BMS INSTITUTE OF TECHNOLOGY AND MANAGEMENT

III SEMESTER
ELECTRONIC DEVICES PRESENTATION
MODULE 5

PROCESS OF DIFFUSION

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DOPING

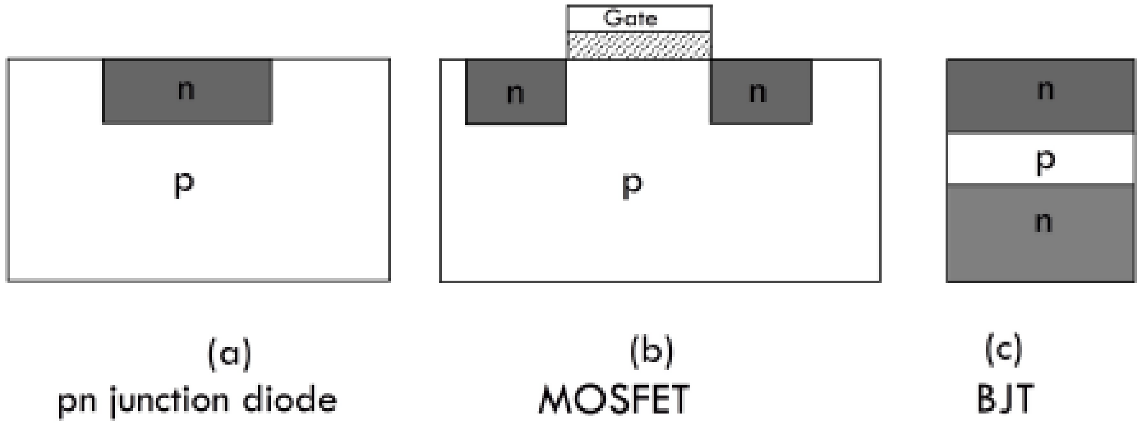


Figure 1: Schematic of a (a) diode, (b) MOSFET, and (c) BJT. These are made by adding p and n type dopants to different parts of a base wafer. In (a) and (b) the base wafer is p type while it is n type in (c).

