Fall 2003

UNIVERSITY OF CALIFORNIA
College of Engineering
Department of Electrical Engineering and Computer Sciences

EE143 Midterm Exam #1

Family Name ______________________ **First name**__________________________

Signature____

Make sure the exam paper has 5 pages + 3 pages of data for reference

Instructions: DO ALL WORK ON EXAM PAGES
This is a 90-minute exam (4 sheets of notes allowed)

Grading: To obtain full credit, show correct units and algebraic sign in answers. Numerical answers which are orders of magnitude off will receive no partial credit.

Problem 1 (25 points)_______________

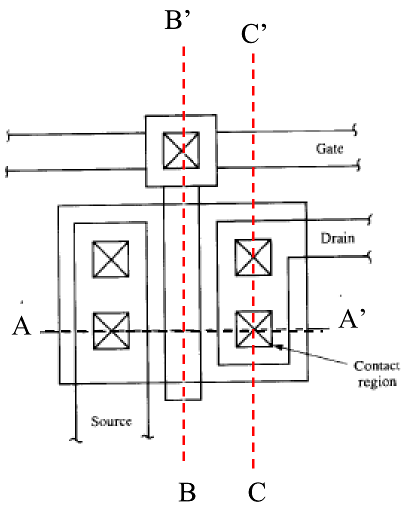
Problem 2 (25 points)______________

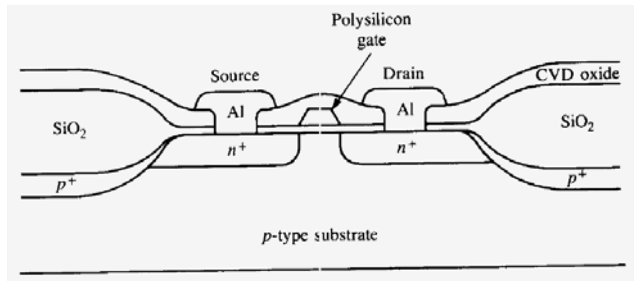
Problem 3 (25 points) _______________

Problem 4 (25 points) _______________

TOTAL (100 points) _________________

Problem 1 Simple Transistor structure and Process Sequence (25 points total)
Figures below (taken from your Jaeger textbook) show the top view and cross-section of a MOSFET along the line A-A' .





(a) (5 points) Sketch the cross-section of the device along the line B-B' [Hint: the drain, source , and gate interconnects show in top view are all aluminum]. Label all important features.

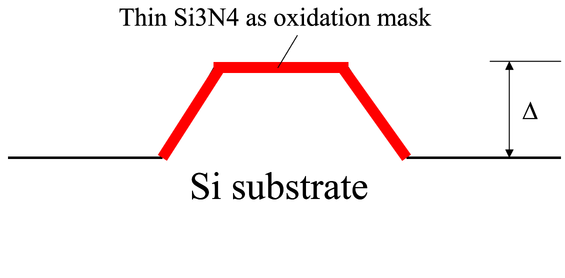
(b) (5 points) Sketch the cross-section of the device along the line C-C'. Label all important features.

(c) (10 points) How many lithography steps are needed to fabricate this device ? Describe the functions of each masking step.

(d) (5 points) Can the polysilicon gate be replaced with an aluminum gate in this process sequence? Explain why/ why not .

Problem 2 Thermal oxidation (25 points total)

(a) (7 points) A Si wafer is patterned and etched to form Si lines with a finites sidewall slope. The height of the lines is Δ. Silicon nitride is then deposited by CVD and then patterned such that it protects the top and sidewalls of the Si lines (see figure below).



The structure is then subjected to a thermal oxidation step such that the oxide grown has a thickness Δ in the unprotected area. Sketch the cross-section after the oxidation step.

