Building College-University Partnerships for Nanotechnology Workforce Development

Thermal Evaporation

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PennState

Welcome

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Welcome

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Review of Vacuum Science

Vacuum Ranges

The removal of gas molecules from a chamber to achieve a pressure lower than atmosphere.

Atmospheric pressure = 760 T
1 atmosphere = 760 T

Ranges:
Low Vacuum (Rough Vac) Atm- 10^{-3} Torr
High Vacuum 10^{-3} Torr to 10^{-6} Torr
Ultra High Vacuum 10^{-6} Torr and lower

Vacuum Pumps

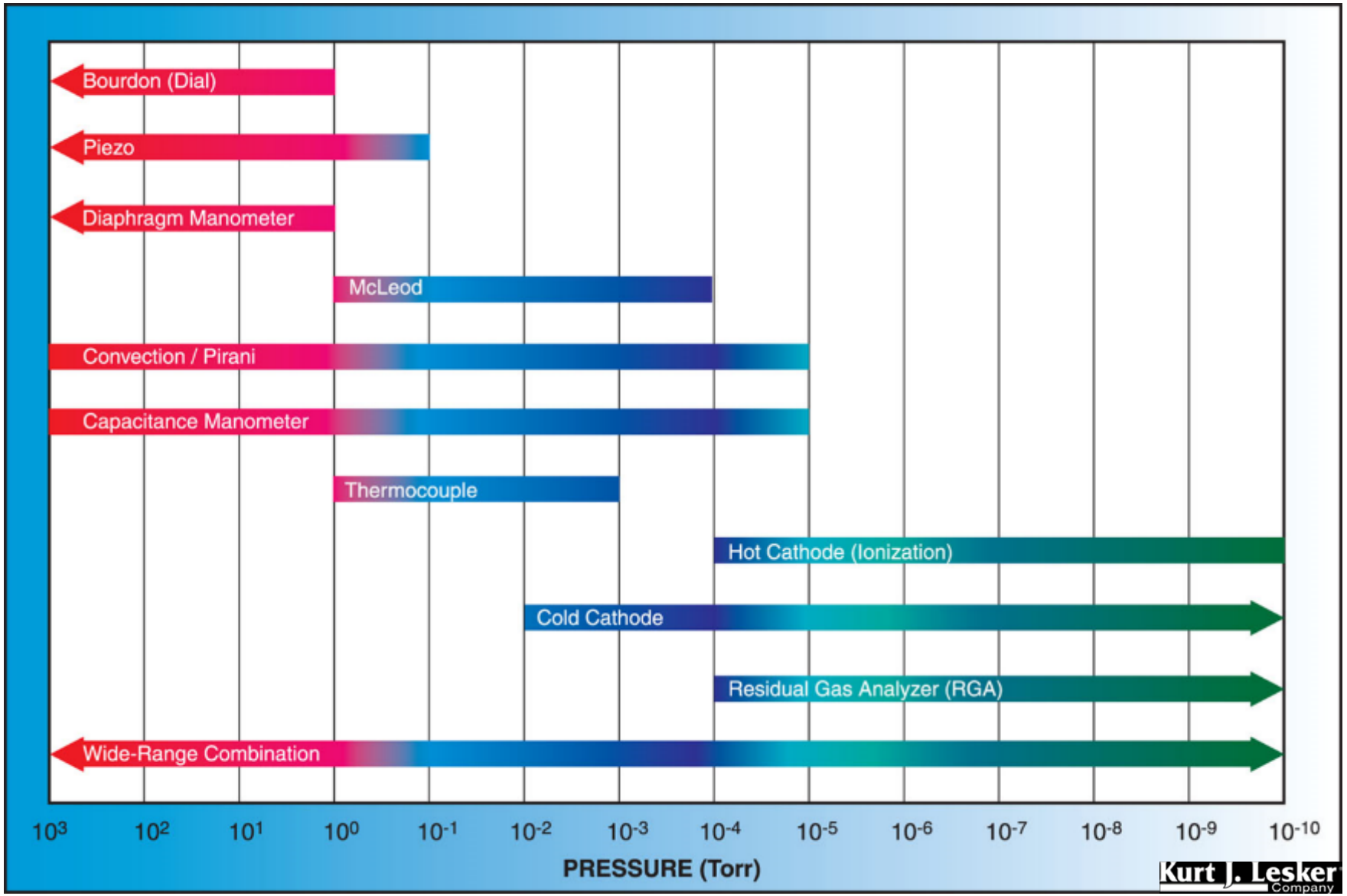
Mechanical (Rough) pumps

- Rotary Vane
- Diaphragm
- Scroll
- Dry Piston

High Vacuum Pumps

- Oil diffusion
- Cryogenic
- Turbomolecular
- Ti sublimation pump

Vacuum Gauges



Vacuum Components









Kurt J. Lesker Company

Cost of Vacuum Equipment

Vacuum Pumps

- Rough Vacuum: $1,500-$22,000
- High Vacuum: $3,500-$50,000
- Ultra High Vacuum: $3,500-$15,000

Gauges

- Rough Vacuum: $50-$1,000
- High Vacuum: $150-$1,000
- Ultra High Vacuum: $750-$1.200

