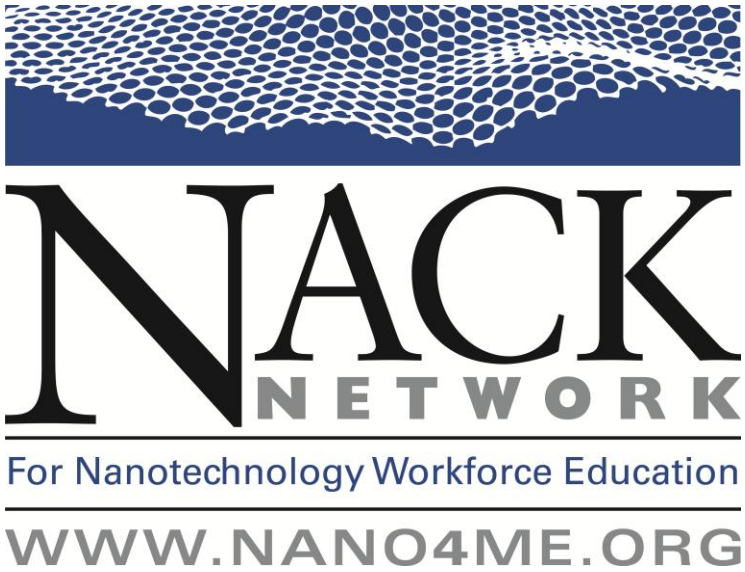


# Basic Nanotechnology Processes

E SC 212

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# Unit 6
# Physical Deposition

# Lecture 1
# Physical Vapor Deposition

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# Outline

- Introduction
- Thermal and e-gun evaporation
- Sputtering
- Laser ablation

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# Introduction

- Physical Vapor Deposition (PVD) basically consist of vaporizing a source (target) in order for the transfer to and deposition on a substrate
- The processes are preformed under vacuum to prevent contamination issues
- PVD allows for very precise atomic layer film growth in thickness ranging from nanometers to millimeters
- Normally there is no chemical reaction throughout the deposition process. However, in some methods (e.g. sputtering) new growth-species can be created chemically in the vapor phase and deposited on the substrate
- There are many types of physical deposition methods and systems, three of which will be presented here

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# Outline

- Introduction
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# Thermal Evaporator

- Thermal energy is used to atomize elemental metals. Alloys tend to separate due to melting temperature
- Metal selection is based on temperature, with a nominal limit of Platinum
- Vacuum level is important to minimize contamination. Generally a base vacuum of  10-5 Torr is desired to prevent water contamination
- This originates 'shadowing' phenomena with 3D objects, especially in those regions not directly accessible from the evaporation source substrate surface is generally low (order of kT, i.e. tenths of eV). This affects seriously the morpholgy of the films, often resulting in a porous and little adherent material

