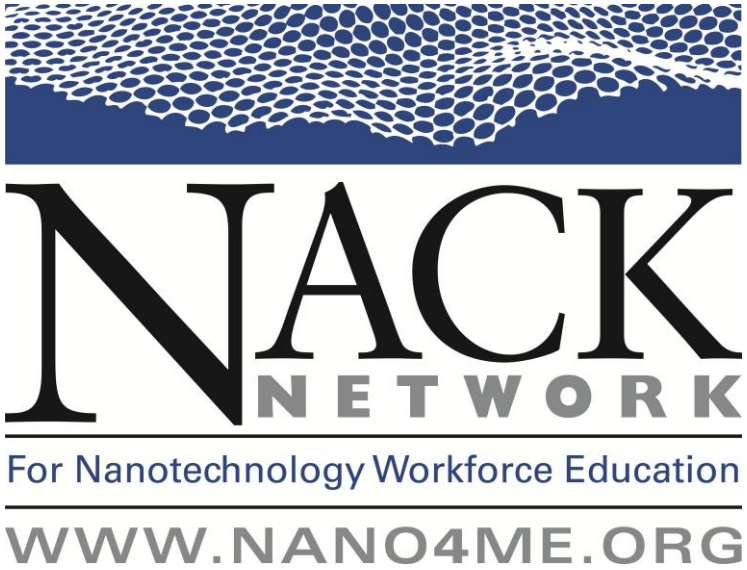


Basic Nanotechnology Processes

E SC 212

Unit 2
An Introduction to Uses of Plasma in Processing

Lecture 2
Additive Processes and Sputtering

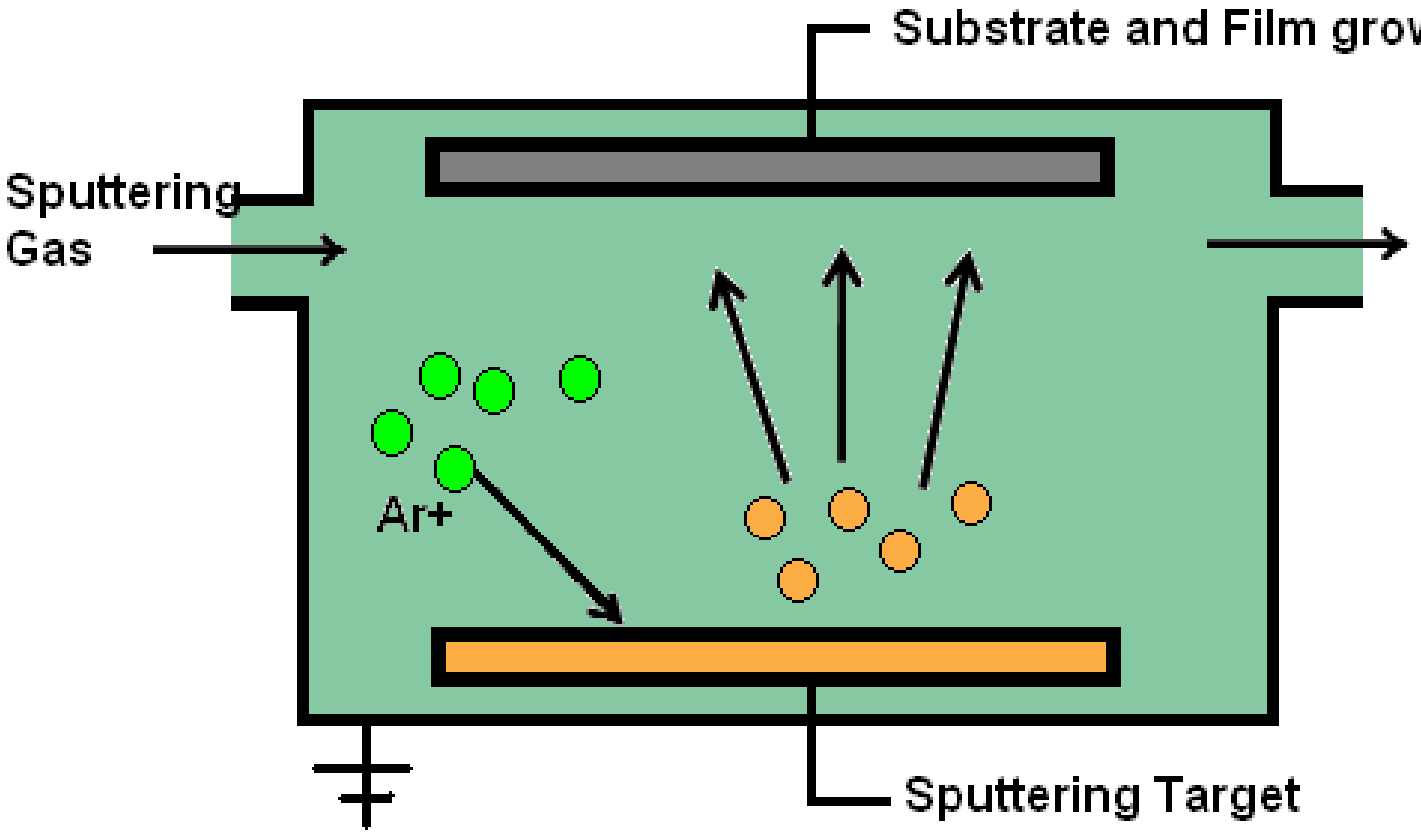
Outline

- Additive processes
- Sputtering
- Types of sputtering