Components: $20-$15,000 includes chambers

Pump down the chamber…

Picture of an Example Vacuum Setup

Rough Vacuum System

A – Chamber

B – Vacuum Pump

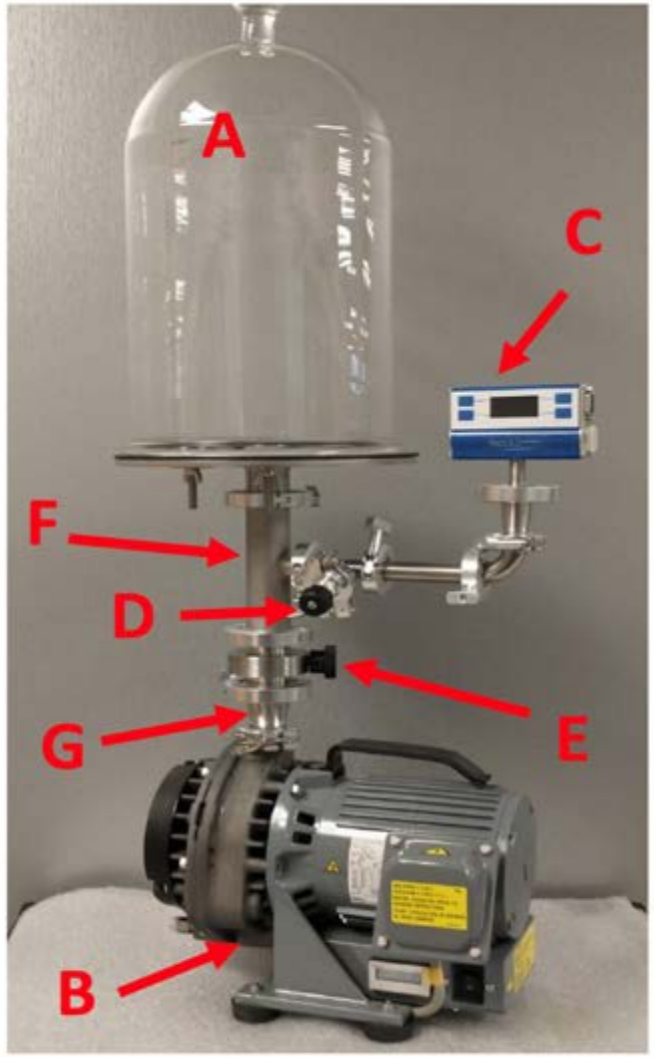
C – Pirani Gauge

D – Vent Valve

E – Butterfly Valve

F – T-piece Pipeline with KF40 coupling

G – KF40 to KF16 Reducer Nipple



SUNY ERIE
State University of New York

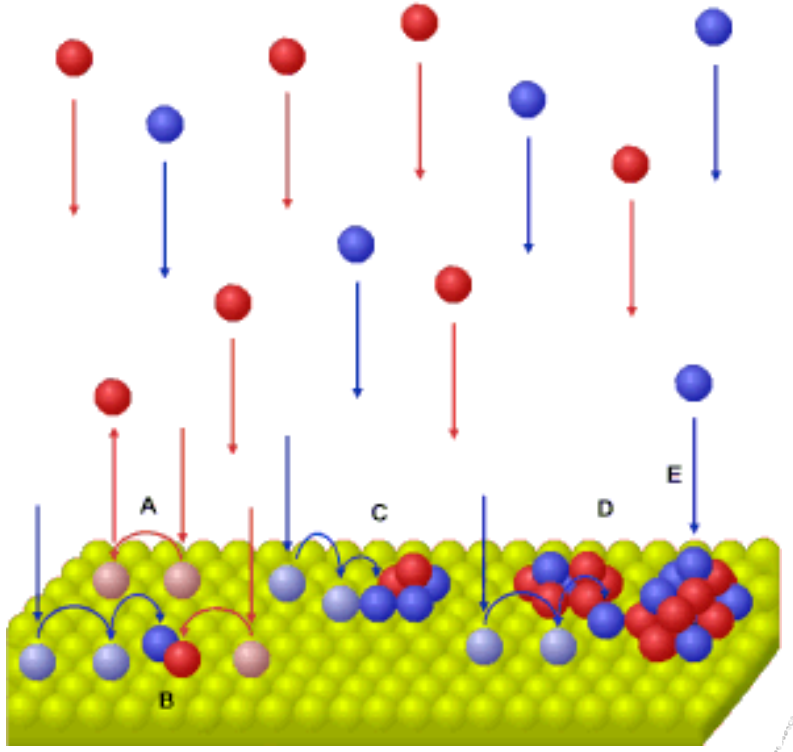
What is Thermal Evaporation?

My bathroom mirror is foggy

What is thermal evaporation?

Physical Vapor Deposition (PVD)

- Adatoms “hop” around until they form a bond with the substrate
- How long adatom is mobile is critical to film characteristics
  - Energy of incoming atom
  - Temp of substrate
  - Flux and energy of ions and electrons



PVD Techniques

3 Main Types:

- Evaporation
  - Thermal
  - Electron gun
- Sputtering
- Laser Ablation

Others (less common):

