Chapter 6-Ion Plating

-Introduction
-Bombardment: Surface and Near-Surface Effects
-Bombardment: Effects on Adhesion, Film Growth and Properties of Deposited Material
-Sources of Depositing Material
-Sources of Bombarding Particles
-Substrate Potential
-Applications

Introduction

Also called Ion Assist (IA) deposition, Ionization Assisted Deposition (IAD), Ion Vapor Deposition (IVD) Physical Vapor Deposition (PVD) where periodic bombardment of particles is utilized

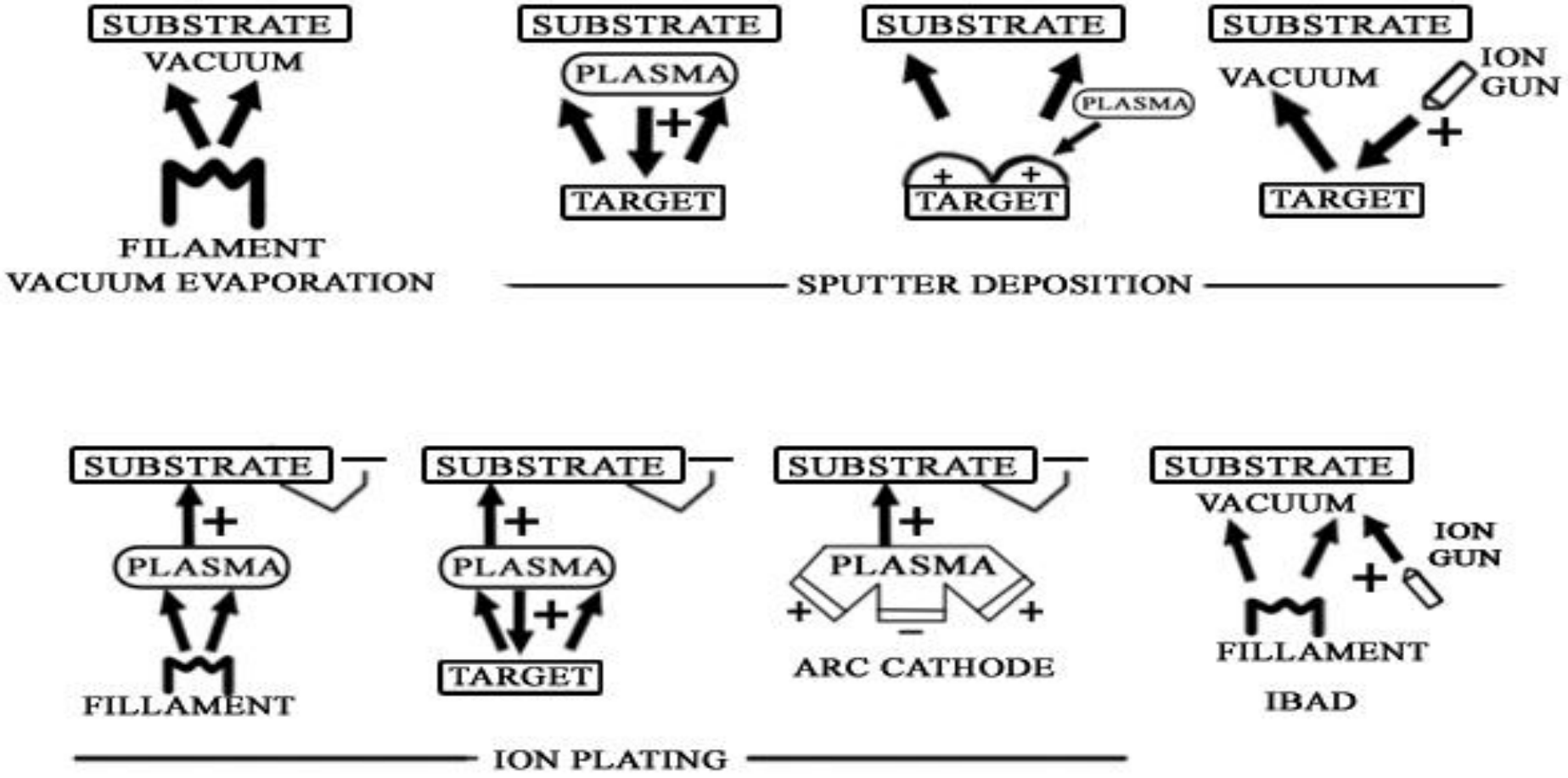
Bombardment prior to deposition: sputter cleans the surface
Bombardment during deposition: Good adhesion, densify the depositing material, aid in chemical reactions, modify residual stress, modify the structure.

