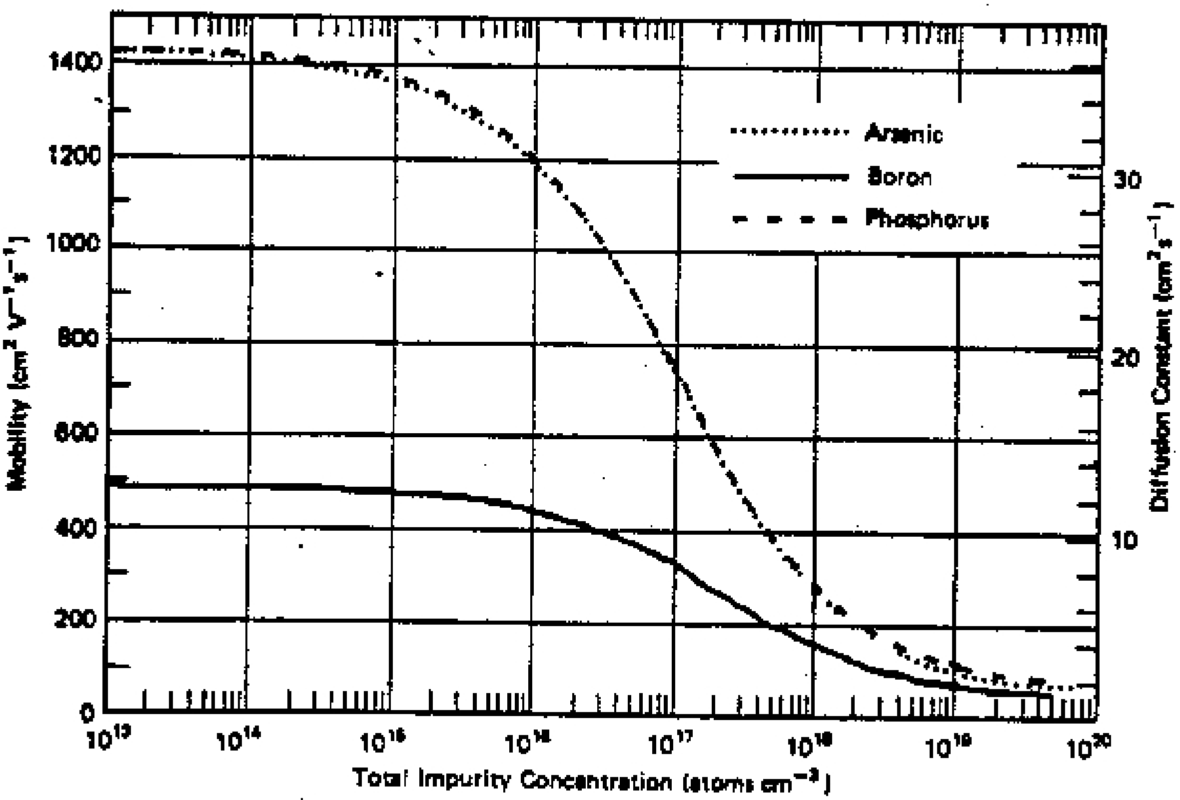
EECS 130 Midterm Exam #1 : N. Cheung, Spring '93

GENERAL INFORMATION



q=1.6 x 10^-19
εs = 1.036 x 10^-12 F/cm for Si
n_i of Si = 1.45 x 10^10 cm^-3 at 300K
Eg of Si = 1.12 eV at 300K
Electron Affinity of Si = 4.05 eV
D/μ= KT/q = 0.0259 volts at 300K
n_i^2 = NcNv exp [-Eg/kT]

Electric potential of semiconductor:
φ= (Ef - Ei) / q

n = n_i * exp(qφ/kT)
p = n_i * exp (-qφ/kT)

Step pn junction depletion width:
x_d = [2εs/q (φ- Va) (1/Na + 1/Nd)] ^(1/2)

Poisson's Equation:
d^2 φ/ dx^2 = -q/εs {p - n + Nd - Na}

Small-signal capacitance/unit area: C = εs/ x_d

Sheet resistance Rs = 1 / (Nq<μ>)

Problem 1 (20 points total)

(a) (8 points) Energy gaps and intrinsic carrier concentration at 300K are given for the following three semiconductors:

Si: Eg = 1.124 eV, n_i = 1.45x10^10/cm^3
Ge: Eg = 0.66 eV, n_i = 2.4x10^13/cm^3
GaAs: Eg = 1.424 eV, n_i = 1.79x10^6/cm^3

The three semiconductors are doped such that at 300K, Na- - Nd+ = 1x10^15/cm^3. Which semiconductor has the most sensitive change to temperature for its minority carrier? Explain.

