Physical Vapour Deposition : Sputtering

1 DC Sputtering

2 RF Sputtering

(i) Sputtering uses Neutral (Sometimes Active) gas plasma to sputter the Target (Material to be deposited), essentially which displaces the atoms and deposites on the Substrates

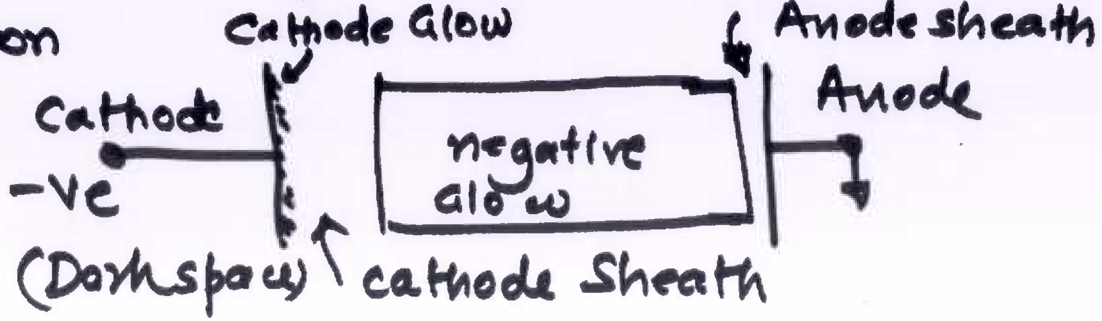
(ii) It normally requires moderate vacuum 1-100 mtorr.

(iii) It is useful in deposition of metals, alloys, compounds and even insulators.

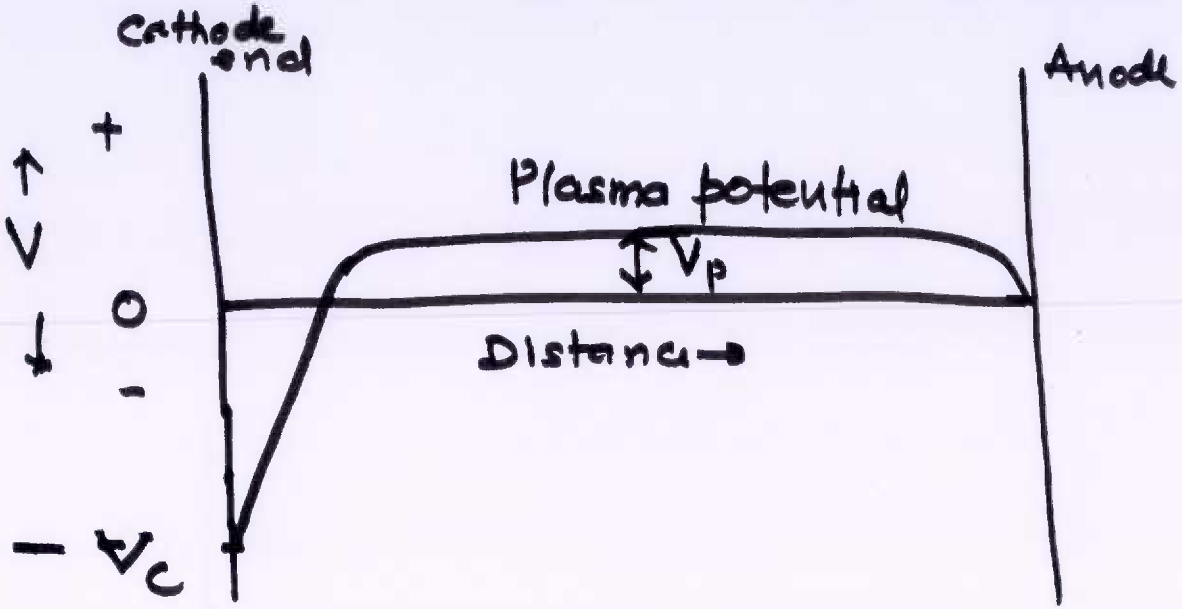
(iv) The neutral gas (Inactive or Inert) generally used is Argon.