- MBE
- Ion plating

Fundamentals of Thermal Evaporation

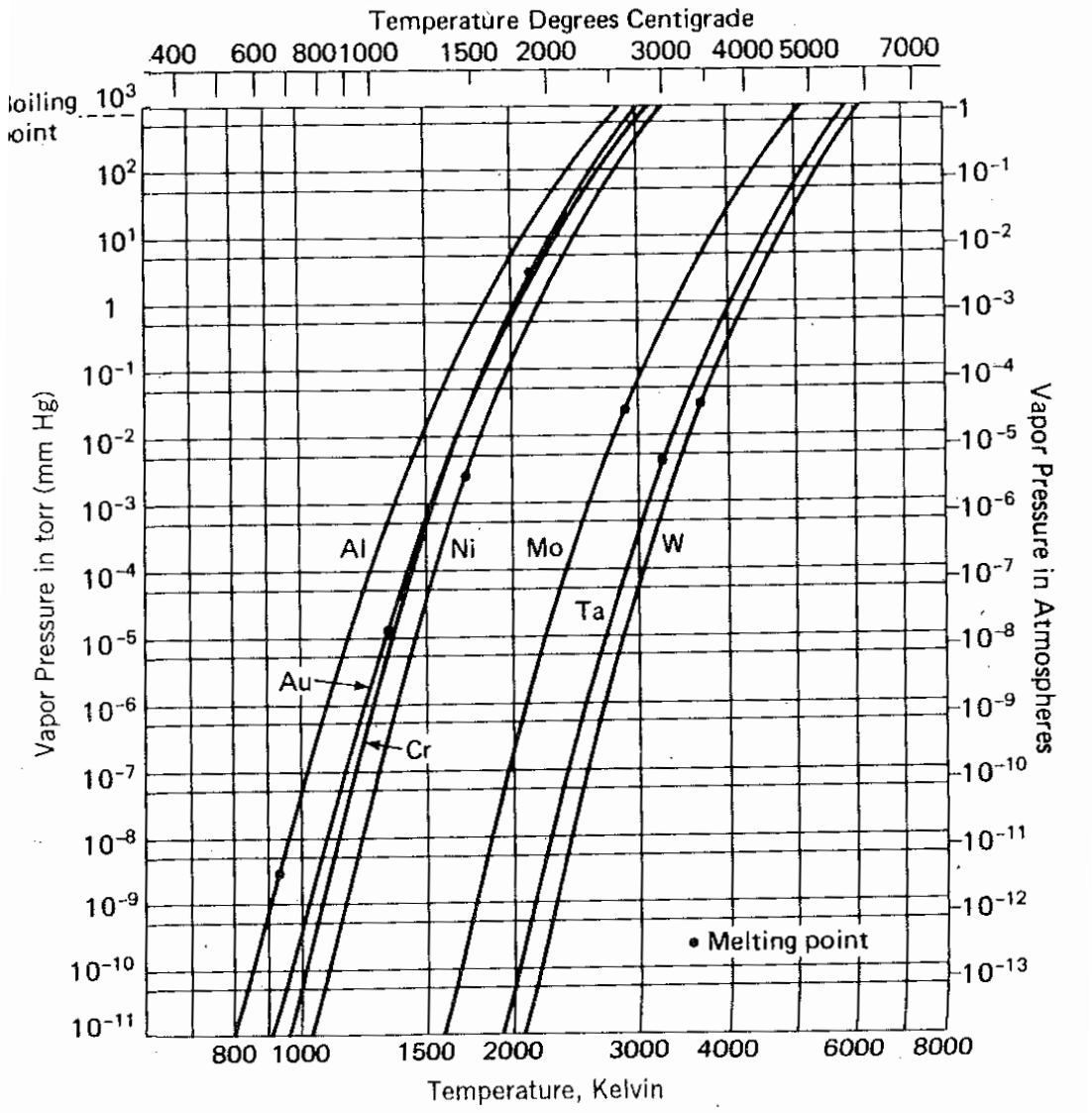


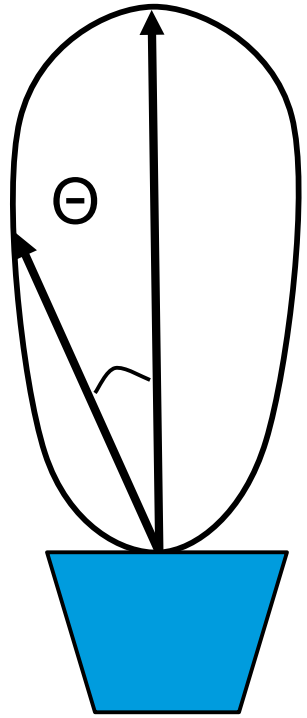
Fig. 8.1 Vapor pressure curves for selected materials. Adapted from [2].

- As pressure decreases, vaporization temperature decreases
- Al, Au, Cr, Ag can be thermally deposited
- Mo, Ta, W can not be practically thermally deposited