- Applications of sputtering

Additive processes

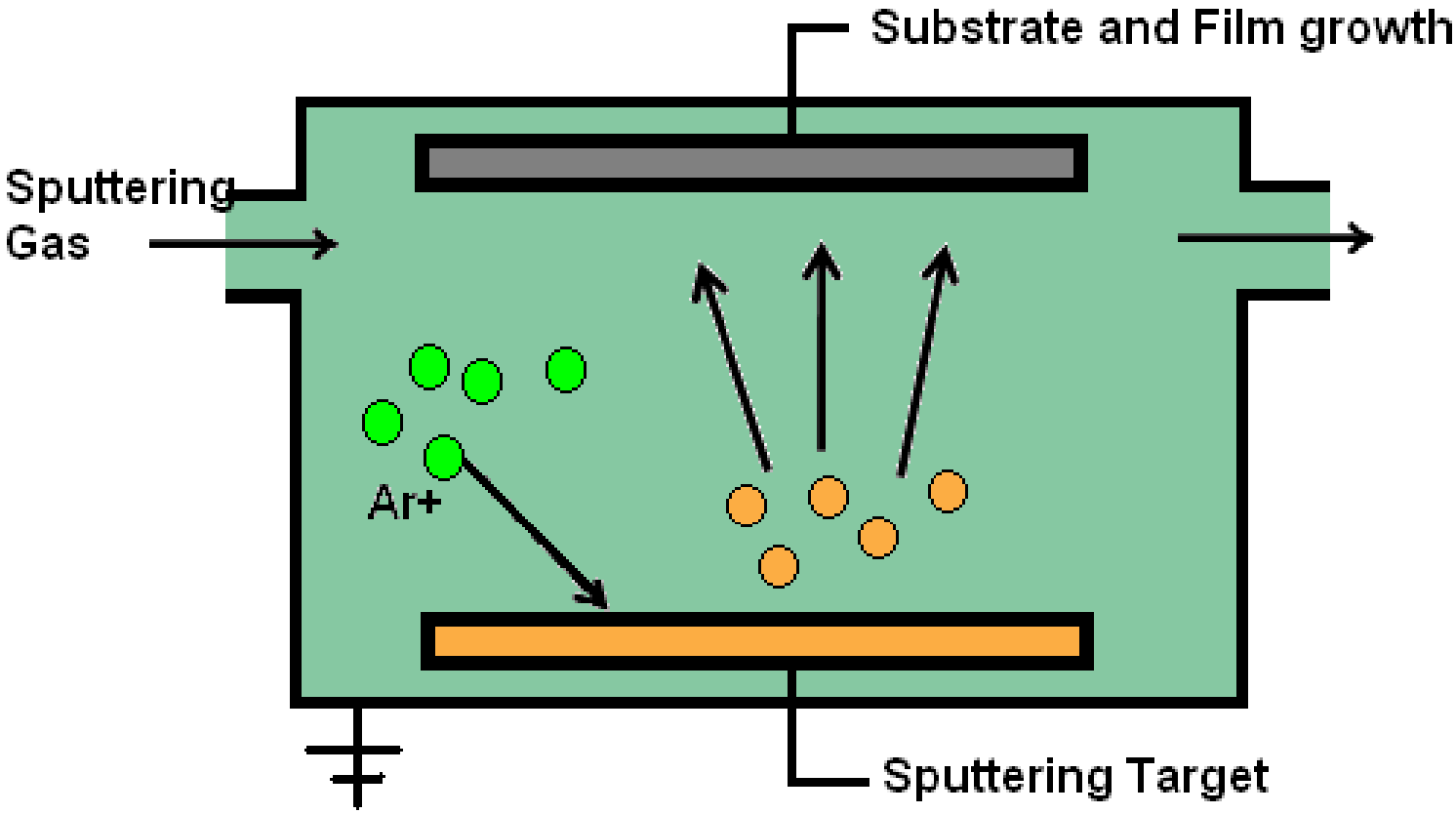
- These are what are termed deposition processes--- adding a thin film of a material
- There are many types; e.g., evaporation, sputtering, chemical vapor deposition, plasma enhanced deposition, atomic layer deposition.

