Problem 1 Chip Speed

Data

$\rho_{Cu} := 1.724 \cdot 10^{-6} \cdot ohm \cdot cm$

$\rho_{Al} := 2.824 \cdot 10^{-6} \cdot ohm \cdot cm$

$n_{SiO2} := 1.$

$\varepsilon_o := 8.854 \cdot 10^{-12} \cdot \frac{F}{m}$

$\varepsilon_{SiO2} := n$

$Thickness := 0.25 \cdot \mu m$

$Gap := 3 \cdot Th$

$Height := 3 \cdot Thickness$

$Length := 2000 \cdot Thickness$

$Area_{wire} := Height \cdot Thickness$

$Area_{plate} := Length \cdot Height$

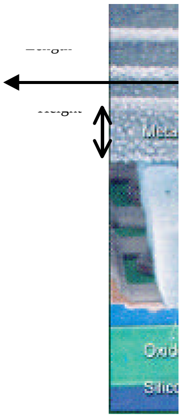
$R := \rho_{Al} \cdot \frac{Length}{Area_{wire}}$

$C := \varepsilon_{SiO2} \cdot \varepsilon_o \cdot \frac{2 \cdot Area_{plate}}{Gap}$

$Chip\_Speed := (R \cdot C)^{-1}$

$Chip\_Speed = 0.624\,GHz$

Al wiring



$R := \rho_{Cu} \cdot \frac{Length}{Area_{wire}}$

$Chip\_Speed := (R \cdot C)^{-1}$

$Chip\_Speed = 1.023\,GHz$

Cu wiring

Problem 2 A Crystal Growth via BL MT

Silicon Properties

$\frac{1}{6} \cdot Hz = 10 \frac{1}{min}$ = rpm

$\omega := 2 \cdot \pi \cdot \frac{1}{6} \cdot Hz$

$D_{boule} := 30 \cdot cm$

$T := T_{eq} - 2 \cdot K$

$\rho := 2.33 \cdot \frac{gm}{cm^3}$

$\mu := 0.1 \cdot poise$

$Mw := 28 \cdot \frac{gm}{mole}$

$T_{eq} := 1685 \cdot K$

$\nu := \frac{\mu}{\rho}$

$\nu = 4.292 \times 10^{-6} \frac{m^2}{s}$

$k := 1.48 \cdot \frac{watt}{cm \cdot K}$

$D := 8 \cdot 10^{-4} \cdot \frac{cm^2}{s}$

$\Delta H_f := 50550 \cdot \frac{joule}{mole}$

$$S(T) := \exp\left(\frac{-\Delta H_f}{R_g \cdot T_{eq}} \cdot \frac{T - T_{eq}}{T}\right) \qquad S(T) = 1.004$$

$$\mathrm{Flux}_C(S) := 0.62 \cdot D^{\frac{2}{3}} \cdot C_{eq} \cdot \nu^{\frac{-1}{6}} \cdot \omega^{\frac{1}{2}} \cdot (S - 1) \qquad \mathrm{Flux}_C(S(T)) = 0.033\,\frac{\mathrm{mol}}{\mathrm{m}^2\mathrm{s}}$$

$$\mathrm{GrowthRate}_C(S) := \frac{\mathrm{Flux}_C(S) \cdot Mw}{\rho} \qquad \mathrm{GrowthRate}_C(S(T)) = 3.982 \times 10^{-4}\,\frac{\mathrm{mm}}{\mathrm{s}}$$

Problem 2 B Crystal Growth via BL HT uses Data from 2A

$$\alpha := \frac{k}{\rho \cdot C_p}$$

$$h := 0.62 \cdot \left[\left(\frac{\omega}{\nu}\right)^{\left(\frac{1}{2}\right)} \cdot \left(\frac{\nu}{\alpha}\right)^{\left(\frac{1}{3}\right)} \cdot k\right]$$

