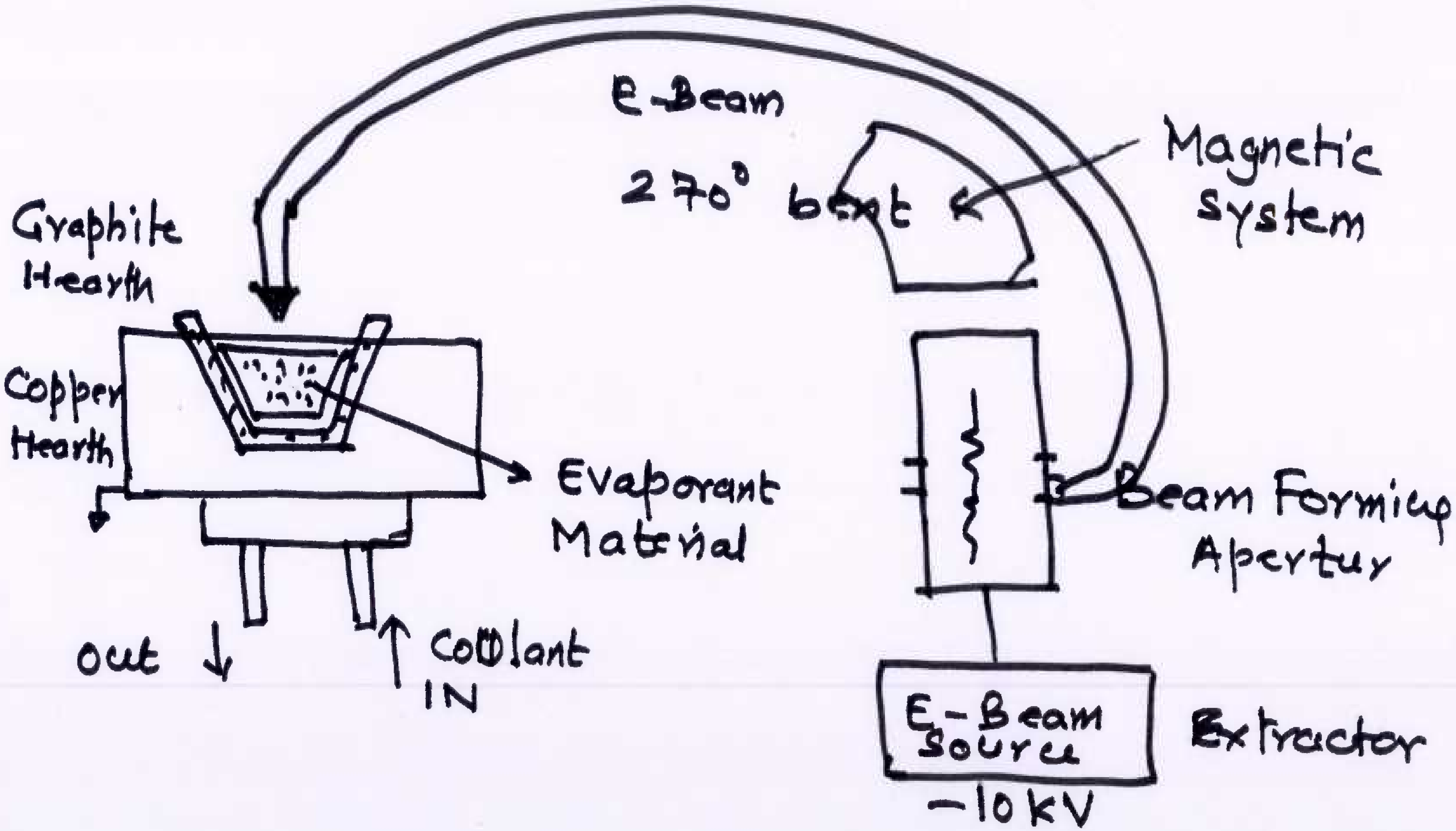
(ii) Electron Beam Evaporation



a. E-beam is complex and costlier than simple evaporating System.

b. Extractor voltages are around 5-10 KV

c. Temperatures achieved could be around 3000°C

d. Can evaporate all that Resistive Heated System can do. That apart it can evaporate
   - Ni, Pt, Ti, V, Zr, W, Mo, Ta, Rh
   - Al_2O_3, SiO, SiO_2, Tin Oxide, Titanium Oxide etc

e. Radiation Damage on wafer

Plasma Processes in IC Manufacture

1. Plasma Implantation
ii Sputtering
iii Plasma CVD (PECVD)
iV Plasma Etching (Dry Etching)
v Plasma Anodisation

So what is Plasma ?