Sputtering



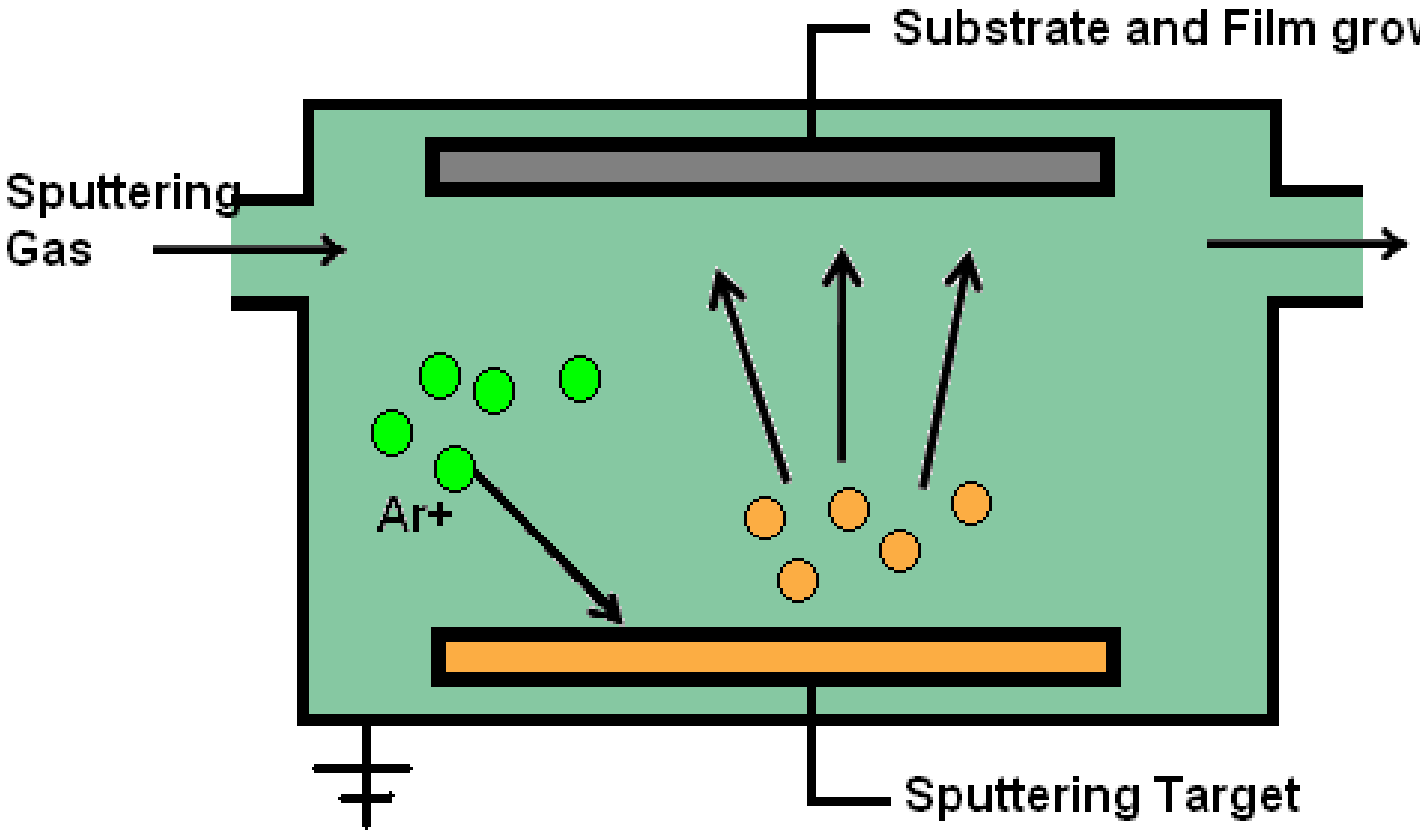
In this example of sputtering, a film is being deposited on the substrate by argon ions (green). These ions act as hammers knocking film atoms (orange) off the target (orange too). A negative voltage attracts the Ar ions to the target.

Sputtering



Plasma used for sputtering can be AC or DC Generated.
Which is better?