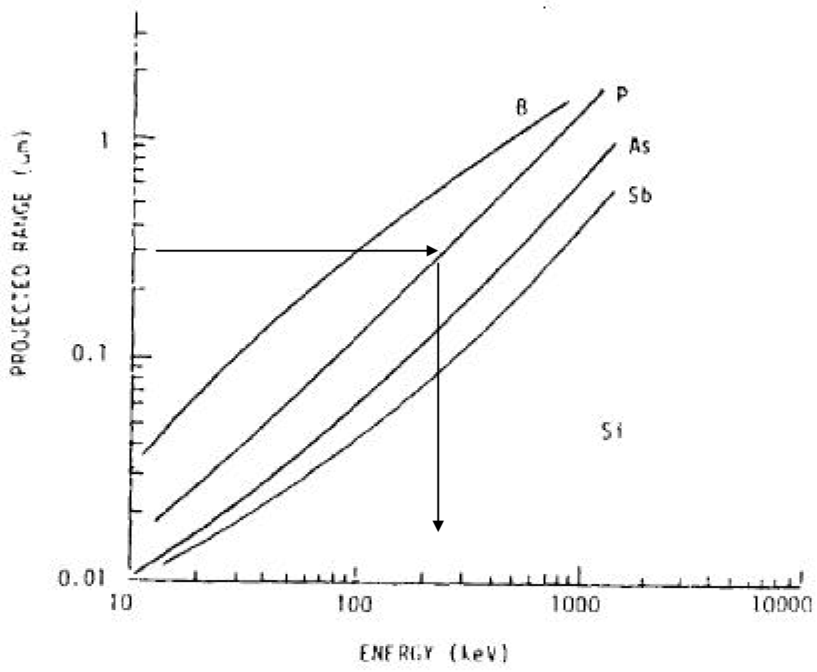
$$T = 1.683 \times 10^{3}\,\mathrm{K}$$

$$\mathrm{Flux}_H(T) := \frac{h \cdot \left(T_{eq} - T\right)}{\Delta H_f} \qquad \mathrm{Flux}_H(T) = 0.652\,\frac{\mathrm{mol}}{\mathrm{m}^2\mathrm{s}}$$

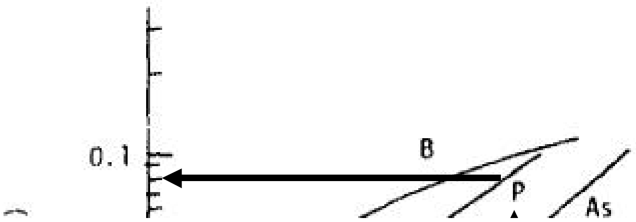
$$\mathrm{GrowthRate}_H(T) := \frac{\mathrm{Flux}_H(T) \cdot Mw}{\rho} \qquad \mathrm{GrowthRate}_H(T) = 7.83 \times 10^{-3}\,\frac{\mathrm{mm}}{\mathrm{s}}$$

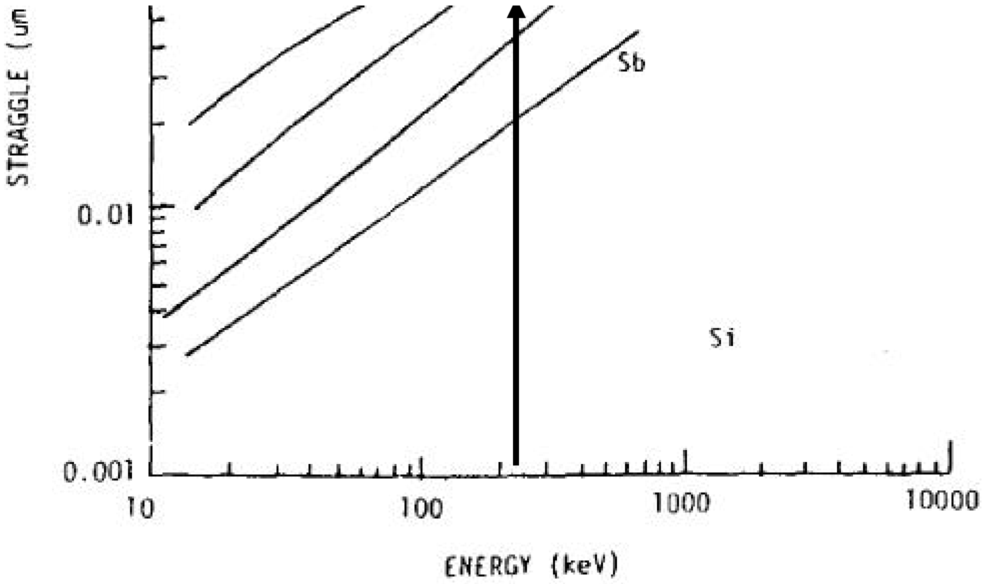
BL-MT gives the slower growth rate, thus MT is rate determining.