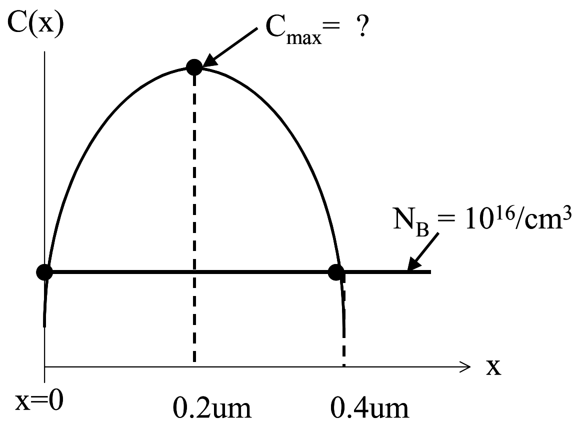
(b)(8 points) For a particular oxidation process, it is known that the oxidation rate (dx_{ox}/dt) is 0.48μm /hour when the oxide thickness is 0.5 μm and it slows down to 0.266 μm /hour when the oxide thickness is 1 μm. Find the linear oxidation constant (B/A) and the parabolic oxidation constant B. Give answers in proper units.

(c) (5 points) List two processing advantages of growing a thermal oxide at high oxidant gas pressure.

(d) (5 points) What types of oxide charges are generally observed in thermally grown SiO2? What are the general practice to minimize such oxide charges ?

Problem 3 Ion Implantation (25 points total)

Phosphorus ions (P+) are implanted into a p-type silicon wafer ($N_B=10^{16}/cm^3$) . The Gaussian concentration profile versus depth x is plotted below.



(i) (3 points) What is the energy of the P+ ion ?

(ii) (5 points) What is the implantation dose ?

(iii) (7 points) Use the **Irvin Curves** to calculate the sheet resistance of the implanted layer. Show clearly the steps you use to derive your answer [No credit will be given for answers using the 1/ (q μ.ϕ) approximation]

(v) (5 points) To avoid intentional ion channeling, one usually tilt the Si wafer by 7 degrees. However, a small channeling tail still occurs. Explain the origin of this small channeling tail.

(vi) (5 points) After implantation of dopants, it is typically followed by a 900 °C annealing step. Why do we need this annealing step ?

Problem 4 Diffusion and Sheet Resistance (25 points total)
(a) (10 points) A boron predeposition diffusion step is performed on a Si wafer uniformly doped with 10^{15} As/cm^3

The boron diffusion conditions are :
Diffusion Temperature = 950 ^oC
Diffusion time = 600 seconds
Boron diffusion constant = 6.6 x E-15 cm^2/sec
Boron solid solubility = 3.9 × E20/cm^3
Diffusion profile = erfc function

Use the Irvin curves to calculate the sheet resistance of the boron diffused layer. Show all calculations.

(b) (5 points) **Assume** singly-charged positive vacancy is the **only** diffusion mechanism for Boron diffusion in Si. Write down the expression for the diffusion constant which include high concentration diffusion effects.

(c) (5 points) An old diffusion process design gives a half-gaussian **phosphorus** drive-in profile. Is it possible to duplicate an identical doping profile by using **arsenic** diffusion (assuming there is no high concentration diffusion effect) ? Explain your answer.

(d) (5 points) Why is the transient enhanced diffusion mechanism only "transient ? Also, explain why this effect is desirable / not desirable for shallow junction formation.

Information for reference

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

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

n_i of Si $= 3.69 \times 10^{16} \times T^{3/2} \exp[-0.605\text{eV}/kT]$ cm^{-3}