Sputtering

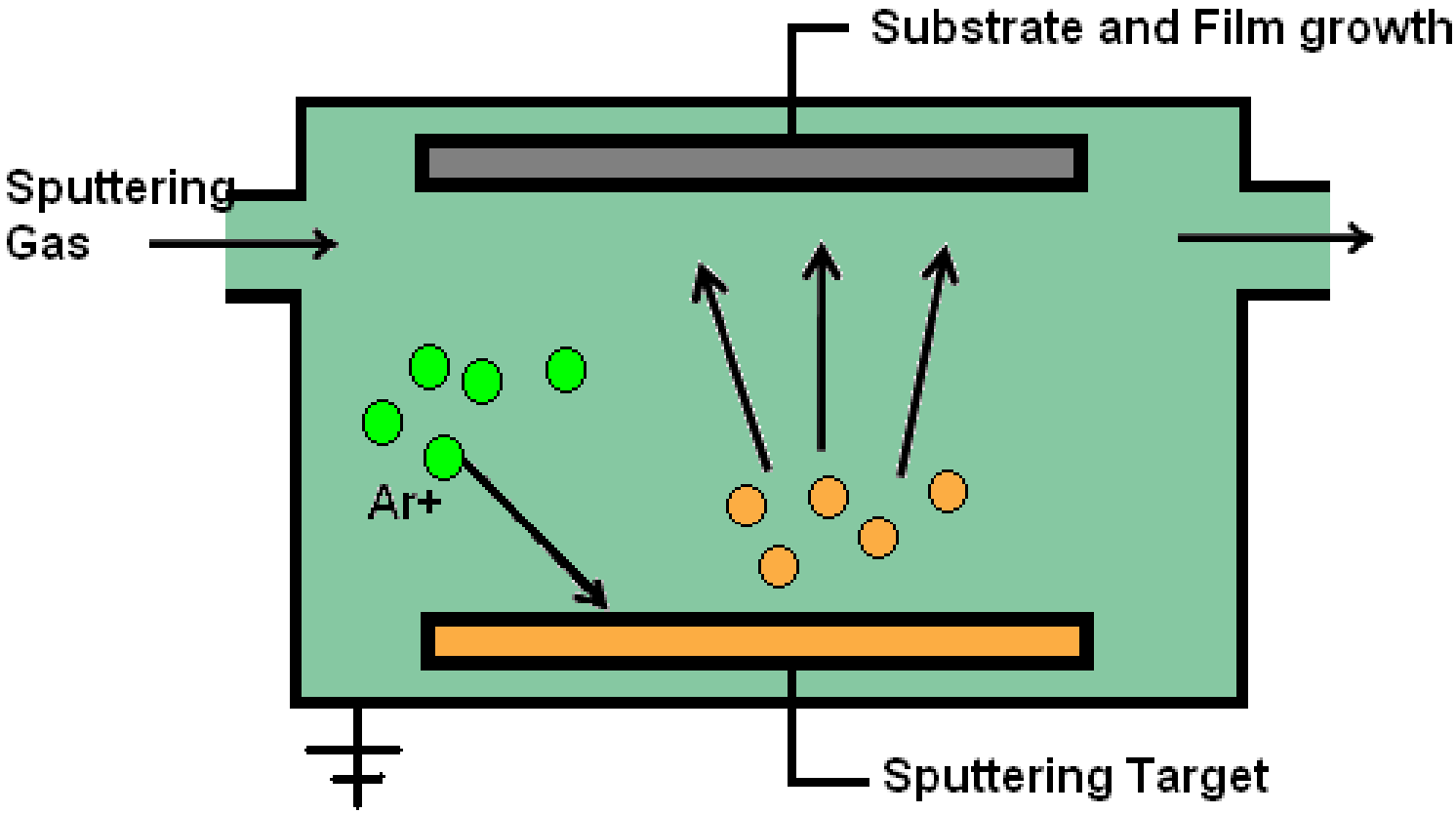


Deposition Process can be purely physical or it can be physical and chemical.

Reactive Sputter Deposition

add reactive gas to chamber during deposition (evaporation or sputtering)
oxygen, nitrogen
chemical reaction takes place on substrate and target
