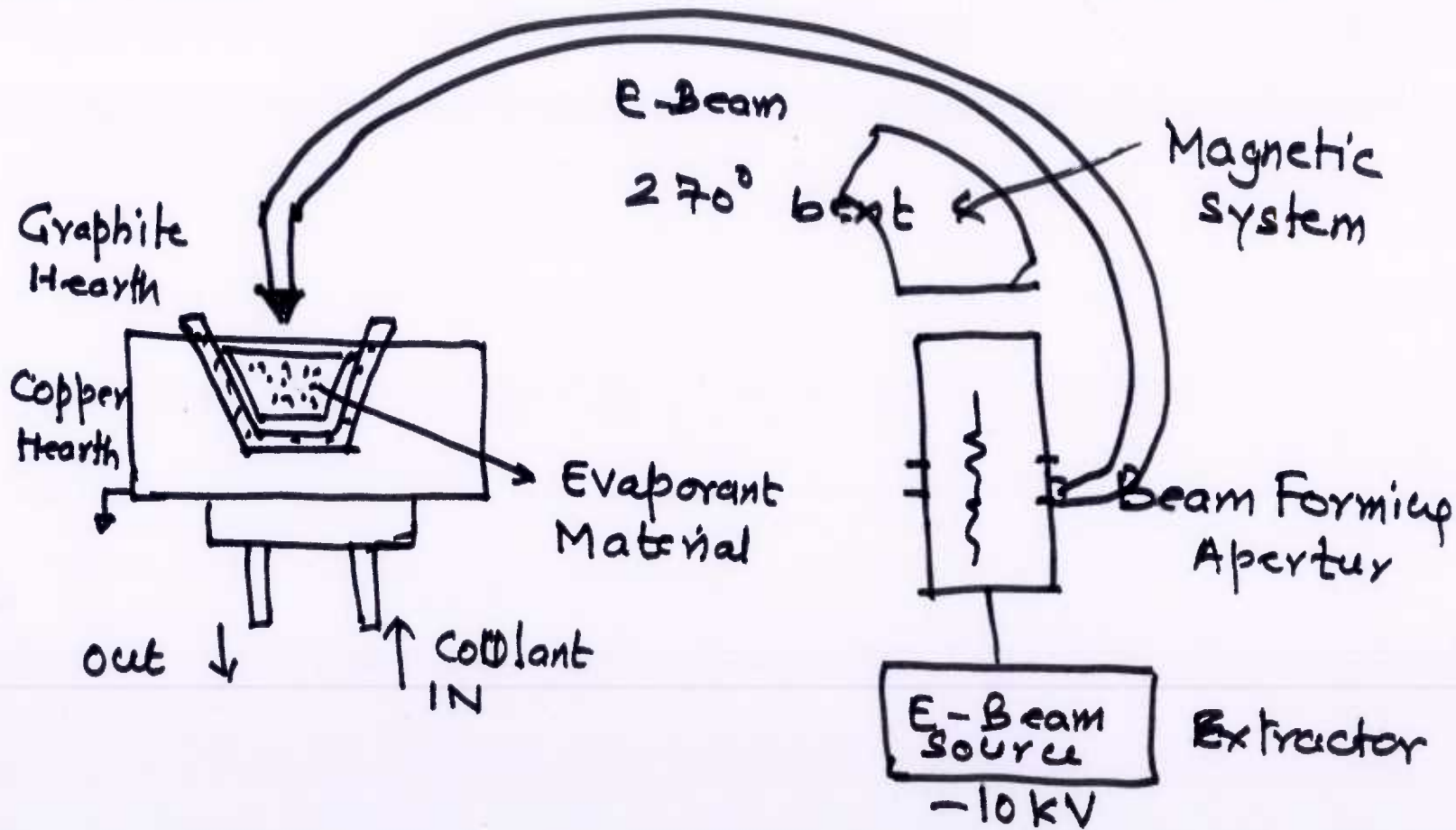


(ii) Electron Beam Evaporation



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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



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Plasma Processes in IC Manufacture

- i. 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



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



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(e) If ^{one} wants a material to change its state from Solid to Liquid or Liquid to Gas, one needs 10^{-2} eV/particle energy (Typical).