- Alloy evaporation is very difficult

Ghandhi, Sorab K. VLSI Fabrication Principals 2nd Ed. New York: Wiley – Interscience Publication, 1994

Thermal Evaporation

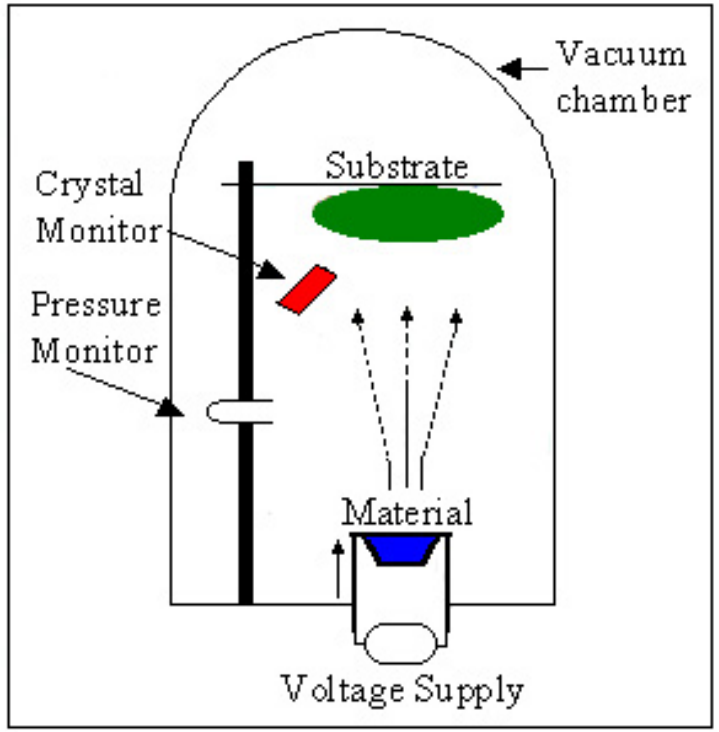
- Material heated until vaporizes
  - Easier with low MP metals
- Low pressure (~ 10^{-5} Torr)
  - Prevents contamination