Important processing variables: Energy, Flux and Mass of bombarding particles, ratio of bombarding to depositing particles

Introduction

- Depositing particles from evaporation, sputtering, arc vaporization or decomposition of chemical vapor precursor
- Bombardment particles are ions of inert or reactive gas. Ions from Plasma or Ion Gun

- Properties of films depend primarily on deposition conditions and minimally on the source of depositing atoms/molecules


SUBSTRATE
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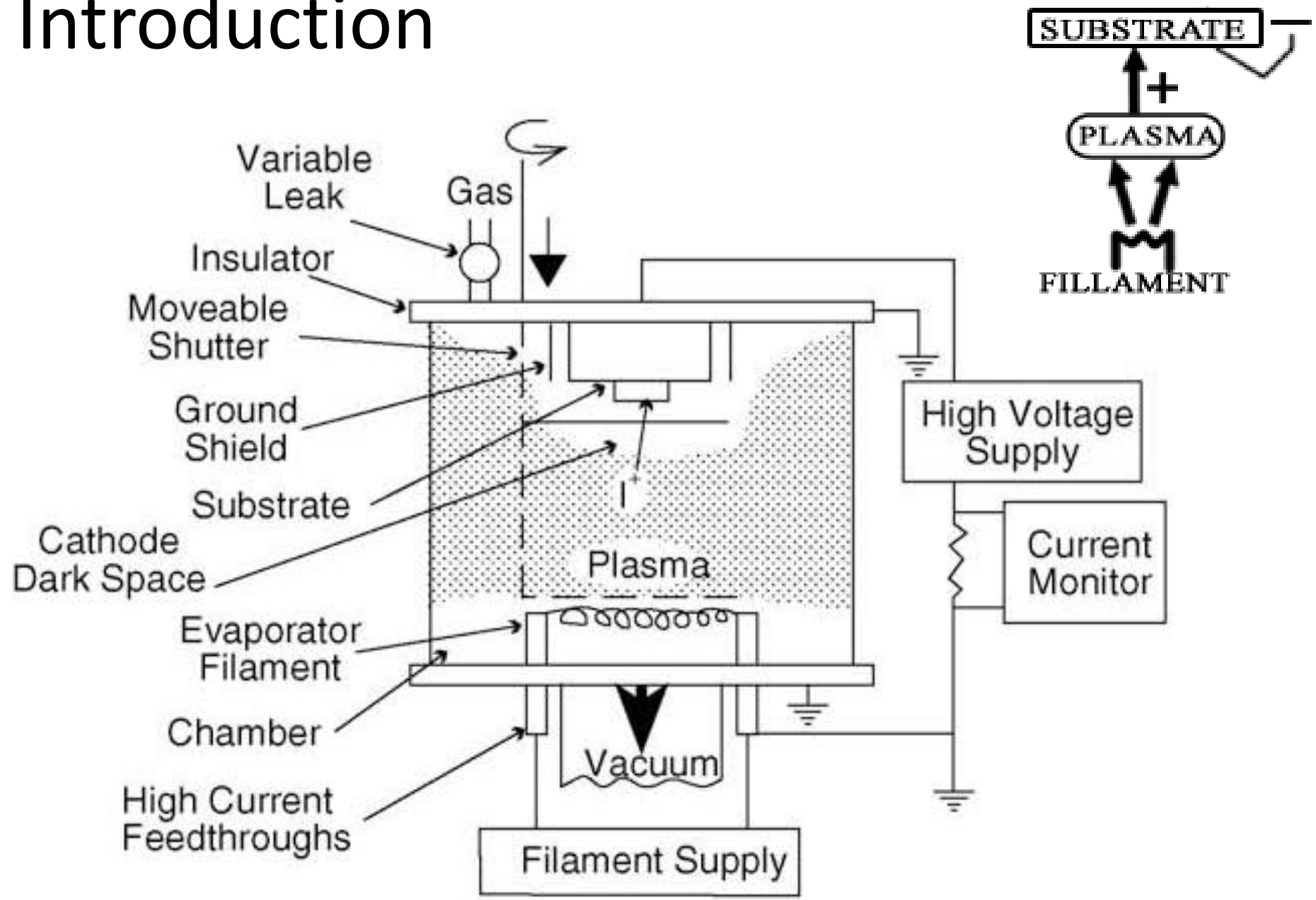
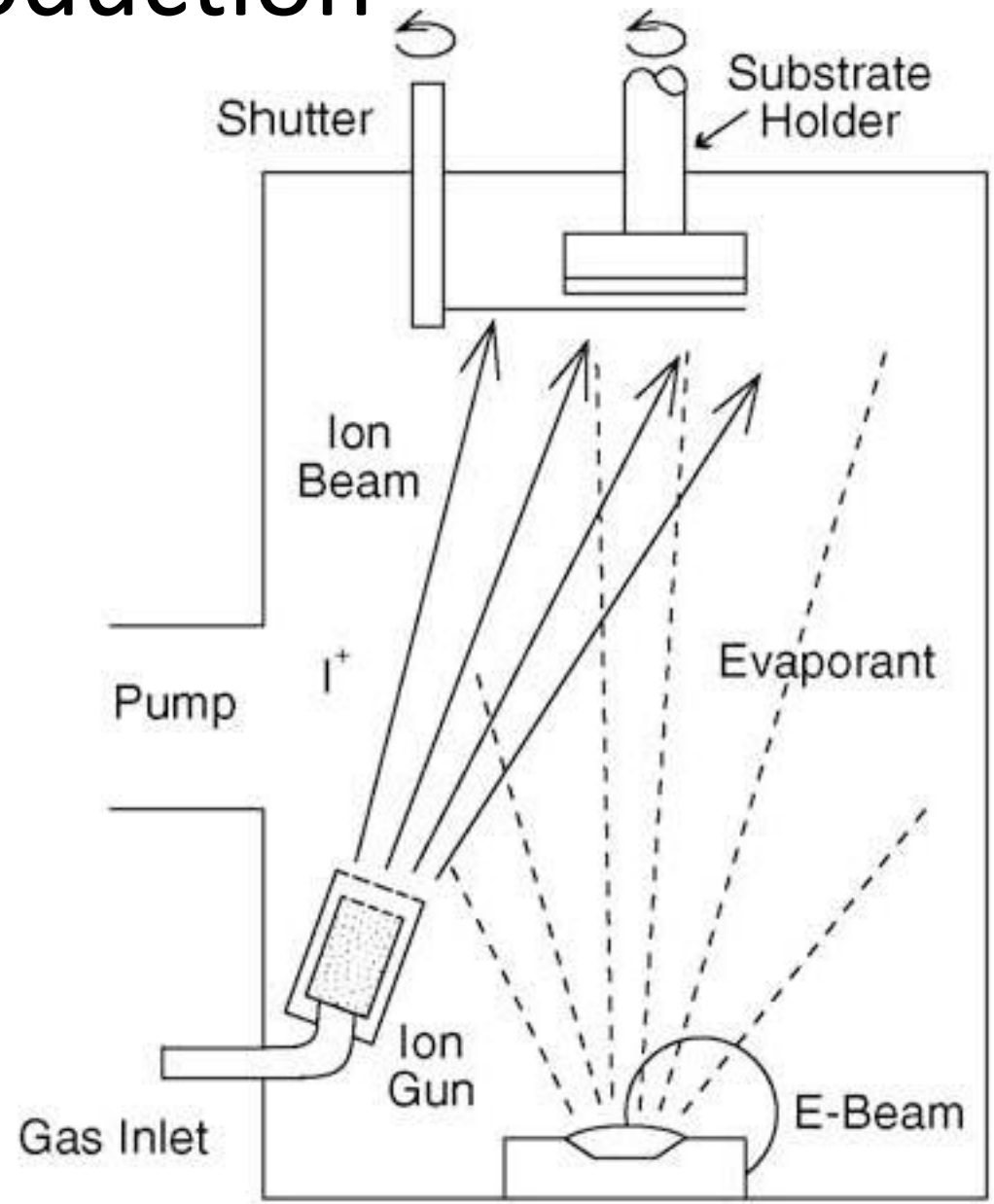
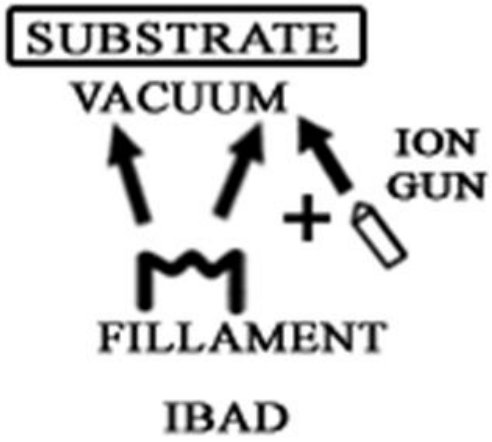
Introduction