can poison target if chemical reactions are faster than sputter rate
adjust reactive gas flow to get good stoichiometry
without incorporating excess gas into film

Sputtering



Target can be simple or compound (alloyed, mixed, multiple)

Some Sputtering Facts

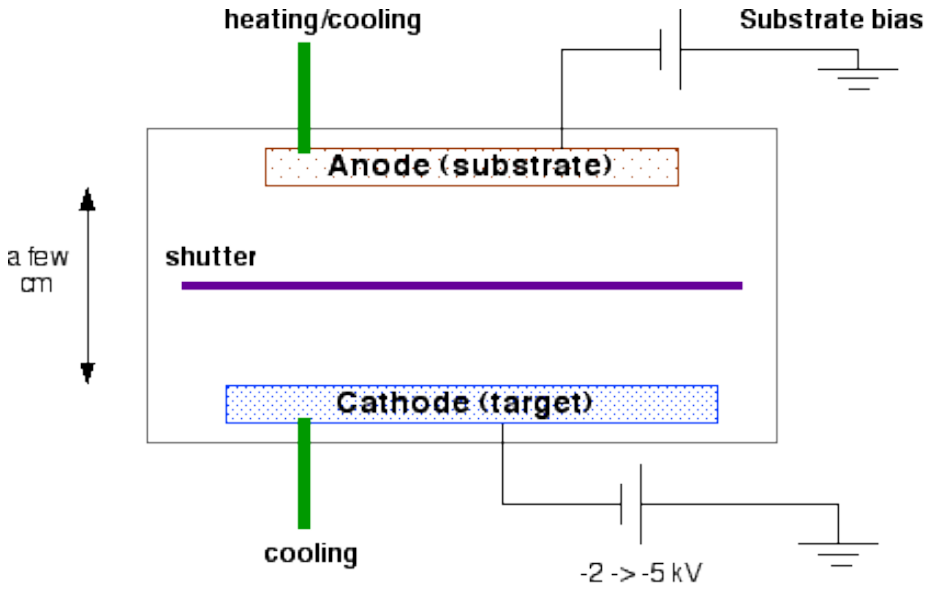
- Use of magnets can help
- Threshold for sputtering is about 40eV

