Notes on Thin film deposition by evaporation in vacuum

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High-temperature depositions under vacuum

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- Evaporation is a common method of thin-film deposition. The source material is evaporated in vacuum. heating a crucible containing the material to be deposited. The vacuum allows vapor particles to travel directly to the target object (substrate), where they condense back to a solid state. Evaporation is used in microfabrication, and to make macro-scale products (mirrors, metallized plastic films ...).

Evaporation - Basics

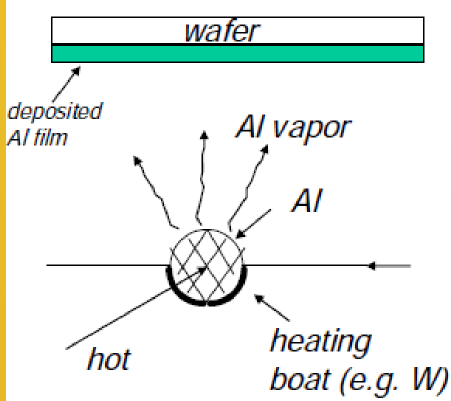
- Mean free path as a function of pressure
- Velocity distribution depends on T (m)

$$\lambda = \frac{kT}{\sqrt{2}\,\pi d^2 P}$$

where n = molecular density = N/V,
d = molecular diameter

[Note] For air at 300 °K, $\lambda = \frac{6.6}{P(\text{in Pa})} = \frac{0.05}{P(\text{in torr})}$

with λ in mm

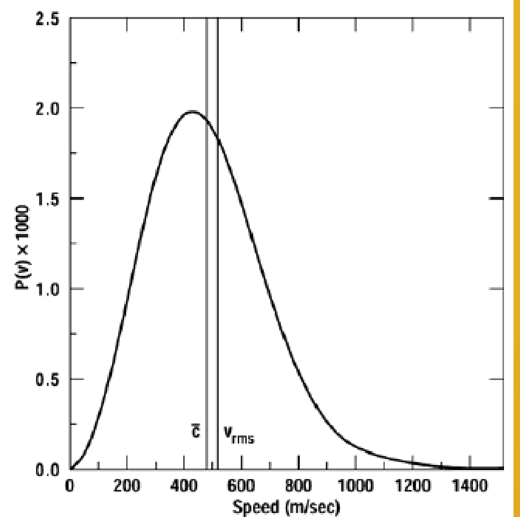


Thermal Evaporation

Assumes Maxwell-Boltzman Velocity Distribution

$$\bar{v} = (8kT/\pi m)^{1/2}$$

where m = molecular weight of gas molecule



Evaporation rates

- Impingement rate
- Dalton's law of partial pressure

Φ = # of molecules striking unit surface /unit time.

$$= 3.5 \times 10^{22} \times \frac{P}{\sqrt{MT}}$$

in #/cm^2-sec with P in torr, M is the molecular weight

For mixture of non-reactive gases in a common vessel, each gas exerts its pressure independent of others.

$P_{total} = P_1 + P_2 + \ldots + P_N$ (Total P = Sum of partial pressure)

$N_{total} = N_1 + N_2 + \ldots + N_N$

$P_1V = N_1kT$

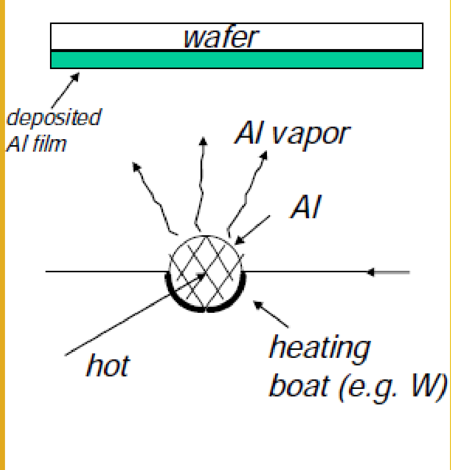
$P_2V = N_2kT$

....

