N.CHEUNG EE143,Sp 2006

Homework Assignment #3 (Due Feb 16, Thur, 8am)

Reading Assignment

1) Chapter 5 of Jaeger on Ion Implantation [Overview]
2) 143Reader : Chapter by Mayer and Lau on Ion Implantation [mechanisms]
3) 143 Reader Projected Range and Straggle data notes

Problem 1 Sheet resistance and junction depth of implanted layer

(a)Phosphorus is implanted into p-type Si substrate to form a n-p junction. **Estimate** the sheet resistance (use $R_S \sim \dfrac{1}{q \bullet \mu \bullet \text{atomic dose}}$) of the n-type surface if 100 keV phosphorus (P^+) ions with a dose of 1.2 $\times 10^{13}/cm^2$. To find mobility data, use the attached electron/hole mobilitiy curves. You can either use the R_p and ΔR_p curves from Jaeger or from the curves given in the EE143 Reader.

(b) If the background substrate doping concentration (p-type) is $10^{15}/cm^3$, find the junction depth of the np junction formed.

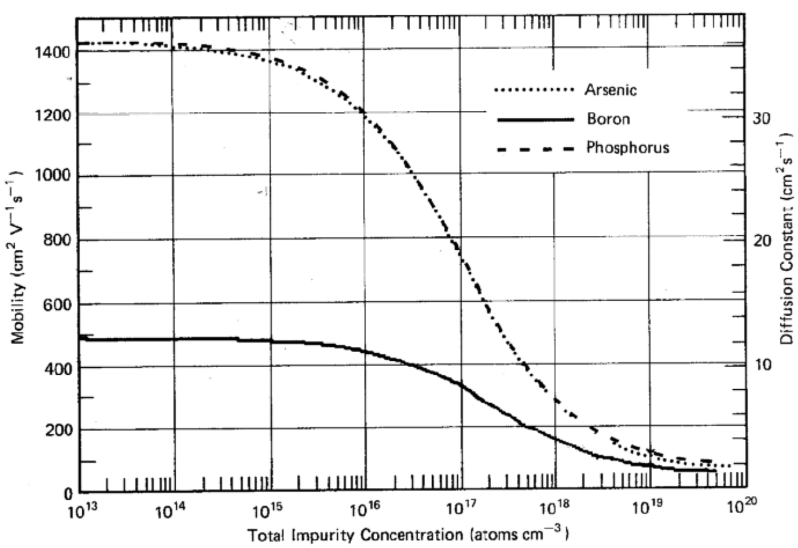


Figure 1.15 Electron and hole mobilities in silicon at 300 K as functions of the total dopant concentration. The values plotted are the results of curve fitting measurements from several sources. The mobility curves can be generated using Equation 1.2.10 with the following parameter values:[3]

Problem 2 How to choose energy and dose

Design the **energy** and **dose** required to produce a boron implant into Si with the profile peaks 0.4μm from the surface and a resultant sheet resistance = 500Ω/square.

[Hint: the **dose** design will need the mobility curve for holes and a trial-and-error approach]

Problem 3 Acceleration voltage, implant energy, multiply charge state, molecular ion implant

(a) An ion implanter with an **accelerating voltage** of 50kV is used to implant the following ions into Si to an ion dose of 10^{15} **ions**/cm^2: Use the full gaussian approximation to ***estimate*** the **maximum** concentration of the Boron profile [in B atoms /cm^3]. You can either use the R_p and ΔR_p curves from Jaeger or from the curves given in 143 Reader /class handouts. Show all calculations.

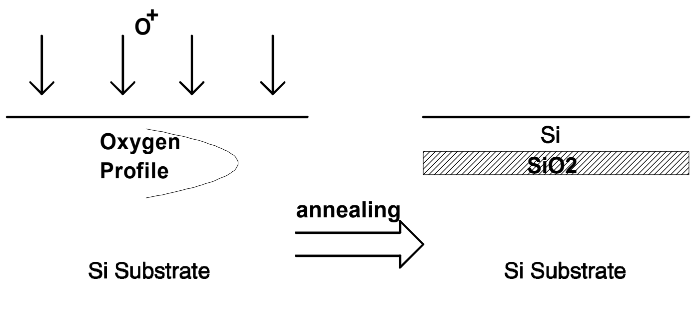
(1) B^+ (atomic Boron ion, singly charged)
(2) B^{2+} (atomic Boron ion, doubly charged)
(3) B_2^+ (diatomic Boron molecular ion, singly charged)