Thermal Evaporation source with bombardment form a plasma

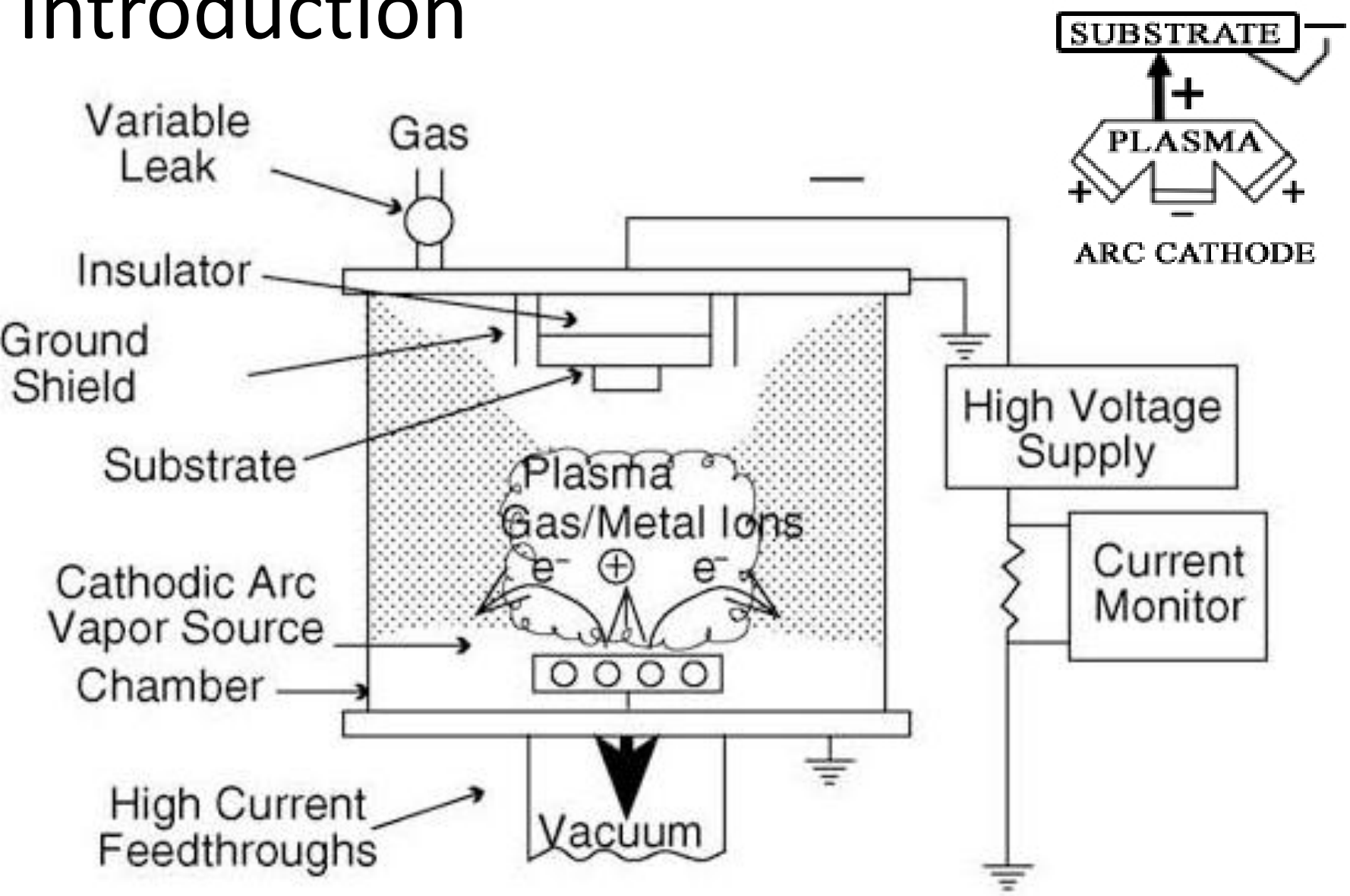
Introduction





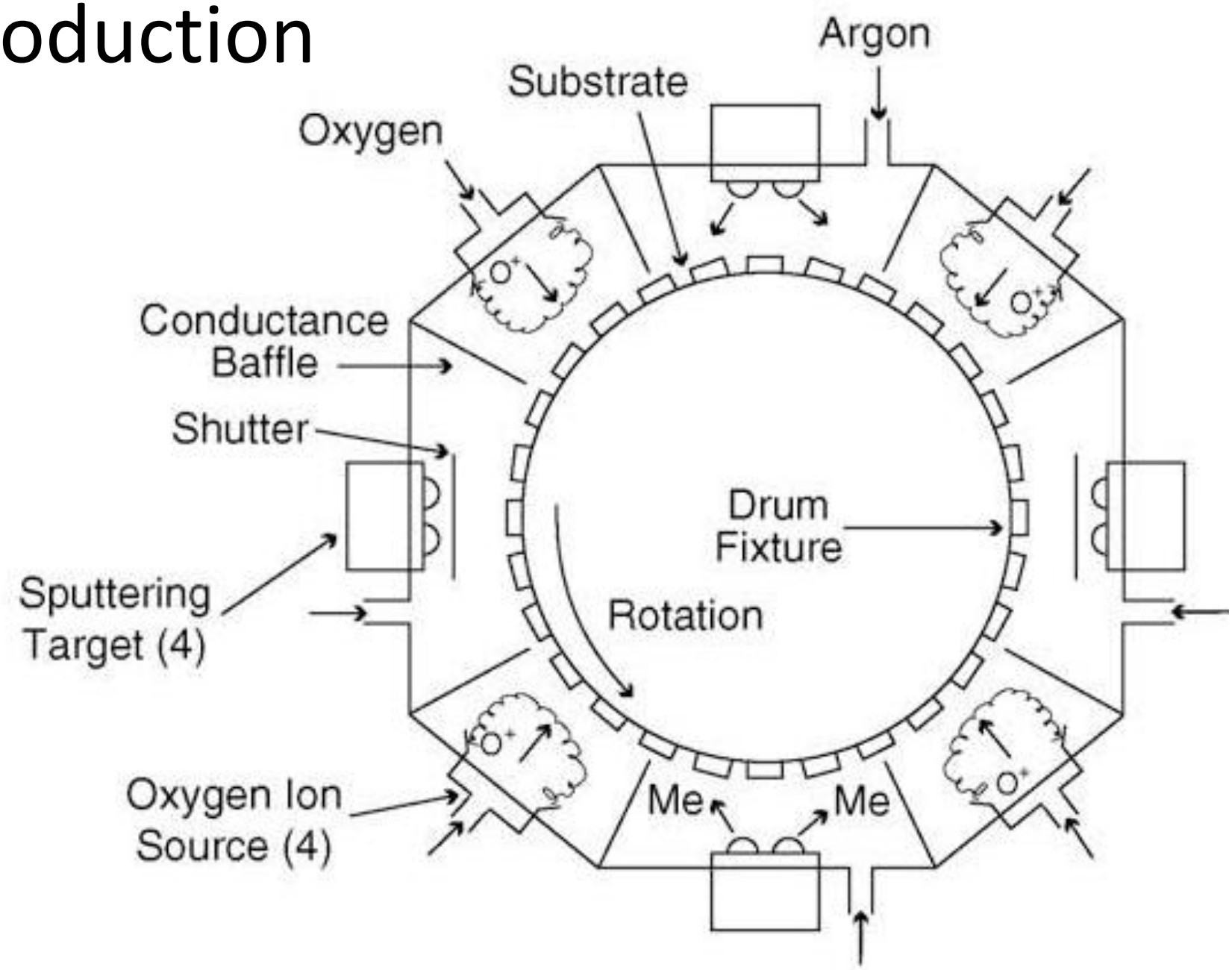
Electron beam evaporation source in vacuum with bombardment from an ion source