Summary: Basic Sputtering Techniques

- DC (diode)
- RF (radio frequency)
- magnetron

DC sputtering

simplest - basically what we have talked about so far



Parameters:

Parameters:

Pressure

Sputter voltage

maximize sputter yield (S)

typically -2 to -5 kV

Substrate Bias Voltage

substrate is being bombarded by electrons and ions from target and plasma

sputtering film while you deposit

neutral atoms deposit independently

put negative bias on the substrate to control this

can significantly change film properties

Substrate temperature

control with substrate heater

heating from deposited material

increases with increasing sputter voltage

decreases with increasing substrate bias

Deposition rate

changes with pressure

increases with sputter yield

usually increases with high voltage

Particle Energy

increases with increasing sputter voltage

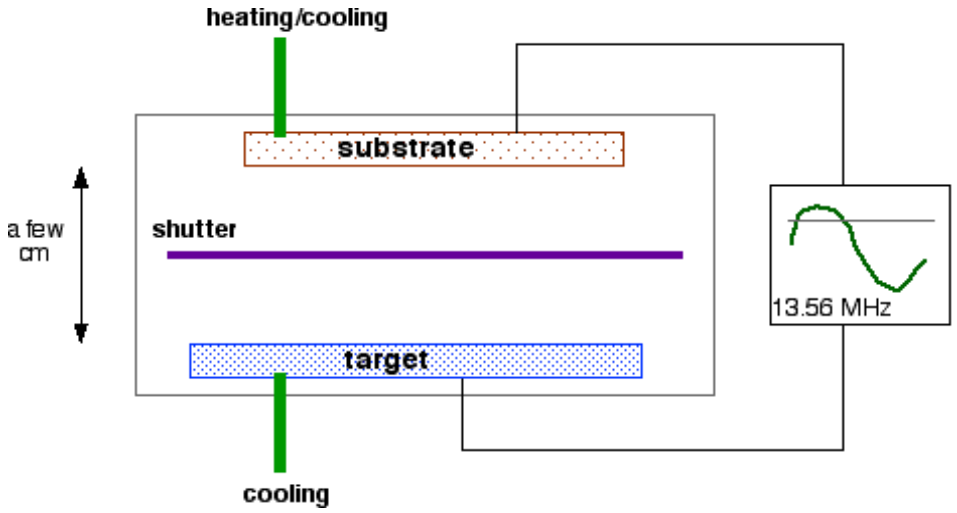
decreases with increasing substrate bias

