Ch. 7 CMOS Fabrication

Process integration

- * well-defined collection of s/c process steps required to fabricate CMOS integrated circuits starting from silicon wafers.
- * design rules determined, in part, by limitations in fab processes
- * start by focusing on <u>unit</u> processes

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CMOS unit processes

- Wafer manufacture
  (not a unit process)

- Thermal oxidation
- doping processes
- photolithography
- thin-film removal
- thin-film deposition

Ch. 7 CMOS process integration

Silicon is the second most abundant material in earths crust

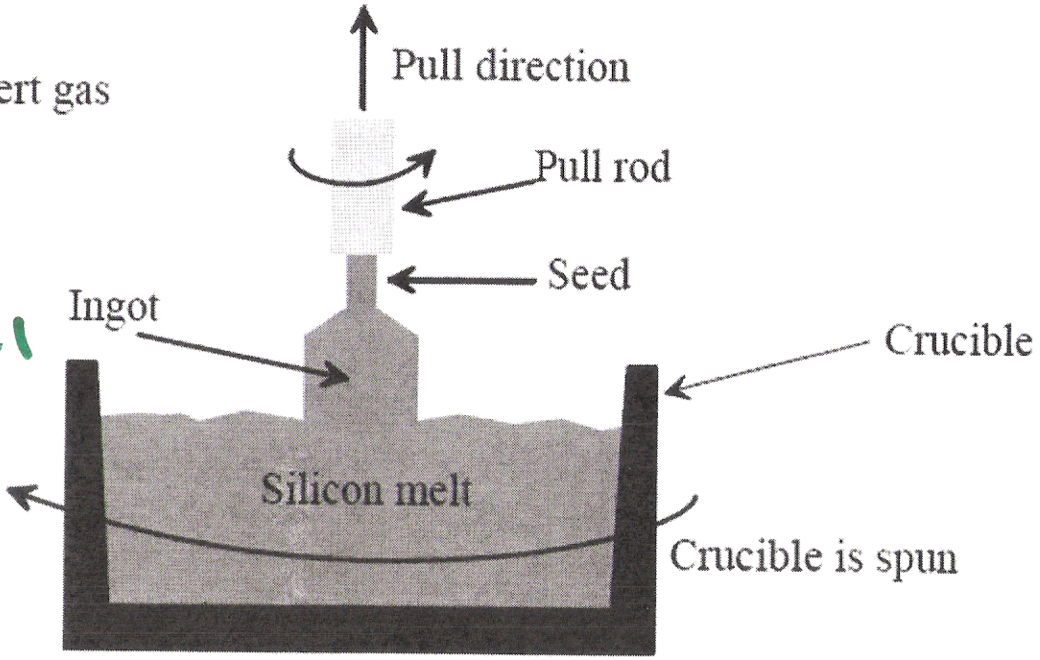


Figure 7.1 Simplified diagram showing Czochralski (CZ) crystal growth.

Metallurgical Grade Silicon (MGS)

Electronic Grade Silicon (EGS)

MGS & EGS

MGS – silicon refinement, crystal growth, and wafer formation.

SiO_2 (solid) + 2C (solid) →

Si (liquid) + 2CO (gas)

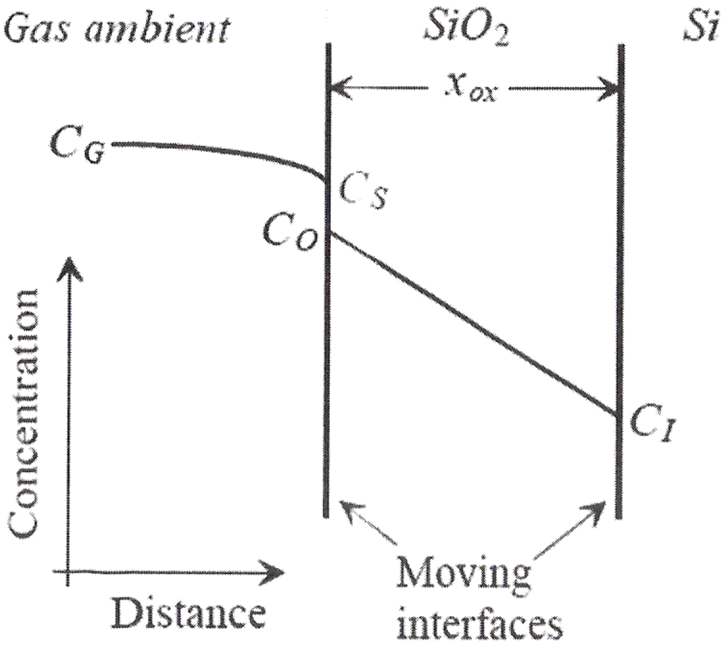
MGS → 98% pure Si

EGS –

MGS (solid) + HCL (gas) → Silane (SiH_4) (liquid)

+ trichlorosilane ($SiHCL_3$) (liquid)

7.1.2 Thermal oxidation



C_G = Oxidant concentration in the bulk gas

C_S = Oxidant concentration at the surface

C_O = Oxidant concentration just inside the oxide surface

C_I = Oxidant concentration at the Si/SiO_2 interface

Figure 7.2 A simple model for thermal oxidation of silicon. Notice the oxidant concentrations (boundary conditions) in the gas, oxide, and silicon.

