EE 527 MICROFABRICATION

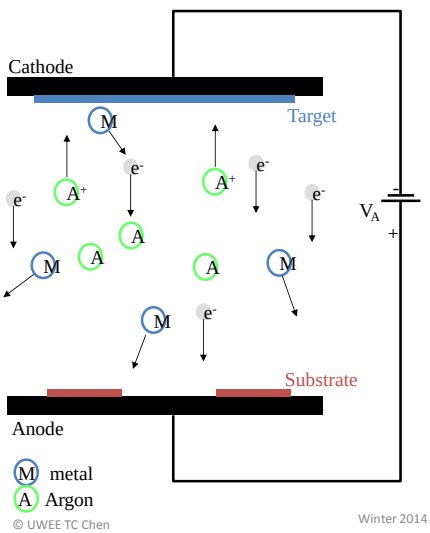
Lecture 9

Tai-Chang Chen
University of Washington

UNIVERSITY OF WASHINGTON

SPUTTERING/SPUTTER DEPOSITION

- **Most important PVD method.**
- Non-directional transfer of atoms/clusters from target to substrate.
- Glow discharge plasma is initiated by applying a large voltage across a gap containing a low P gas.
- Heavy inert Ar gas is ionized.
- Ar^+ is accelerated toward the cathode, impacts and ejects the target atoms.

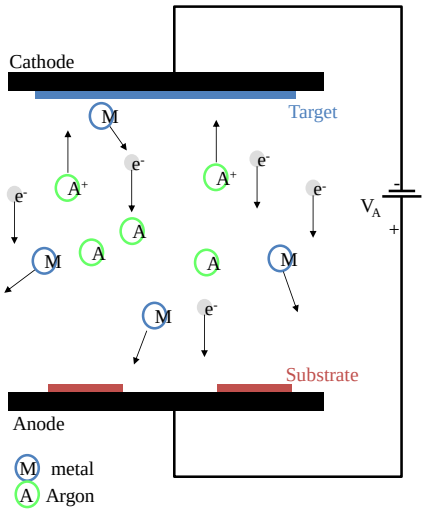


Winter 2014

UNIVERSITY OF WASHINGTON

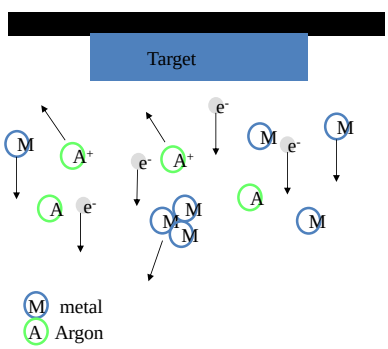
SPUTTERING/SPUTTERING PROCESS

- Collisions between ions/electrons and gas creates more ions/electrons.
  - Avalanche effect.
- Typical sputtering rates are 1-10 nm/s.
- Typical sputtering chamber pressures are 1-10 mTorr.



SPUTTERING/TARGET EJECTION

- Energy ≥ 10,000 eV
  - Surface penetration.
  - Damage to target.
  - Incident ions eject atoms from target.
  - Escape at 10 to 50 eV.
  - 100x energy of an evaporated ion.
    - Surface mobility.



SPUTTERING/ADVANTAGES

- Can sputter a wide variety of metals and dielectrics.
- No high temperatures necessary.
- Low vacuum: pressure around 10 milli-torr.
- Non-directional uniform coverage.
- In situ cleaning.
- Reflow.

SPUTTERING/DISADVANTAGES

- Cooling required: target and substrate heat up because of high energy impacts and current.
- Higher risk of contamination in deposited film:
  - gas: Ar
  - chamber materials.
  - substrate materials.
- Substrate damage.

SPUTTERING/SPUTTERING METHODS

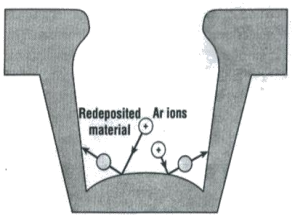
- DC – Conductive
- Conductive, impinging ions need to recombine with electrons to avoid charge accumulation on cathode.
  - Au, Pt, Al, Cr, W, Ti
- RF - Dielectrics and Oxides
  - RF field provides discharge for conducting and isolating substrates.
  - Non-electrical materials
  - SiO_2, ZnO, TiO_2, Si

SPUTTERING/MAGNETIC SPUTTERING

- Magnetic field in a plasma causes the electrons to spiral around the direction of the magnetic field lines.
- Orbital motion increases probability that they will collide with neutral species and create ions.
- Formation of plasma at lower pressures.
  - 10^{-5} - 10^{-3} torr

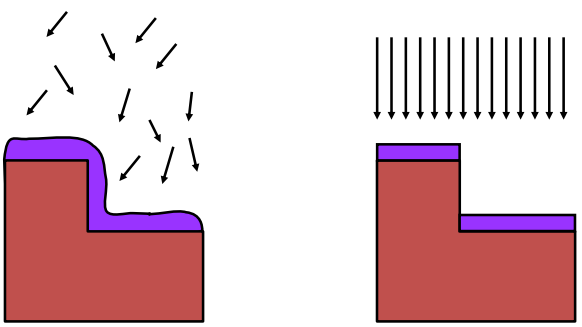
SPUTTERING/BACKSPUTTERING

- Reverse polarity of sputter system:
  bombard substrate with inert ions
  physical etching
- Useful for removal of native thin films.
  - films that change electrical or mechanical properties of the interface.
    - films that reduce adhesion.
    - especially native oxides.



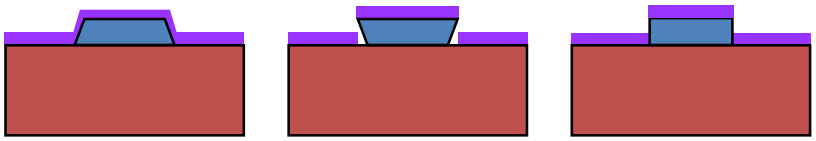
SPUTTERING/STEP COVERAGE

- Good step coverage desired
  - To ensure good electrical connection in metal layers with substantial topography (e.g., multi-layer back-end metallization; vias)
- No step coverage desired
  - Lift-off

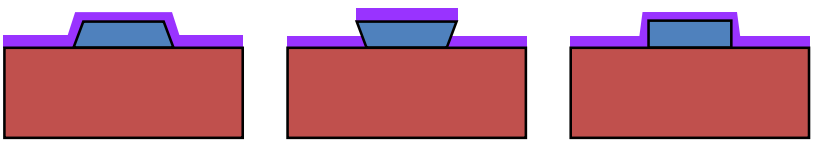


SPUTTERING/STEP COVERAGE

- Evaporation



- Sputtering



	Evaporation	**Sputtering**
Choice of materials	Limited	Almost unlimited
Purity	Better	Possibility of incorporating impurities
Substrate heating	Very low	higher
Surface damage	Very low, with e-beam x-ray damage is possible	Ionic bombardment damage
In-situ cleaning	Not an option	Easily done with a sputter etch
X-ray damage	Only with e-beam evaporation	Radiation and particle damage is possible
Changes in source material	Easy	Expensive
Uniformity	Low	Easy over large areas
Capital Equipment	Low cost	More expensive
Number of deposition	Only one deposition per charge	Many deposition can be carried out per target
Shadowing Effect	Large	Small