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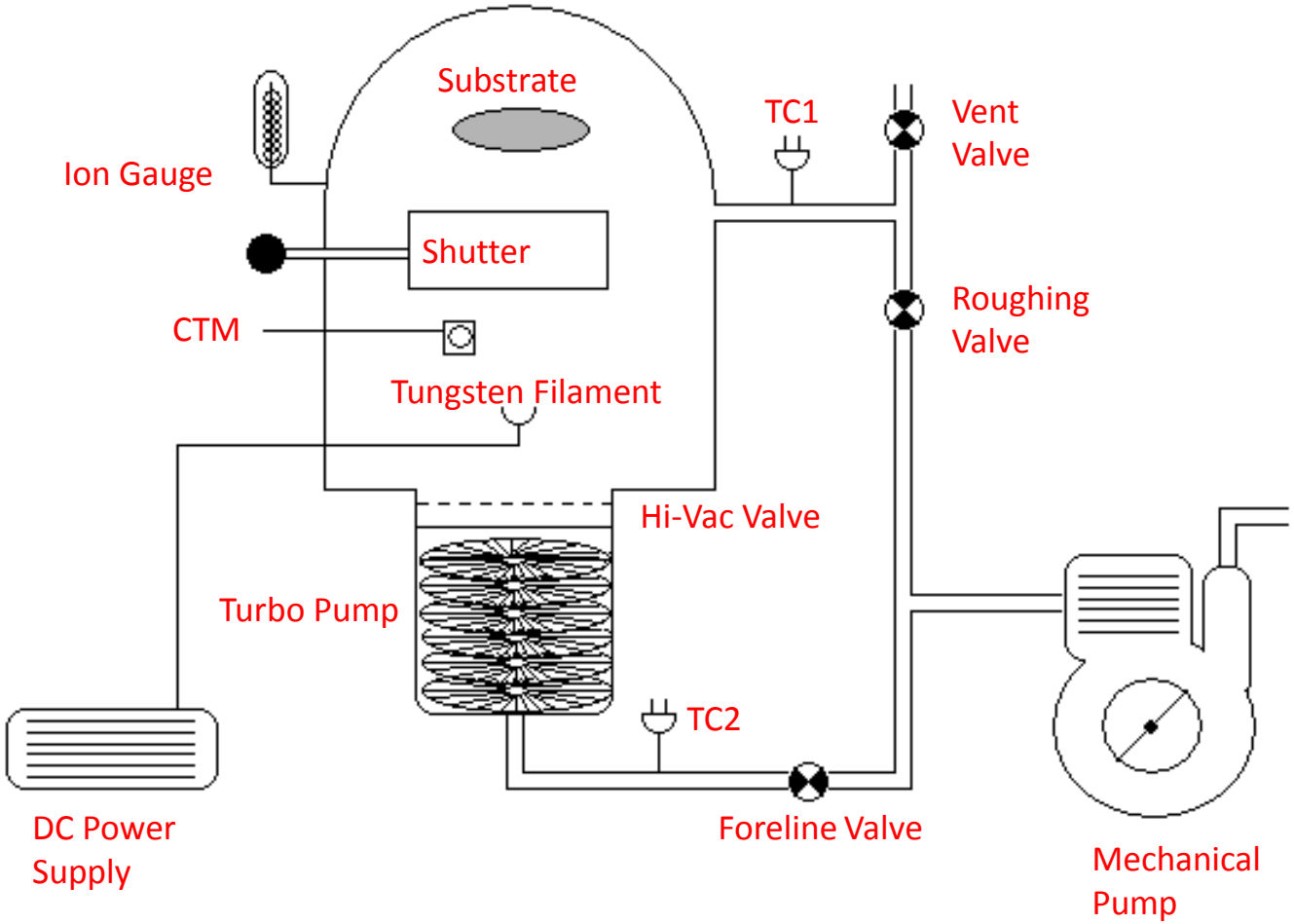
# Thermal Evaporator

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# E-Gun Evaporator

- E-beam source permits the use of metals that have a higher melting temperature than the evaporator.
- Crucible materials are selected to prevent contamination

- Crucible selection chart…….

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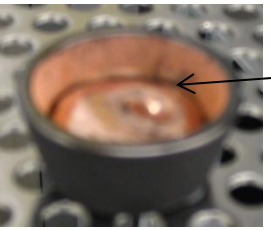
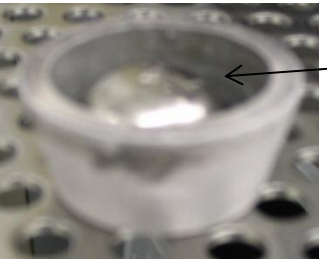
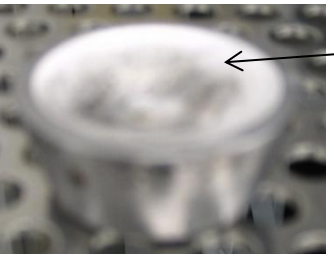
# E-Gun Crucible Chart

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| Crucible Type | Source Material |
|---|---|
| Standard Graphite | Antimony |
| Glassy Coated Graphite | Aluminium, Chromium, Gold, Nickel, Silicon |
| Alumina (Aluminum Oxide) | Antimony, Copper, Gold, Iron, Nickel, Platinum, Silver |
| Boron Nitride | Antimony, Aluminium, |
| Molybdenum | Barium, Copper, Silver |
| Tantalum | Barium, Copper, Silicon, Titanium Dioxide |
| Tungsten | Alumina $Al_2O_3$, Barium, Gold, Zirconium Oxide |

