# Feature Size control and Anisotropic Etch Mechanism

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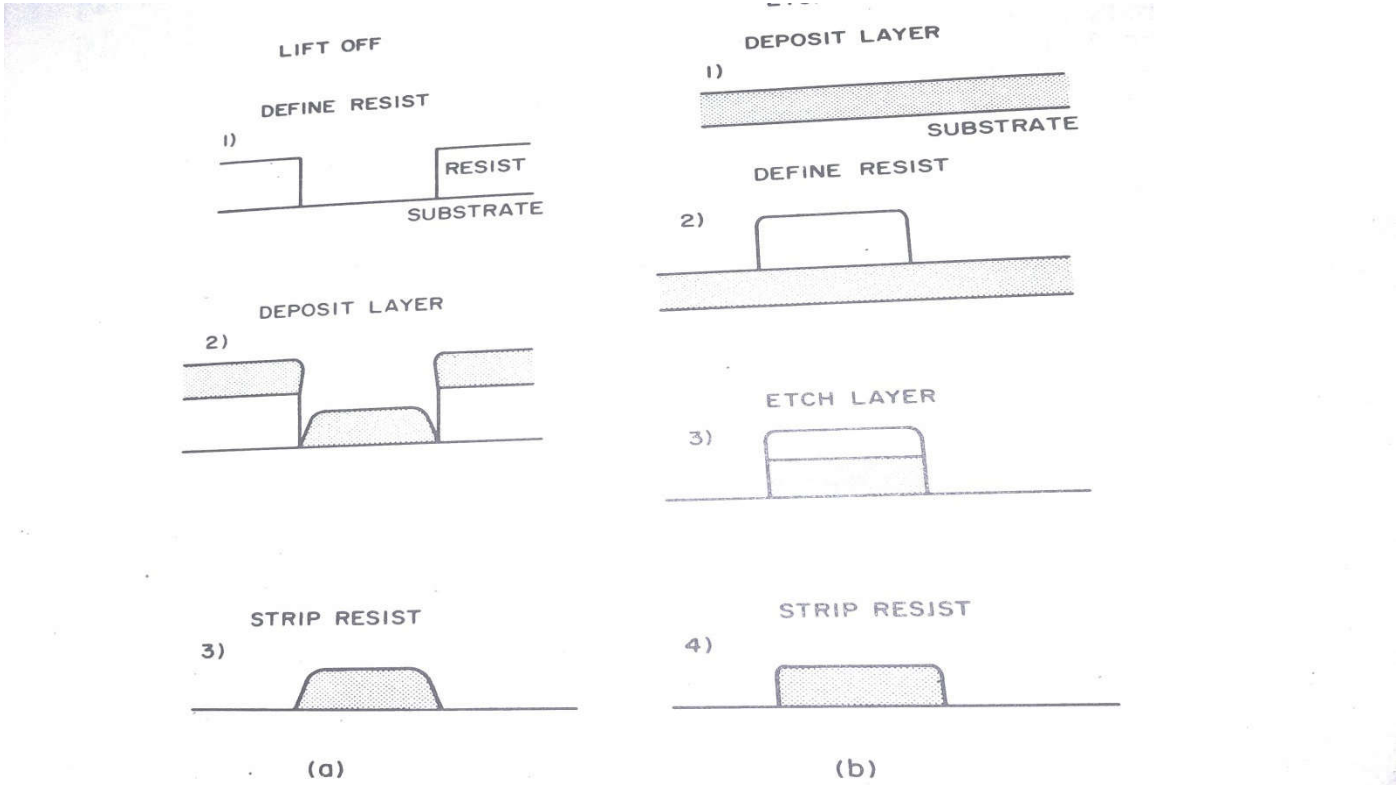
# Feature Size control and Anisotropic Etch Mechanism

- To define the pattern of any type of deposited layer is first define in a polymeric resist film and then transferred to the layer.
- As shown in fig. there are two technique of pattern transferring i.e lift off technique and etching technique.
- For lift-off technique, the pattern resist fim is formed first followed by a blanket deposition of the layer.Dissolving away the resist and then “lift-off” the unwanted material.
- Two disadvantage of this technique are a rounded features profile and temperature limitation. Because of shadowing the deposited feature profile  made with the lift-off technique has rounded top.With lift-off, the deposition technique is also limited to temp below 200-300 degree C, at which point resist begins to degrade.