decreases with increasing Ar pressure

DC SPUTTERING RATES

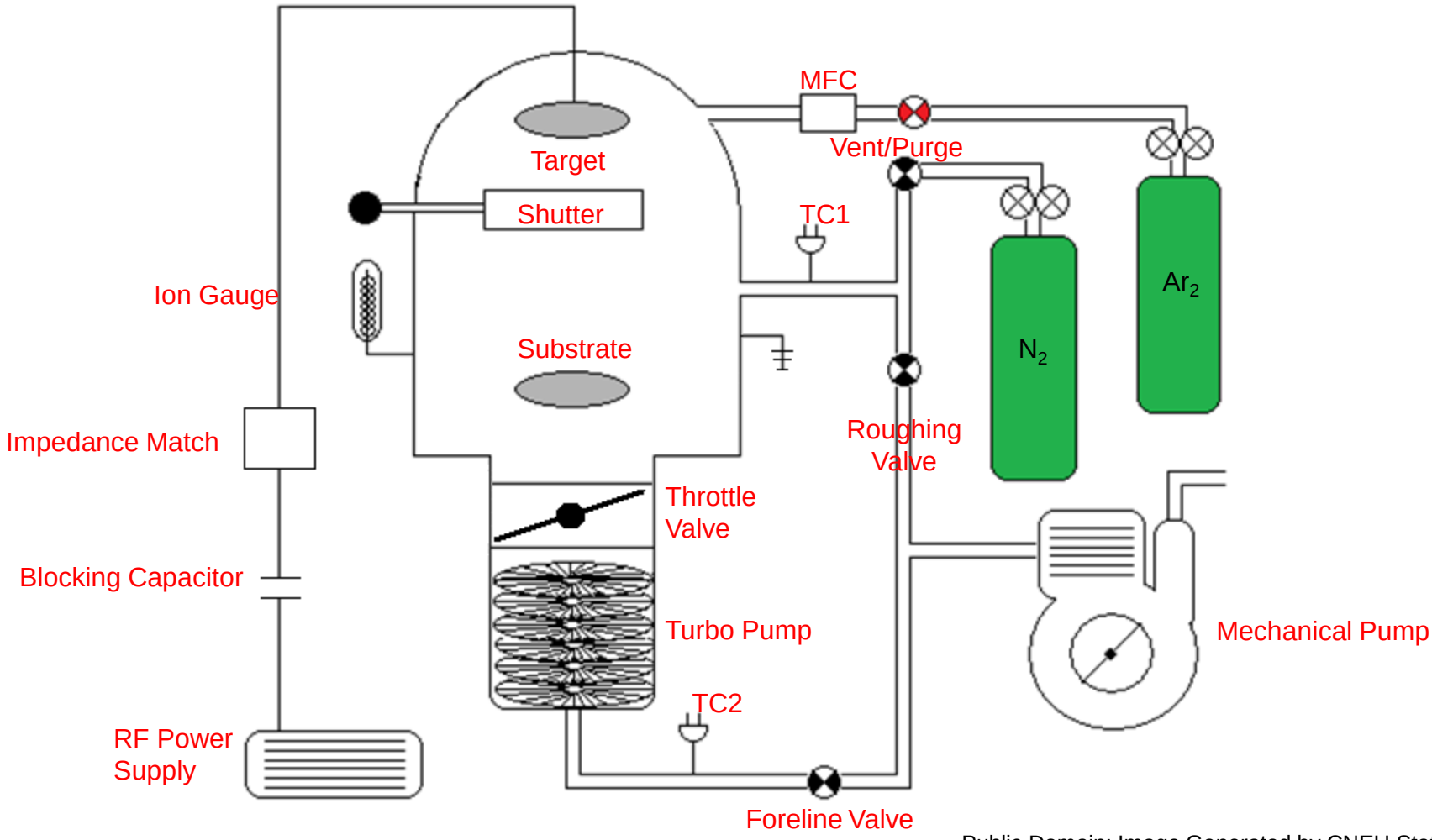
Material	Atoms/ion Sputter Yield @ 400 Volts	Rate Relative to Cu	Static Rate (Angstroms/Minute) Measured @ 4" Source-to-Substrate Distance @ 70 watts/in^2 DC @ 1 Millitor
Ag	2.70	2.41	24,955
Al	0.80	0.69	7,130
Au	2.00	1.80	18,400
Cr	1.10	0.70	7,250
Cu	1.62	1.00	10,350
Mo	0.70	0.57	5,870
Pd	1.73	1.32	13,570
Pt	1.20	0.88	8,980
Doped Si	0.33	0.33	3,335
Ta	0.28	0.26	2,650
Ti	0.42	0.39	4,025
W	0.28	0.23	2,300