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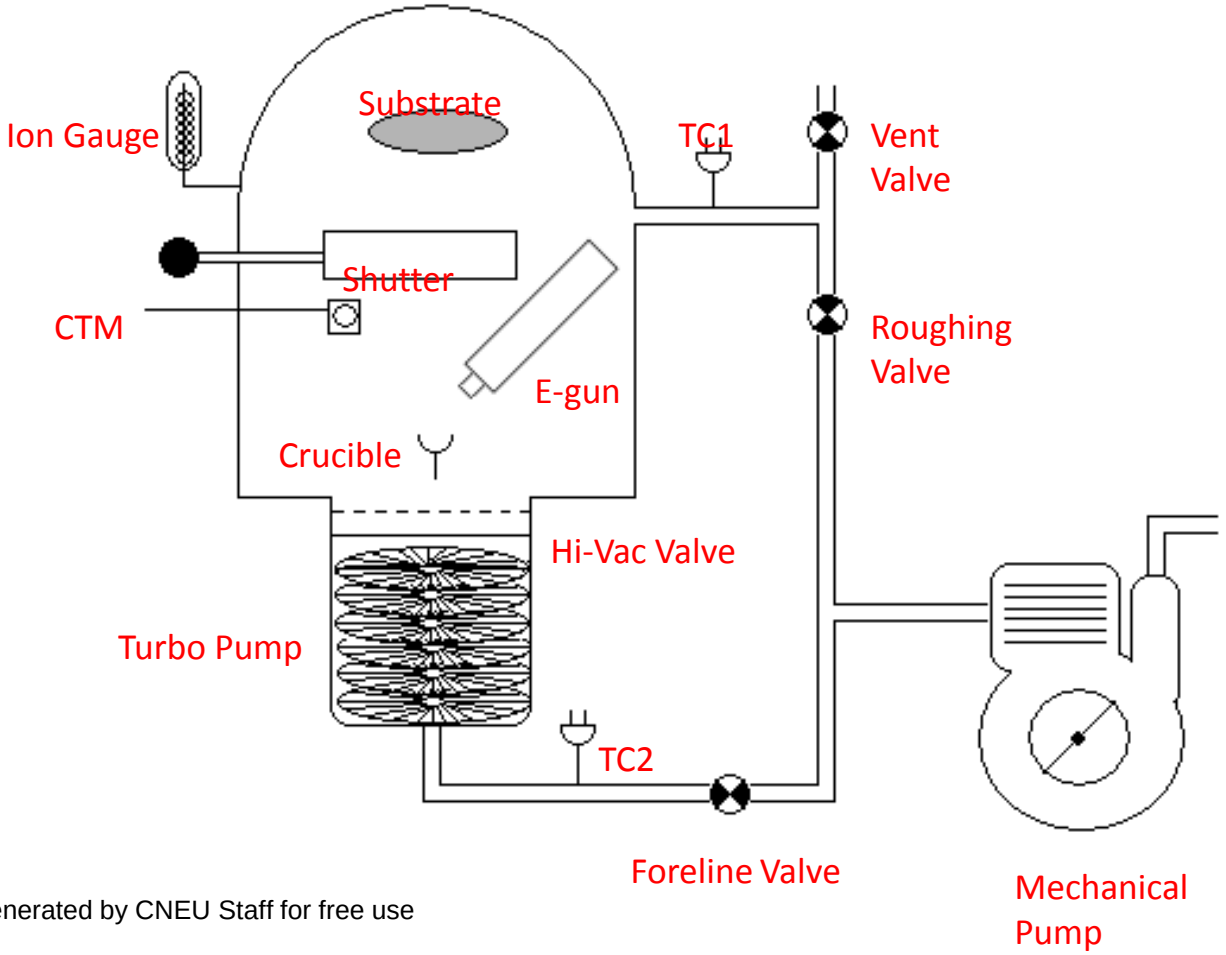
# E-Beam Evaporator