[A] Plasma is the 4th State of Matter, other three being Solid, Liquid and Gas

[B] 99% of Universe is in Plasma State.

⇒ [c] Plasma Consists of +tive, -ve and neutral particulates

(d) However it should be noted that Plasma is Neutral

(e) If one wants a material to change it's state from Solid to Liquid or Liquid to Gas, one needs 10^{-2} eV/particle energy (Typical). But to change Gasious State to Plasma State, we may require 1 - 30 eV/particle energy.

(f) Plasma Processes are called 'Cold-Processes' Ambient Temperature could be < 300°C, but Electron Temperature could be in Thousands of °C. (kT energy)

(g) In a Plasma system, one observs Three regions of discharge, each with different characteristic.

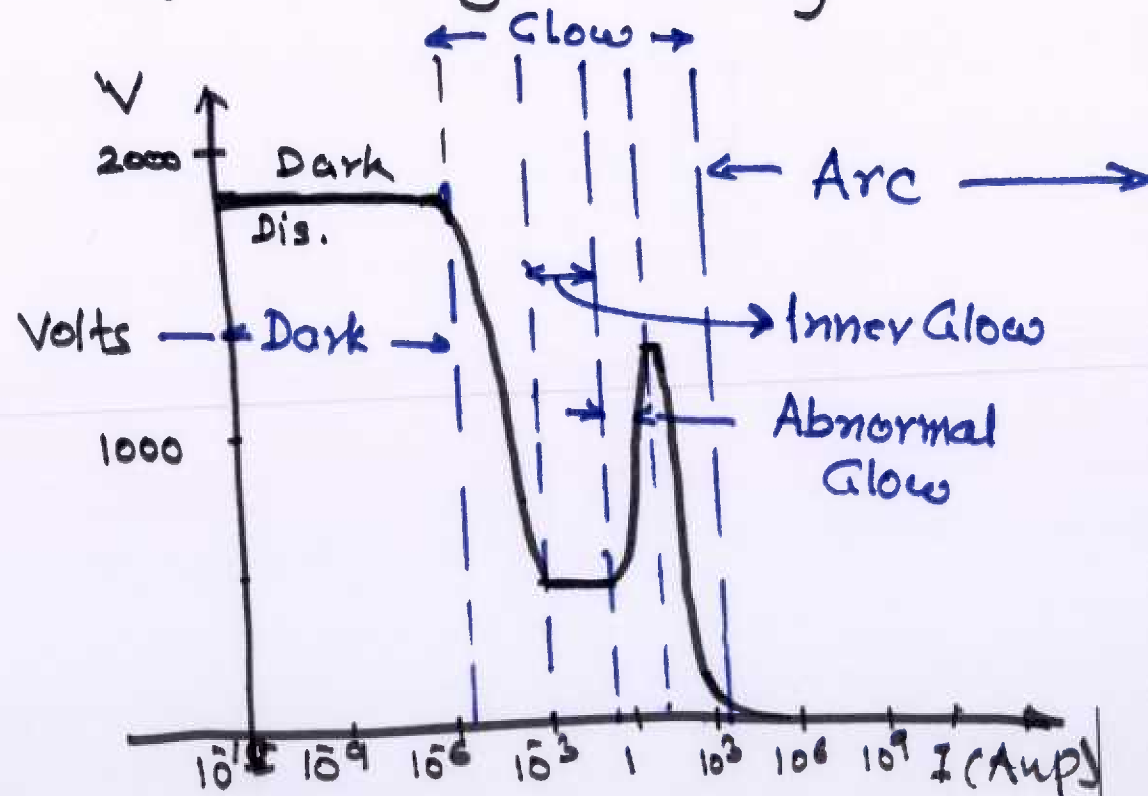
(h) There are Three zones of Discharge namely