$Si + O_2 \rightarrow SiO_2$ (dry oxide)

$Si + 2H_2O \rightarrow SiO_2 + 2H_2$ (wet oxide)

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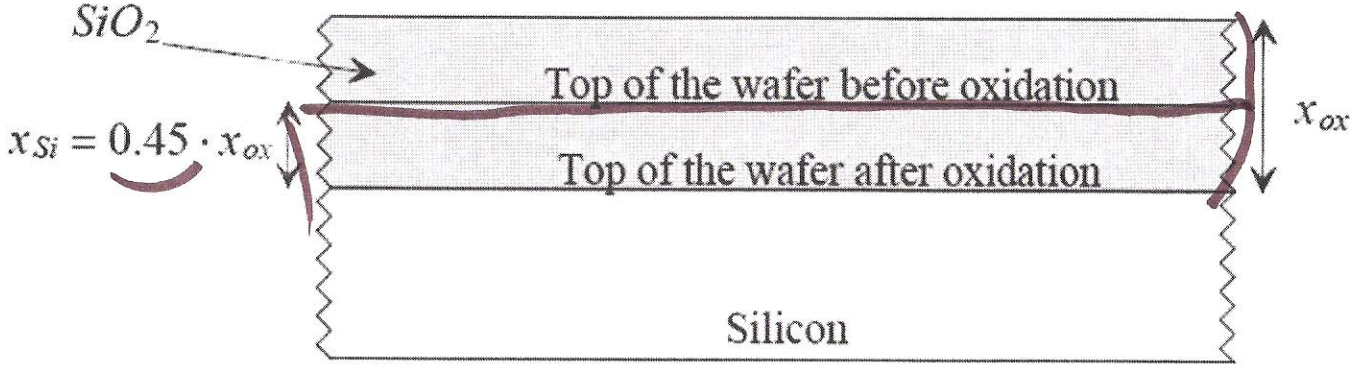

Figure 7.3 Silicon/oxide growth interface. See also Fig. 2.4.

Key point - growth SiO_2 consumes Silicon.

dry oxide → 2,000 Å = .2μm

wet oxides → < 10,000 Å = < 1μm

6)

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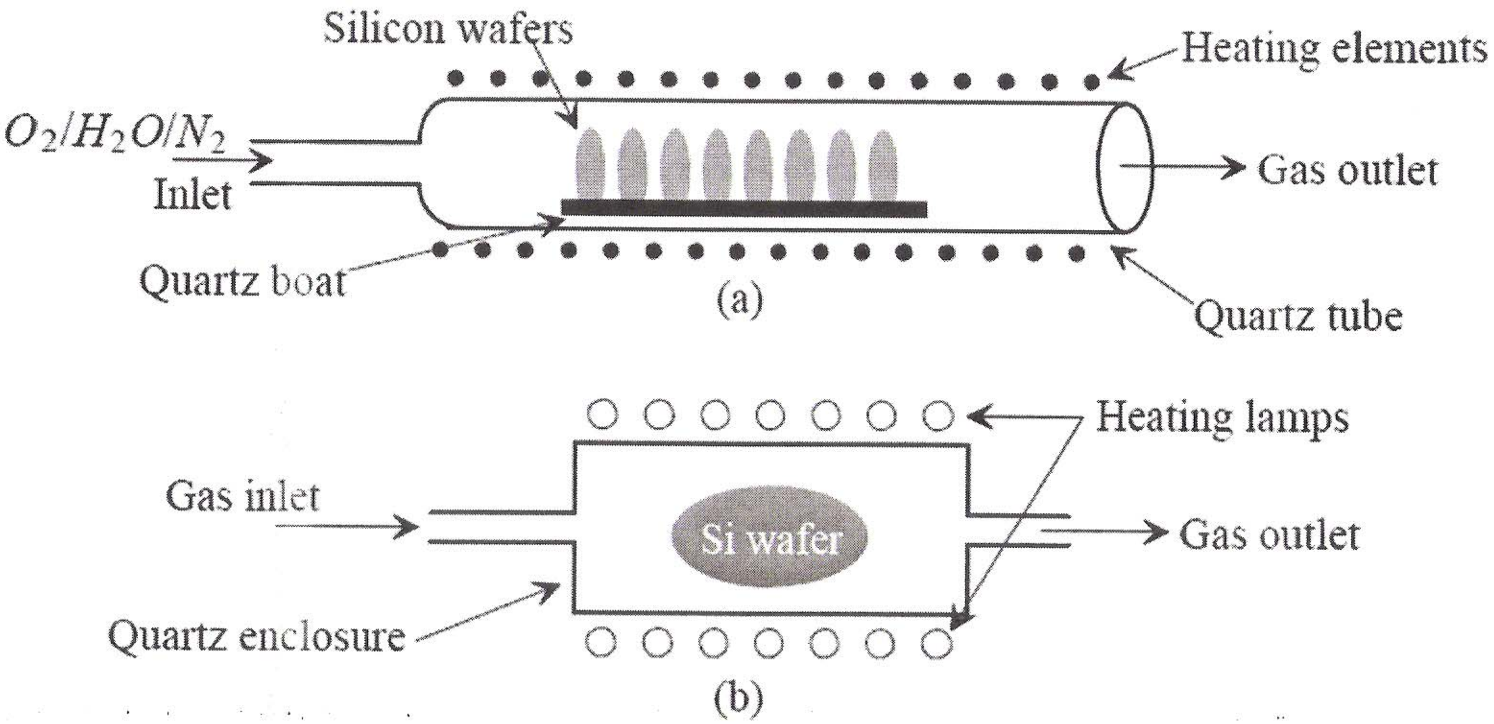