When ionised creates, Ar^+ ions and equal no. of Electrons. Some Argon atoms are not ionised and hence are neutral. Thus we have Argon Plasma available for Sputtering

(v) As disussed typical Plasma system used has cathod and Anode and distance between them is kept small. This allows a system as shown



The corresponding Potential profile is



At Cathode we have -ve Bias of $-V_c$. Then we have cathode Dark space which has Voltage increasing from $-V_c$ towards '0'. Voltage in the Argon Plasma, V_p, is +tive with reference to both Cathode and Anode

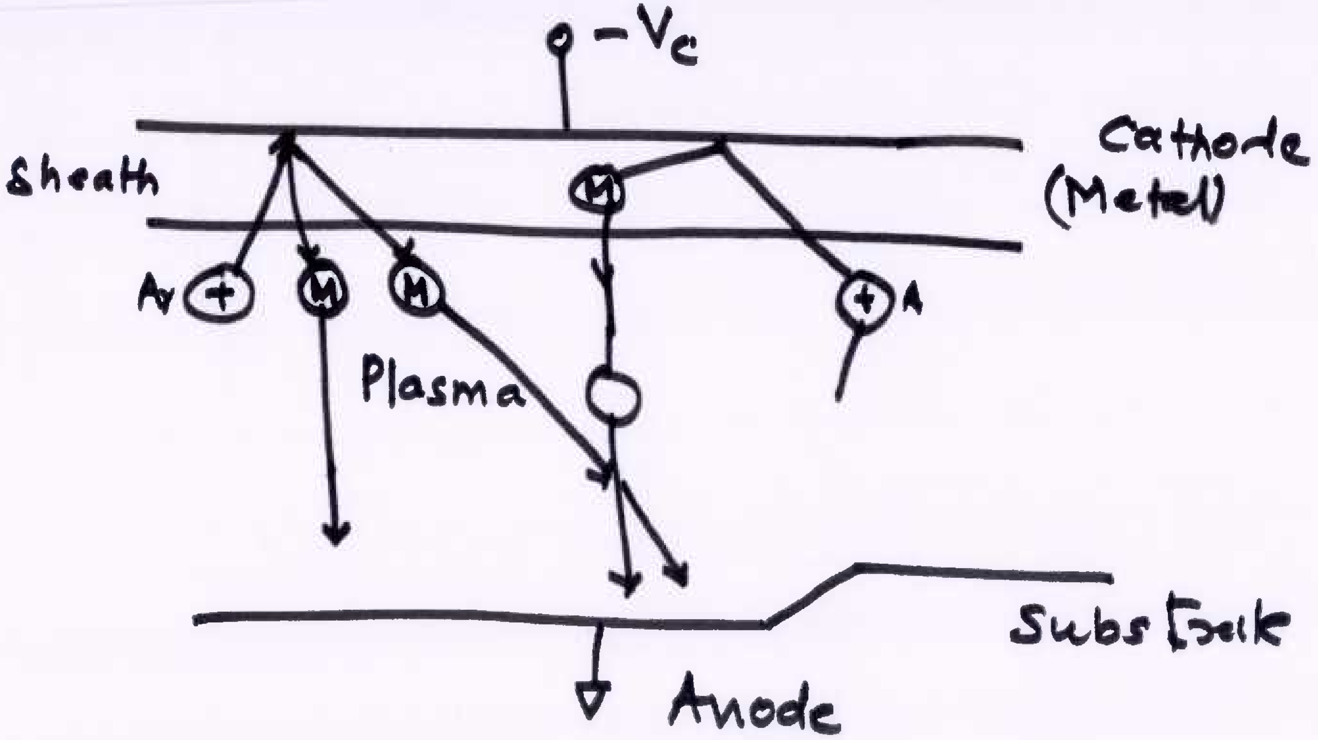
(vi) Ar^+ ions accelerates towards cathode crossing (Cathode) Sheath towards $-V_c$ potential. Ar^+ ions have sufficient K.E. now as they bombard cathode. In our case Cathode is the Target plate and Anode is the Substrate.

