Experimental Techniques in Materials MATE 515

Physical Methods for Materials Characterization:

Lecture 3

Optical Microscopy

Course materials:

http://in.materials.drexel.edu/blogs/515_experimental_techniques/

Instructor : Peter Finkel

QUESTIONS HW 2

A

Outline

- Optical Microscopy (week 3-4)
- •Geometrical Optics: Imaging and Diffraction
- •The Elements of Optical Microscopes
- •Specimen Preparation
- •Image Contrast
- •Reflection
- •Absorption
- •Polarization
- •Phase
- •Interference
- •Deonstration: Transmission/reflection OM

Optical Microscopy

OUTLINE VACUUM SYSTEMS

Outline

- Vacuum principles
- Vacuum pumps
- Vacuum materials and components
- Vacuum instrumentation
- Vacuum systems

Vacuum

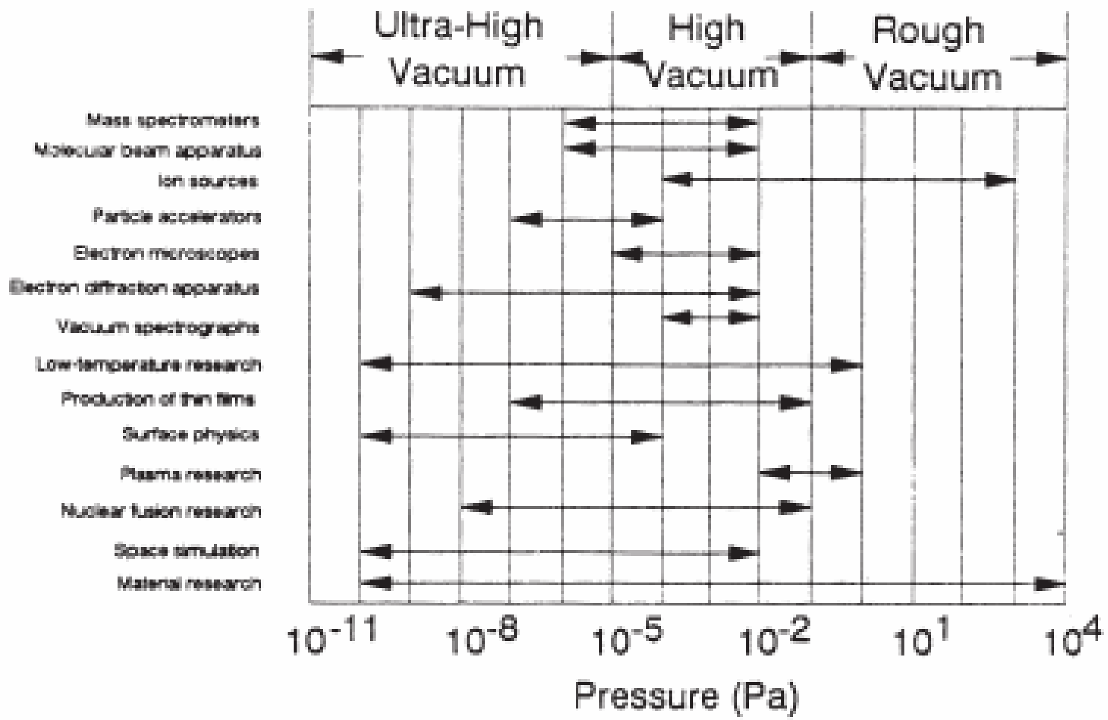


Figure 3.1. Pressure regions based upon existing terminology and their relationship to some common microstructural evaluation techniques.

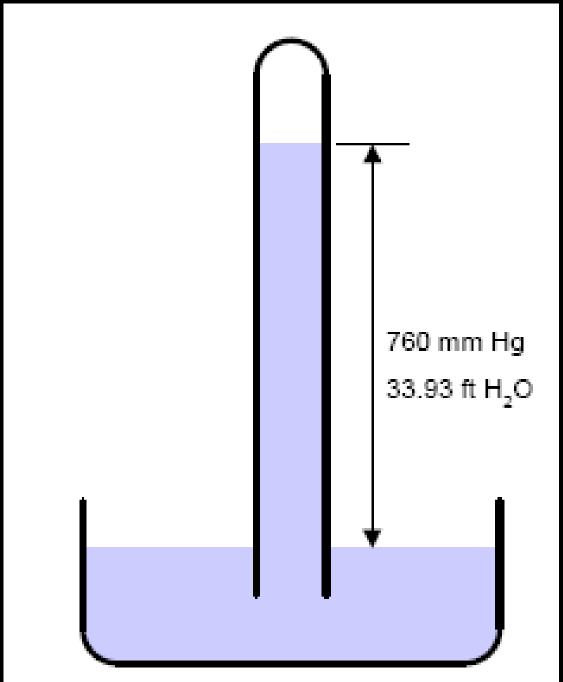
VACUUM

Rough Vacuum	High Vacuum	Ultra-High Vacuum
wafer chucks load locks sputtering reactive ion etching (RIE) low pressure chemical vapor deposition (LPCVD)	evaporation ion implantation	surface analysis molecular beam epitaxy (MBE)

Units

- 1 atmosphere =
  - 760 mm Hg = 760 torr
  - 760,000 millitorr or microns
  - 29.9213 in. Hg
  - 14.6959 psi
  - 1.01325 bar
  - 1013.25 millibar
  - 101,325 pascals (Pa)
  - 407.189 in. H_2O
  - 33.9324 ft. H_2O