(b) (12 points) A piece of p-type Si has an acceptor concentration profile: Na(x) = No exp(-Kx), where x is the position for the region of interest. No and K are constants.

(i) Find an expression for the hole diffusion current density Jp diffusion(x) at thermal equilibrium.

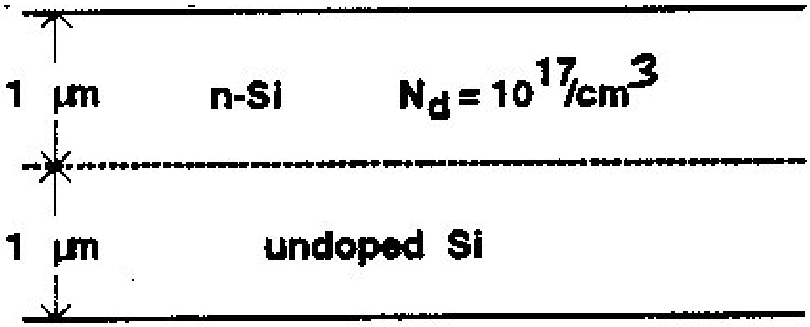
(ii) Find an expression for the electron diffusion current density Jn diffusion(x) at thermal equilibrium.

(iii) Find an expression for the electric field E(x) at thermal equilibrium.

(iv) What are the reasons that Jp diffusion (x) is not equal to Jn diffusion (x)?

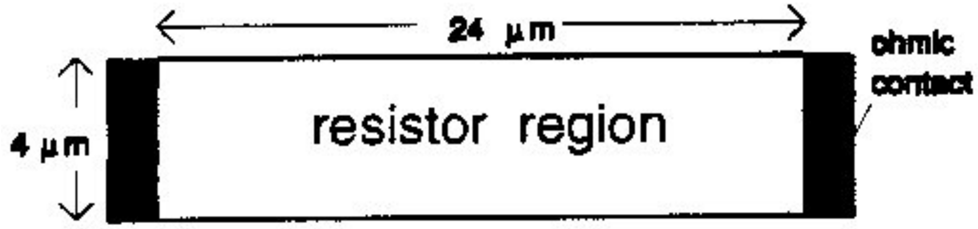
Problem 2 (20 points total)

A piece of Si has a thickness of 2 µm. The top 1 µm is doped to an n-type with Nd = 10^17/cm^3. The bottom 1 µm is undoped.



(a) (7 points) Calculate the sheet resistance Rs at 300K.

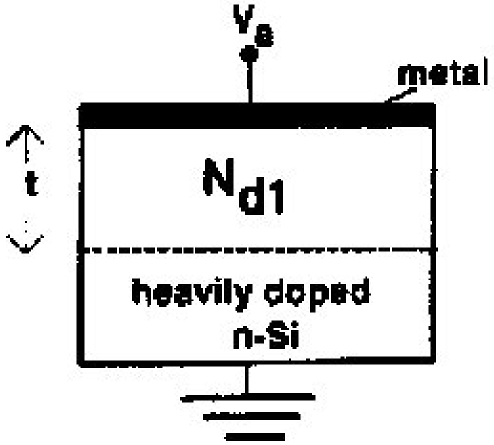
(b) (3 points) A resistor pattern is laid out for an integrated circuit as shown in the sketch below. Find the resistance of this IC resistor.