# Feature Size control and Anisotropic Etch Mechanism




A schematic representation of two techniques for transferring resist features into a layer. (a) Shows the resist/deposition strip sequence of lift off, and (b) shows the deposit/resist/etch/strip sequence of etching.

# Feature Size control and Anisotropic Etch Mechanism

- For this reason most patterns are transferred using the etching technique. Here the layer is first blanket deposited then the pattern ed resist is formed and the layer is etched using the resist as a mask.
- If the etching process attack the layer surface equally in all direction the etch is said **isotropic** .Most liquid etch are isotropic and the result in under cut of the mask and the narrowing of the feature.
- Once the amount of feature narrowing for an isotropic etch is known, then the designed features size can be achieved by making the mask larger.

# Feature Size control and Anisotropic Etch Mechanism

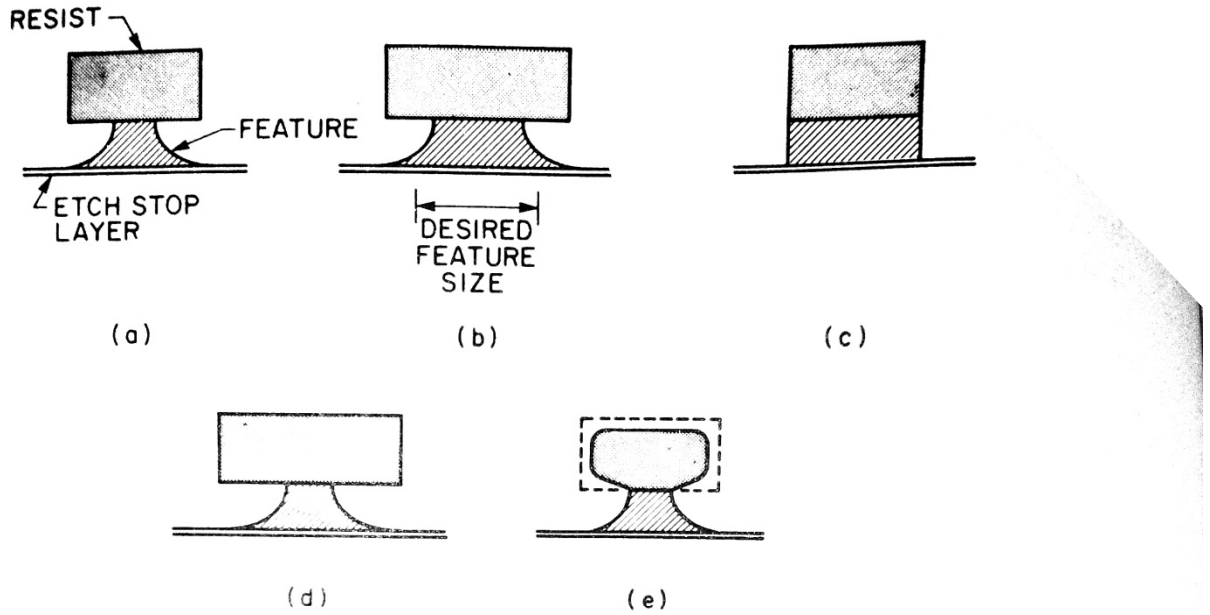



**FIGURE 10**
A schematic representation of some commonly observed etched profiles: (a) purely isotropic etch, (b) isotropic etch with a compensated mask, (c) anisotropic etch with no horizontal component, (d) isotropic etch with overetch, and (e) isotropic etch with isotropic etching of the mask.

# Feature Size control and Anisotropic Etch Mechanism

- For VLSI device, in which feature heights have comparable dimensions to feature linewidth and space, mask compensation is impossible. For this reason plasma etch technique, which are capable of anisotropic etching, are so important to VLSI technology .