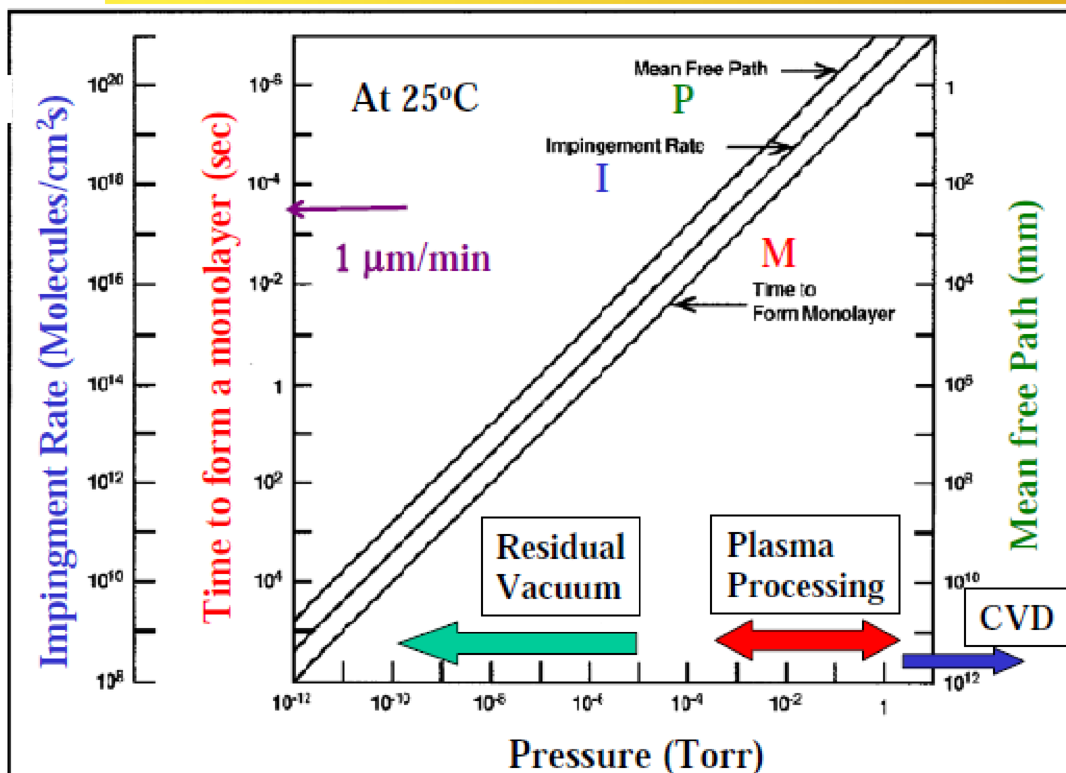
$P_NV = N_NkT$

– 1 bar = 10^5 Pa = 750 torr

– 1 torr = 133.3 Pa

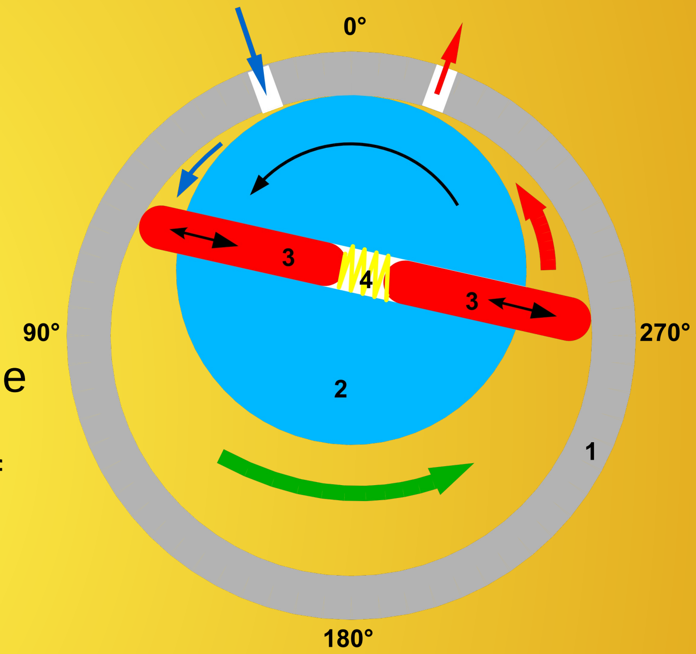


Thermal Evaporation



From atmosphere to Vacuum – pre-pumping
Rotary vane pump

- A rotary vane pump consists of vanes mounted to a rotor that rotates inside of a cavity. Vanes can have variable length and/or be tensioned to maintain contact with the walls as the pump rotates. It was originally invented in 1874 and continuously improved.
- The simplest pump has a circular rotor rotating inside a larger circular cavity. The centers of these two circles are offset (eccentricity). On the intake side of the pump, the vane chambers are increasing in volume and are filled with fluid forced in by the inlet pressure. On the discharge side of the pump, the vane chambers are decreasing in volume, forcing fluid out of the pump. The action of the vane drives out the same volume of fluid with each rotation. Single-stage rotary pumps reach typical pressures of 0.1-1 mbar (10-100 Pa). Multistage pumps can attain pressures as low as 10−6 mbar (0.1 Pa).



Turbomolecular pump

- In a turbomolecular pump, a rapidly spinning fan rotor 'hits' gas molecules from the inlet of the pump towards the exhaust in order to create or maintain a vacuum.
- It can generate many degrees of vacuum from intermediate vacuum (~10−2 Pa) up to ultra-high vacuum levels (~10−8 Pa) by rapid rotation (10-70 kcicles/minute).
- Most turbopumps need a minimum vacuum (10-100 Pa) for starting operations.

