Course name:
Growth and Characterization of Nano-electronic Materials (EE728)

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Metallization Process in IC fabrication in VLSI

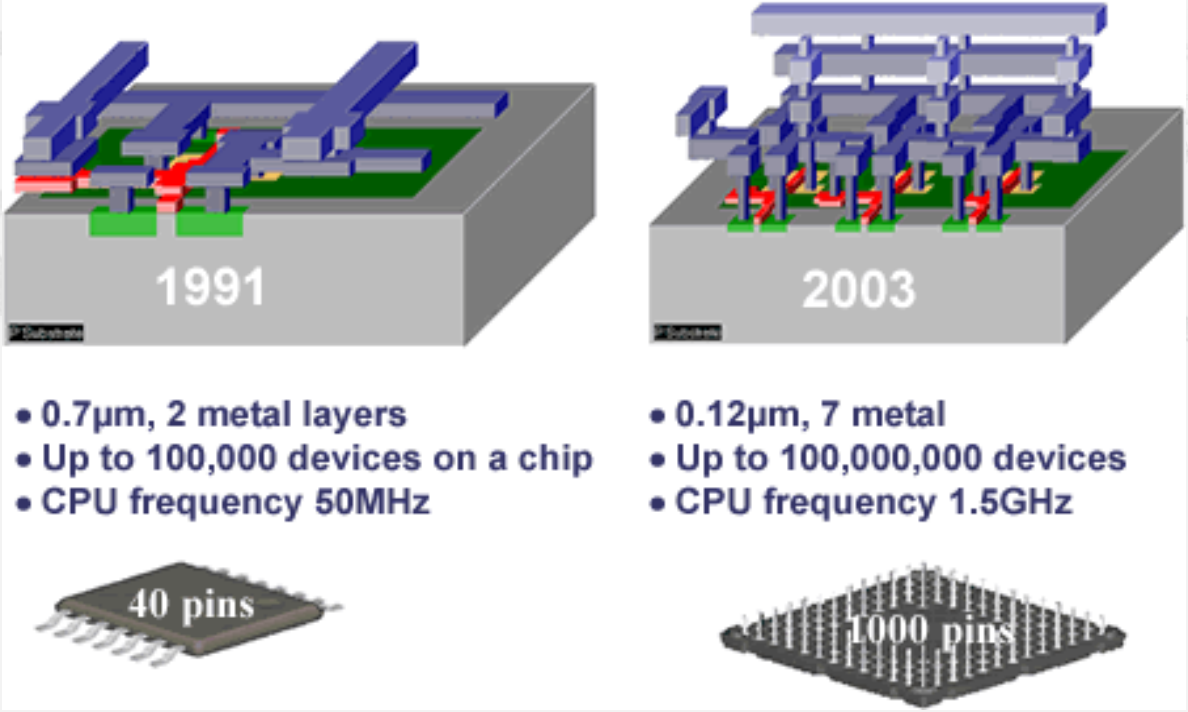
EE669 VLSI Technology

Outline

- **Introduction.**
- **Material requirements for metallization.**
- **Nature of Contacts.**
- **Different metallization technique.**

INTRODUCTION

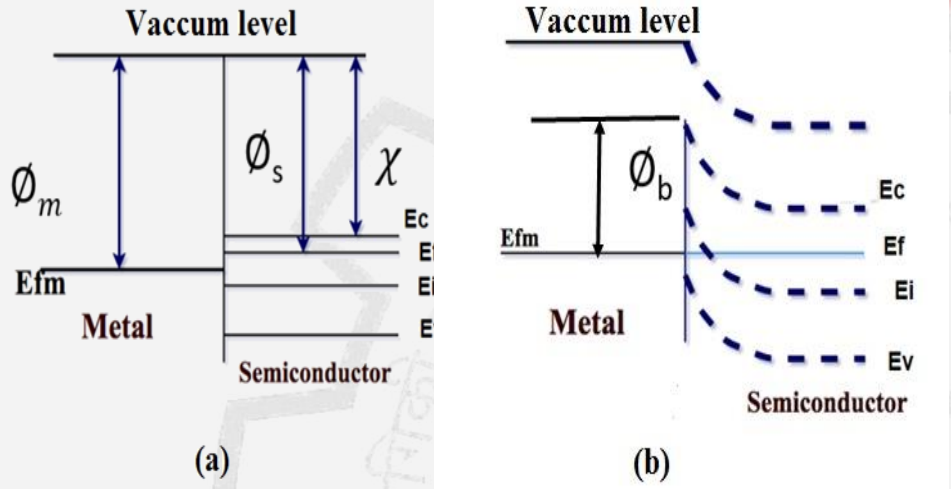
- Metallization is the final step in the wafer processing sequence.
- Metallization refers to the “wiring” of the various components together to get a functioning circuit.
- Depending upon scaling and area available for contact the multilayer metallization are also done.
- Presently more than 10 layer of metal for inter-connect in IC