Introduction



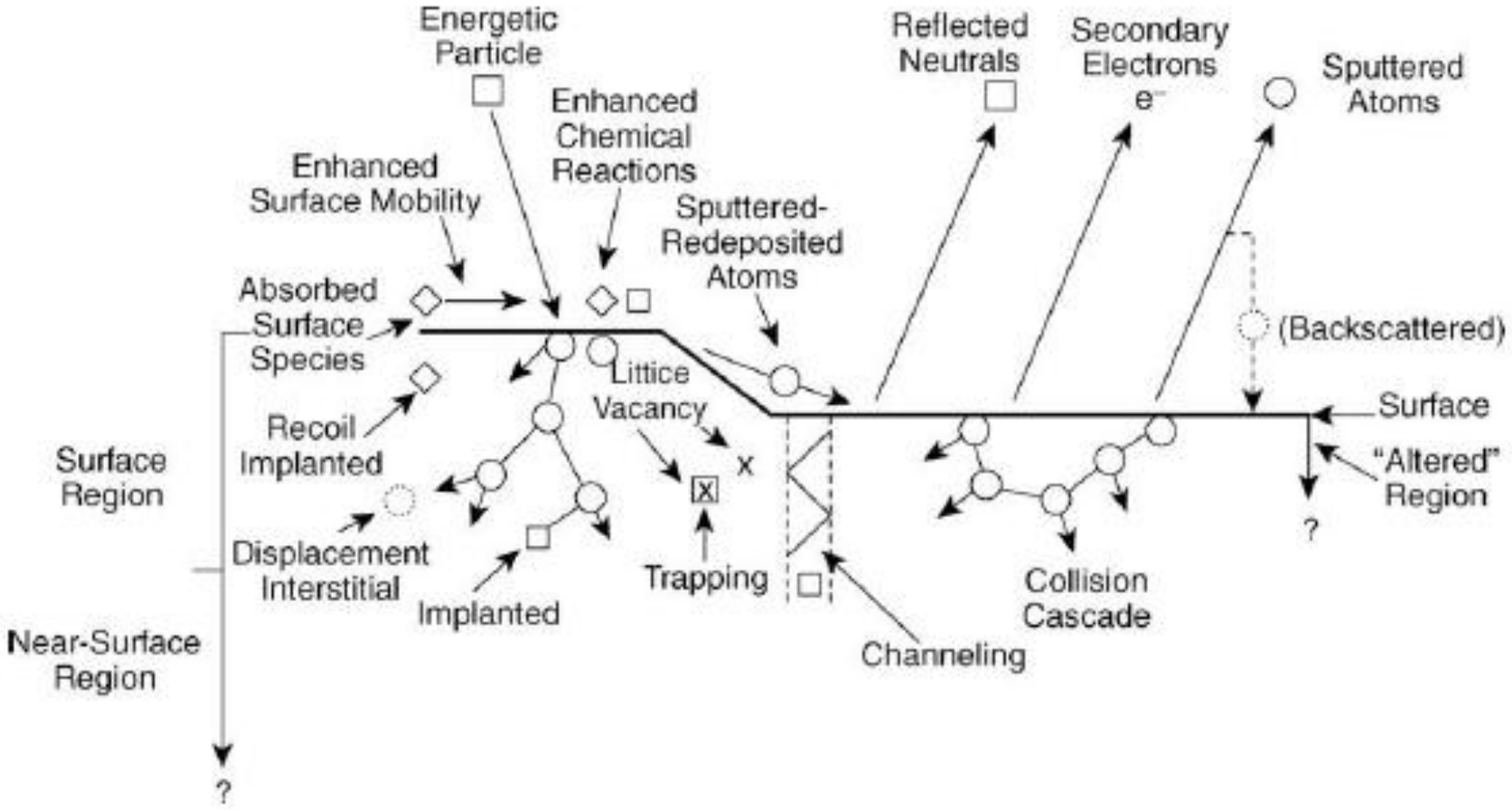
Arc vapor source with bombardment from plasma