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# E-Beam Evaporation

- Target anode is bombarded with an electron beam given off by a charged tungsten filament under high vacuum
- 
- Vacuum level is important to minimize contamination.  Generally a base vacuum of 10-5 Torr is desired to prevent water contamination

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# Outline

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# Sputtering

- RF power is used to create ions that impinge on the target.
- Ion bombardment “grinds down” the target, and the resulting material is deposited on the substrate
- The product of ion impingement energy and substrate temperature create a unique morphology of the deposited material
  - Permits the use of many materials.
    - Compounds
    - Pure metals
    - Mixtures
    - Alloys

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# Sputtering Advantages

- Reproducibility
- Thickness Control
- Stronger Adhesion
- Deposits More Materials
  - Compounds
  - Pure metals
  - Mixtures
  - Alloys

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# Sputtering

- Benefits
  - Ability to deposit complex compounds while maintaining their stoichiometry
  - Capability to deposit high-temperature and refractory metals
  - Ability to deposit controlled, uniform films on large substrates and components
  - Can be part of a multi-chamber cluster tool
  - Can be used as a pre-process substrate cleaning tool

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# Sputtering Disadvantage

- Higher quality equipment
- Higher costs
- Lower deposition rates
- Organic material integrity is easily degraded by ion bombardment

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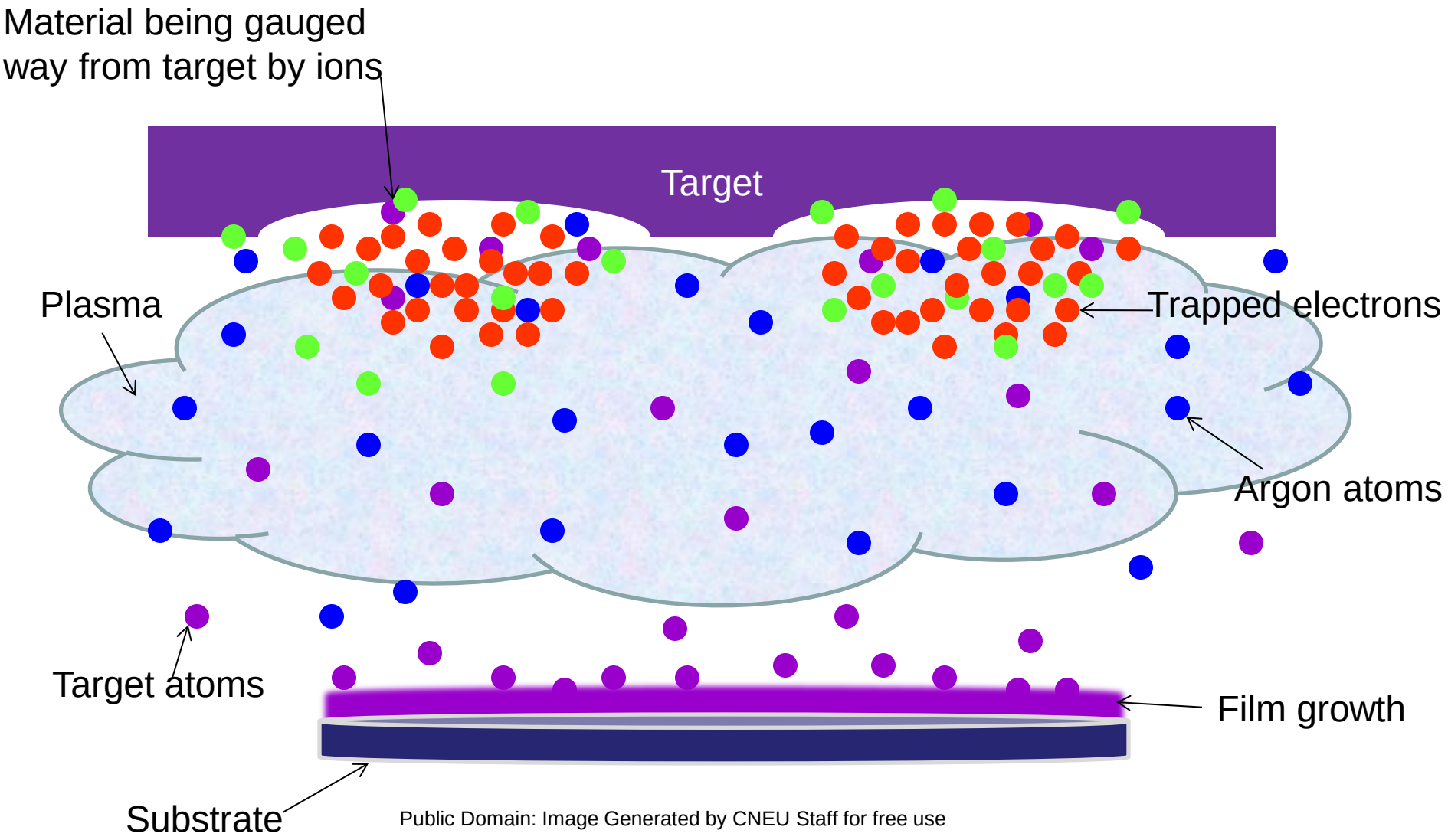
# Sputtering Diagram