1 Pascal = 1 N/m^2
1 Torr = 1 mm Hg
1 micron = 1 µm Hg



Vacuum Ranges

- Low or Rough Vacuum (LV)
  - 760 to 10^{-3} torr
- High Vacuum (HV)
  - 10^{-3} to 10^{-8} torr
- Ultra-High Vacuum (UHV)
  - 10^{-8} to 10^{-12} torr

Partial pressures

Partial Pressures of Gases in Air at STP

Gas	Symbol	Volume Percent	Partial Pressure, Torr
Nitrogen	N_2	78	593
Oxygen	O_2	21	159
Argon	Ar	0.93	7.1
Carbon Dioxide	CO_2	0.03	0.25
Neon	Ne	0.0018	1.4×10^{-2}
Helium	He	0.0005	4.0×10^{-3}
Krypton	Kr	0.0001	8.7×10^{-4}
Hydrogen	H_2	0.00005	4.0×10^{-4}
Xenon	Xe	0.0000087	6.6×10^{-5}
Water	H_2O	Variable	5 to 50, typ.

Outgasing

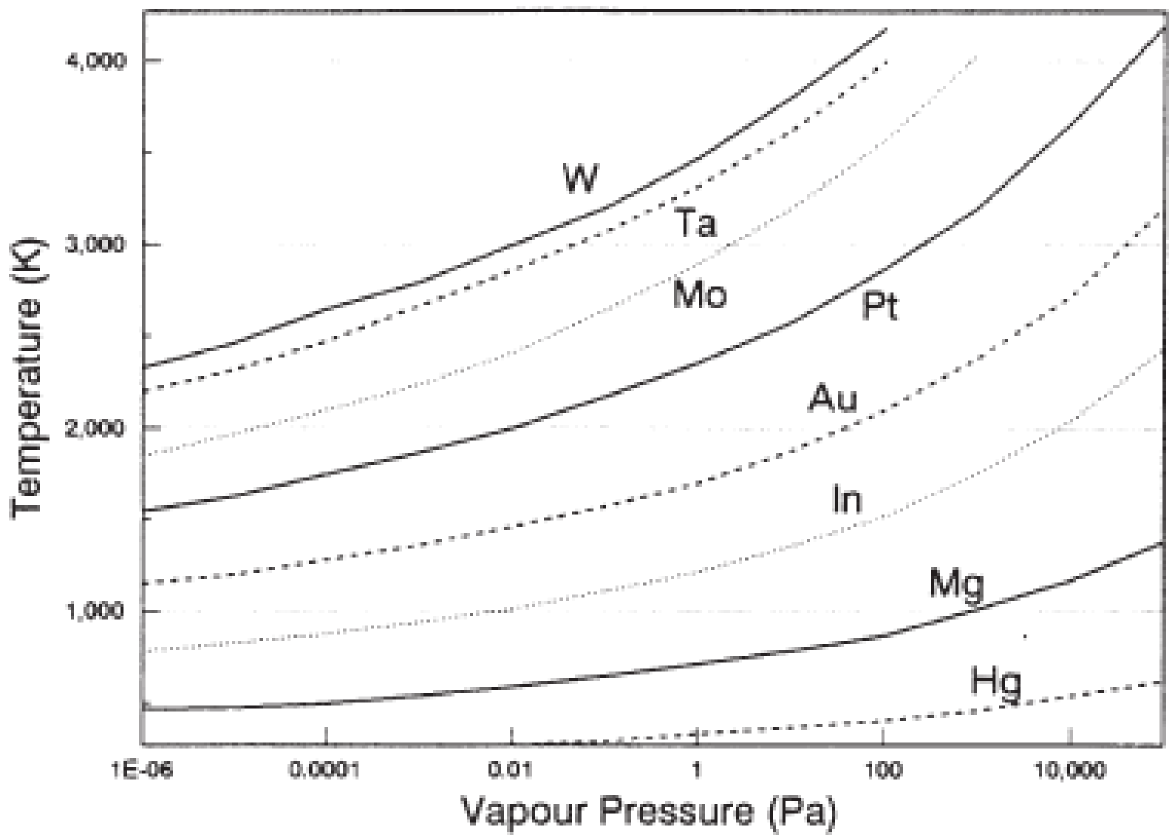


Figure 3.3. Outgassing rates of some common elements as a function of temperature.

Ideal Gas Law

Ideal Gas Law - 1

- V = volume of enclosure
- N = number of molecules
- N_m = number of moles = N/N_A
- n = particle density = N/V
- P = pressure
- T = absolute temperature
- k_B = Boltzmann's constant = 1.381 x 10^{-23} J/K
- N_A = Avogadro's number = 6.022 x 10^{23} particles/mole
- R = Gas constant = $N_A k_B$ = 8.315 J/mole-K

$$PV = N_m RT$$

$$PV = Nk_B T$$

$$P = nk_B T$$

Ideal Gas Law - 2

Historical Laws:

- Boyle's Law: $P_1V_1 = P_2V_2$ at constant T
- Charles' Law: $V_1/T_1 = V_2/T_2$ at constant P
- Gay-Lussac's Law: $V = V_0(1 + T/273)$

Kinetic Gas Theory

- Velocity of a molecule is $\vec{v} = v_x\hat{x} + v_y\hat{y} + v_z\hat{z}$
- Mean square velocity is $\overline{v^2} = \overline{v_x^2} + \overline{v_y^2} + \overline{v_z^2}$
- Pressure exerted on a wall in the x-direction is $P_x = nm\overline{v_x^2}$
- If velocities for all directions are distributed uniformly, $\overline{v^2} = 3\overline{v_x^2}$
- Thus, $P = \frac{1}{3}nm\overline{v^2} = nk_BT$ $\qquad \frac{1}{2}m\overline{v^2} = \frac{3}{2}k_BT$
- Each molecular DOF has an average excitation of $k_BT/2$