MATERIAL REQUIREMENTS FOR METALLIZATION

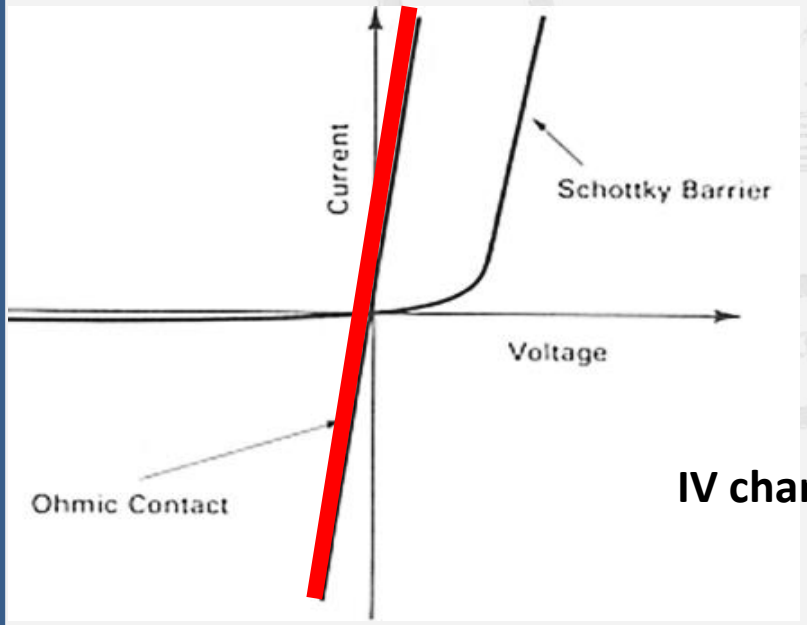
- Nature of contact should be **Ohmic** nature.
- Low resistance, low contact resistance between metal and semiconductor.
- Excellent adhesion on silicon oxides (insulators between metallization layers).
- Low susceptibility to corrosion for long life times.
- High purity of the metal.
- Examples: Al , Cu, Au, Ni, Ti, Ag

NATURE OF CONTACT



Work function	N-type	P-type
$\emptyset_m > \emptyset_s$	Rectifying (Schottky)	Ohmic
$\emptyset_m < \emptyset_s$	Ohmic	Rectifying (Schottky)

Fig: Energy band diagram of Metal semiconductor junction (a) Just at time of contact (b)s After equilibrium state cell



IV characteristics of different contacts

DIFFERENT METALLIZATION TECHNIQUE

1. Thermal Evaporation
2. E-beam Evaporation
3. Sputtering

- ❑ Excellent step coverage.
- ❑ Large throughput.
- ❑ Low-temperature processing.

THERMAL EVAPORATION

1.The deposition materials is vaporized in a vacuum from its liquid (or solid) phase,

