Tutorial 4

1.

Draw the schematic diagram of a Reactive Ion Etching (RIE) System.

a. **Name the electrode which is connected to the RF generator.**
b. **Suggest several ways to increase the etching rate of the system.**
c. **If $\frac{Vc}{Va} = 10^4$ and the diameter of the cylindrical cathode is 40 cm, determine the area of the anode.**

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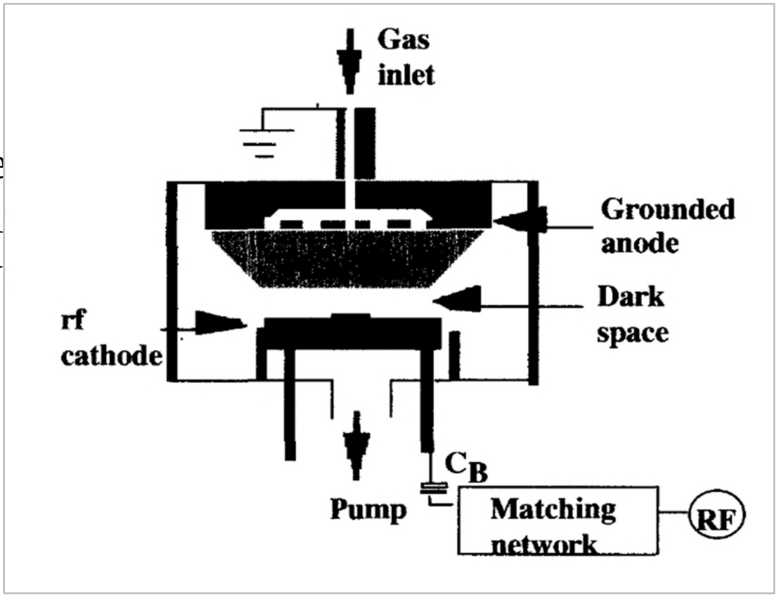
1. Draw the schematic diagram of a Reactive Ion Etching (RIE) System

(a) Cathode

(b) Any 2 of the possibilities: Increase the Anode Are Decrease Cathode Area, Increase Power Densi Introduce higher temperature, Introduce inert gas w heavier atomic weight.



Reactive Ion Etching (RIE) System

(c) $|V_c| = V_a \left(\frac{A_a}{A_c}\right)^4$; since $\left|\frac{V_c}{V_a}\right| = 10^4$;

Therefore, $A_a = 10 * A_c$; $A_c = \pi r^2 = 0.50\, m^2$

Hence, $A_a = 5\, m^2$

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2. **Explain what is a reactive plasma and how it is generated in a DC glow discharge? What are the advantages and disadvantages of reactive ion etching versus sputter etching? Cite an example of when one might want to use sputter etching rather than RIE?**

Reactive plasma describes a discharge process in which ionisation and fragmentation of gases take place and produce chemically reactive species. Such species are reactive both in gas phase and with solid surface. These reactive species are used to interact and etch or remove the surfaces that are not masked by the lithography pattern. Electron collision are inelastic and will result in ionised species or excited neutral species in the plasma via ionization, relaxation, recombination, etc

RIE gives more selectivity; sputtering etches almost everything, at about the same rate.

Use sputter etching when etching multilayer stack of different materials on the substrate, when etching substrate a little doesn't matter. Selectivity is not important here so there is no need to develop an RIE process for this.

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3. Using a suitable schematic diagram, describe the operation principles of a parallel plate capacitive coupled plasma etching system. Suggest one method that can be used to increase the plasma bombardment energy on the wafer.

For the above system, explain the origin of the plasma sheath. Sketch the voltage distribution between the electrodes when the electrodes are of different surface area. Briefly explain your answers.