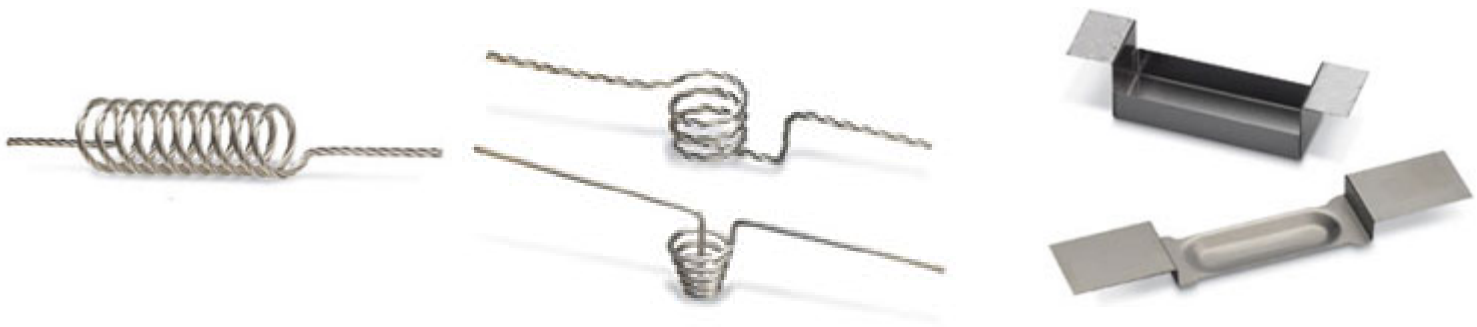


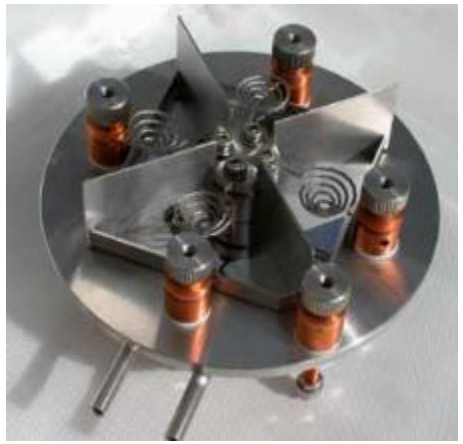
- Evaporant leaves source in a line-of-sight cosine distribution
- “shadowing”
  - Not good for high aspect ratio filling
  - Planetary rotation