# Feature Size control and Anisotropic Etch Mechanism

- If the etching process attacks the layer significantly faster in the vertical direction than in the horizontal, the etch is said to be anisotropic. The degree of anistropy of an etch process can be expressed as

$$A=1-Vh/Vv$$

A=degree of anisotropy

Vh=horizontal etch rate

Vv=vertical etch rate

If A=0 ⟶ Isotropic etching

A=1 ⟶ Anisotropic etching

# Others Properties of etch process

- **Selectivity**
- The selectivity of a process is a measure of etch rate of the layer to be etched relative to the other material on the wafer surface .The selectivity is normally expressed simply as the ratioof these two rates:

$$S_{ab} = E_a / E_b$$

Ea=etch rate of the layer to be etched

Eb=etch rate of the second material

- Selectivity to the masking material and to the layer immediately under the layer to be etched are two important process parameter .The former usually determine the intial height of resist necessary to accurately transfer the pattern into a layer.

# Others Properties of etch process

- **Uniformity**
- The etch rate uniformity refers to the constancy of an etching process at every site on every wafer in the process. Intra wafer uniformity rate refers measured within a single wafer while inter-wafer uniformity refers to rate measured from wafer to wafer.
- **Throughput**
- The number of wafer entered per unit time is refered to as the throughput of a process.

# Etching

- Selective removal of material in silicon IC process is known as etching. The process may be chemical and physical.
- By **physical** means etching can be done by the KE associated with the bombarding ions in the ion stream or plasma .In this process the direction of the charged particle can easily be controlled so that finer line definition and greater anisotropicity can be achieved.
- By **chemical** means greater selectivity can be achieved and it is possible by chemical interaction which are standard electronic bonding processes that result in the formation or dissociation of chemical species o the surface.

# Etching

- Etching can be classified as **dry** and **wet etching.**
- In case of **dry etching**, the wafer is bombarded by ions, radicals or atoms in the vapour phase.
- The process can be partially or totally physical.
- The substrate or wafer is subjected to ion bombardment either in plasma environment or by scanning of a focussed ion beam in a vaccum environment.

# Etching

- So dry etching process is classified into- **plasma based** and **ion based.**

In ion beam etching technique

- If a directed ion beam process with an inert ion species is used for the removal of material,it is known as ion beam etching or ion milling.
- If reactive ion species are used the process is called **reactive ion beam etching (RIBE).**

# Plasma Etching

- Modern VLSI uses reactive plasma etching.
- Reactive plasma is a discharge in which ionization and fragmentationof gases take place and produce chemically active species.
- During plasma process, the target wafer are bombarded by serveral energetic ion species.the interaction with the wafer can either be a chemical reaction, a physical one (sputtering of material) or both.
- In plasma etching, the wafer are introduced in plasma environment created by a gas mix.

# Properties of Plasma

**1.DC plasma Excitation**

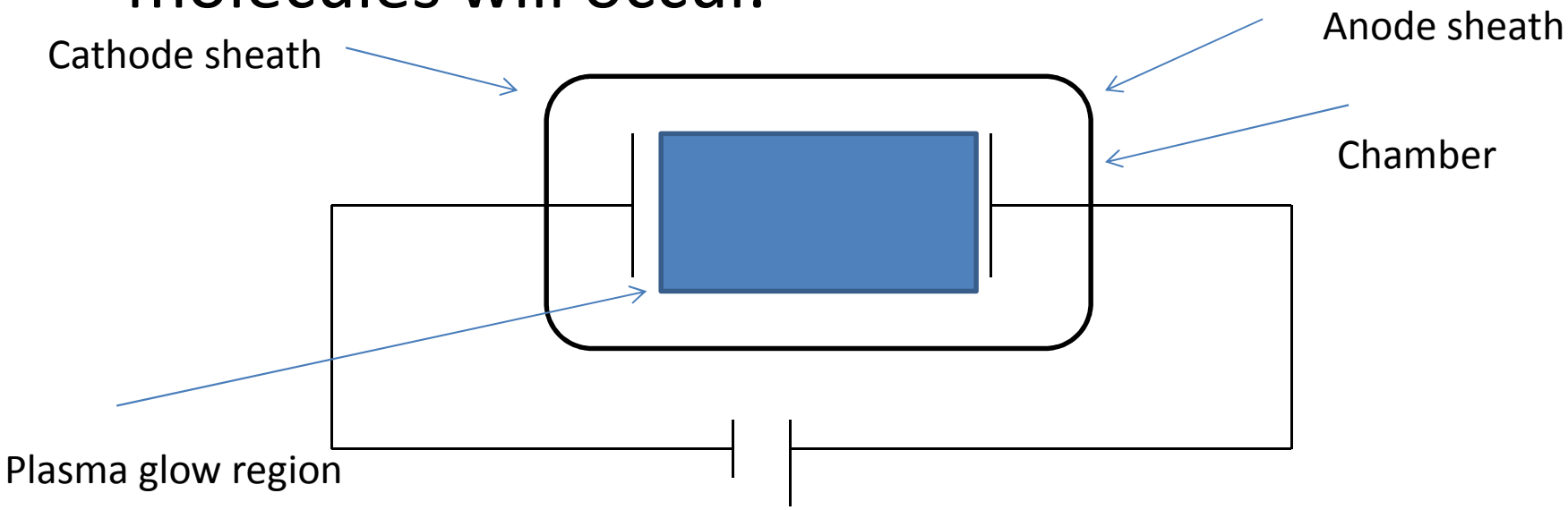
A plasma can be considered as a collection of electrons, singly and multiply charged positive and negative ions along with neutral atoms and molecules and molecule fragments.