METHODS OF DOPING

1. Thermal diffusion
2. Ion implantation

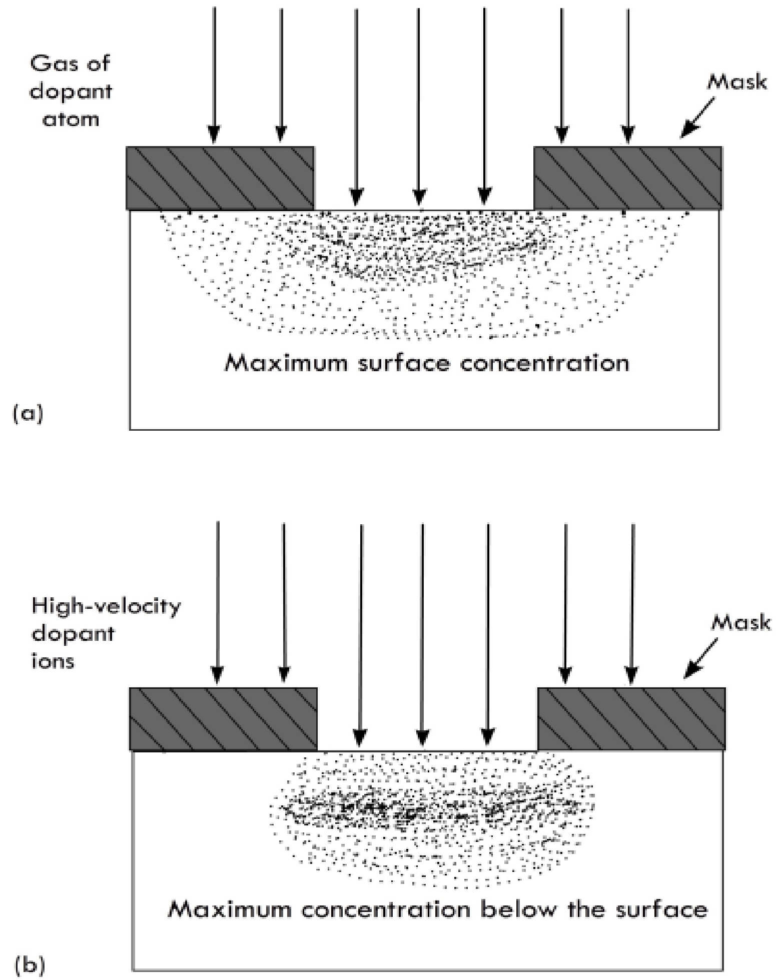
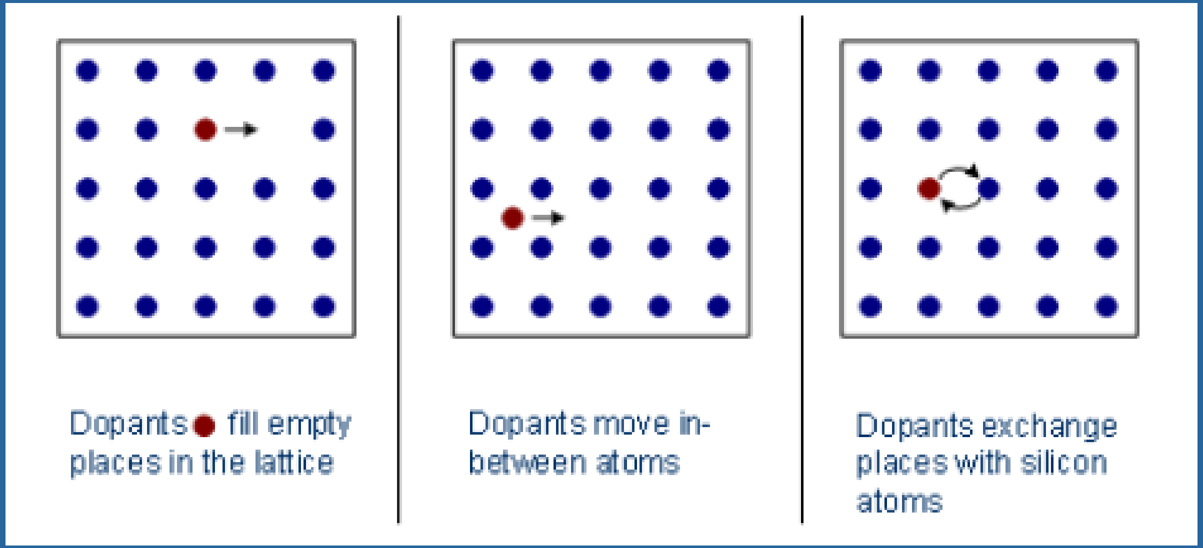


Figure 2: Types of doping. (a) Thermal diffusion (b) Ion implantation. In thermal diffusion, the maximum concentration is at the surface and dopants diffuse into the wafer. In ion implantation, the dopants are embedded below the surface. Adapted from *Microchip fabrication* - *Peter van Zant*.

WHAT IS DIFFUSION ?