Thermal Evaporation

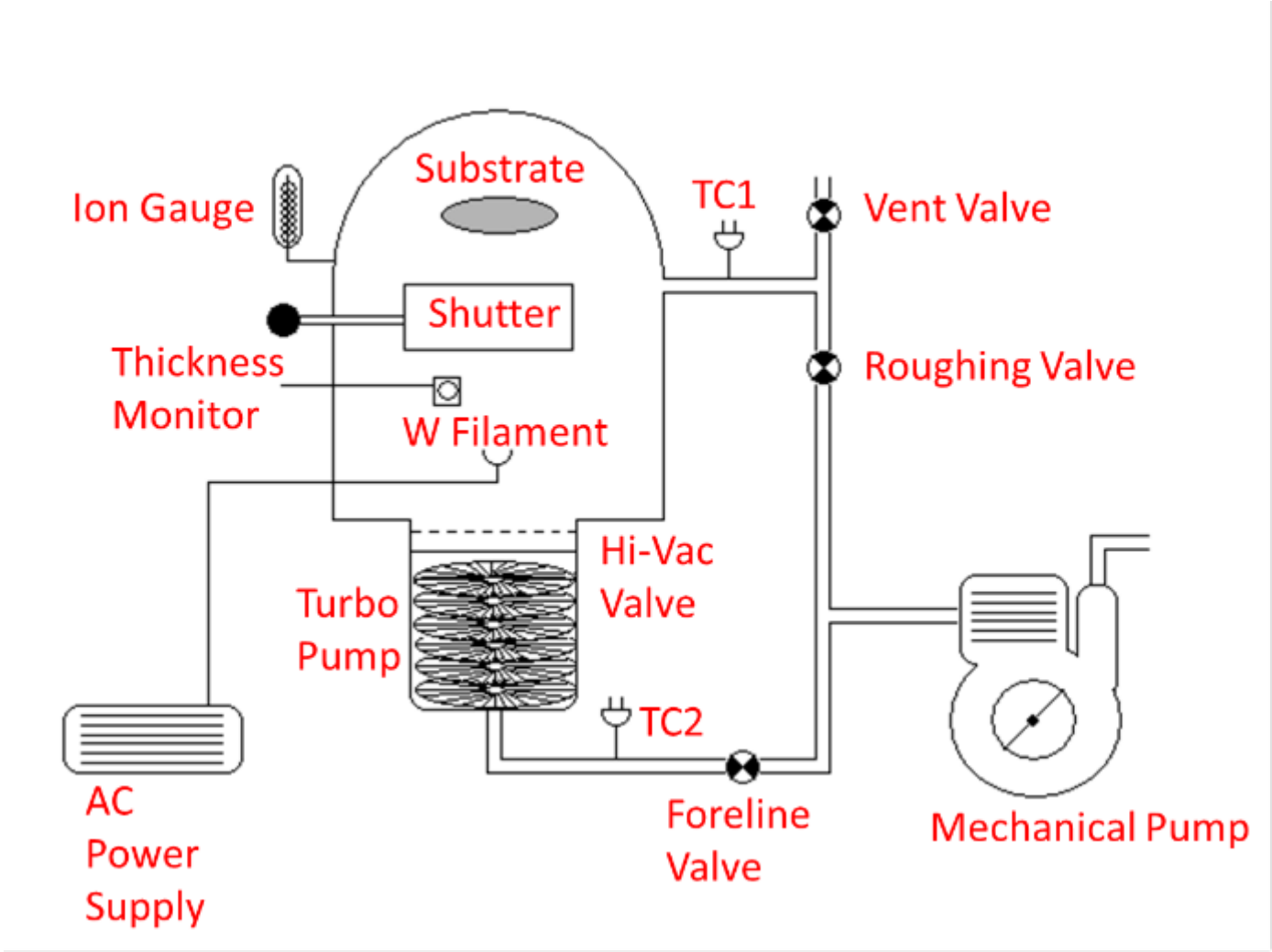
- Material is resistance heated
  - Filament
  - Basket
  - Boat





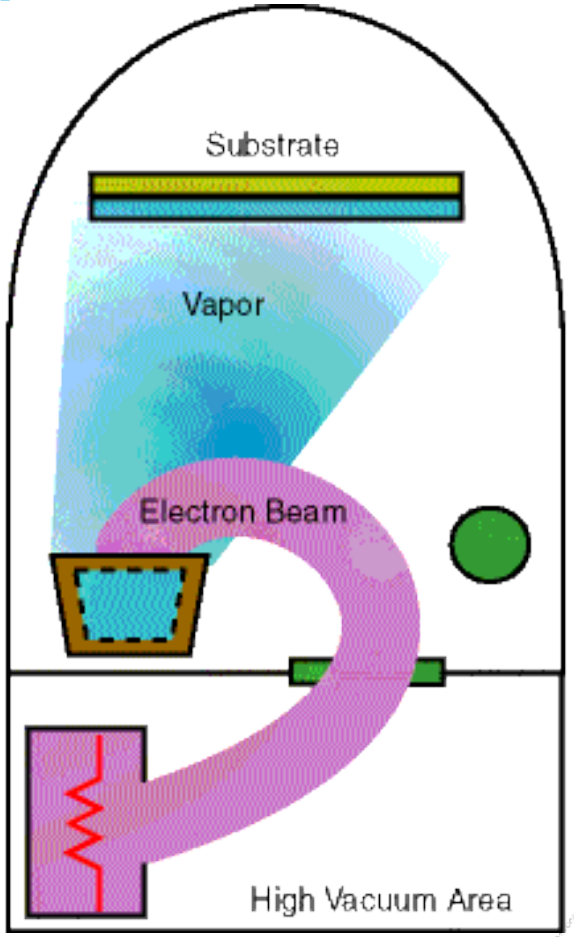


Typical Thermal Evaporator



Electron Beam (e-beam) Evaporation

- electron beam from filament
  - Usually W
  - Accelerated by anode
  - Directed by magnetic field towards target
  - Can melt metals with higher MP's
- Small volume in crucible melted
  - Melt doesn't touch
  - Low contamination
- High evaporation rates
  - Up to 1000 Å/s