These particles are confined in a reaction chamber.

These charged particles result from the interaction of the applied gas with the applied electric fields.

# Properties of Plasma

- Fig below shows a simple method of exciting a plasma by placing DC potential across two conducting electrodes in te chamber. At a high local field, ionization of a neutral gas molecules will occur.



# Properties of Plasma

The released electron then accelerates towards the positive electrode and along the way undergoes a series of collision which further ionize neutral species in the plasma by

Dissociation attachment

$e + AB \longrightarrow A^- + B^+ + e$

Dissociation

$e + AB \longrightarrow A + B + e$

Ionization

$e + A \longrightarrow A^+ + 2e$

# Properties of Plasma

- Some collision yield more electrons , which raise the state of ionization or the density of ionization .Additional electron are generated by secondary emission from energetic positive ions colliding with the negative electrode..Elastic electron collision can cause neutrals and ions to be raised to excited state and later decay by photo emission.
- These collisions may also lower the ionization level in the plasma by neutralization through collision with the chamber wall.

# Properties of Plasma

**AC plasma Excitation**

The periodic change in the position of the cathode and anode dark spaces take place if the polarity on conducting electrodes is altered at a low frequency.

As shown in fig , if a rf signal is applied to an electrode through an impedance matching network the response of the plasma to the positive and negative cycle are different. When the electrode is positive, many highly mobile electrons are accelerated towards the electrodes causing accumulation of negative charge.

For negative electrode, heavy immobile ions are accelerated toward it.