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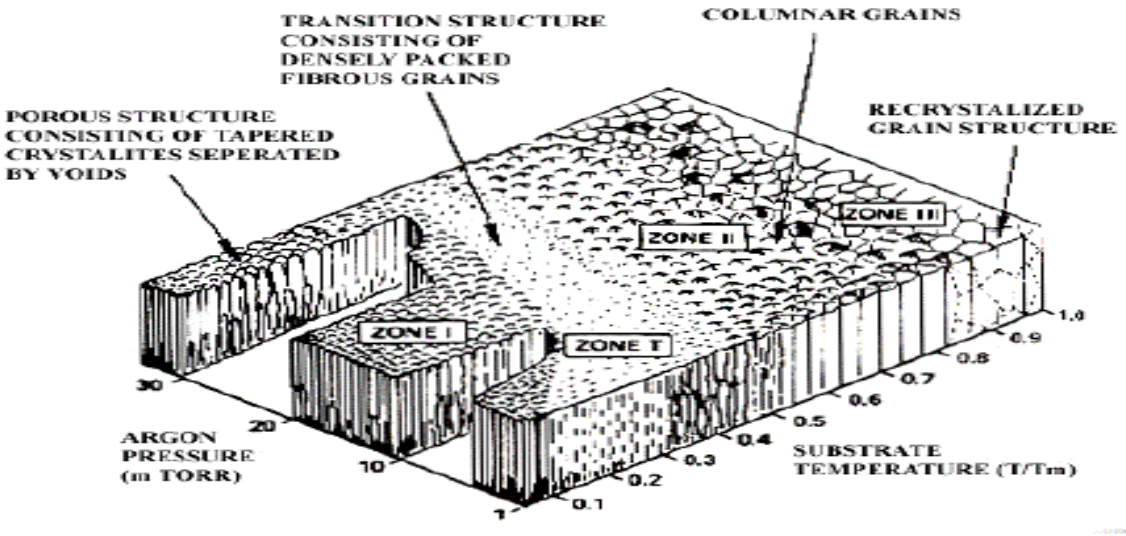
# Film Integrity (Thornton Structure)

- Illustrates relationship between
  - Coating morphology
  - Deposition temperature
  - Pressure




Lieberman, M.A., Lichtenberg, A.J. *Principles of Plasma Discharges and materials Processing*. Wiley. New York. 1994