(b)If the Si substrate is n-type (background concentration of $10^{16}/cm^3$), explain ***qualitatively*** which ion in part (a) will give the deepest junction depth?
(c) Calculate the approximate sheet resistance of the implant profile in part (b) using

$$R_S \sim \frac{1}{q \bullet \mu \bullet \text{atomic dose}}$$

Problem 4 Material Synthesis by Implantation : Silicon-on-insulator (SOI) Substrate

Separation by Implantation of Oxygen (SIMOX) is one method of forming Si on Insulator (SOI) substrates. Oxygen ions are implanted ***deep below*** the Si surface with a high dose. The as-implanted oxygen depth profile is approximately gaussian. With a high temperature post-implantation annealing step (> 1200°C), the implanted oxygen atoms will coalesce to form a continuous buried layer of pure SiO_2.

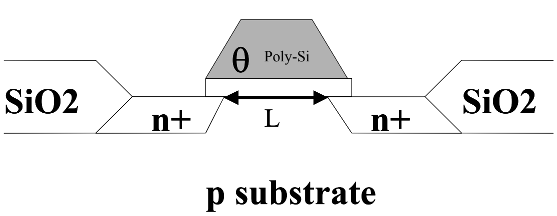


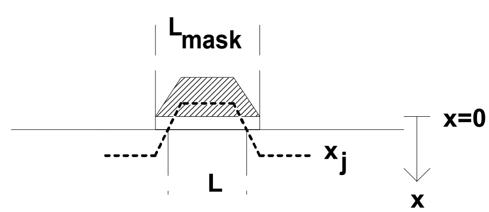
(a) What is the oxygen ion dose (in O atoms/cm^2) required to form a buried SiO_2 layer 0.1 μm thick? [**Hint**: To get the dose required, you only have to know the oxygen concentration of SiO_2 and its final thickness. Molecular density of SiO2 is 2.3×10^{22} molecules/cm^3. *You do not need* R_p *and* ΔR_p *information to solve this problem, why ?].*

(b) Calculate the required implantation time to implant a 200mm-diameter Si wafer if the beam current is 10mA? Assume the ion beam is rastering a 20cm x 20cm square area.

Problem 5 Implantation through a tapered mask

(a) Doping of the source and drain of a MOSFET is formed by ion implantation. The channel length L is defined as the distance between the junction depths x_j at the Si surface (see sketch below). If the poly-Si gate has a tapered sidewall with angle θ , indicate in the following table whether the channel length L will increase or decrease (↑= increase and ↓ = decrease) when one of the parameters changes while the others remain constant.





Parameter	Channel Length L

Implant Dose ↑	
Ion Energy (E)↑	
Substrate conc. N_B ↑	
Sidewall Angle θ ↑	
Ion Mass (M) ↑	

(b) The poly-Si gate has a thickness of 0.45 μm and the gate oxide has a thickness of 0.05 μm. For L_{mask} = 2 μm (the bottom width of poly gate in figure), $\theta = 45°$, $N_B = 10^{15}$ / cm^3, implant dopant = arsenic , ion energy = 200 keV , dose = 10^{15} /cm^2 ,

(i) Calculate approximately the channel length L. Assume transverse straggle (ΔR_t) of implantation =0 in this calculation and assume SiO_2 has the same stopping power as Si. [Hint: You DO NOT have to use the erfc functions due to lateral straggle because we assume $\Delta R_t = 0$ for simplicity.]

(ii) If ΔR_t is finite instead of being zero, ***comment qualitatively*** whether the value of channel length L will be **larger** or **smaller**.

Problem 6 Implantation mechanisms

Use cartoons to illustrate your ideas if necessary

(a) Describe the "ion channeling" mechanism and how it will affect the junction depth when dopants are implanted into crystalline Si substrates.

(b) Discuss why one still observe a tiny channeling tail in the implantation profile even if we tilt the Si wafer by ~7^{o} with respect to the ion beam incidence direction.

(c) Discuss why a much higher implant dose of Boron is required to create a surface amorphous Si layer as compared with Arsenic.