# Properties of Plasma

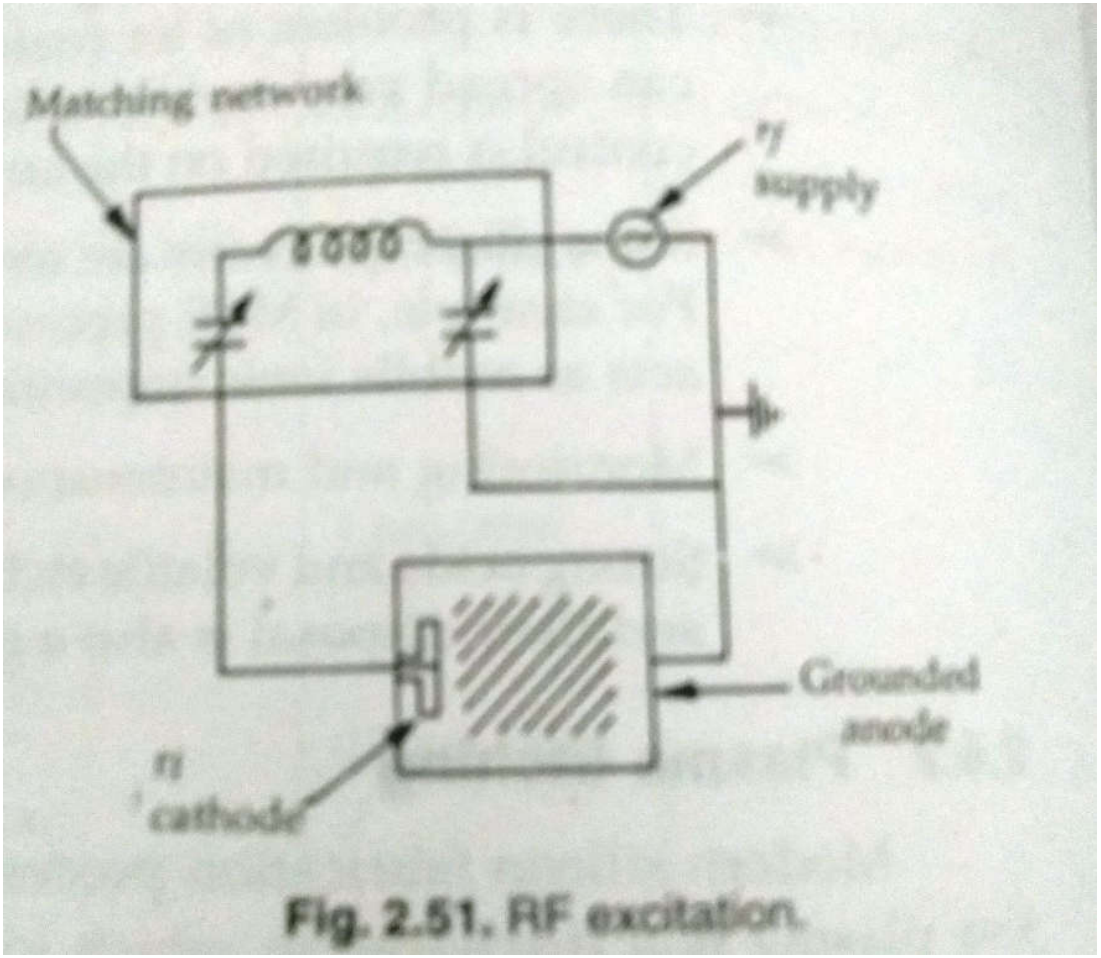



Fig. 2.51. RF excitation.

# Properties of Plasma

The electrode is DC isolated from the power supply by a blocking capacitor Cb which does not allows the elctrode to discharge through the power supply.

High frequency electric fields cause more efficient ionization in a discharge than a DC fields.

# Etching System

**Planar plasma etcher**

Planar etcher are usually more suited to more physical processes like sputter etchng or reactive ion etching.

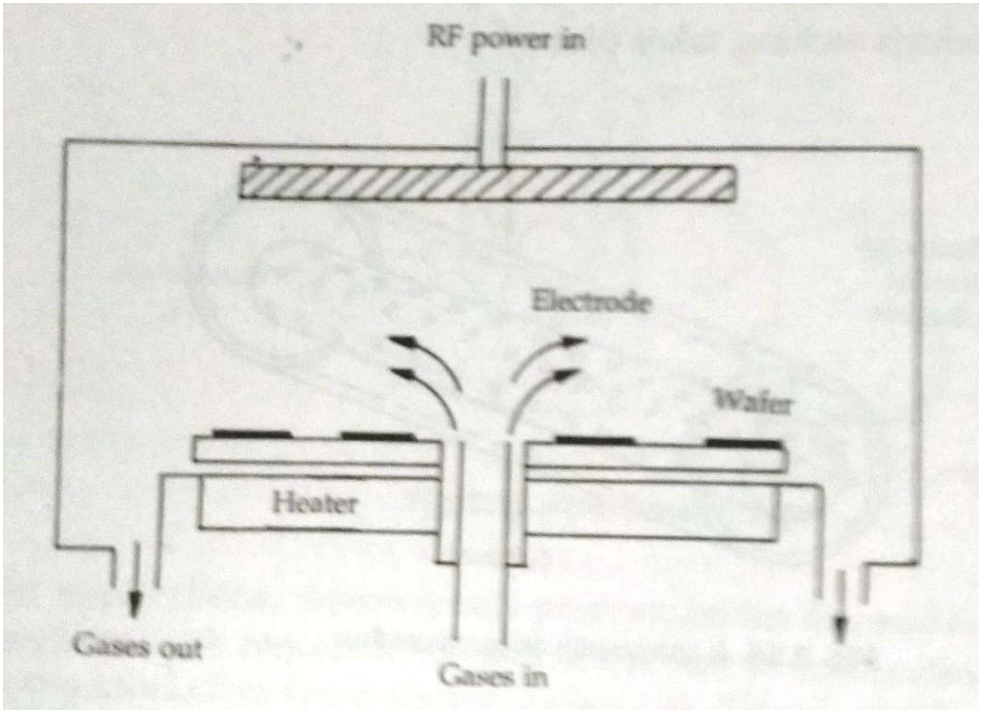
These processes give rise to much greater anisotropicty and fine line definition thought the selectivity is poor.

