Spring 2005

UNIVERSITY OF CALIFORNIA

College of Engineering

Department of Electrical Engineering and Computer Sciences

EECS130 Midterm I

Last Name____________________**First Name**____________________

Instructions:

Print your name on the cover page CLEARLY now

Show major intermediate steps on exam pages to facilitate grading

Make sure your copy of the exam paper has 7 pages (including cover page)

Information that may be useful

$q = 1.6 \times 10^{-19}$ coulombs

Boltzmann constant $k = 8.62 \times 10^{-5}$ eV/ K

n_i of Si= 10^{10} cm^{-3} at 300K

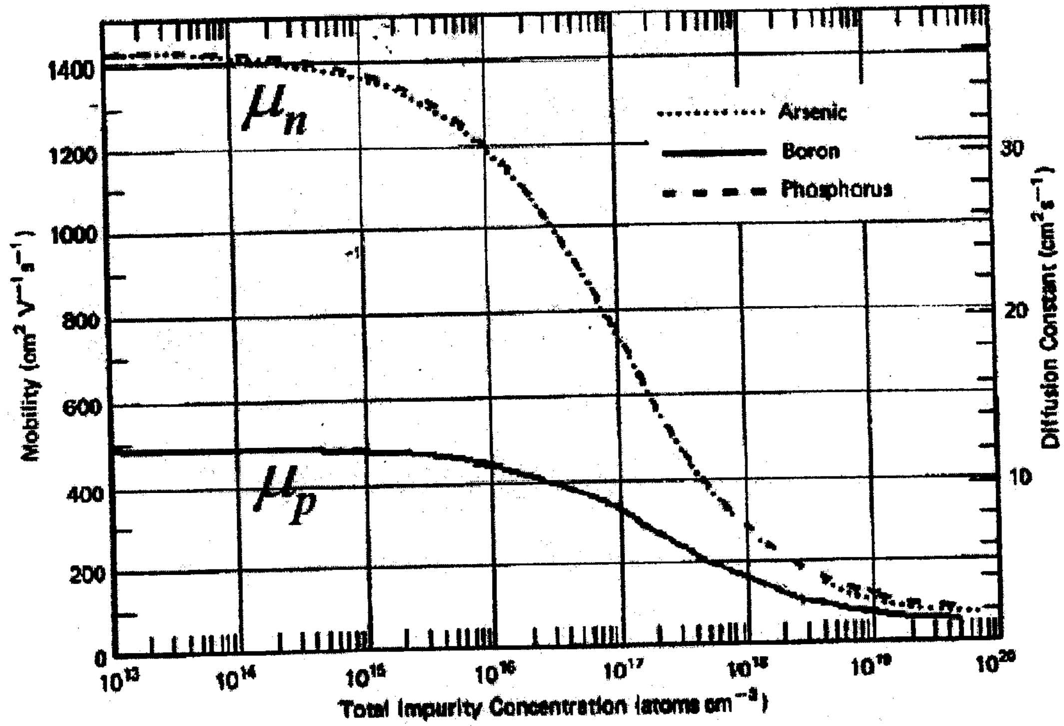
Problem 1 (14 points) ______________

Problem 2 (28 points) ______________

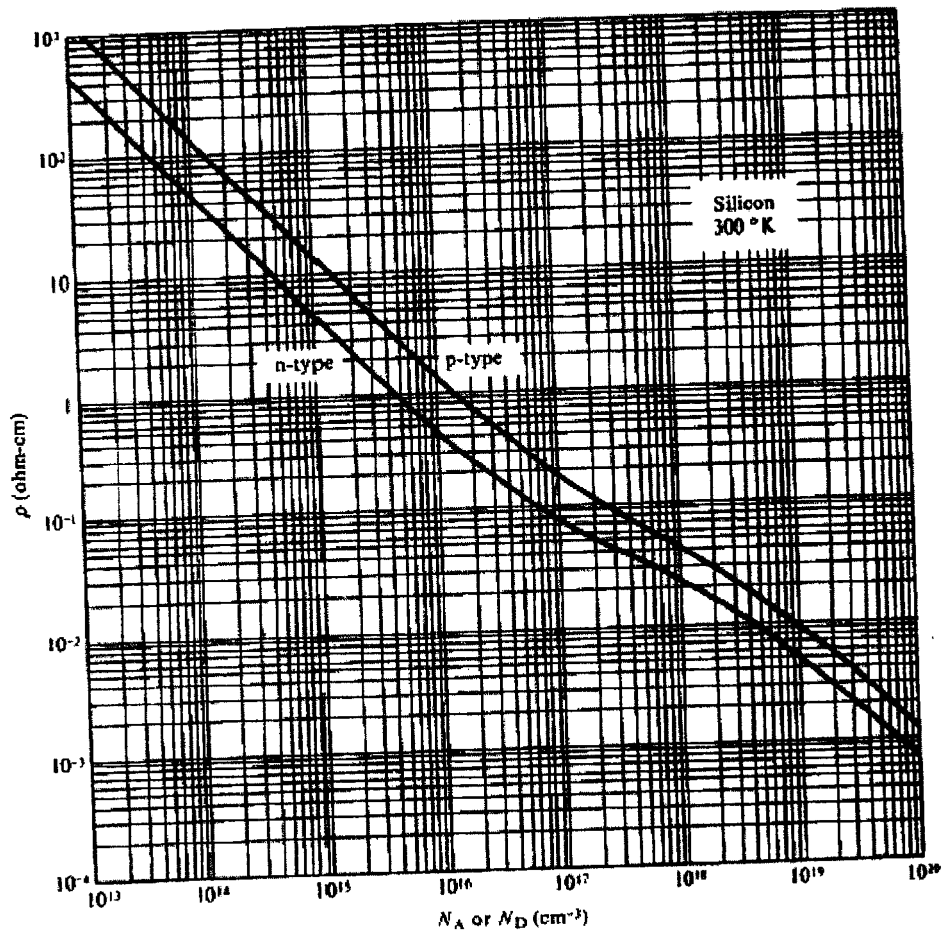
Problem 3 (17 points) ______________

Problem 4 (41 points) ______________

TOTAL (100 points) ________________



1400
1200
1000
800
600
400
200
0
Mobility (cm² V⁻¹s⁻¹)
μn
μp
Arsenic
Boron
Phosphorus
30
20
10
Diffusion Constant (cm²s⁻¹)
10¹³
10¹⁴
10¹⁵
10¹⁶
10¹⁷
10¹⁸
10¹⁹
10²⁰
Total Impurity Concentration (atoms cm⁻³)



10³
10²
10
1
10⁻¹
10⁻²
10⁻³
10⁻⁴
ρ (ohm-cm)
Silicon
300 °K
n-type
p-type
10¹³
10¹⁴
10¹⁵
10¹⁶
10¹⁷
10¹⁸
10¹⁹
10²⁰
NA or ND (cm⁻³)

Problem 1 (14 points)

A donor-doped silicon sample at 300K has resistivity of 0.1 Ω-cm.

a) What is the doping density? (3 points)

b) What is the hole concentration? (2 points)

c) What is electron diffusion constant? (4 points)

d) Now acceptor density, N_A=3×10^{16} cm^{-3} is added to above sample. What is conductivity of the sample? (5 points)

Problem 2 (14×2=28 points)

Answer each with one or two sentences, or phrases or define with an equation. Unless otherwise specified answer the questions for Si at 300K. You may assume that commonly used parameters are given.

a) What is the electron concentration given $N_A = N_D = 5 \times 10^{15}$ cm^{-3}?