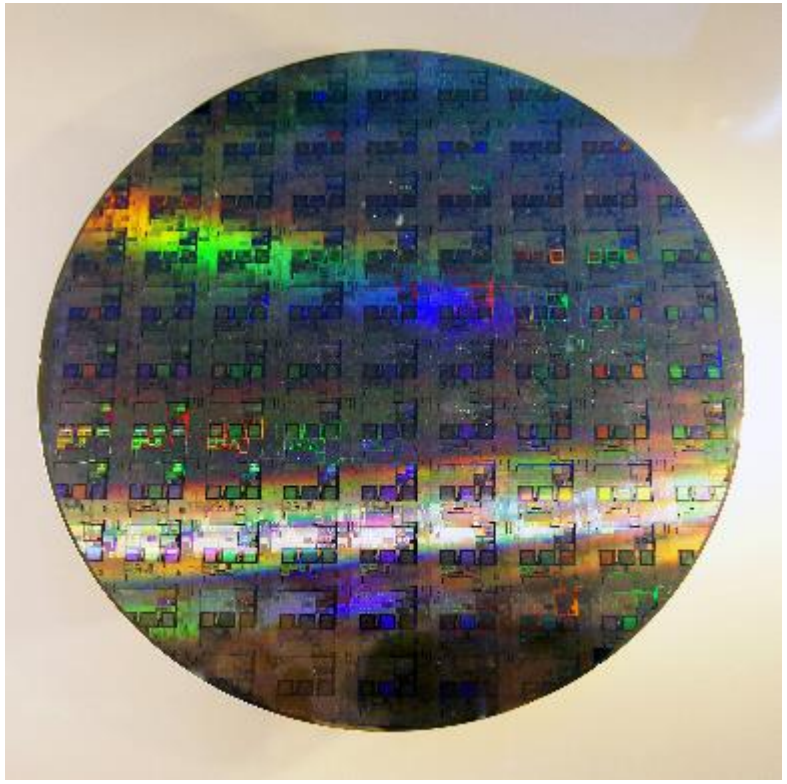


http://www.tungsten.com/ebevap.html

Applications for Thermal Evaporation

It’s more than just semiconductors

Applications of Thermal Evaporation



Evaporation Demonstration

Let’s see it pop!

Cost of Evaporation Equipment

Equip	Model	Manufacturer	Cost
Rough Vacuum Pump	RV3 rebuilt	Edwards	$1,695
Baseplate with feedthrough holes	AVT-04012015-15	Anderson Dahlen – Applied Vacuum Division	$280
Vacuum gauge	300 Series Gauge	Kurt J. Lesker	$550
Vent valve		Varies	$134
Isolation valve	KF40 Butterfly valve	Varies	$299
Vacuum components		Kurt J. Lesker	$437.30
Variable Transformer	3PN116C	Superior Electric	$626
Bell Jar	S30956	Fisher Scientific	$316
Power transformer	266V6B	Hammond	$87
Feedthrough Qty.2	EFT0013754	Kurt J. Lesker	$467
Evaporation source	EVF23025W	Kurt J. Lesker	$26
Evaporation Material	EVMAL1199U50	Kurt J. Lesker	$57
		Total	$4,975