Introduction



Deposition from a deposition source and bombardment from an ion source

Bombardment: Surface and Near-Surface affects



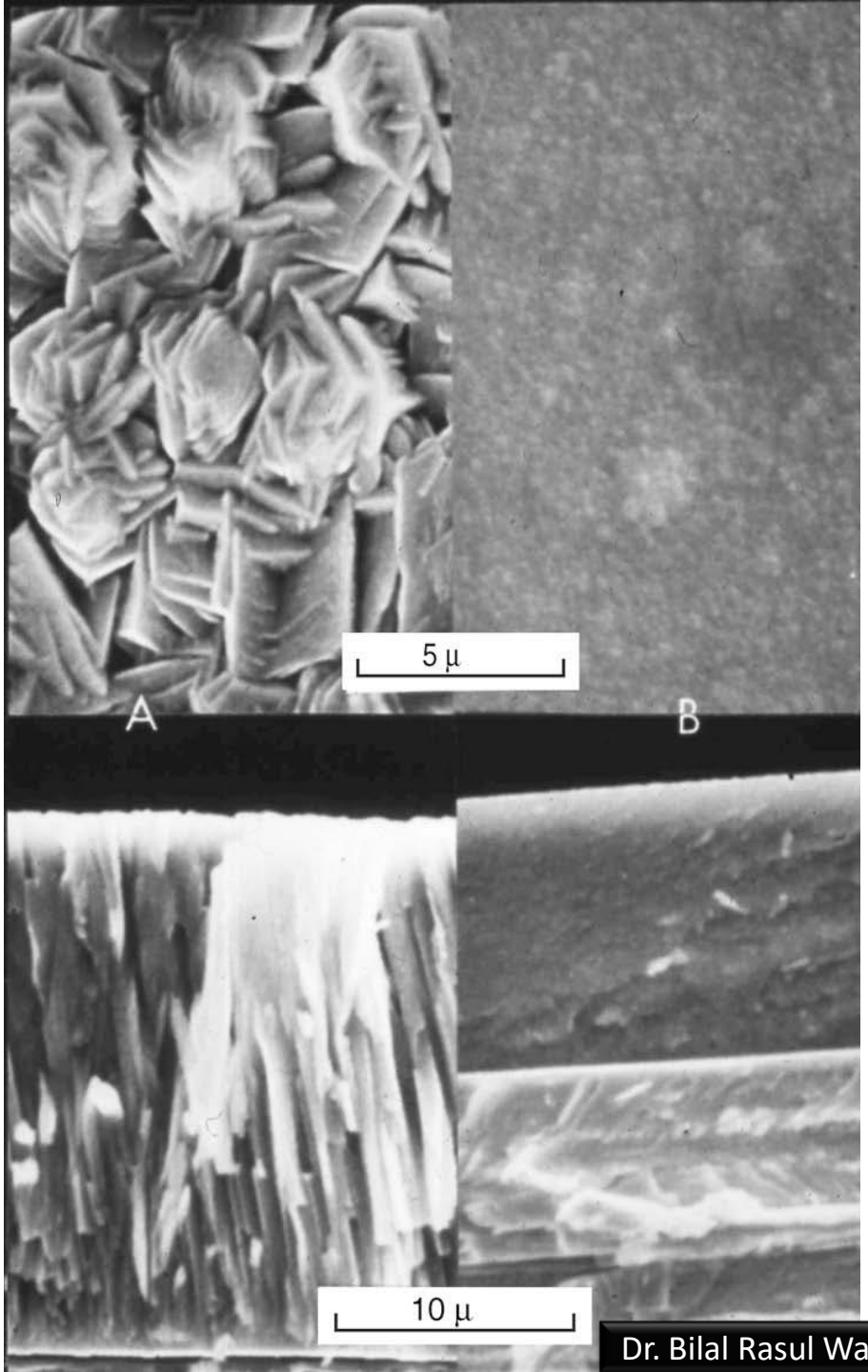
Bombardment: Affects on Adhesion, Film Growth and Properties of Deposited Material

- Matchstick Morphology is developed both for crystalline and amorphous materials: Structure Zone Models show low density, high surface area if deposit is made on a substrate with temperature below half of the M.P. of the material
- Cr without and with Ar^+ bombardment,