The throughput is relatively low depend on the area of the planar electrode.

A planar plasma etcher using two parallel placed electrodes, in which one of the electrode is grounded on which the wafer to be etched are loaded.

# Etching System

- The other electrode is connected to RF supply through an appropriate matching network to ensure maximum power transfer.



# Etching System

- It is important in such system that sputtering does not occur.
- For this potential difference between the electrodes is kept low and pressure should be high.
- The reactor has controlled gas inlets to regulate the input gases.the gaseous etch products are pumped out by vaccum system.
- Only one side of the wafer is exposed to plasma, the other side is protected

# Etching System

## Barrel Etcher

A schematic of a barrel etcher is shown in fig .

Higher pressure are used normally.

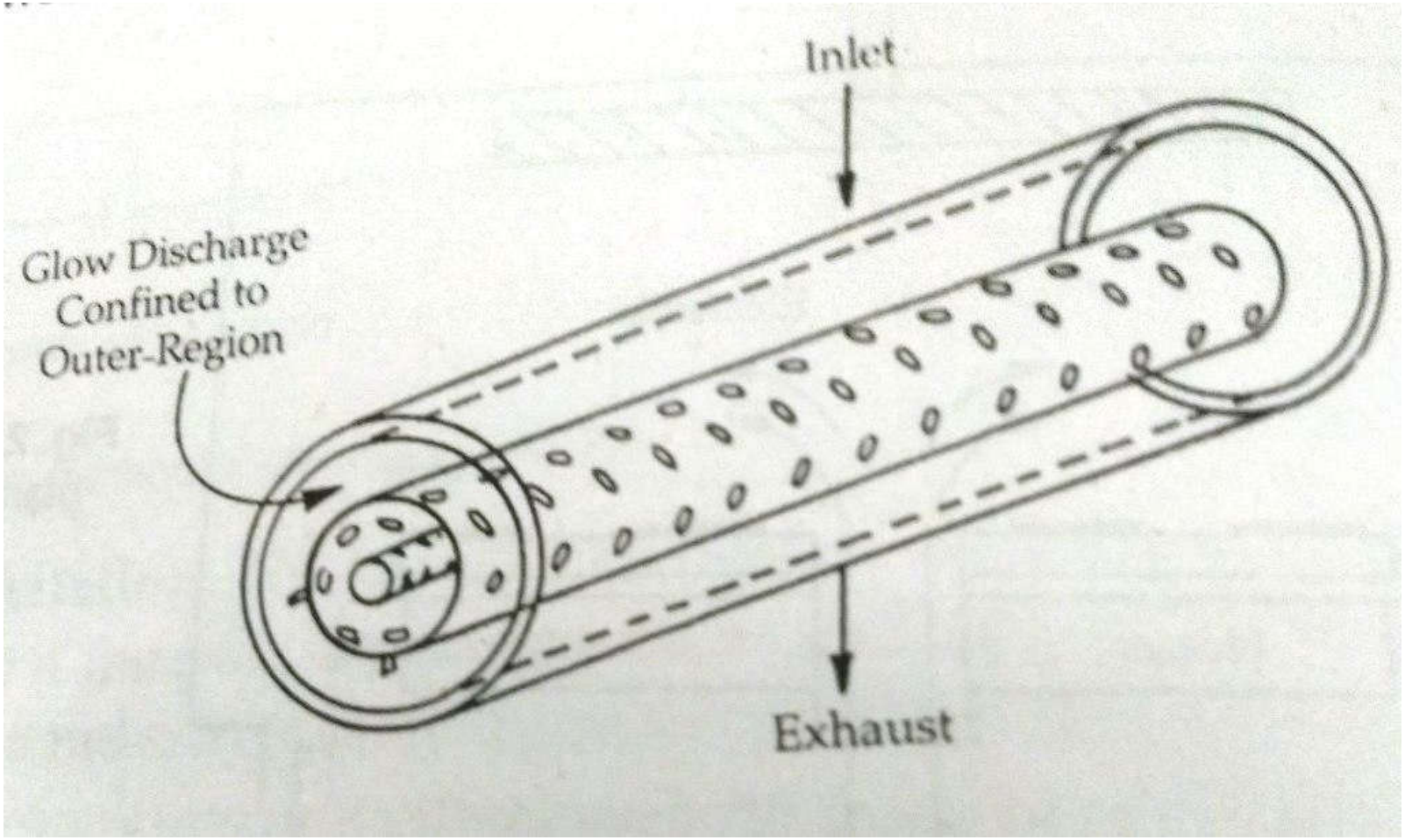
The system consist intrinsically of twohollw concenteric cylinders between which the plasma discharge is confined.