(i) Dark Discharge

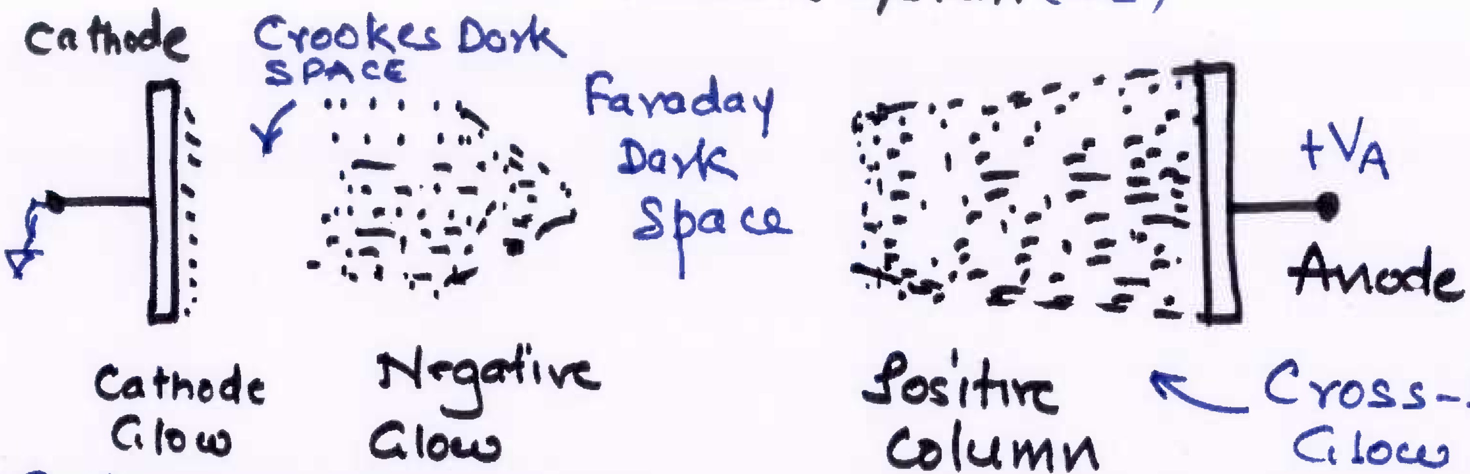
(ii) Glow Discharge

(iii) Arc Discharge

I-V Characteristics of a Plasma is shown →



Low Pressure System (Gas)



← Cross-Sectional View of Glow Discharge

Explanation of I-V :→

If Applied Voltage > Breakdown voltage, Current flows from Anode to Cathode. Breakdown voltage is defined as on-set of Plasma after conversion from Gas.

This is <u>Dark Discharge</u>

Electrons emitted at Cathode travel to Anode and had fixed ionic collisions, then such created ions travels to Cathode

Some of these ions impinge on cathode with finite velocity acquired during travel. These ions produce Secondary Electrons from Cathode Surface. Glow at the cathode is called Cathode Glow and is Self Sustaining.

If current in external circuit is quite large, there is huge plasma containing electrons and ions. This is the region called Arc Discharge. As Conductivity is high, voltage drops.

In Glow discharge system as shown, we have next to Cathode Glow a region called Crookes Dark space. In this regions we have only Positive ions. This region is most important region called Sheath which is adjascent to Cathode Glow. It's thickness is Mean free distance of Electrons, traversing towards Anode without collisions. As Electrons gather energy from field, they are capable of creating Plasma. This is called 'Glow' region.

After ionising the Gas, electrons do not sufficiently have energy to ionise, but they gather it further as they travel towards anode. The region where there is no Plasma, is known as Faraday's Dark space.

Beyond that electrons are energetic to create plasma as they reach Anode and this region is called Positive Glow (Closer to Anode)

The Region of Interest for us in 'Glow' region.

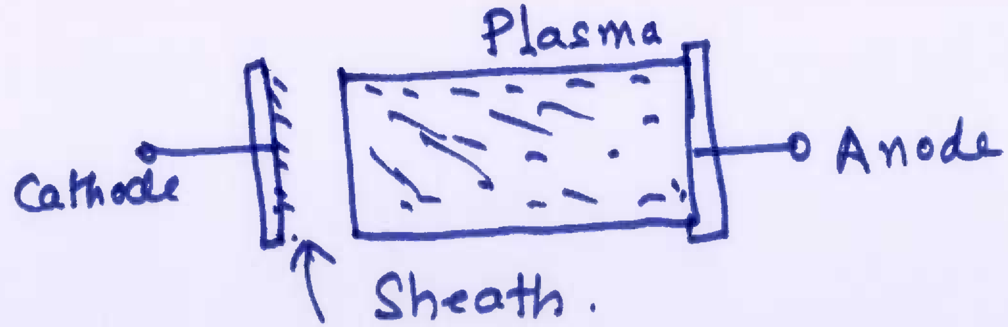
As electrons create Plasma near cathode after Crookes Dark space, initially the area of plasma is smaller than Cathode area. The potential which allows sustainance of Plasma is 'Sheath Potential.' This Glow is called Normal Glow.