Density determined by

Flux, mass, energy, deposition

Rate and angle of incidence

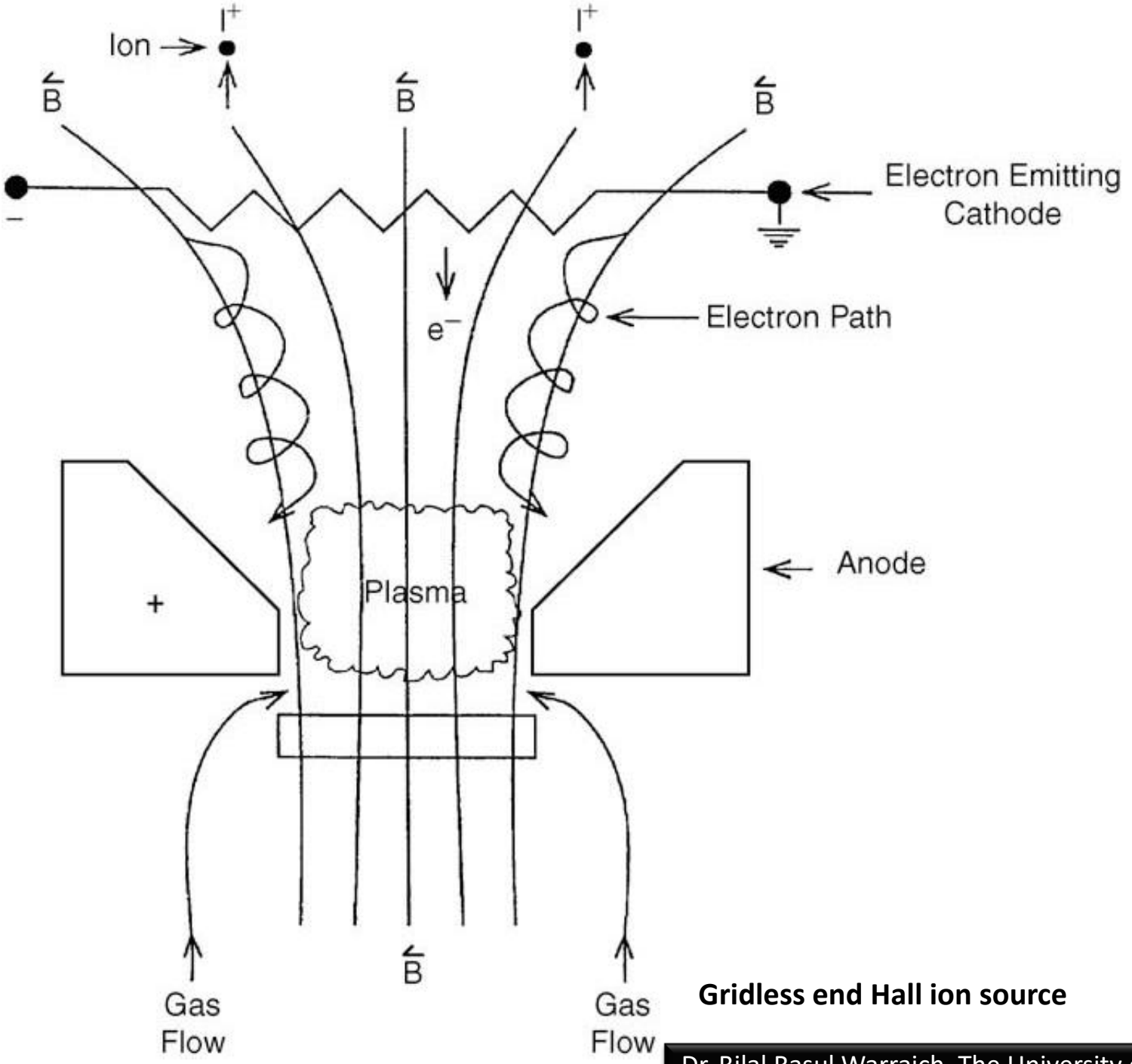

5 µ
A
B
10 µ

Bombardment: Effects on Adhesion, Film Growth and Properties of Deposited Material

- Energy Profile
  - Small energy: thermally evaporated atoms or sputtered atoms, columnar structure
  - Few eV of energy: higher surface mobility, epitaxial structure
  - Higher energies: adatoms and surface atoms are knocked, densifying deposited material

Bombardment: Effects on Adhesion, Film Growth and Properties of Deposited Material

- Reactive Deposition
  - Reactive species release energy to form compound
  - Reactive species have been activated in plasma, more reactive
  - Reactive Sputter Deposition: Heavy gaseous species (Ar)with lighter reactive species(N_2, O_2). Partial pressures need to be controlled
  - Continuous bombardment or periodic deposition e.g. rotating drum