The inner cylinder is perforrated aluminium sheild and the wafer to be etched are placed vertically in a wafer holder place axially along the core of the inner cylinder.

Inner cylinder acts as the floating anode of the plasma system.

Quartz is used to make the outer cylinder.

# Etching System



# Etching System

- In the quartz tube a suitable inlet for gases is provided.
- The perforated aluminum mesh allow the reactive species n the plasma to penetrate into the inner cylinder with in which etching take place.
- Barrel reactors are relatively cheaper and can process many wafer simultaneously.

# Etching System

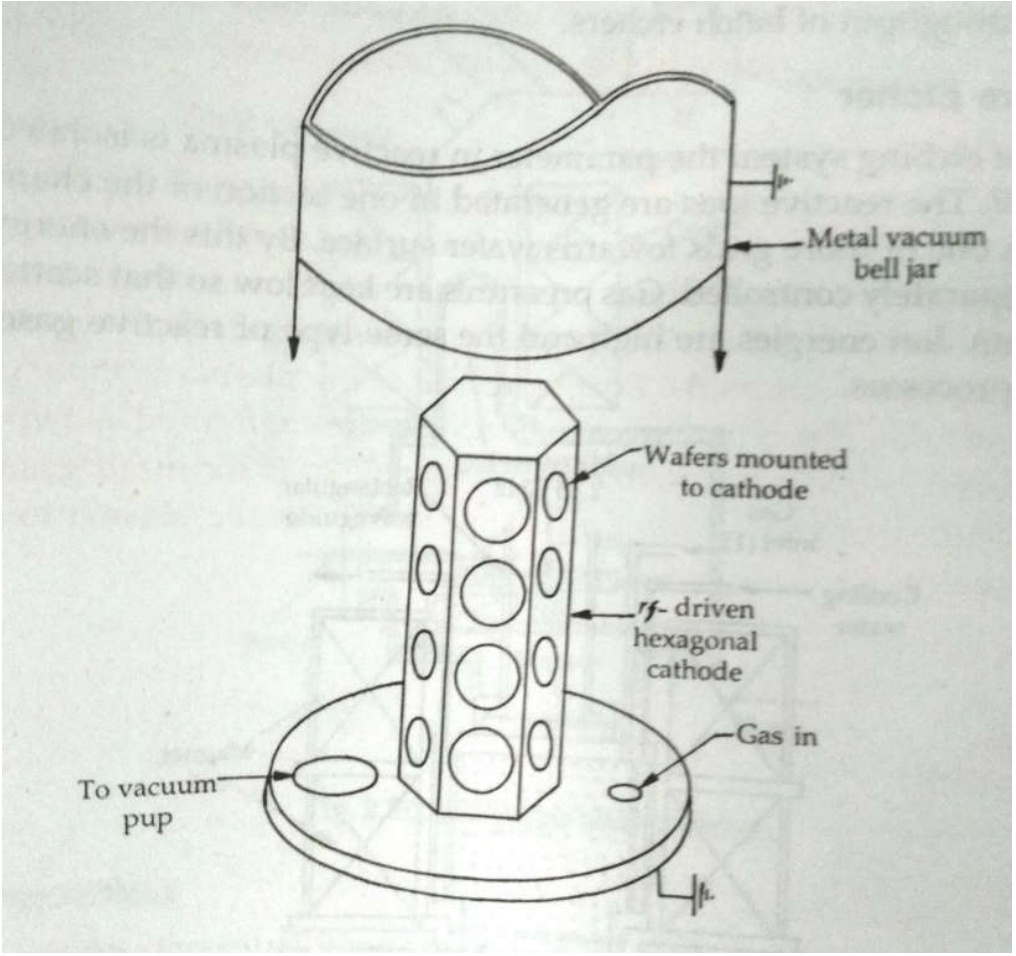
**Reactive Ion Etcher (RIE)**

In RIE, the rf driven electrodes hold the wafer instead of the grounded electrode.