Problem 3 Implantation



A) Implantation Energy from figure is 250 keV





Standard Deviation of Projected Range σx=0.08 µm

$$\frac{0.08\cdot\mu m}{0.3\cdot\mu m} = 0.267$$

$\sigma_x := 0.08\cdot\mu m$ taken from figure above

$D_{wafer} := 30\cdot cm$

Silicon Data

$N_{Av} := 6.023\cdot 10^{23}$

$\rho := 2.33\cdot\frac{gm}{cm^3}$

$Mw := 28\cdot\frac{gm}{mole}$

$C_{eq} := \frac{\rho\cdot N_{Av}}{Mw}$

$C_{eq} = 5.012\times 10^{2}$

Dopant Dose Calculation

$N_{max} := 0.00001\cdot C_{eq}$

$$N_{max} = \frac{N_{dose}}{\sqrt{2\pi}\cdot\sigma_x}$$

$N_{max} = 5.012\times 10^{17}\frac{1}{cm^3}$ # atoms/cr

$$N_{dose}(N_{max},\sigma_x) := N_{max}\cdot\left(\sqrt{2\pi}\cdot\sigma_x\right)$$

$N_{dose}(N_{max},\sigma_x) = 1.005\times 10^{13}\frac{1}{cm^2}$

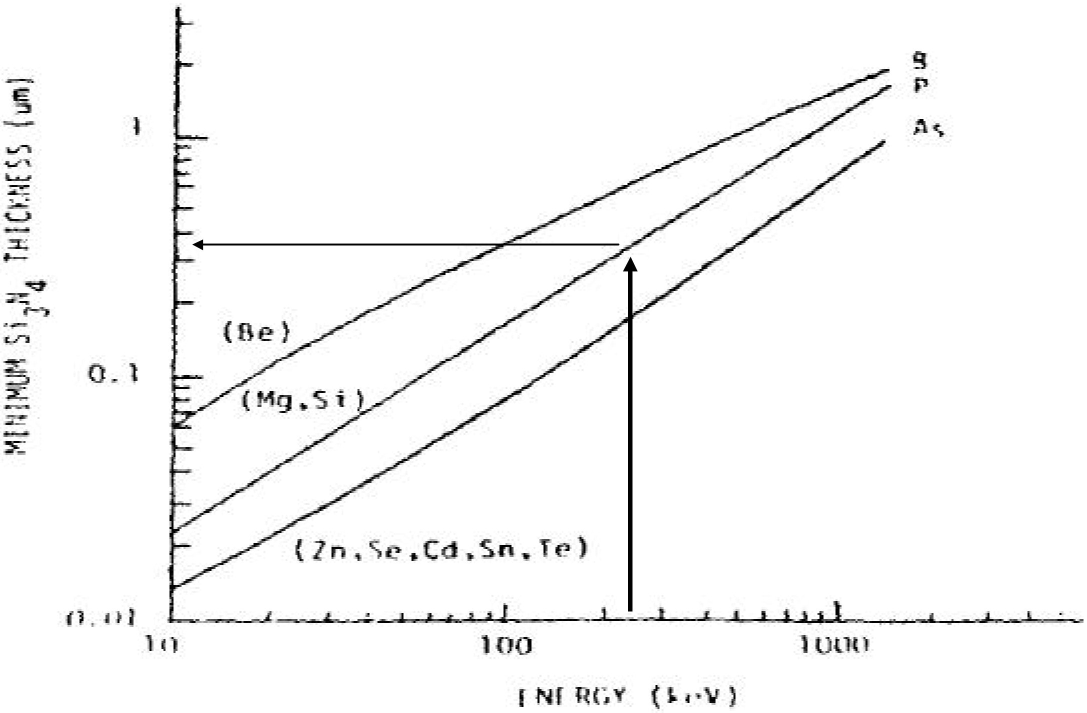
$$Q_{dose}(N_{max},\sigma_x) := N_{dose}(N_{max},\sigma_x)\cdot\left(1.602\cdot 10^{-19}\cdot coul\right)\cdot\left(\frac{\pi}{}\cdot D_{wafer}{}^2\right)$$

$Q_{dose}(N_{max}, \sigma_x) := N_{dose}(N_{max}, \sigma_x)\cdot(1.602\cdot 10 \quad coul)\cdot\left(\frac{\quad}{4} D_{wafer}\right)$ $Q_{dose}(N_{max}, \sigma_x) = 1.138 \times 10^{-3} A\cdot s$

Notice this is a short tim

Remember the Video w
the wafers are put into a
speed carriage and pas
and out of the implantat
for many ver short peric