However as Power (I.V) increases beyond this part, the Glow covers entire Cathode area, which in turns increases current density at cathode. This results in increased secondary electron emission.

In this small Power region, Voltage is higher and current is also high. This results in stronger Plasma Glow called Abnormal Glow. This is the zone of INTEREST in VLSI Fab.

After Glow, we see increased current but very small voltage drops (Intense Plasma). This is called Arc - Discharge.

Since distance to reach Anode has no direct impact on Glow near cathode, we can reduce, this length of tube from Cathode to Anode. Bringing anode closer to cathode, removes Positive Glow, as well as Faraday Dark space. Even part of Negative Glow reduces. Thus we have picture of Plasma

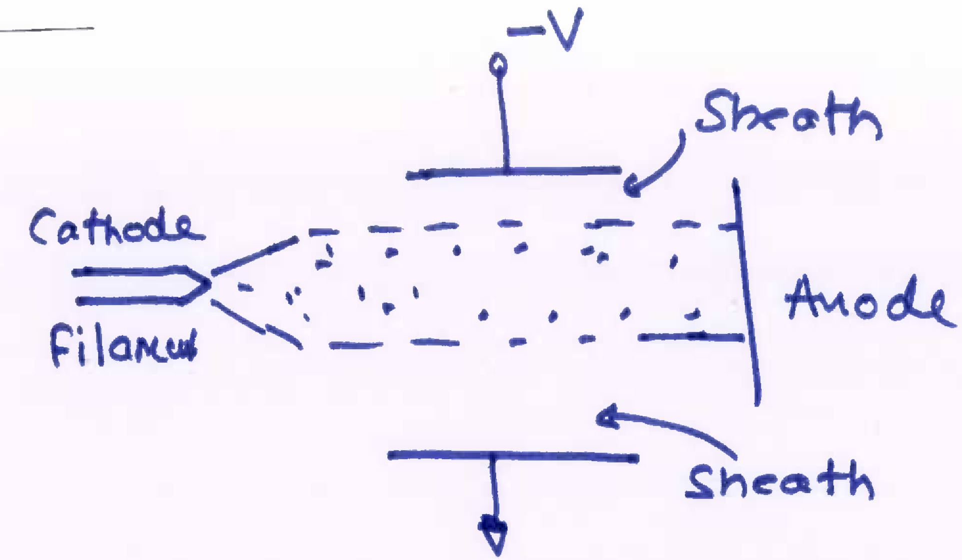


DC Discharge normally occures at Pressures of 3×10^{-2} torr and applied voltage in the range 100 V to 300 V.

If we reduce Pressure, we have the following issues:

1. Mean Free Path Increases. Hence
2. Unlikely event of Collision and hence Creation of Plasma may be inhabited.

However this occurs due to lower no. of Secondary Electrons availability at Low Pressure.
However if we have heated filament, which can supply, requisite electrons, then Plasma can be sustained



Low Pressure system.

(B) AC / RF Discharge :

At AC bias with Low Frequency, the (DC bias like) (Glow) Plasma alternates between Anode & cathode

However at Larger Frequencies, DC Plasma is difficult to start or Sustain.

But electrons can pick-up enough energy during Oscillations and may create Plasma.