2.The vapor is then transported

3.Deposited onto the substrate by

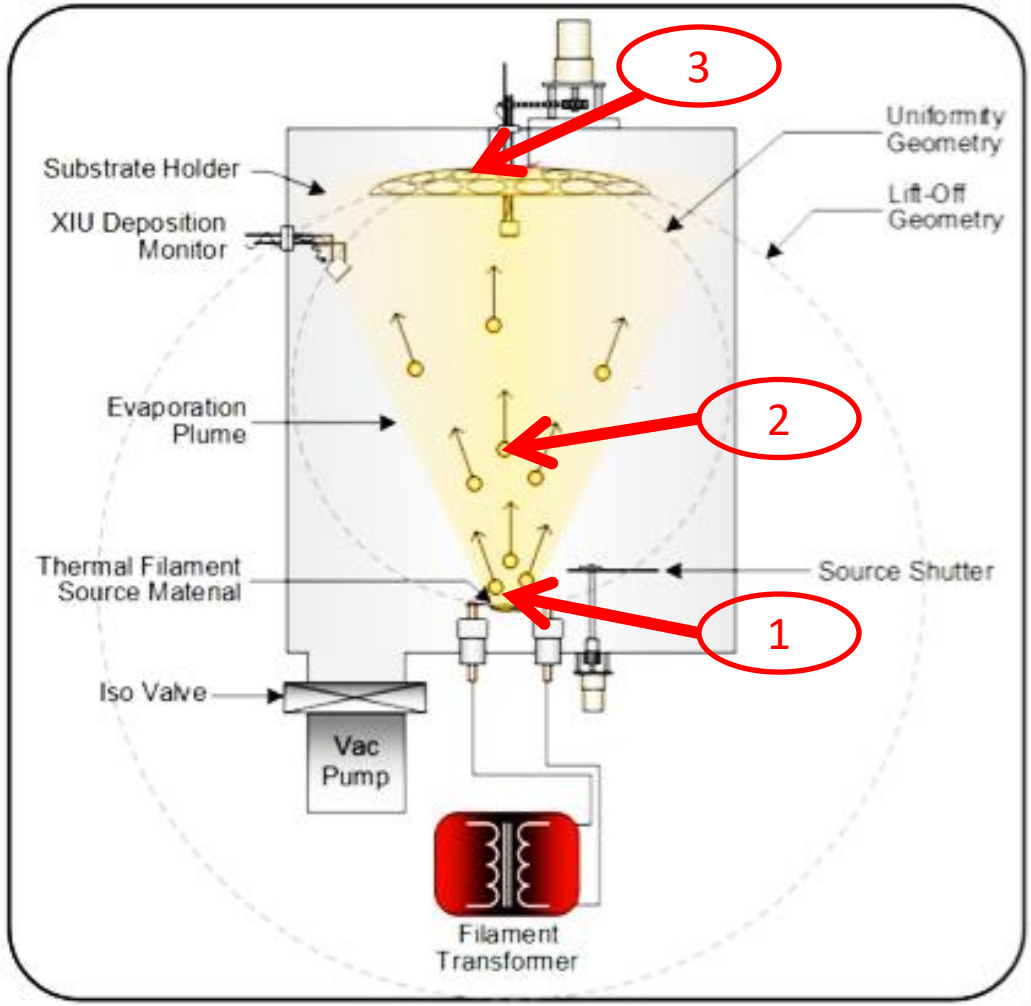
nucleation and growth .