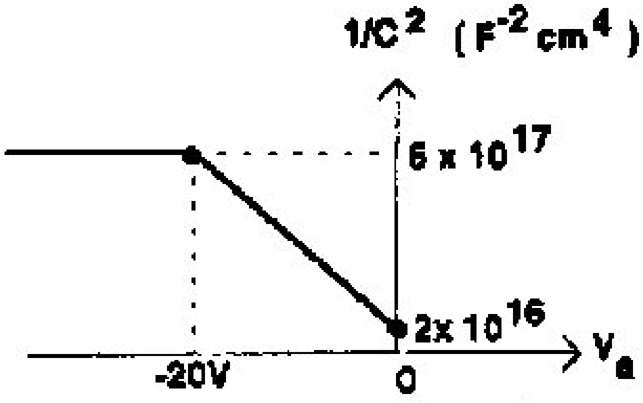


(c) (10 points) A uniform concentration of boron (= 10^17/cm^3) then added to the top 1 µm region. Calculate the new sheet resistance.

Problem 3 (30 points total)

A Schottky rectifying contact is made using a thin uniformly doped Si layer (concentration = Nd1) on top of a very heavily doped Si substrate. Small-signal capacitance measurements were made and the 1/C^2 - Va plot is shown below.





(a) (6 points) Find the doping concentration Nd1.

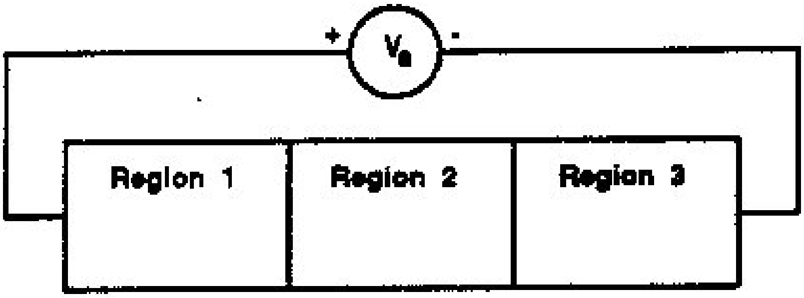
(b) (6 points) Find the thickness of the Nd1 layer.

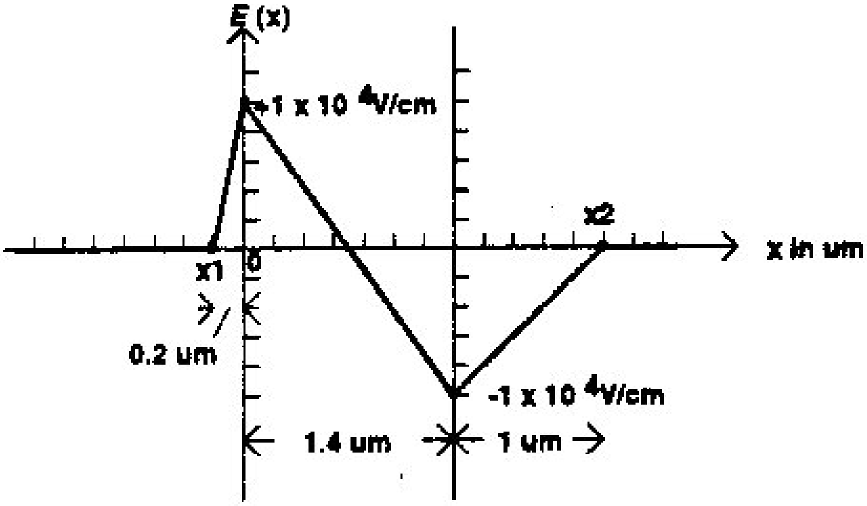
(c) (10 points) Find the Schottky barrier height of the contact $q\phi_B$. [Hint: you may want to draw a rough sketch of the energy band diagram to identify the various components for $q\phi_B$]

(d) (8 points) If avalanche breakdown will occur at an electric field of 7x10^4 V/cm, find the required Va. Show the procedures which give you the answer.

Problem 4 (30 points total)

A piece of Si has three regions of different doping. At a certain bias Va0, the electric field profile is shown below.





(a) (12 points) Answer the following questions:

(i) Region 1 is n-type / p-type (circle one) and has a doping concentration of ________________ .

(ii) Region 2 is n-type / p-type (circle one) and has a doping concentration of ________________ .

(iii) Region 3 is n-type / p-type (circle one) and has a doping concentration of ________________ .

(b) (8 points) Find the potential difference between position x1 and x2 (i.e., ϕ(x1) - ϕ(x2)).

(c) (10 points) Sketch the corresponding energy band diagram. Show Ec, Ev and the Fermi levels in the quasi-neutral regions of Region 1 and Region 3.