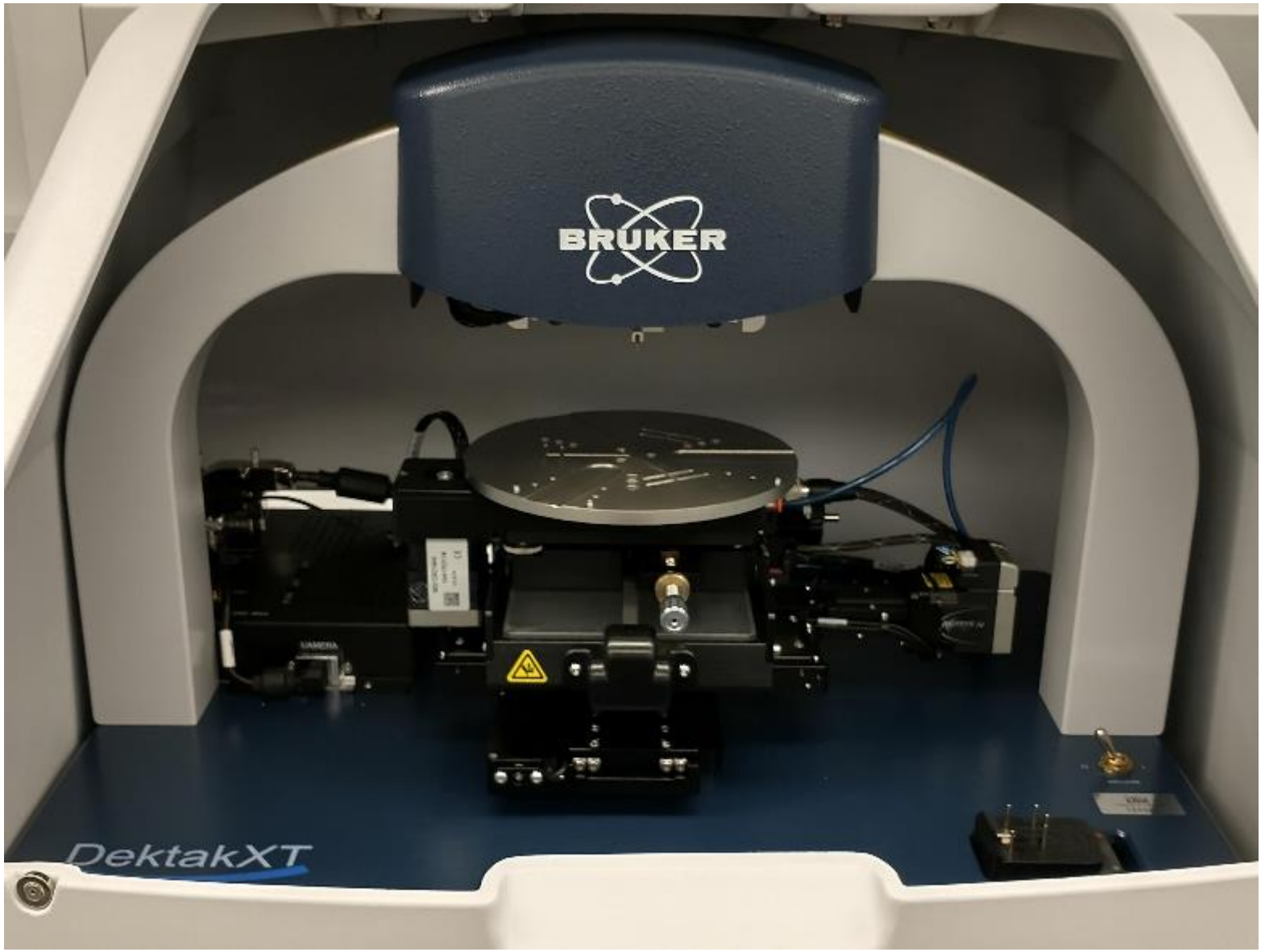
Quick Intro to Surface Contact Profilometry

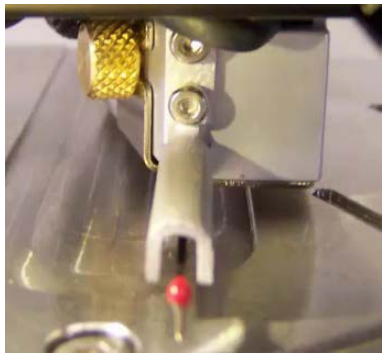
• Typically uses a diamond tipped probe that physically contacts the surface to determine the topography of the substrate's surface and is considered a destructive tool.

• Used to measure:

- large features (1Å to 6.55 µm)
- Film thickness
- Surface topography
- Step heights

Thickness measurement





Commercial Thermal Evaporators

Low-cost Commercial Thermal Evaporator

Lowest Cost Thermal Evaporator

Summer 2022 Workshop

Take home a low-cost thermal evaporator!

Discussion

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Thanks! Please keep in touch

#teachnano

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Email Peter: peter.kazarinoff@pcc.edu

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Link to Resources

https://micronanoeducation.org/

https://www.lesker.com/

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