4. The processing vacuum is < 10^{-5} Torr.

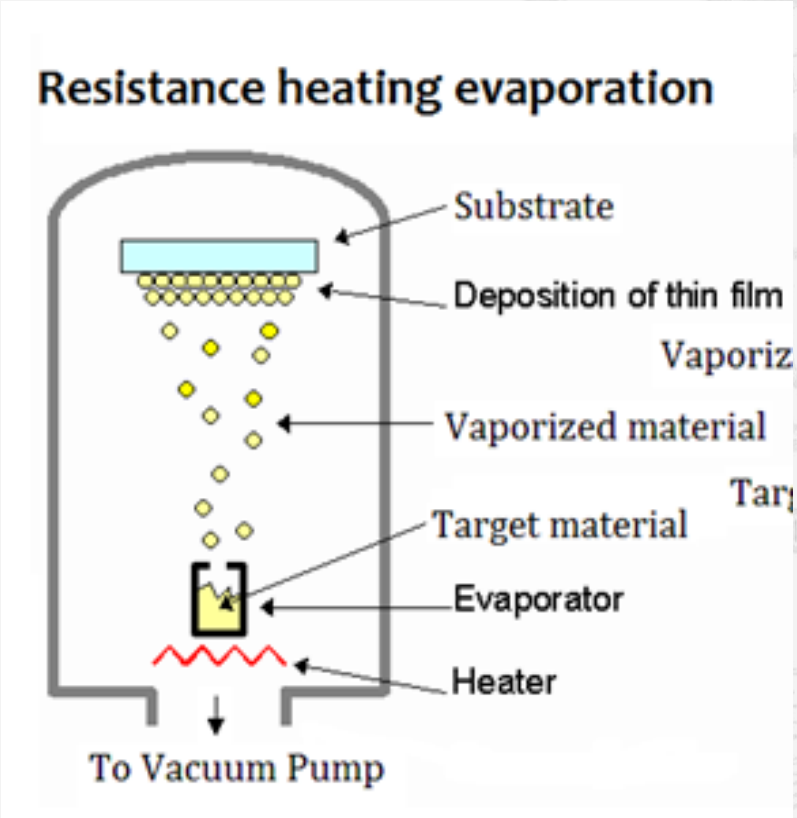
5. Mean free path of order of 1m,

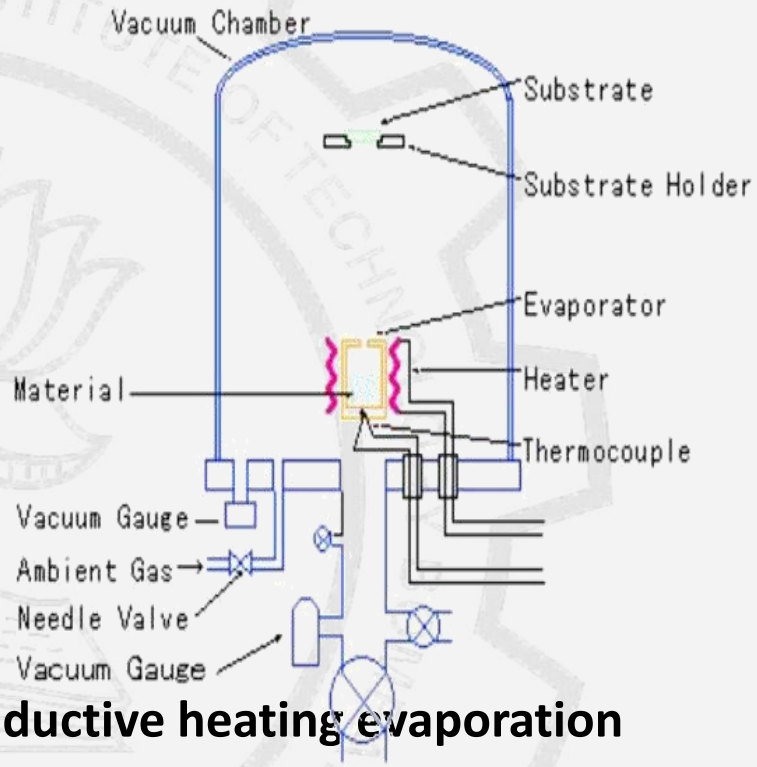
6. So no collision and follow a straight line path.

4.Aluminum and Copper are deposited.

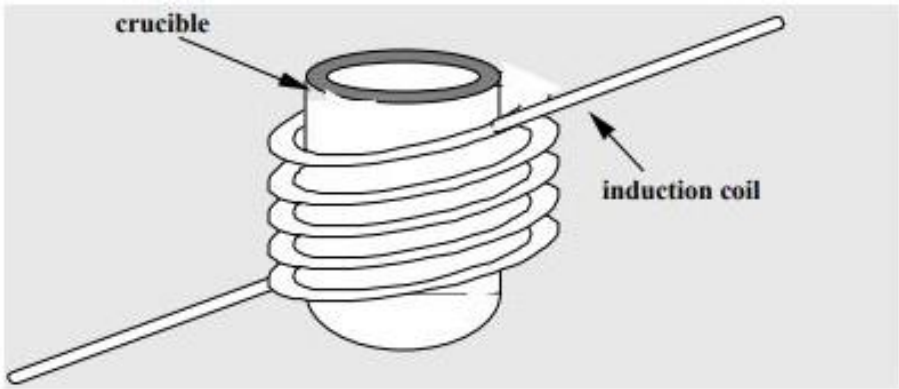


EVAPORATION OF SOURCE





Inductive heating evaporation



SOURCES HOLDER

Source	Holder material/Crucible
Aluminium	Boron nitride
Titanium (Ti)	Copper
Beryllium (Be)	Copper