But to change Gaseous State to Plasma State, we may require 1-30 eV/particle energy.

(f) Plasma Processes are called 'Cold-Processes' Ambient Temperature could be $< 300^\circ\text{C}$, but Electron Temperature could be in Thousands of $^\circ\text{C}$,
(kT-energy)

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



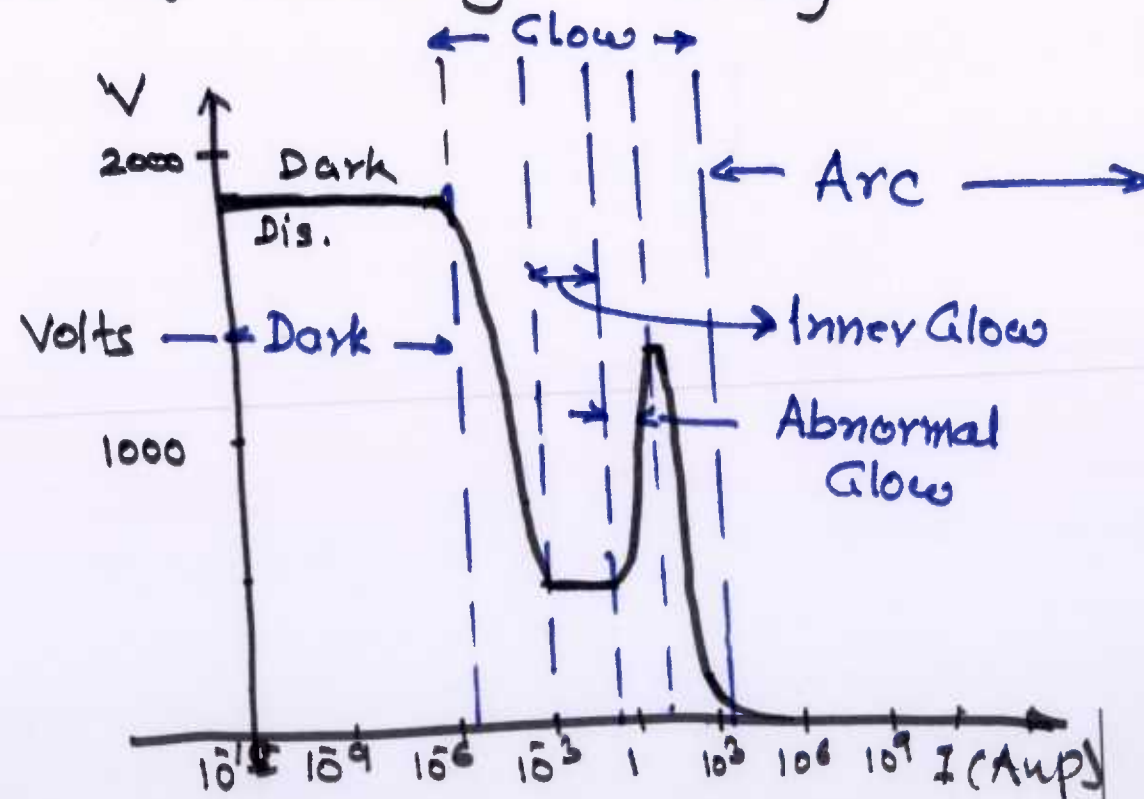
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(h) There are Three zones of Discharge namely

- (i) Dark Discharge
- (ii) Glow Discharge
- (iii) Arc Discharge

I-V Characteristics of a Plasma is shown →





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Low Pressure System (Gas)



Cathode Glow
Negative Glow

Positive Column

← Cross-sectional View of Glow Discharge

Explanation of I-V : →

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

This is Dark Discharge

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.



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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 adjacent to Cathode Glow. Its 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)



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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 sustenance 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.



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