EE 527 MICROFABRICATION

Lecture 7 Tai-Chang Chen University of Washington



SILICON WAFERING PROCESS

- · Ingot diameter grinding: after ingot has cooled down, it is ground to exact diameter and cut into 50 cm stocks.
- Ingot crystal orientation by XRD: the stocks are measured for crystal orientation by X-ray diffraction.
- Flat grinding: a flat or a notch is ground into the ingot to establish orientation.
 - The flat or notch of a <100> wafer is oriented along the [110] direction.
- Sawing ingot into wafers: Feed Wire Silicon Ingo http://www.crs-reprocessing.com/resources/ahierarchy-of-slurry-reprocessing-options Used Wire





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SILICON WAFERING PROCESS

- Lapping: waviness and taper from sawing are removed by lapping.
 - Lapping ensures parallelism of wafer surfaces.
 - Rounds the edges
- Laser Scribing: marks the wafers
- Etching to remove lapping damage.
- Final polishing



http://www.laserimpressions.com/laser-engraving-siliconwafers-for-serialization/



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THIN-FILM MATERIALS AND PROCESSES (CHAPTER 5)



THIN-FILM MATERIALS AND PROCESSES

- Thin films are needed to make metal wires and to insulate those wires, to make electrical components and structures.
- Thin films have roles as permanent parts of finished devices, but they are also used as protective films as sacrificial layers and as etch and diffusion masks.



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THIN FILM VS. BULK MATERIALS

- The density of thin films is often very low compared to bulk materials.
 - Thin films contain porosity due to fabricating processes.
 - Porosity leads to long-term instability: water vapor can be absorbed in the pores, and high surface area makes the film reactive.
- The resistivity of thin film is always more than that of the bulk materials.
- Thin films can be amorphous, polycrystalline or single crystalline as deposited. During high temperature treatment,
 - Single crystals remain single crystals.
 - Polycrystalline films experience grain growth.
 - Amorphous films either stay amorphous or crystallize.



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PHYSICAL VAPOR DEPOSITION

• The general idea of physical vapor deposition (PVD) is material ejection from a solid target material, transported in a vacuum to the substrate surface where film deposition take place.



EVAPORATION/RESISTANCE HEATED EVAPORATION

- Simple, robust, and in widespread use.
- Can only achieve temperatures of about 1800°C.
- Use W, Ta, or Mo filaments to heat evaporation source.
- Typical filament currents are 200-300 Amperes.
- Exposes substrates to visible and IR radiation.
- Typical deposition rates are 1-20 Angstroms/second.
- Common evaporant materials:
 - Au, Ag, Al, Sn, Cr, Sb, Ge, In, Mg, Ga



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EVAPORATION/RESISTANCE HEATED EVAPORATION SOURCES





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EVAPORATION/ELECTRON BEAM HEATED EVAPORATION SOURCE





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EVAPORATION

• Evaporation of elemental metals is straightforward: hot metals have high vapor pressures and in a high vacuum chamber, the evaporated atoms will be transported to the substrate.

Equilibrium Vapor Pressure

- *P** is the partial pressure of a gas in equilibrium with its condensed phase at a given temperature *T*.
 - No net transfer of material from one state to the other.
- For a given material, *P** is only a function of *T*.
 - But the dependence of *P** on *T* is rather complicated.



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http://plasmasciences.biz/sites/all/themes/torr/images/rotat © or/thermal-evap.jpg Winter 2014

EVAPORATION/EVAPORATION RATES - 1

- *P** is the equilibrium vapor pressure of the evaporant at *T*.
- *P* is the ambient pressure acting upon the evaporant in the condensed phase.
- Heinrich Hertz found experimentally that the evaporation rate was proportional to (*P** *P*).
 - This is consistent with kinetic theory in which the impingement rates are proportional to pressure.
 - Hertz also found that the evaporation rate could not be increased by supplying more heat unless the equilibrium vapor pressure was also increased by this action.
 - Thus, there is a maximum evaporation rate set by P^* , and this is only achieved in a vacuum, where P = 0.



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EVAPORATION/EVAPORATION RATES - 2

• Knudsen postulated that the evaporant vapor molecules impinging upon the condensed phase surface may be reflected back.

 $- \alpha_v$ = sticking coefficient for vapor molecules onto the surface. This can be viewed as two opposing fluxes:



The net evaporation flux is the difference between the impingement rates for the two fluxes: This gives the general Hertz-Knudsen equation:

$$\frac{dN_e}{dt} \propto \alpha_v (2\pi m k_B T)^{-1/2} (P^* - P)$$

EVAPORATION/COSINE LAW OF EMISSION

• Effusion (Lambertian emission)

$$dM_c = M_e \cos(\varphi) \frac{d\omega}{\pi}$$

Where M_e is the total mass of evaporated material

Directional Dependence of Condensation

• The area upon which the evaporant is condensed is

$$dA_c = \frac{r^2 d\omega}{\cos(\psi)}$$

 The deposited evaporant mass per unit area of condensation surface is thus:

$$\frac{dM_c}{dA_c} = \frac{M_e}{\pi r^2} \cos(\varphi) \cos(\psi)$$



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K-cell

dA

volume V

EVAPORATION/APPLICATION OF THE COSINE LAW - 1

The cosine law was verified by Knudsen by depositing a perfectly uniform coating inside a spherical glass jar:

$$\cos(\varphi) = \cos(\psi) = \frac{r}{2r_0}$$

Then

 $\frac{dM_c}{dA_c} = \frac{M_e}{4\pi {r_0}^2} = \text{uniform coating}$

This geometry is commercially used for coating the inside surfaces of spherical vessels, e.g. light bulbs, as well as for planetary wafer tooling in vacuum coating equipment.

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