Target atoms are displaced from cathode and due to process of reversal of momentum, move towards substrate (Anode) and deposites there.

(vii) We define a term Sputtering Yield S as

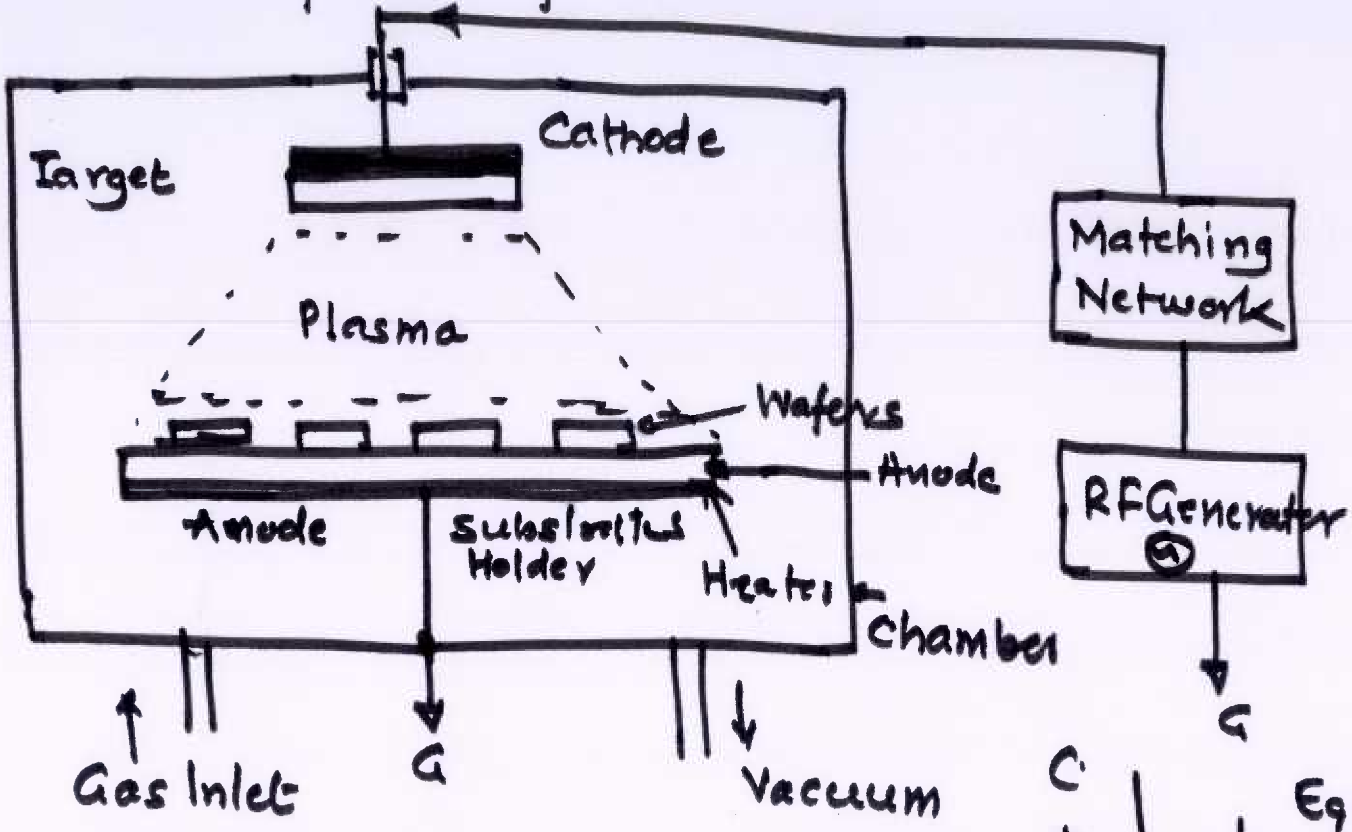
$$S = \frac{\text{No of atoms (molecules) ejected from Target}}{\text{Incident Ion}}$$

The sputtering Yield does depend upon the mass of ions incidenting on target as well as energy they have when they hit the Target.