STAGES OF DIFFUSION

1. Deposition
2. Drive-in

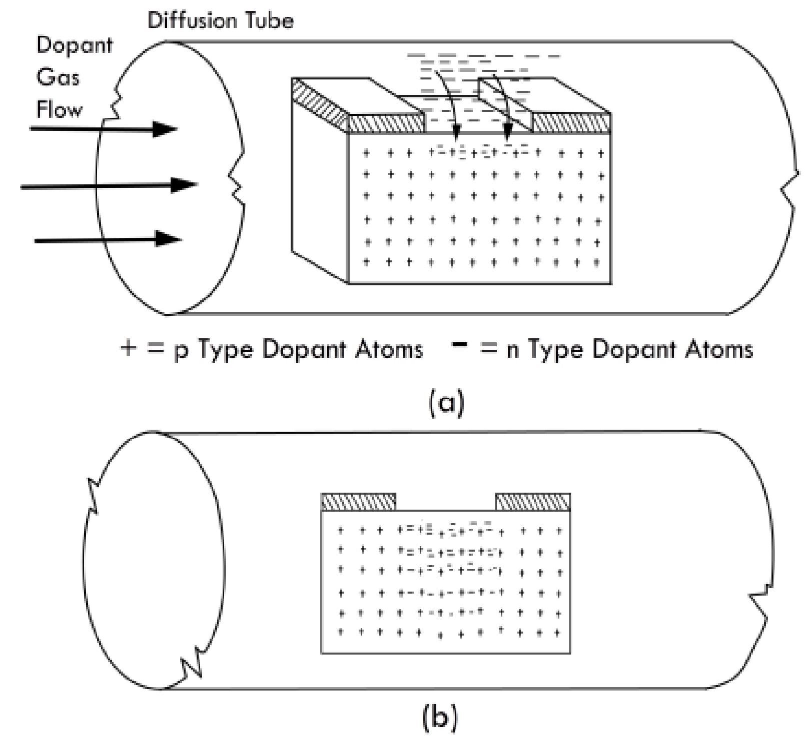


Figure 3: (a) The stages in thermal diffusion. The dopant atoms are introduced at the wafer surface and they diffuse into the wafer. (b) A cross section schematic showing the final concentration distribution. Adapted from *Microchip fabrication - Peter van Zant.*

DIFFUSION SOURCES

Table 1: Some commonly diffusion sources in silicon. The compound and its state is also included. The use of dopants in different state determines the shape of the concentration profile within the wafer. Adapted from *Microchip fabrication - Peter van Zant.*

Type	Element	Compound	Formula	State
n-type	Antimony	Antimony Trioxide	Sb_2O_3	solid
	Arsenic	Arsenic Trioxide	As_2O_3	solid
		Arsine	AsH_3	gas
	Phosphorous	Phosphorous oxychloride	$POCl_3$	liquid
		Phosphorous Pentoxide	P_2O_5	solid
		Phosphine	PH_3	gas
p-type	Boron	Boron Tribromide	BBr_3	liquid
		Boron Trioxide	B_2O_3	solid
		Diborane	B_2H_6	gas
		Boron Trichloride	BCl_3	gas
		Boron Nitride	BN	solid

DIFFUSION OF LIQUID AND GASEOUS SOURCE

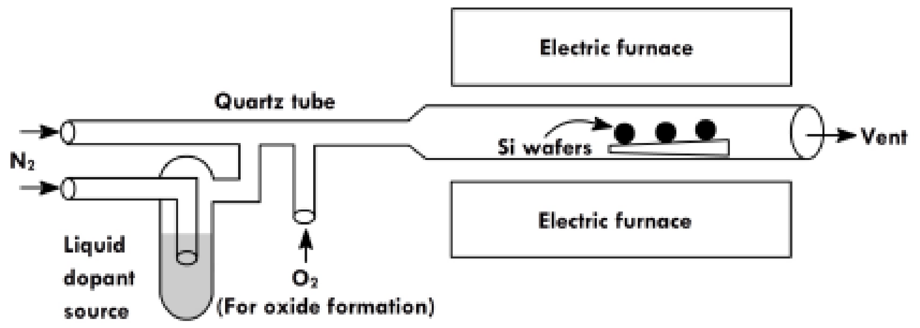


Figure 4: Thermal diffusion setup with a liquid dopant source. A carrier gas like nitrogen is bubbled through the dopant liquid and the vapor is carried into the furnace. Oxygen is also used when an oxide surface needs to be created along with doping. Adapted from *Fundamentals of semiconductor manufacturing and process control - May and Spanos.*

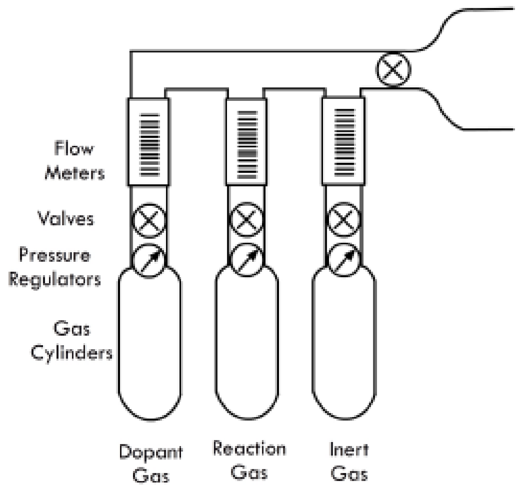


Figure 5: The gas manifold system for a thermal diffusion system. The dopant gas and inert gas are mixed to get the right dopant concentration. There is also a reaction gas, like oxygen, if an oxide layer also needs to be formed. Adapted from *Microchip fabrication - Peter van Zant.*