Figure 7.4 (a) Simplified representation of an oxidation tube furnace and (b) simplified diagram for rapid thermal processing.

7)

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Doping processes

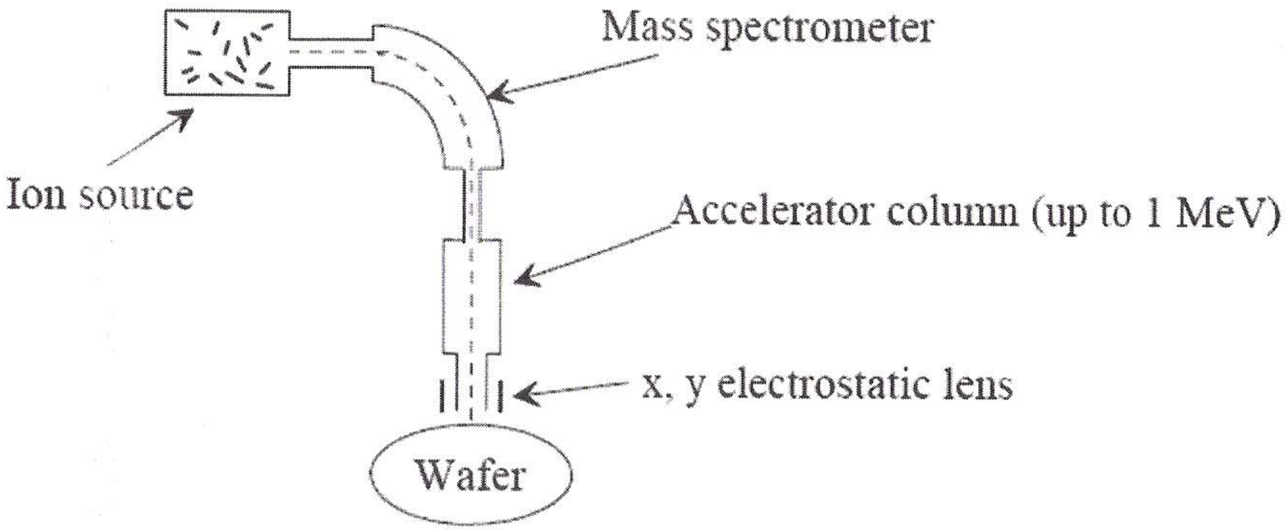

Figure 7.5 Simplified diagram of an ion implanter. The ions are created by an RF field where they are extracted into a mass spectrometer. An electrostatic lens scans the ion beam on the surface of a wafer to achieve the appropriate dose. Electrostatically, the ions can be counted to provide the real-time dose.

$$N(x) = N_p e^{-(x-R_p)^2/2\Delta R_p^2}$$

projected range

ΔR_p - straggle

peak concentration

see next page.