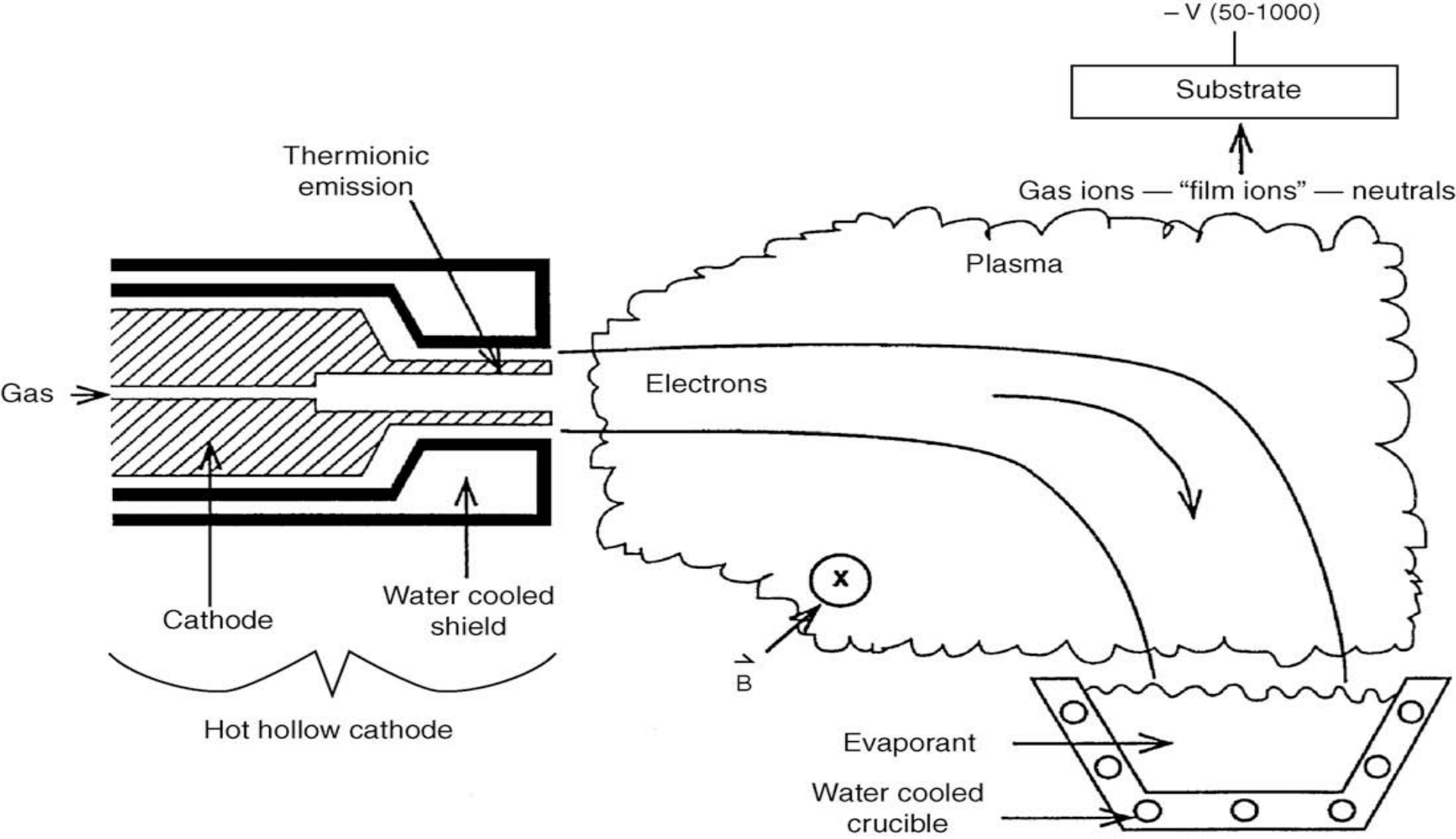
Gridless end Hall ion source

Sources of Depositing Material

- Vacuum Evaporation
  - Resistively heated evaporation source
  - High-voltage e^- beam heating
    - Plasma is generated by 'electrically isolated substrate holder e.g. cathode or RF electrode'
      - Pressure raised to 0.5-15 mtorr
- High pressures
  - Gas scattering and 3-body collisions result vapor phase nucleation (sooting), In plasma, these are -vely charged and don't reach substrate if -vely biased
  - Scattering may cause out-of-line-of-sight coverage

Sources of Depositing Material

- High current, low voltage e^- beam from hot hollow cathode e^- emitting source are used to thermally evaporate materials
- Plasma in high voltage, focused e^- beam evaporation not suitable as ions may sputter the filament. Filament in a separate chamber



Hollow cathode electron source for electron beam melting/evaporation

Sources of Depositing Material

- Plasma based sputter deposition
  - Non-Magnetron DC configuration
    - Substrate is bombarded by electrons accelerated away from cathodic target
  - Magnetron sputtering configuration
    - Magnetic field is configured to let some electrons escape the confinement and form plasma between the source and substrate
- Ionized Physical Vapor Deposition
  - Plasma inside vapor source, by RF coil, hollow cathode e-emitter, hollow filament e-emitter. HIPPMS-high ionization fraction. 3 MW power, 1 A/cm^2, kHz pulsing freq.
  - Ion Gun
- Cathodic arc vaporization
  - Cathodic arc runs over surface, large fraction of vaporized material is ionized

Sources of Bombarding Particles

- Energetic gaseous ions
  - Ions from plasma are accelerated if substrate is biased
  - Ion Gun
- High energy neutral bombardment

  Reflection of ions from sputtering cathode as neutral atoms, have high energies because of the long MFP i.e. low pressures

  charge exchange between a high energy ion and low energy neutral

Applications

- Adherent coatings
- Dense coatings
- Conformal coatings
  - Al coatings of aircraft fasteners to prevent galvanic corrosion
  - Coatings on strip steel
  - Coatings on aero engine parts
  - Densification of films on optical components
  - Hard coatings of compound materials(Ti, Al, Zr…)
  - Adhesion layer for electroplating material(Zr, U, Ti)