This allows the grounded electrode to have a larger area because it is the chamber itself.

The larger area combined with low operating pressure leads to a higher plasma sheath potentials at the wafer surface which results in higher energy ion bombardment.

# Etching System



# Etching System

- The hexagonal cathode etcher is shown in Figure. In this system the wafer are first mounted on to a rectangular holder or tray that are subsequently clamped on to the six vertical facets of the hexagonal prism.
- The whole metal bell jar which is the top of the process chamber act as a grounded anode.
- The facet can hold more wafer therefore it has better throughput the planar system

# Etching System

**Reactive Ion Beam etching (RIBE)**

In this kind of etching system the parameter in reactive plasma is isolated. The system is shown in fig. The reactive ion is generated in one section of the chamber and then accelerated through one or more grids towards wafer surface. By this ,energy and density of the ions can be separately controlled.

Gas pressure are kept low so that scattering does not decollimate the beam.

Ion energies are high and the same type of reactive gases are used as in reactive plasma processes.

# Etching System

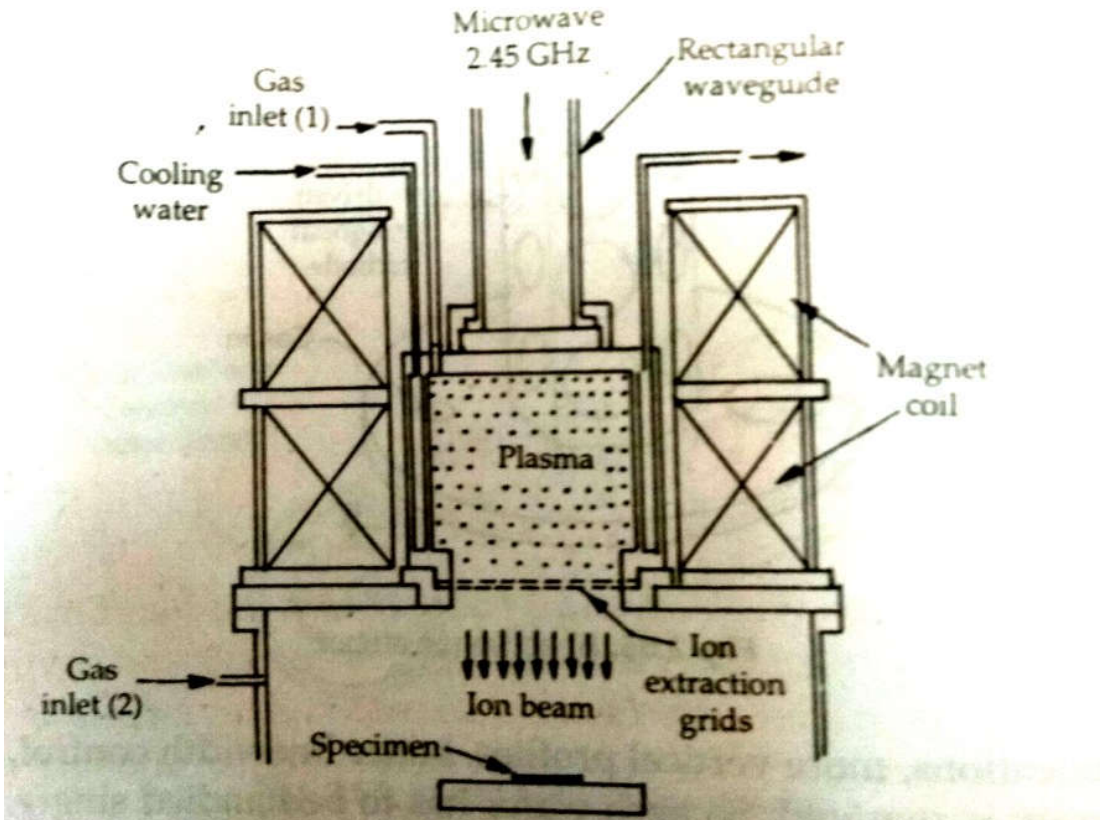



Fig. 2.57. Reactive ion beam etcher.