RF Sputter Deposition



Good for insulating materials

Typical AC Sputtering Tool



Public Domain: Image Generated by CNEU Staff for free use

Magnetron Sputter Deposition

•use with DC or RF

•goal: increase ionization of Ar

•Why? Higher sputter rates at lower Ar pressures (down to 0.5 mTorr)

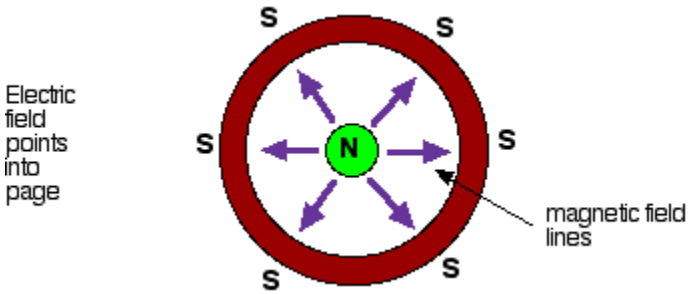
- •fewer gas collisions - more line of sight

•How ? increase probability of electrons striking Ar

- •increase electron path length
- •use electric and magnetic fields

Most common configuration: crossed electric and magnetic fields

Put magnets (200 Gauss) behind target:



•traps electrons near cathode

- •more ionization near cathods (10x)
- •fewer electrons reach substrate (less heating)

Evaporation and Sputtering

- What is the difference?

Comparison of evaporation and sputtering

EVAPORATION	SPUTTERING
low energy atoms	higher energy atoms
high vacuum path •few collisions •line of sight deposition •little gas in film	low vacuum, plasma path •many collisions •less line of sight deposition •gas in film
larger grain size	smaller grain size
fewer grain orientations	many grain orientations
poorer adhesion	better adhesion

Ion assisted deposition

Hybrid: evaporation and sputtering

bombard surface with ions
not necessarily same type as in film

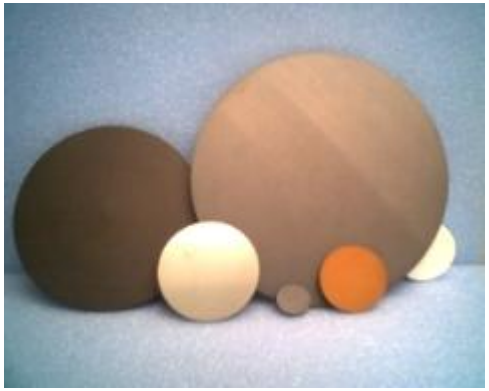
ions typically NOT incorporated in film
relatively low voltages (50 - 300 eV)
|
physical rearrangement

local heating

can change film properties
(for better or worse)

SPUTTERING TARGETS

(Often 99.999% pure)



COMMON SPUTTERING TARGETS MATERIALS

Boron Nitride	**Boron Carbide**	**Silicon Carbide**
Tungsten Carbide	**Silicon Nitride**	**Aluminum Oxide**
Hafnium Oxide	**Calcium Floride**	**Zinc Oxide**
Yttrium Oxide	**Garnet**	**Spinel**
ITO	**Alloys**	**Cerments**
Titanium Diboride	**Hafnium Carbide**	**Titanium Carbide**
Aluminum Nitride	**Titanium Nitride**	**Cerium Oxide**
Titanium Oxide	**Zirconium Oxide**	**Titanium**
Nickel	**Intermetalics**	**Pure Metals**
Siicides	**Silicon**	

Uses of Sputtering

- Depositing thin films for many, many applications
- Can deposit metals, semiconductors, and insulators
- Large areas
- High deposition rates

Summary

- Very versatile technique
- Can be used to deposit many types of films
- High deposition rate
- Can cause damage