In Case of DC Sputtering, Target is Conducting

(2) RF Sputtering System

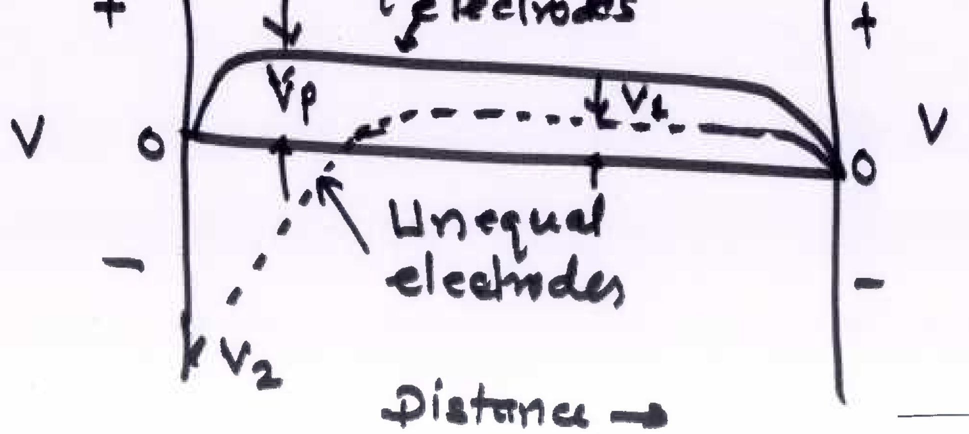


Cathode area = A_1

Anode area = A_2

① $A_1 = A_2$

② $A_1 << A_2$



$$\frac{V_1}{V_2} = \left(\frac{A_1}{A_2}\right)^{-m}$$

$m \simeq 2 \quad (1-2)$

Advantages of RF System

ⓐ Conformal Deposition

ⓑ Even Dielectrics can be Sputtered.

Basic Modeling of Sputtering

Most important parameter in Sputtering is Sputter Yield S, which can be given as

$$S = \alpha \left[E^{1/2} - E_{th}^{1/2} \right]$$

where E is incident ion energy and has mass of M_1

E_{th} is the threshold energy required for dislodging [redacted] target atoms and giving momentum reversal.

α = Proportionality Coefficient = $f(Z_t, Z_x \,\&\, U)$

Z_t = Target atom At. no. ; Z_x = Atomic no. of Gas atoms

& U is called Sublimation energy or SBE.

If M_2 is the atomic mass of Target, then max. energy transferred to it by incident energetic ion (E with Mass of ion M_1) is

$$E_{max} = \frac{4 M_1 M_2}{(M_1 + M_2)^2} E$$

Typically E_d is defined energy received by Stationary atom for dislodging it. Then we can say $E_{th} = E_d$

Generally E_d lies between 10 – 35 eV

Please note that if Incident Ion have higher Energy, than mean energy of Stationary atom, then it gets Implanted.

The proportionality Coefficient α is given by

$$\alpha = \frac{5.2}{U} \cdot \frac{Z_t}{\left[Z_t^{2/3} + Z_x^{2/3}\right]^{3/4}} \left[\frac{Z_x}{Z_x + Z_t}\right]^{0.67}$$

All Internal energies are used in units of eV/mol

Conversion : 1 Kcal/mol. = 0.0434 eV/mol

The incident ion energy and E_{th} are used in KeV

Thus Cathode Voltage of (-100V) will give incident ions of energy = 0.1 keV

For a case of Tungsten (W) deposition with cathode bias of 100V, we get $S \cong 0.2$ atoms/ion