ADVANTAGE AND DISADVANGE OF THERMAL EVAPORATION

Advantage

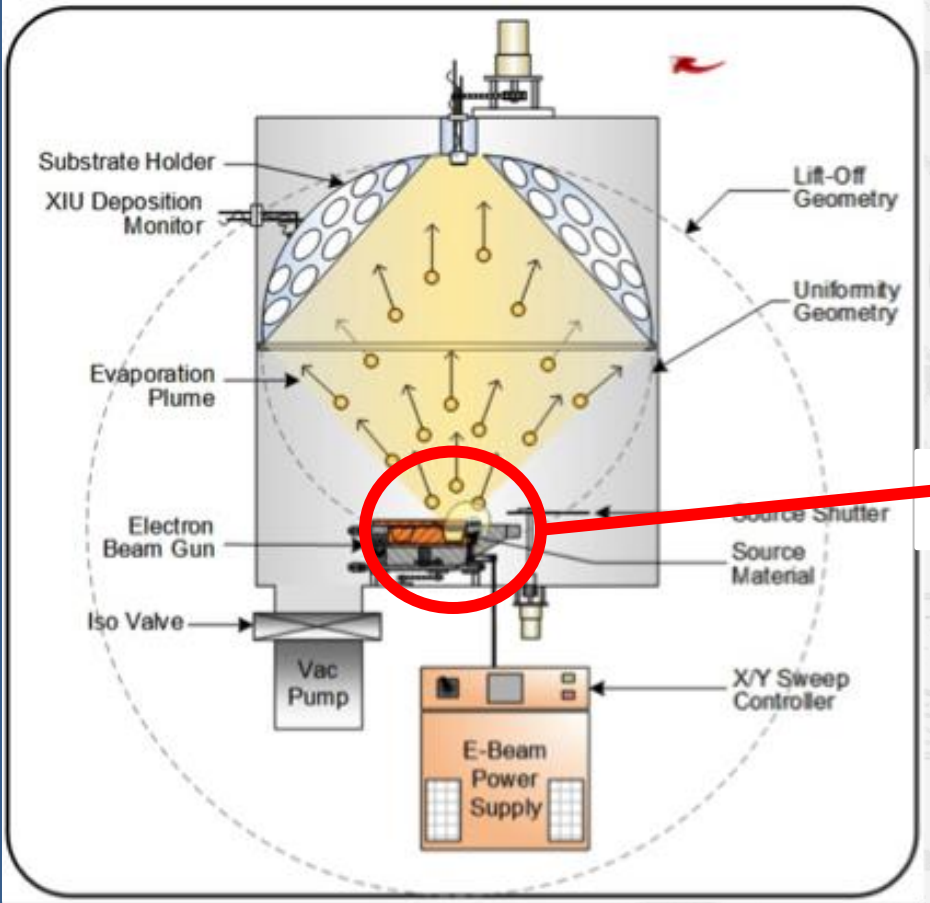
- Low contamination of the deposited thin films.
- Improved control of deposition rate.
- Larger charges can be loaded per deposition run.