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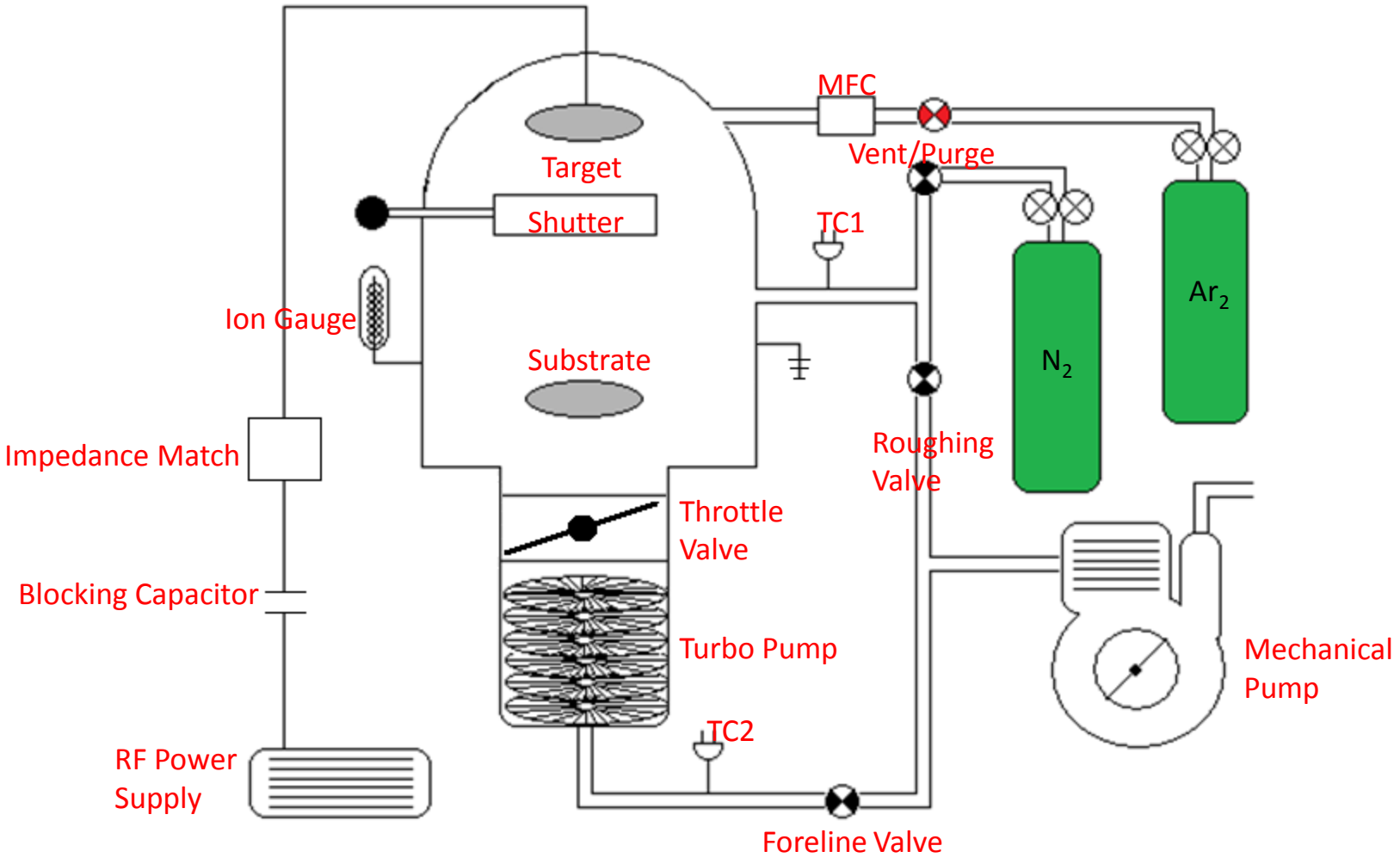
# Sputtering Tool

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# Laser Ablation

- The laser's wavelength is chosen based on the source material's absorption characteristics
- At low laser flux, the material is heated by the absorbed laser energy and evaporates or sublimates
- At high laser flux, the material is typically converted from the source into a plasma the components of a least some of which deposits on the substrate
- Pulsed lasers are usually used but it is possible to ablate material with a continuous wave laser beam if the laser intensity is high enough

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# Laser Ablation Advantages

- Laser ablation can effectively deposit complex films
- Laser ablation allows the control of the deposition material when solid *and the vapor composition* when depositing

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# Laser Ablation Disadvantages

- Laser ablation systems have a far more complex design, thus high cost associated with them
- Finding the best wavelength for evaporation can be difficult
- Laser ablation often has a low conversion efficiency

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