DIFFUSION OF SOLID SOURCE

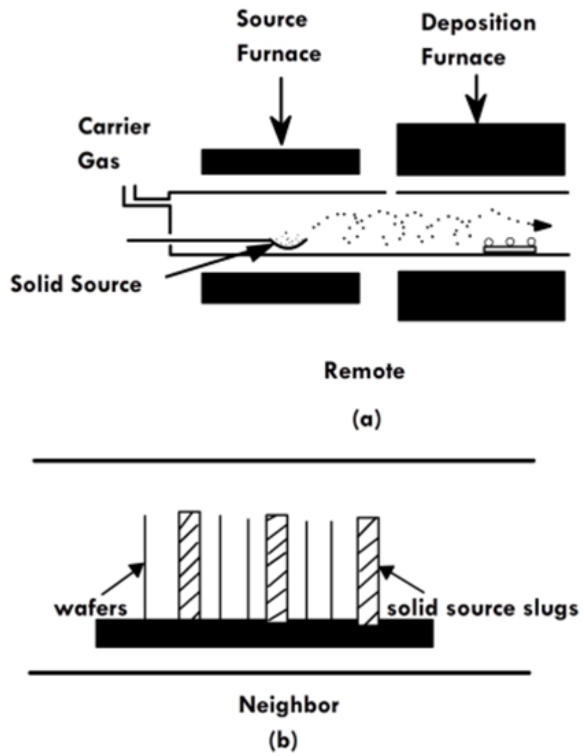


Figure 6: Solid sources for thermal diffusion can be either (a) remote or (b) neighbor sources. In a remote source the solid is vaporized and the vapors are passed into the furnace. In neighbor sources, the solid is loaded in the furnace along with the wafers. Both sources produce different concentration profiles in the wafer. Adapted from *Microchip fabrication - Peter van Zant.*

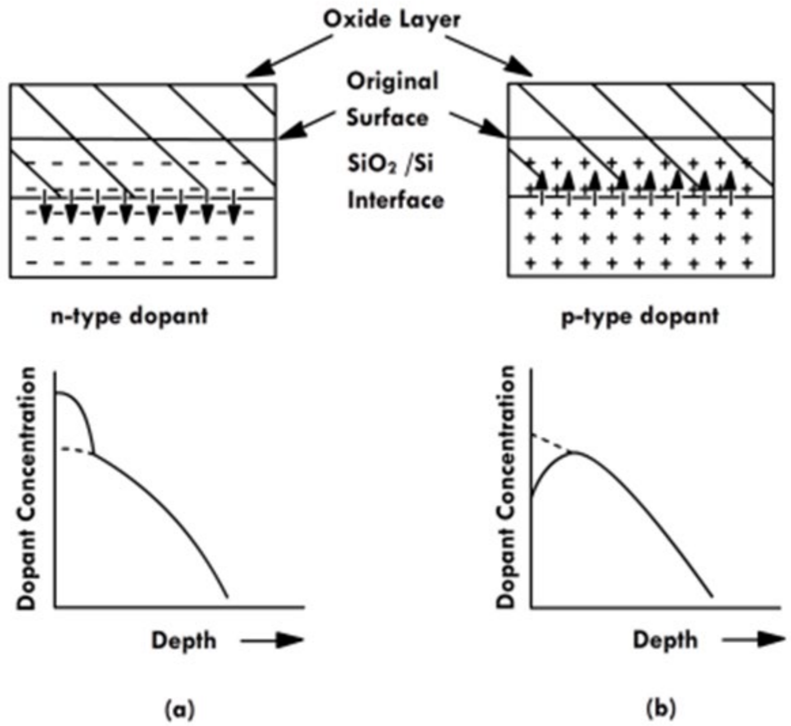


Figure 7: Growth of oxide layer on Si can cause (a) pile-up of n type impurities and (b) depletion of p type impurities. The oxide layer can be grown along with dopant diffusion or once diffusion is complete. Adapted from *Microchip fabrication - Peter van Zant.*