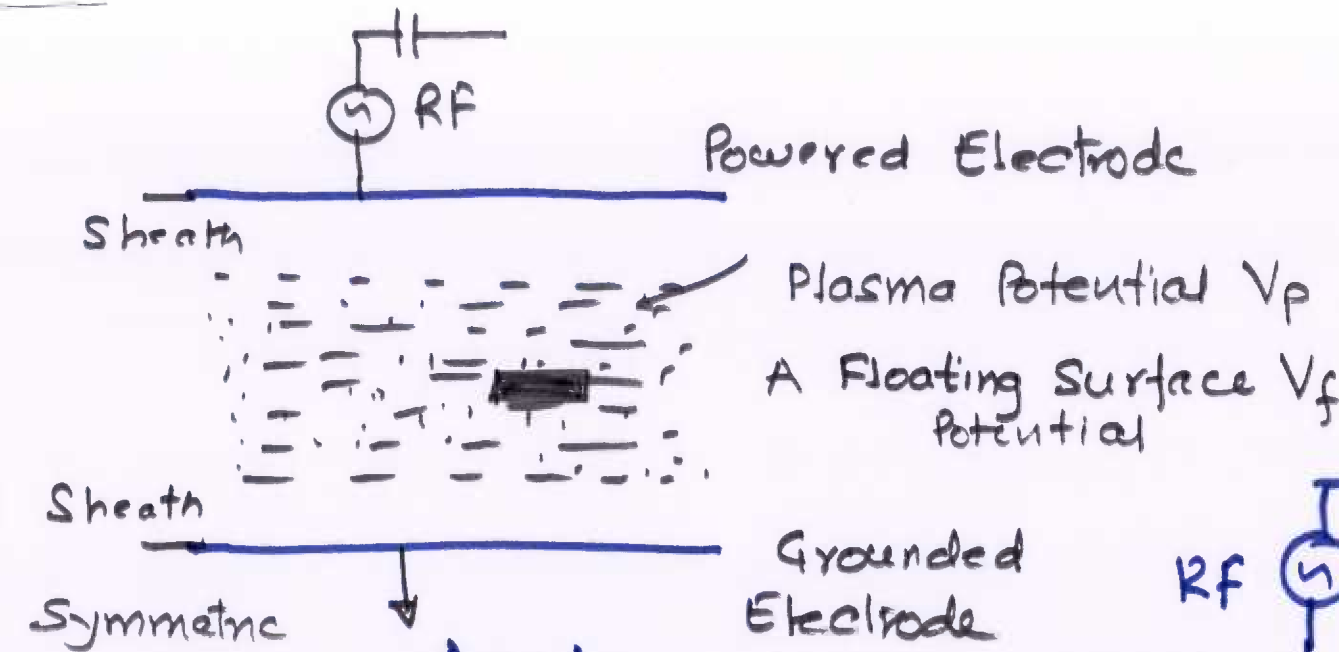
CDEEP
IIT Bombay

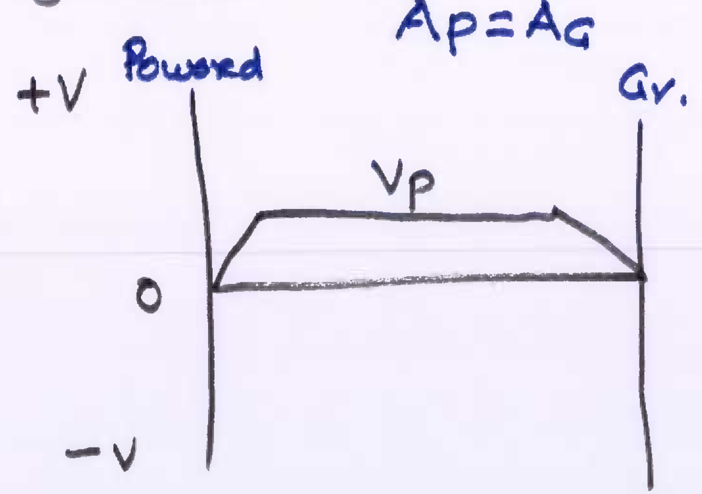
It is seen that for RF discharge, we have