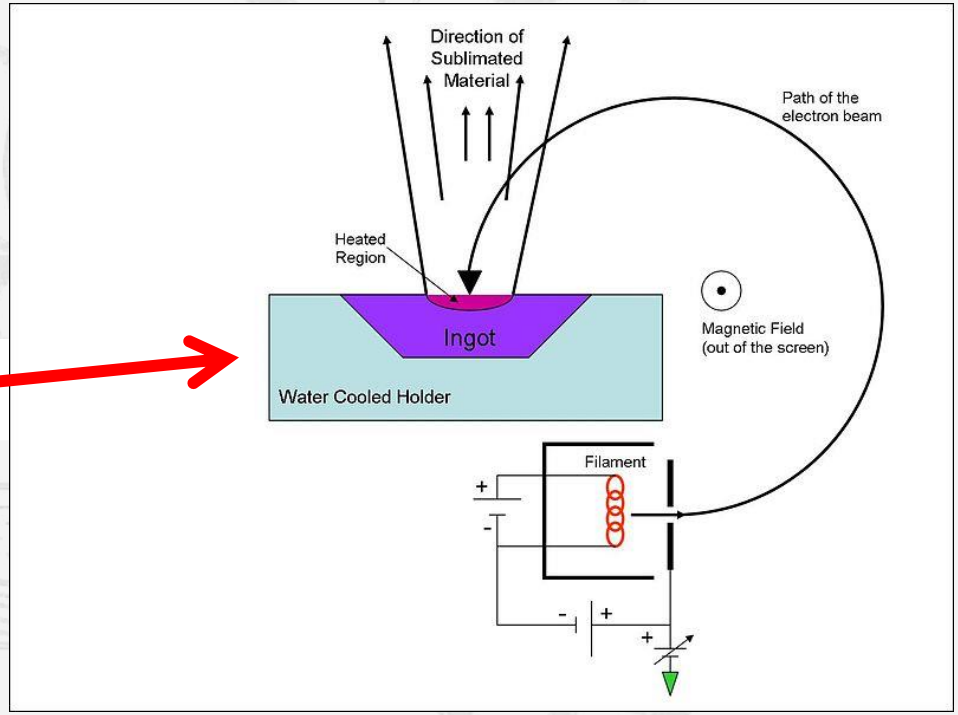
Disadvantage

- Chemical interaction between the charge and crucible can occur.
- RF power supplies are large and costly.
- Focusing aperture and filament may be over coated

For high melting temperature at atomic level is thermal evaporation is good or not ?

E-BEAM EVAPORATION



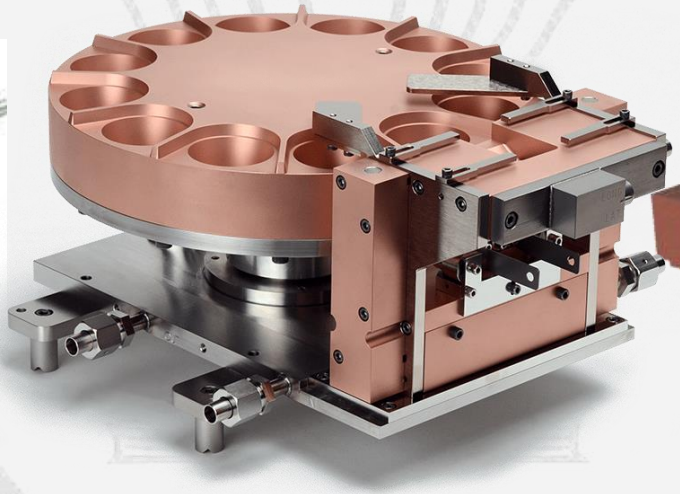


[1].http://www.semicore.com/news/89-what-is-e-beam-evaporation

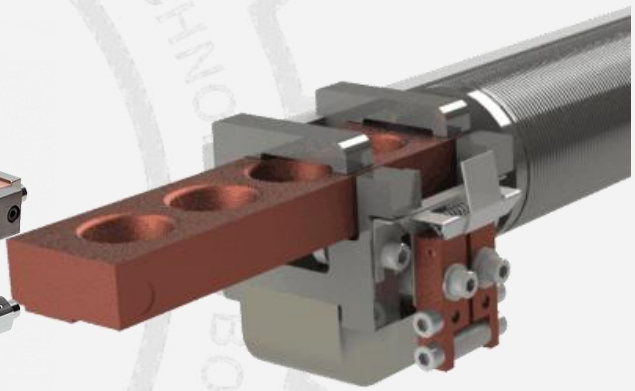
DIFFERENT SOURCE HOLDER FOR E-BEAM EVAPORATION

1. Single pocket

2.Rotatory pocket



3.Linear pocket [2]



[2]https://telemark.com/uhv-e-beam-sources/compact-linear-uhv-sources/

ADVANTAGE AND DISADVANGE OF E-BEAM EVAPORATION

Advantage

- Use for high melting point metal
- High deposition rate from any 0.1nm to 100 nm/min
- Multiple target material can be placed together for multiple layer coating.
- High density of film.
- Increase adhesion to the substrate.
- Line of sight deposition.

Disadvantage

- Due to high energy ionic radiation may occurs.
- Filament degradation results in non-uniform evaporation rate.
- High vacuum >10^{-4} Torr results in scattering of ions atoms.
- Challenge in alloy deposition
- Different vapor pressure of different elements at one temperature