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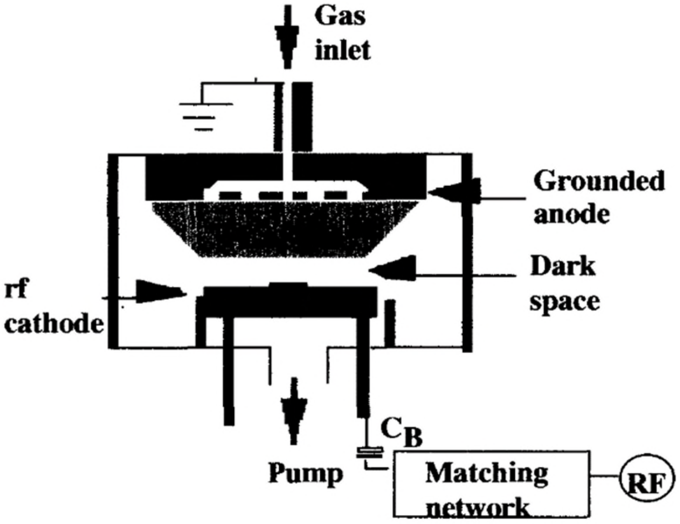
- The etching chamber consists of two parallel electrode plates.
- Top electrode is grounded and the bottom electrode is driven by an 13.56 MHz rf generator, connected through a capacitor and an impedance matching circuit.
- Sample is placed on the bottom electrode.
- Etch gas is fed into the etch chamber which is kept under a pumped evacuated environment.
- Free electrons in the chamber gain energy by following the oscillation of the applied rf power which leads to the formation of plasma.
- The rf driven electrode of the RIE system is dc isolated from the power supply by a capacitor C_B.



A parallel plate capacitive coupled plasma etching system

- The function of the capacitor is to block the electrode from discharging through the power supply.
- When the electrode is positive, many highly mobile electrons are accelerated towards the electrode causing a significant accumulation of negative charge.
- When the electrode (the cathode) is negative, heavy, immobile ions are accelerated towards. However, only relatively few of these ions strike the electrode compared to the number of electrons on the previous cycle.

To increase the plasma bombardment energy on the wafer – increase RF power supply or reduce cathode area

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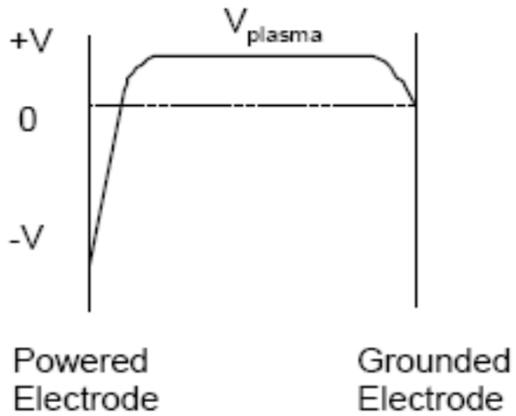
(ii)

Therefore, a high electric field region is formed around the cathode. This region is known as the plasma sheath, or the dark space, where ion acceleration takes place before bombarding the electrode.

The plasma potential is determined by the expression: $$|Vc| = Va\left(\frac{Aa}{Ac}\right)^4$$

Where *Vc* is the potential difference between the powered electrode (cathode) and the plasma, *Va* is the potential difference between the ground electrode (anode) and the plasma and

$\frac{Aa}{Ac}$ is the ratio of the respective electrode areas.



Larger magnitude in Vc if area of anode is large.

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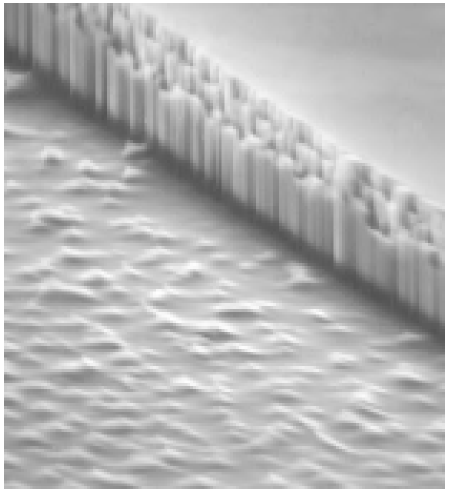
4. (a) Identify three drawbacks associated with wet chemical etching processes?

(b) Figure 4 shows a SEM image of a Si wafer surface after a C_2F_6 dry etch. What can one deduce from such a result of an etching process?



Wet Etching:

- no proper etchant for materials (e.g. Si3N4)
- minimum etching dimension relatively large
- undercutting in isotropic etching

Due to fluorocarbon contamination after C2F6 etch

Figure 4: SEM image of Si Wafer Surface