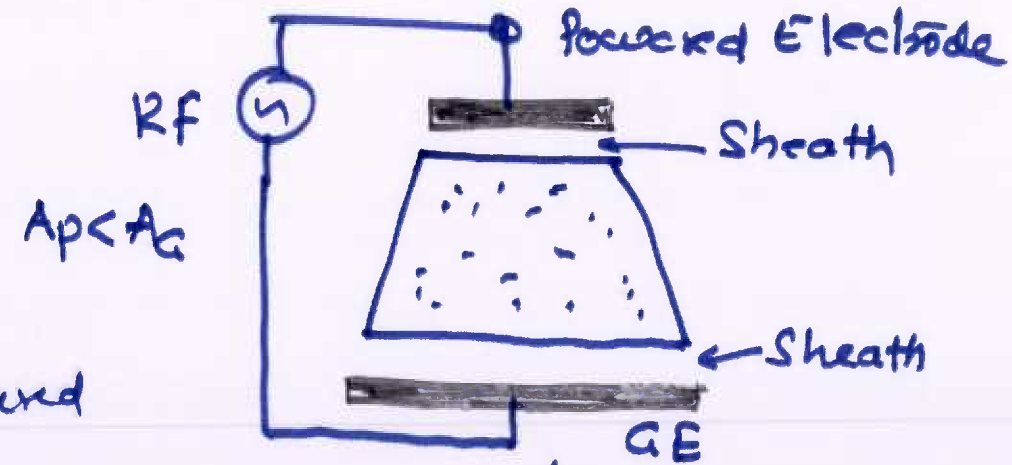
$$P \propto \frac{1}{f}$$

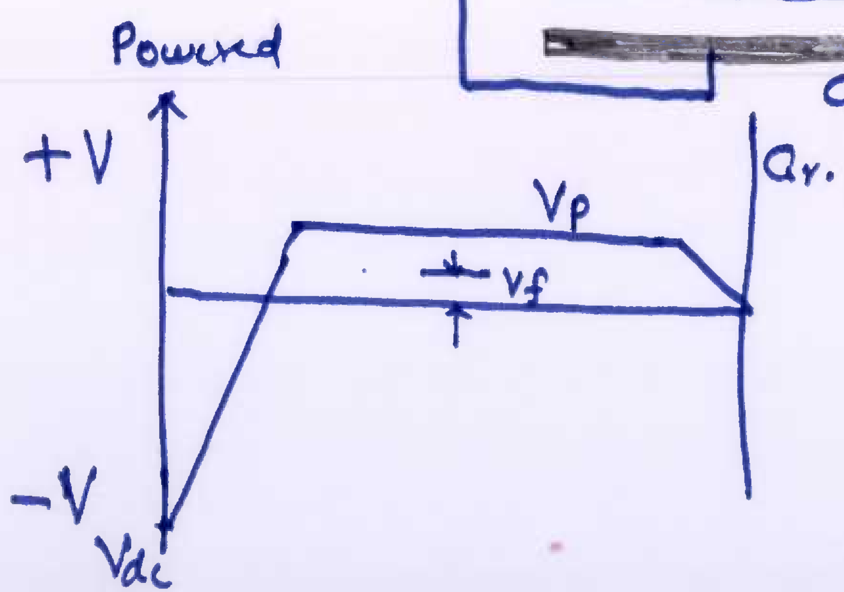
This means at Low Pressure, high frequency Plasma is sustainable. This mode of Plasma creation is called RF Discharge

This technique of RF discharge is the technique used in all Deposition & Etching processes in an IC fabrication sequence.



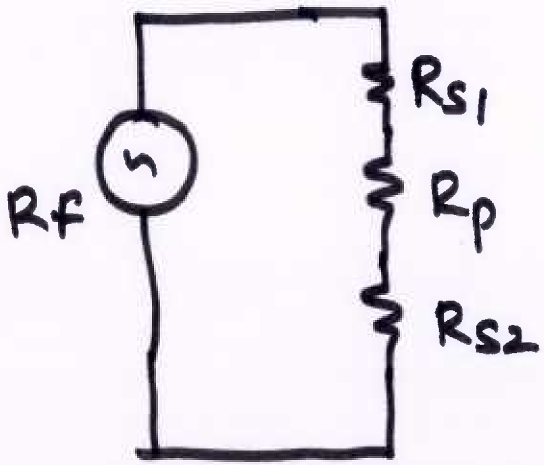




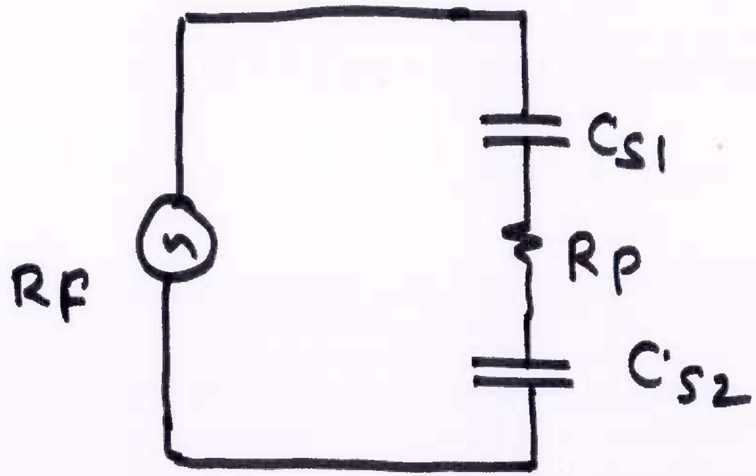


V_{sp} = Sheath Potential

Equivalent Circuit of Plasma



$f \leq 2.5\ \text{MHz}$



$2.5\ \text{MHz} < f < 65\ \text{MHz}$