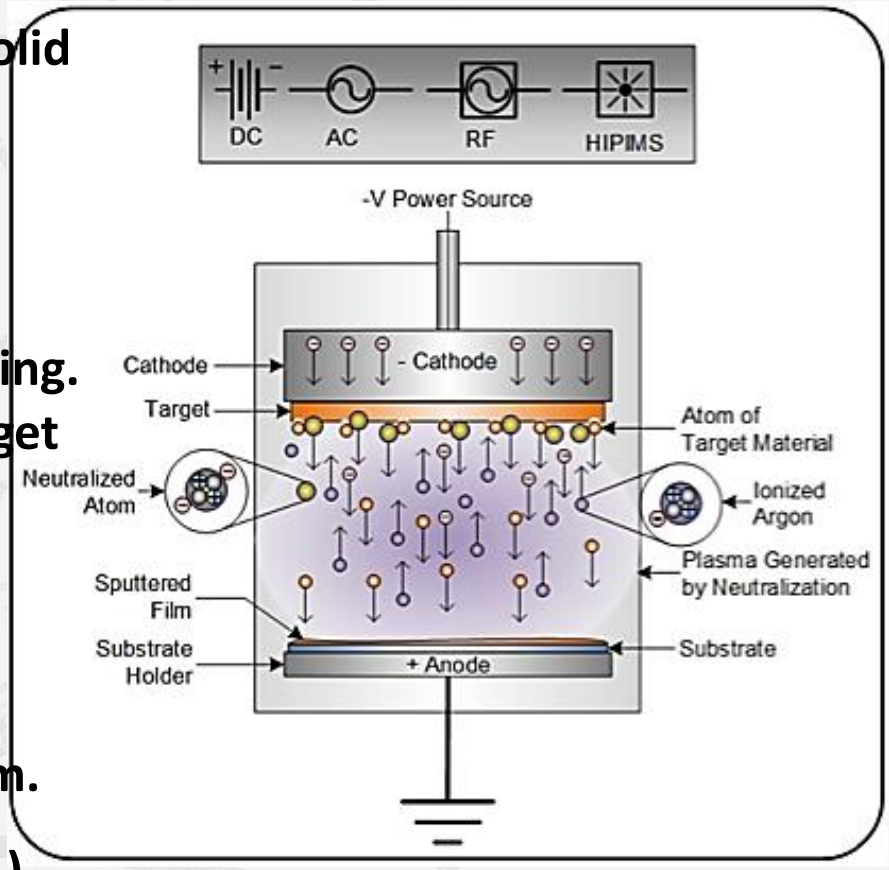
SPUTTERING

1. It is based on the bombardment of a solid surface with energetic ions.
2. Knocking off surface or near-surface atoms.
3. The released atom get deposited on substrate surface to form thin film coating.
4. So inert gas are use to knock off the target material from surface.
5. Different power source

   1. DC power source- Conducting film

   2. AC power source- Non conducting film.

   3. Pulsed DC –Reactive sputtering (SiO_2)



DEPOSITION RATE (D)

1. No of atom arriving at target surface.
2. Efficiency with which they sputter from target surface.
3. Distance b/w target and substrate

$$D \propto J.S/d$$

J=inert gas current density

S= Sputtering yield

d= Spacing between target and substrate material.

$$J \propto V^n.P$$

V= Discharge voltage

p= pressure

$$S \propto E.\lambda'/U$$

E=Energy of ions

λ'

$= Function\ of\ relative\ mass\ of\ ions\ and\ target\ atoms$

TABLE I

Sputtering Yields (Atoms Sputtered per Ion) of Some VLSI Metals[a]

	Bombarding Argon Ion Energy (eV)			
Metal	100	200	300	600
AL	0.11	0.35	0.65	1.24
Cr	0.30	0.67	0.87	1.30
Mo	0.13	0.40	0.58	0.93
Pt	0.20	0.63	0.95	1.56
Ta	0.10	0.28	0.41	0.62
Ti	0.08	0.22	0.33	0.58
W	0.07	0.29	0.40	0.62

[a] From B. Chapman, "Glow Discharge Processes," p. 369. Wiley, New York, 1980.

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ADVANTAGE AND DISADVANGE OF SPUTTERING

Advantage

- Highest deposition rate from any 100000 nm/min.
- Low deposition temperature
- Better step coverage

Disadvantage

- Significant contamination due to high operating pressure
- Stress due to impurity in gas.
- Void formation in case of powder sample.

DC and RF Spttuering

CHARACTERIZATION OF MS CONTACT

- Uniformity of film over sample.
- Electrical property (Contact resistance)
- Optical property (Refractive index)
- Adhesion to substrate surface.
- Resist to corrosion
- Thickness of film.
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