Monday, April 15, 2013
10:34 AM

LECTURE - 44

Fabrication

Requirements

- Elemental Material: e.g. Si not SiO_2
- High purity (no unintentional impurities)
- Crystalline Material
- Controlled Doping for Concentration and Location

Example

Intrinsic Si

$$p_0 = n_0 = n_i = 1.5\times10^{10} \quad cm^{-3}$$

$$\sigma = q(n_0\mu_n + p_0\mu_p) \quad (\Omega - cm)^{-1}$$

$$\sigma = (1.602\times10^{-19})(1.5\times10^{10})(1450+500) = 4.686\times10^{-6} \quad (\Omega - cm)^{-1}$$

Extrinsic Si with shallow donors

$$N_d^+ = 2\times10^{11} \quad cm^{-3}$$

$$n_0 = 2.011\times10^{11} \quad cm^{-3} \qquad p_0 = 1.119\times10^{9} \quad cm^{-3} \qquad (calculated!)$$

$$\sigma = 1.602\times10^{-19}[(2.011\times10^{11})(1450)+(1.119\times10^{9})(500)]$$

$$\sigma = 4.681\times10^{-5} \quad (\Omega - cm)^{-1}$$

Number of Si atoms per unit volume

(8 atoms per unit cell)(1 cell per a^3)=[8/(0.5431*10^{-9} m)^3]=4.994*10^{22} atoms per cm^3

Note that $\sigma_{extrinsic}$ = 10 * $\sigma_{intrinsic}$

$$\frac{4.994\times10^{22}}{2\times10^{11}} = \boxed{2.497\times10^{11}} \text{ Si atoms per one impurity atom}$$

Si Material

Process:

SiO_2(solid) + C + heat → Si(impure solid) + CO_2

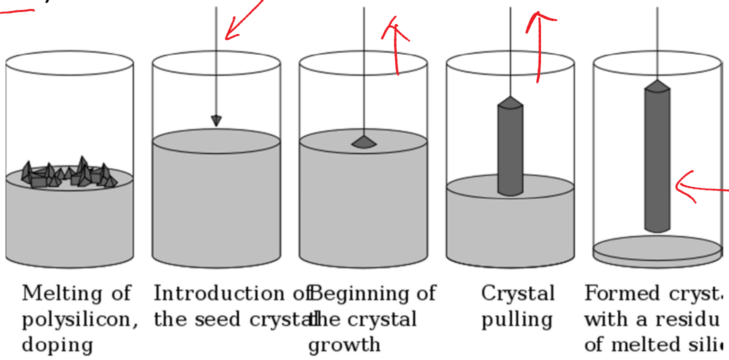
Si + 4Cl → $SiCl_4$(impure liquid) → $SiCl_4$ (pure liquid)

$SiCl_4$ + $2H_2$ + heat → Si(pure solid) + 4HCl

Czochralski Method

Requires:

- Appropriate Temperature
- Appropriate Pull Rate
- Seed Crystal determines Crystal Orientation



Czochralski Boules (cylinders)

- X-rayed: Verify Quality
- "Flat" Ground on Side to Indicate Orientation
- Wafers are Cut

Note: Images taken from Wikipedia

Controlled Doping of Si

Doping of Czochralski Liquid

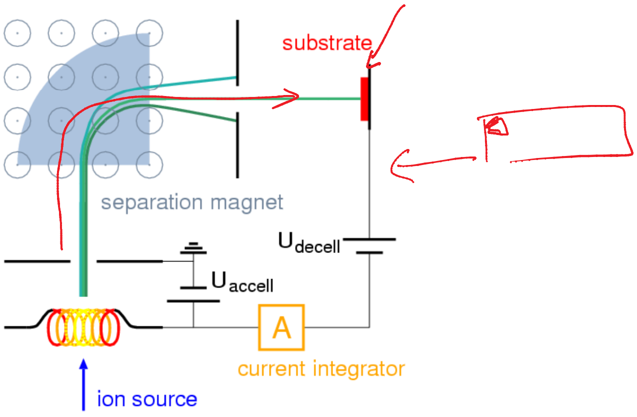
- Good from background doping
- Impractical for Device Structural Doping

Ion Implantation of Dopants

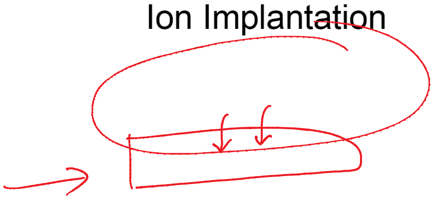
- Bombarding with high energy particles
- Destructive effects: Annealing (heating) step
- High precision of doping concentration

Diffusion Doping

- Si wafer exposed to Dopant gas
- Dopants driven into the wafer at high temperatures via diffusion process
- Old process!
- Good control, but graded concentrations



Ion Implantation

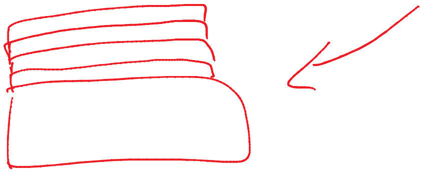


Note: Images taken from Wikipedia

Controlled Doping of Si: Contd.

Epitaxy

- Depositing a monocrystalline film on a monocrystalline substrate
- Layer-by-Layer deposit
- Slow, expensive, but good abrupt structures: BJT, CMOS, Compound Semiconductors



Elemental vs. Compound Semiconductors

Advantages of Elemental Semiconductors

- Less difficult to manage and less expensive to produce.