b) Is silicon a donor or an acceptor in GaAs? (Ga is group III and As is Group V).

c) What is the recombination rate, given n'?

d) Give an expression for Einstein relationship.

e) What is the "excess carrier concentration"?

f) What is wet lithography technology?

g) What is 'end-point detection' in etching process?

h) What type of CVD process is used to deposit oxide at the lowest temperature?

i) What is 'sputtering'?

j) Why is wet oxidation sometimes preferred over dry oxidation?

k) Give two reasons for 'thermal annealing' after ion-implantation even when the shallowest possible junction depth is desirable.

l) Give two reasons why the industry switched from *Al* to *Cu* as interconnect material in advanced silicon technology.

m) What is the depletion region approximation?

n) What is a one-sided junction?

Problem 3 (17 points)

Design a sequence of process steps by using the available process options from the given menu to go from Fig. 1 to Fig. 2.

Process Menu
Annealing
Gas Source doping
Wet etching
Deposition of oxide
Dry etching
Ion Implantation
Sputtering
Solid source diffusion
Lithography

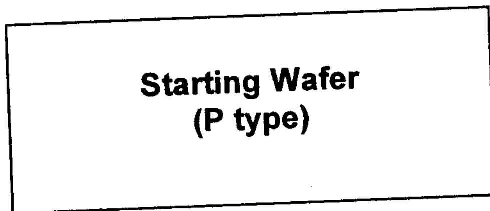


Fig. 1

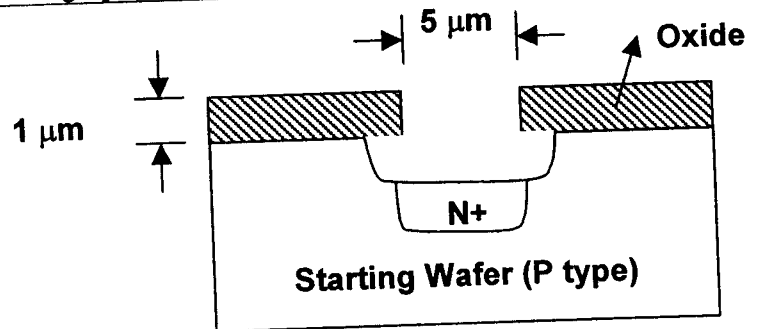


Fig. 2

Problem 4 (41×1=41 points)

For a change in the left-column parameters (each of them assumed to be independent from the other parameters), what is the effect on the parameters in the top row? Answer with ↑ to indicate 'increase', ↓ for 'decrease', and → for 'no effect'. When necessary, assume you are answering for Si with N_D=10^{16} cm^{-3} and T=300K.

Affected Parameter / Changing Parameter	n_i	n	p	E_c-E_f	μ_n	D_p	ϕ_{bi} of PN junction with N_A=10^{18} cm^{-3}	W_{dep}
E_g ↑								
m_n ↑								
m_p ↑								
N_D ↑								×
N_A ↑							×	×
T ↑ (assume N_c and N_v remain constant)					×	×	×	×

No need to fill in boxes that have been crossed out.