NATURE OF DIFFUSION

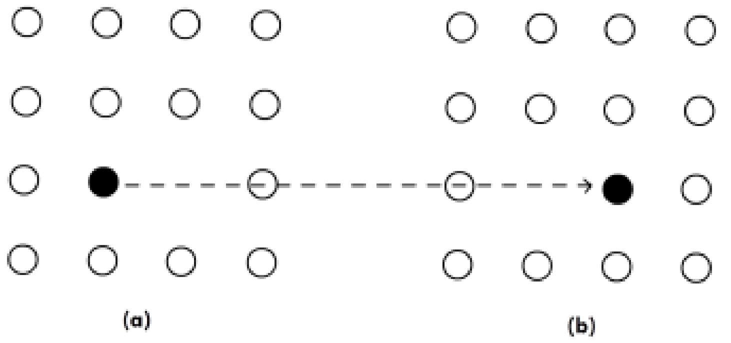


Figure 9: Substitutional diffusion mechanism showing motion of dopant atom from position in (a) to (b). Substitutional diffusion happens when the dopant size is comparable to the Si atom. Adapted from *VLSI fabrication principles - S.K. Ghandhi*

SUBSTITUTIONAL DIFFUSION

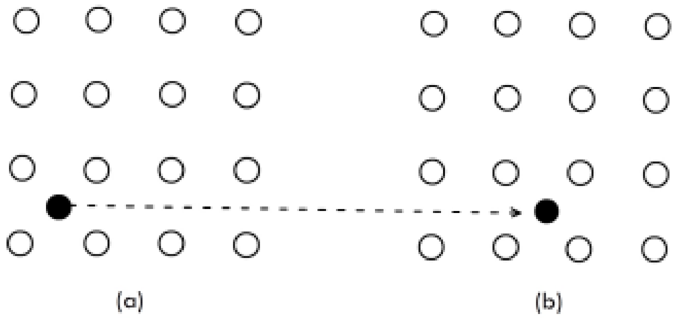
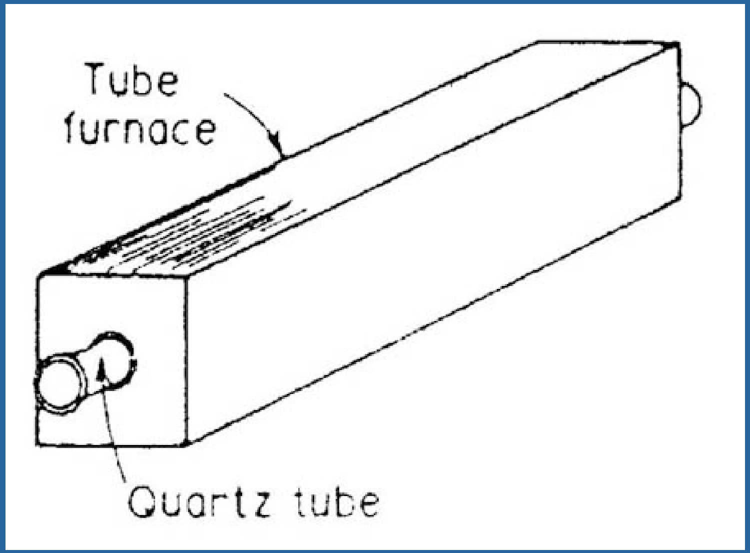
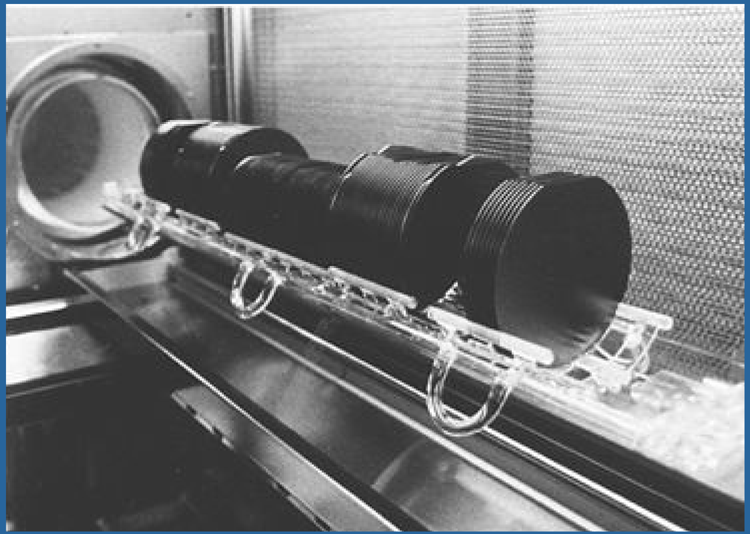