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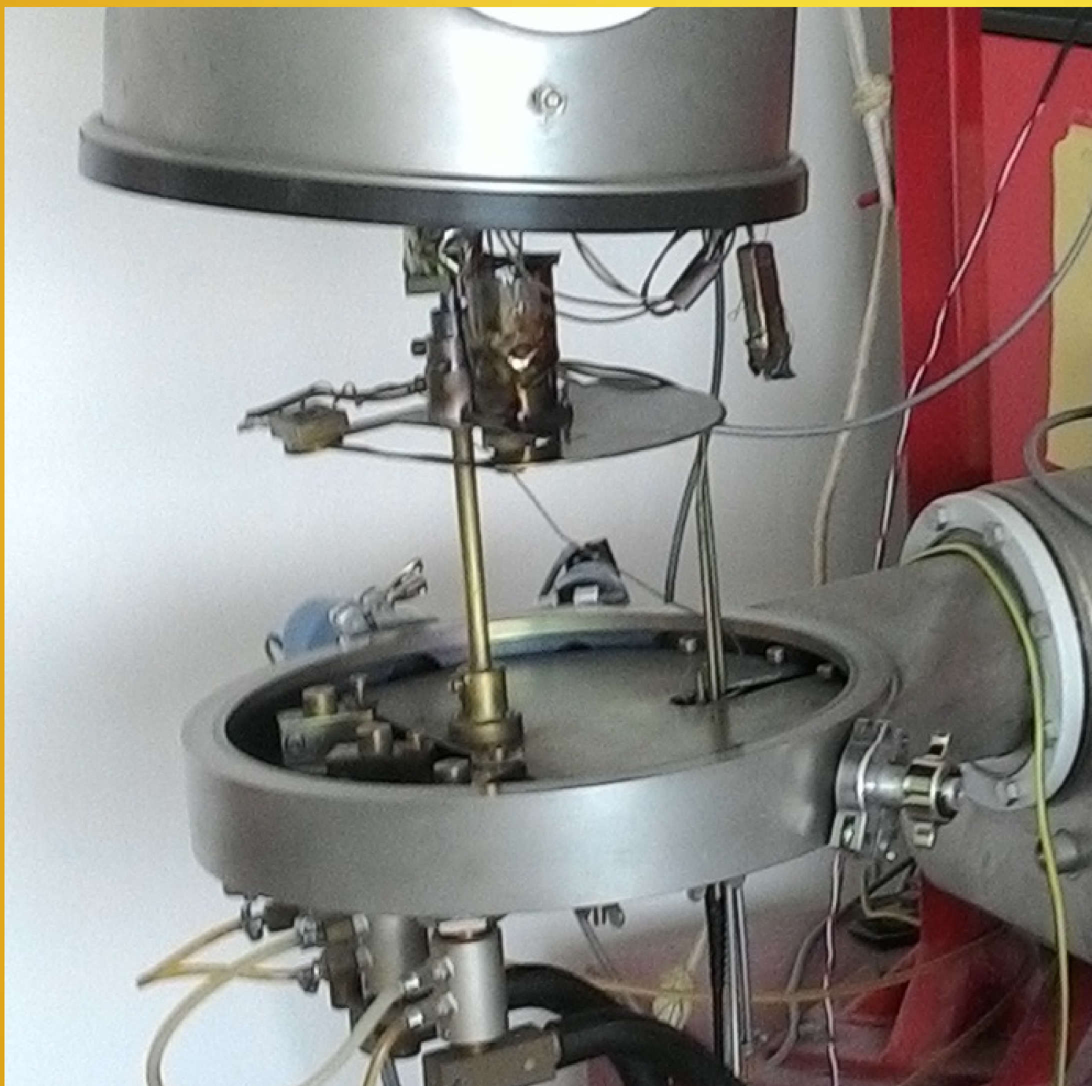
Deposition device at Unicam



Film thickness and pump control system

Film thickness monitor: measures a mass variation per unit area by the change in frequency of a quartz crystal resonator.

Pump control system: operates the two vacuum pumps used for evaporation of materials into a chamber at suitable residual pressures.

Handbooks for thin film deposition

- Melting point, temperature, vapor pressure.
- Crucible materials, substrates.
- Parameters for evaporation control.

Thin Film Evaporation

Common Materials Reference and Guide

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A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Element	Symbol	Melting Point °C	Density (bulk, g/cm^3)	Z-ratio	Temperature°C @ Vapor Pressure (Torr) 10^{-8}	10^{-6}	10^{-4}	Evapora… Meth…
Aluminum	Al	660	2.700	1.080	677	821		
Aluminum Antimonide	AlSb	1080	4.3	--	--	--		
Aluminum Arsenide	AlAs	1600	3.7	--	--	--		
Aluminum Bromide	$AlBr_3$	97	3.01	--	--	--		
Aluminum Carbide	Al_4C_3	1400	2.36	--	--	--		
Aluminum 2% Copper	Al2%Cu	640	2.8	--	--	--		
Aluminum Fluoride	AlF_3	1257 sublimes	3.07	--	410	490 ....sublime…		
Aluminum Nitride	AlN	--	3.26	--	--	--		

Back to Top

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