Advantages of Compound Semiconductors

- Higher performance, such as, speed.
- Direct: LED, LD.

Si is Superior to Ge

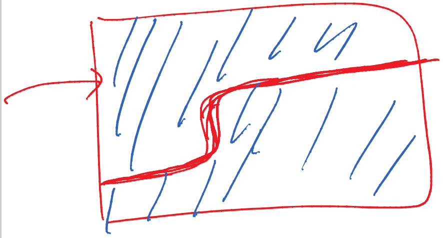
E_G (Si) > E_G (Ge)

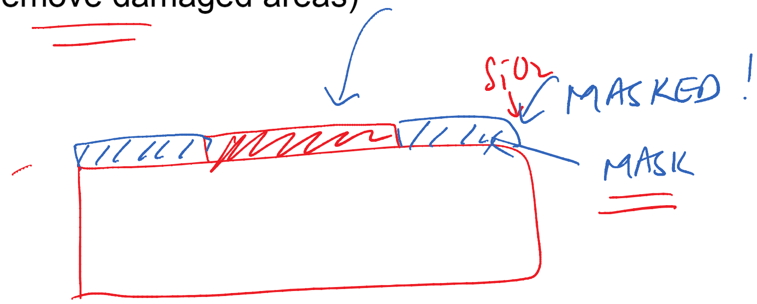
- $n_{i,Si}$ (T) < $n_{i,Ge}$ (T) : Lower doping levels needed for same extrinsic behavior
- Better absorption by Si in photo diode applications for visible light and common visible and NIR laser wavelengths.

NEAR INFRA RED

SiO_2 is Superior to GeO_2

- SiO_2 provides better protection from environment, forms stable skin, ties up surface bonds with less electrical defects.
- SiO_2: easier to grow, better etching and masking properties.
- Device Processes
  - ☐ Surface Passivation
  - ☐ Electrical Insulation
  - ☐ Electrical Isolation
- Fabrication Processes
  - ☐ Diffusion Masks
  - ☐ Cleaning Surface (remove damaged areas)





Friday, April 19, 2013
10:55 AM

OPTOELECTRONIC DEVICES

① BANDGAP AND WAVELENGTH

$$E_p = \frac{hc}{\lambda} \leftarrow$$

FOR ABSORPTION $E_p \geq E_G$

a) GIVEN E_g, FIND λ

$$\lambda = \frac{hc}{E_g}$$

$h \rightarrow 4.136 \times 10^{-15}$ eV-s

$c \rightarrow 2.998 \times 10^{8}$ m/s

$E_g \rightarrow$ eV

$= \left.\begin{matrix} \mu m \\ nm \end{matrix}\right\}$

② ABSORPTION

$$I = I_0 e^{-\alpha_L x}$$

cm^{-1} m^{-1}	$\alpha_L \Rightarrow$	ABSORPTION COEFFICENT
cm m μm μcm	$x \Rightarrow$	DISTANCE
W/m²	$I \Rightarrow$	IRRADIANCE
	$I_0 \Rightarrow$	INCIDENT IRRADIANCE [NEGLECTING REFLECTIONS]

3/4

PHOTODIODE

$$I_{LIGHT} = \frac{\eta\, q\, P \lambda}{hc}$$

EFFICIENCY

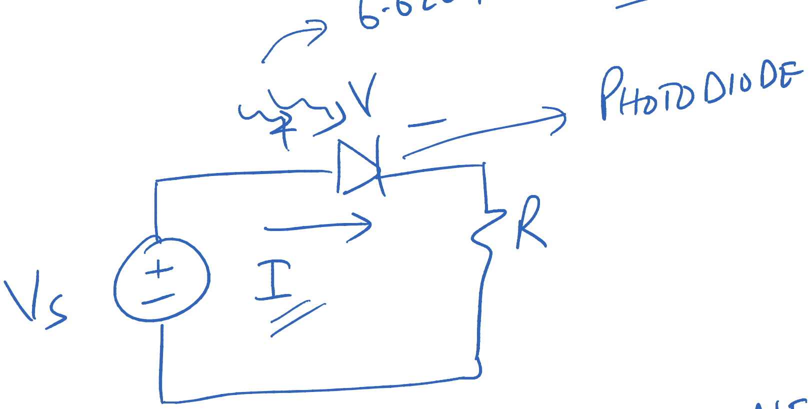
1.602×10^{-19} C

OPTICAL POWER, W

μm, nm

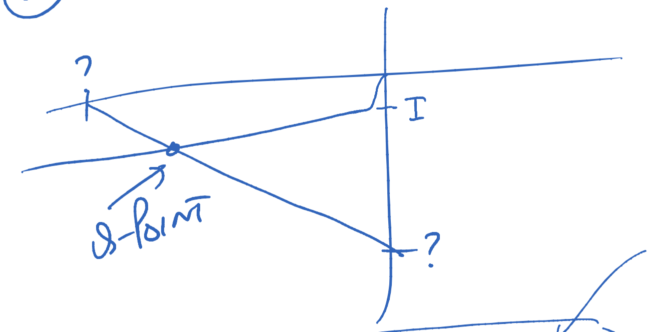
2.998×10^{8} m/s

6.626×10^{-34} Js



① Vs IS ALWAYS NEGATIVE!

② LL EQUATION $V_s = V + IR$



③ $I = \boxed{-I_0 - I_{LIGHT}}$