber condition

DC Plasma

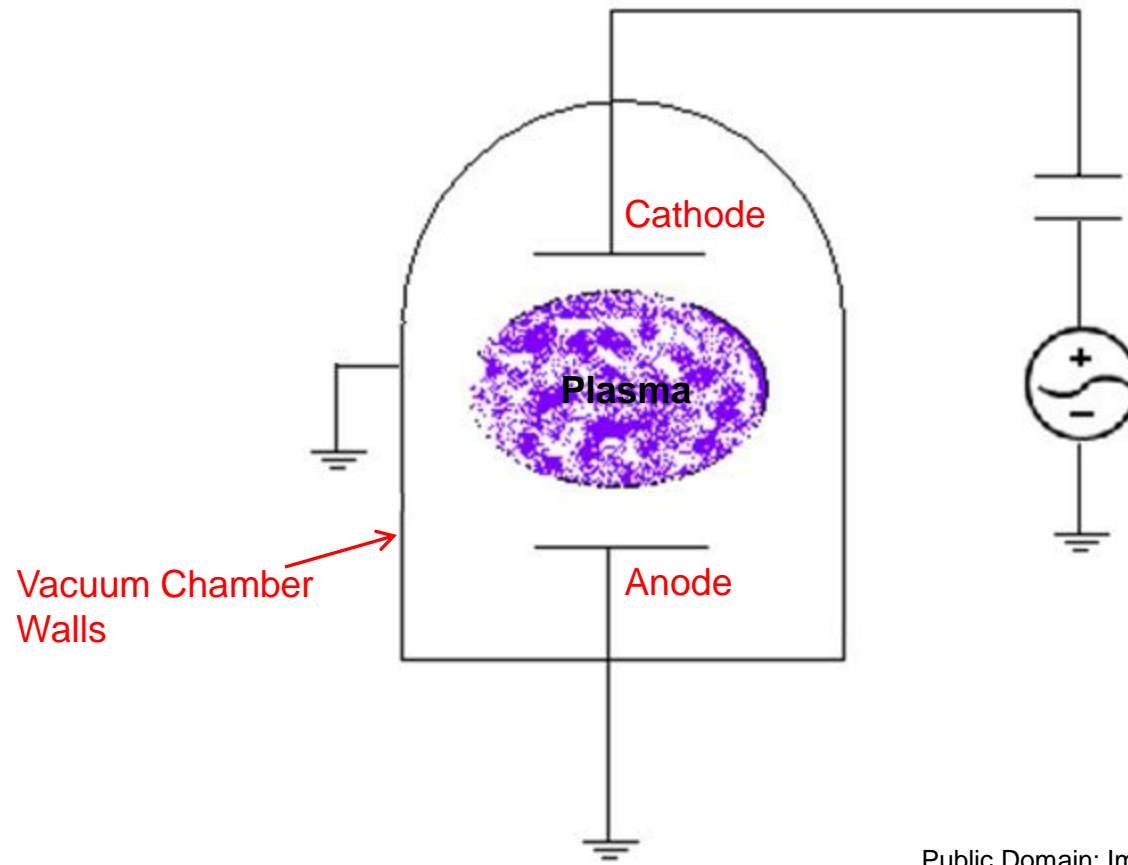


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DC Plasma

- Substrate to undergo processing can be placed on the cathode or anode.
- Substrate on cathode will be impacted by neutral particles (atoms, molecules) and positive ions.
- Substrates on the anode will be impacted by neutral particles (atoms, molecules), negative ions, and electrons.
- Set-up can be designed to have strong positive ion bombardment on the cathode. Material etched off cathode can then be deposited on a substrate placed on the anode. This deposition process is called DC sputtering. The material removal at the cathode is etching. A plasma processing tool can be designed to optimize deposition or etching.

AC Capacitively Coupled



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AC Plasma:

Capacitive Coupling

- Energy is coupled into the plasma through time-changing electric field.
- Usually driven at Radio Frequency 13.56 MHz.
- Resulting plasma can be used for etching and deposition depending on the design of the processing chamber and the gases used.
- Can be designed to have positive ions bombard the cathode.

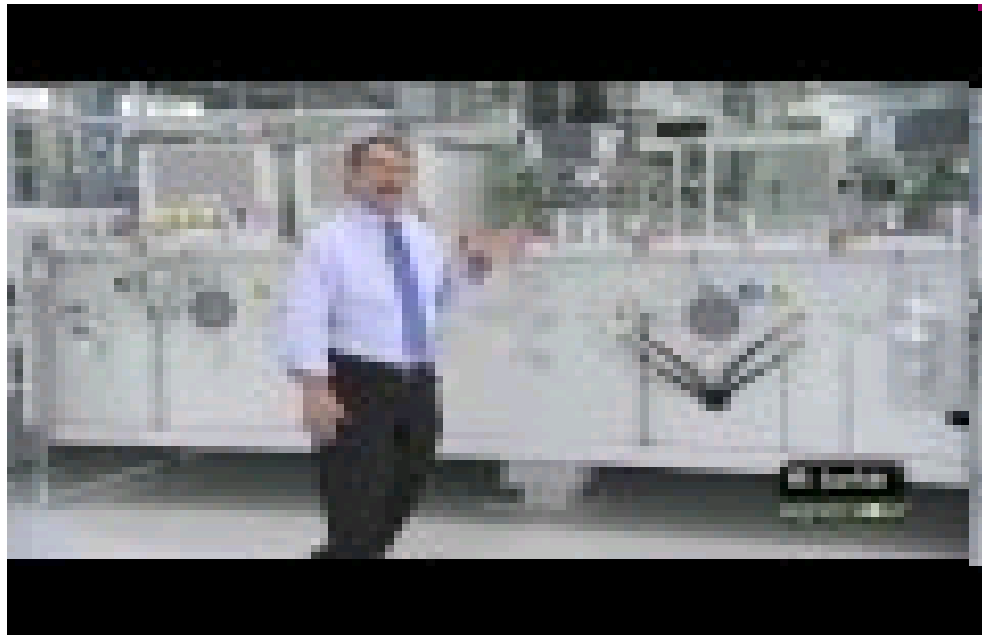
AC Plasma: Inductive Coupling

- Energy is coupled into the plasmas through time-changing magnetic fields.
- There are two common versions:
Inductively Coupled Plasma (ICP) and
Transformer Coupled Plasma (TCP).
- Depending upon the system, they can be driven at RF or microwave energy.
- Resulting plasmas can be used for etching and deposition, depending on the design of the processing chamber and the selected gas.

Overview of Types of Plasma Processes

- Additive processes---using plasmas for deposition
- Subtractive processes---using plasmas for etching

Plasma Processing Today



Summary

- Plasmas play a very big role in nanofabrication
- Biggest role is in top down nanofabrication
- They are important because they open paths to useful chemistry and this chemistry can be done at (relatively) low temperatures
- This chemistry can be used for deposition (additive processes) or etching (subtractive processes)
- Plasmas can be used to exploit chemical and physical phenomena