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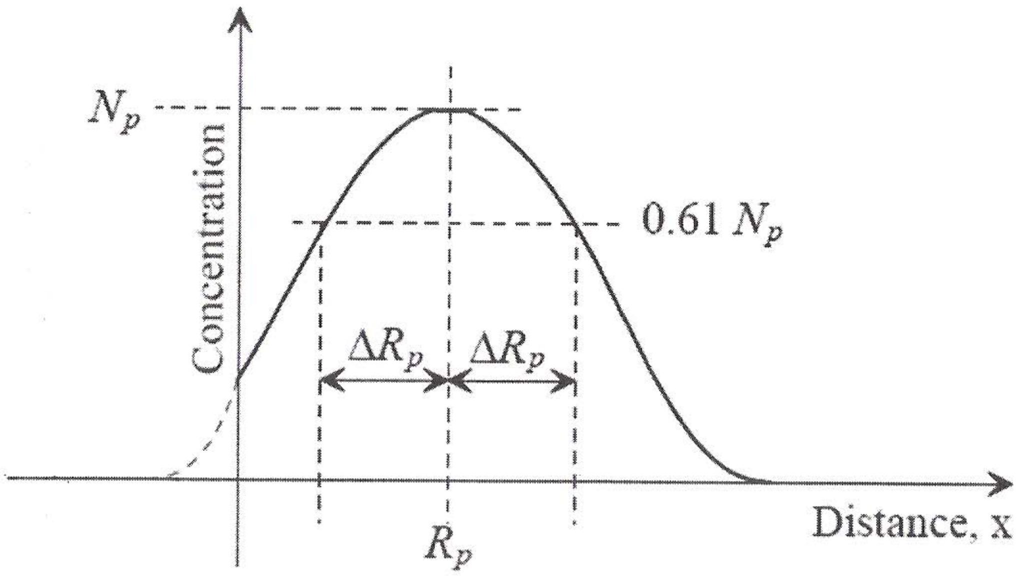

Figure 7.6 Ideal implant profile representing Eq. (7.5). Notice that the peak concentration occurs below the surface and depends on the implant energy.

$$Q_{INP} = \int_0^\infty N(x) \cdot dx$$

$\uparrow$ total implant dose

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Solid-State Diffusion

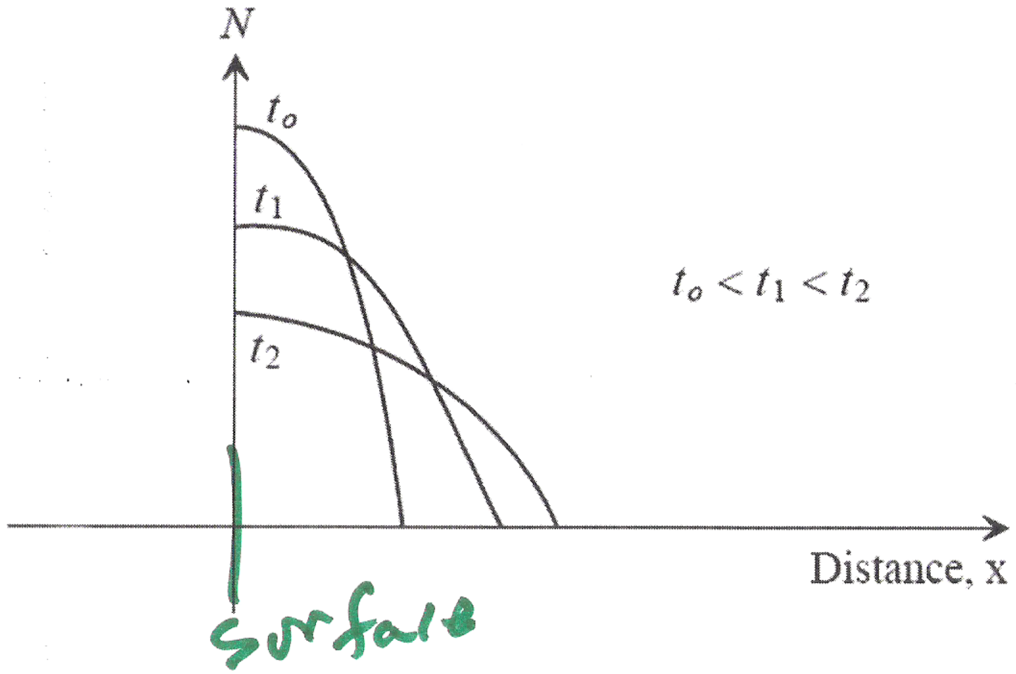

Figure 7.7 Idealized limited-source diffusion profile showing the effects of drive-in time on the profile. Notice that the peak concentration occurs at the surface of the substrate (x = 0) and that the area under the curves is constant.

$$N(x,t) = \frac{Q_{imp}}{\sqrt{\pi D t}\; e^{-x^2/4Dt}}$$