3C) Si3N4 Mask Layer Growth



Minimum Si3N4 thickness = 0.37 µm

3/2 Si(s)+ N2(g) <--> ½ Si3N4(s)   HoRXN = +89.65 kcal/mole

$T := 1100 \cdot K$

$\rho_{Si} := 2.33 \cdot \frac{gm}{cm^3}$ $\qquad \rho_{Si3N4} := 3.44 \cdot \frac{gm}{cm^3}$

$Mw_{Si} := 28.08 \cdot \frac{gm}{mole}$ $\qquad Mw_{Si3N4} := 140.28 \cdot \frac{gm}{mole}$ $\qquad k_o := 1.2 \cdot 10^5 \cdot \frac{cm}{s}$ $\qquad E_A :=$

$H_{fSi} := 0 \cdot \frac{cal}{mole}$ $\qquad G_{fSi} := 0 \cdot \frac{cal}{mole}$ $\qquad S_{Si} := 4.5 \cdot \frac{cal}{mole \cdot K}$ $\qquad Cp_{Si} := 4.78 \cdot \frac{cal}{mole \cdot K}$

$H_{fSi3N4} := -179300 \cdot \frac{cal}{mole}$ $\qquad G_{fSi3N4} := -154700 \cdot \frac{cal}{mole}$ $\qquad S_{Si3N4} := 22.4 \cdot \frac{cal}{mole \cdot K}$ $\qquad Cp_{Si3N4} := 23.84 \cdot \frac{c}{mo}$

$H_{fN2} := 0 \cdot \frac{cal}{mole}$ $\qquad G_{fN2} := 0 \cdot \frac{cal}{mole}$ $\qquad S_{N2} := 45.77 \cdot \frac{cal}{mole \cdot K}$ $\qquad Cp_{N2} := 6.961 \cdot \frac{cal}{mole \cdot}$

$$\Delta H_{rxn}(T) := \left[\frac{1}{2} \cdot H_{fSi3N4} - \left(\frac{3}{2} \cdot H_{fSi} + H_{fN2}\right)\right] \ldots$$
$$+ \left[\frac{1}{2} \cdot Cp_{Si3N4} - \left(\frac{3}{2} \cdot Cp_{Si} + Cp_{N2}\right)\right] \cdot (T - 298.15 \cdot K)$$

$\Delta H_{rxn}(298.15 \cdot K) = -8.96$

$$\Delta G_{rxn}(T) := \Delta H_{rxn}(T) - T \cdot \left[\frac{1}{2} \cdot S_{Si3N4} - \left(\frac{3}{2} \cdot S_{Si} + S_{N2}\right)\right]$$

$\Delta G_{rxn}(298 \cdot K) = -7.73$

$K(T) := \exp\left(\frac{-\Delta G_{rxn}(T)}{R_g \cdot T}\right)$ $\qquad P_{N2eq}(T) := \frac{P}{K(T)}$

$$Flux = \frac{\rho_{Si3N4}}{Mw_{Si3N4}} \cdot Area \cdot \frac{dy}{dt} = \frac{Rate}{Area} = (2) \cdot k_o \cdot \exp\left(\frac{-E_A}{R_g \cdot T}\right) \cdot \left(C_{N2} - C_{N2eq}\right)$$

Film Growth Equation

$C_{N2} := \frac{P}{R_g \cdot T}$ $\qquad C_{N2} = 1.111 \times 10^{-3} \frac{mole}{m^3}$

$C_{N2eq}(T) := \frac{P_{N2eq}(T)}{R_g \cdot T}$ $\qquad C_{N2eq}(T) = 7.571 \times 10^{-13} \frac{mol}{m^3}$ $\qquad P_{N2eq}(T) = 6.814 \times 10^{-14} atm$

Integrate Flux equation

$$y(t, T) := \frac{Mw_{Si3N4}}{\rho_{Si3N4}} \cdot \left[(2) \cdot k_o \cdot \exp\left(\frac{-E_A}{R_g \cdot T}\right) \cdot \left(C_{N2} - C_{N2eq}(T)\right)\right] \cdot t$$

Rearrange

$$t(T) := \frac{0.37\cdot\mu m}{\frac{Mw_{Si3N4}}{\rho_{Si3N4}}\cdot\left[(2)\cdot k_o\cdot \exp\left(\frac{-E_A}{R_g\cdot T}\right)\cdot\left(C_{N2}-C_{N2eq}(T)\right)\right]}$$

$t(T) = 2.187\,min$