Figure 8: Interstitial diffusion mechanism showing motion of dopant atom from position in (a) to (b). Here, the dopant atom is smaller than the silicon atom, so that interstitial doping is possible. Adapted from *VLSI fabrication principles - S.K. Ghandhi*

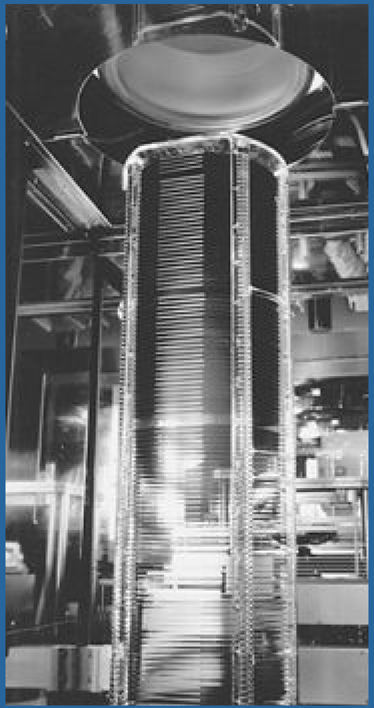
INTERSTITIAL DIFFUSION

DIFFUSION FURNACE





HORIZONTAL FURNACE



VERTICAL FURNACE

PARAMETERS AFFECTING DIFFUSION

1. Diffusion Temperature
2. Diffusion Time
3. Surface Cleanliness

MATHEMATICAL EXPRESSIONS

- $D = D_o\, e^{-(E_A/kT)}$

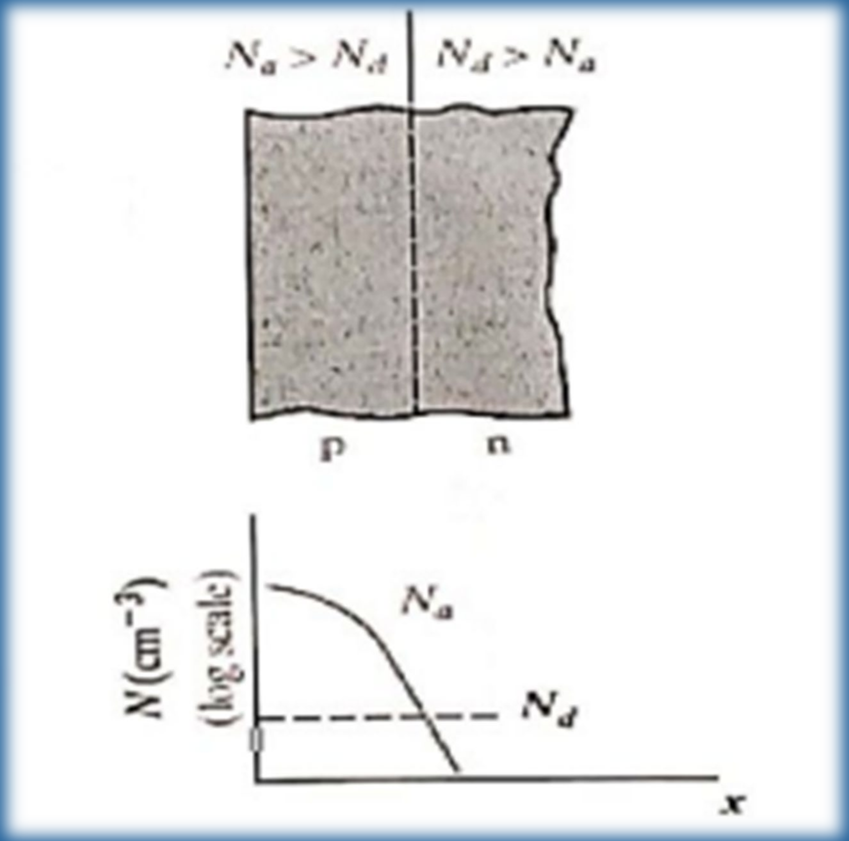
  where D_o is constant depending on material and dopant

  E_A is activation energy
- DIFFUSION LENGTH $=\sqrt{Dt}$

  where D is diffusivity of dopants in solids

  t is processing time
- Thermal budget = Dt

IMPURITY CONCENTRATION PROFILE



THANK YOU