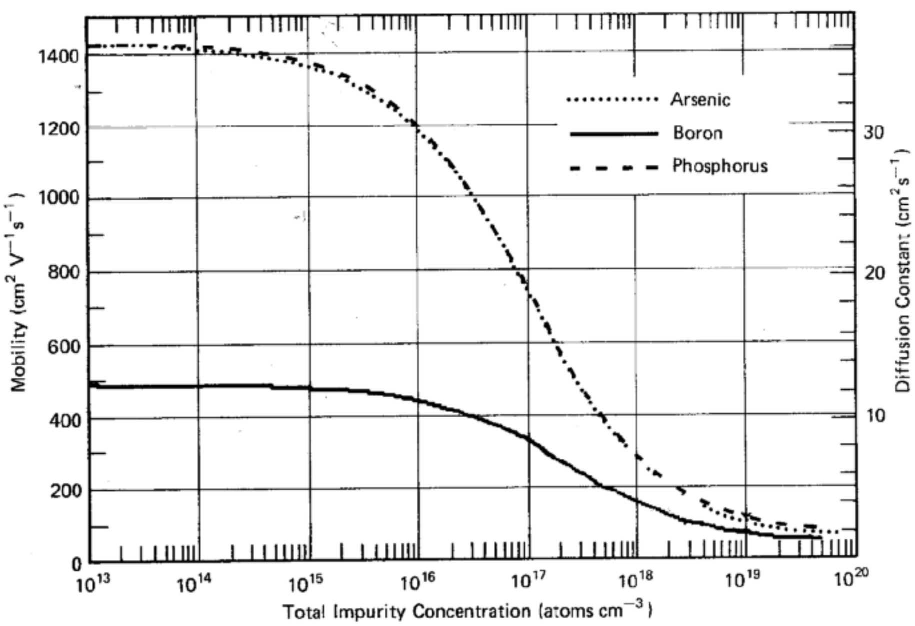
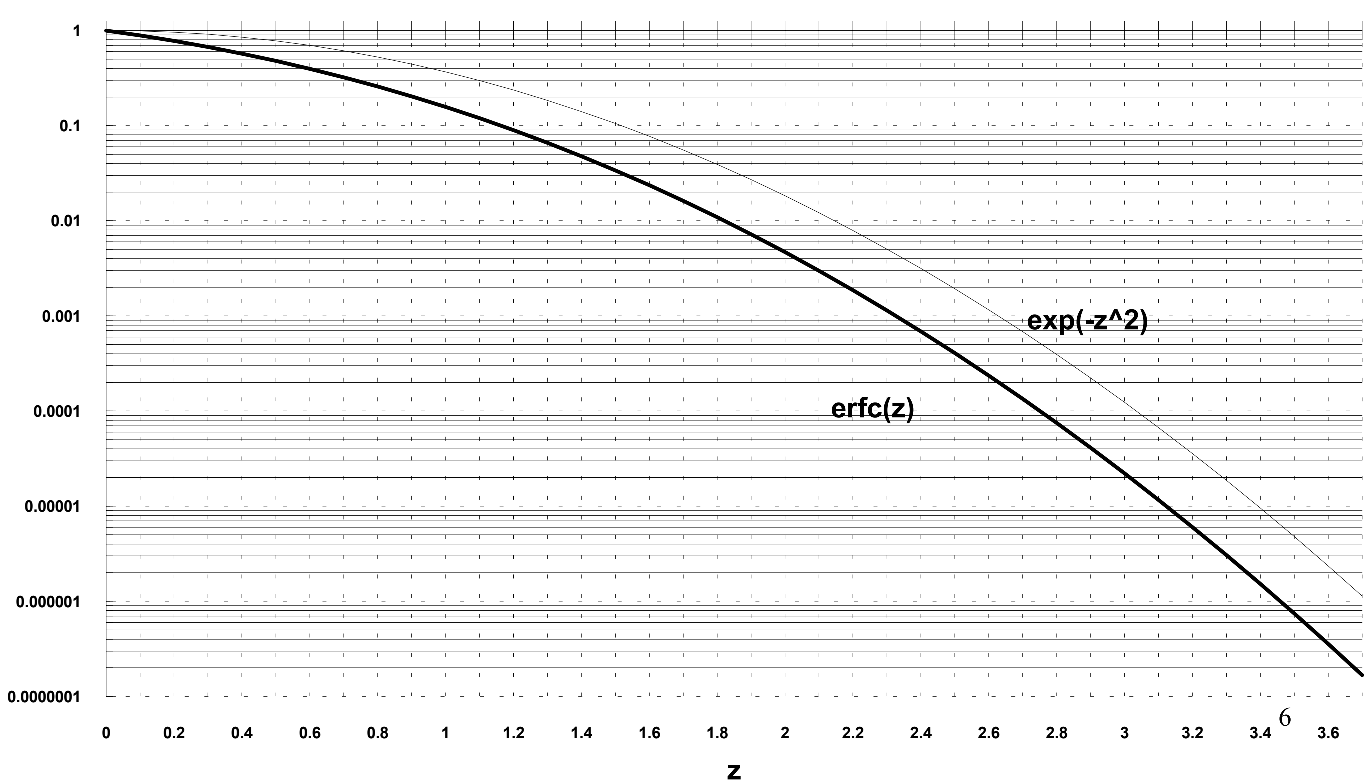
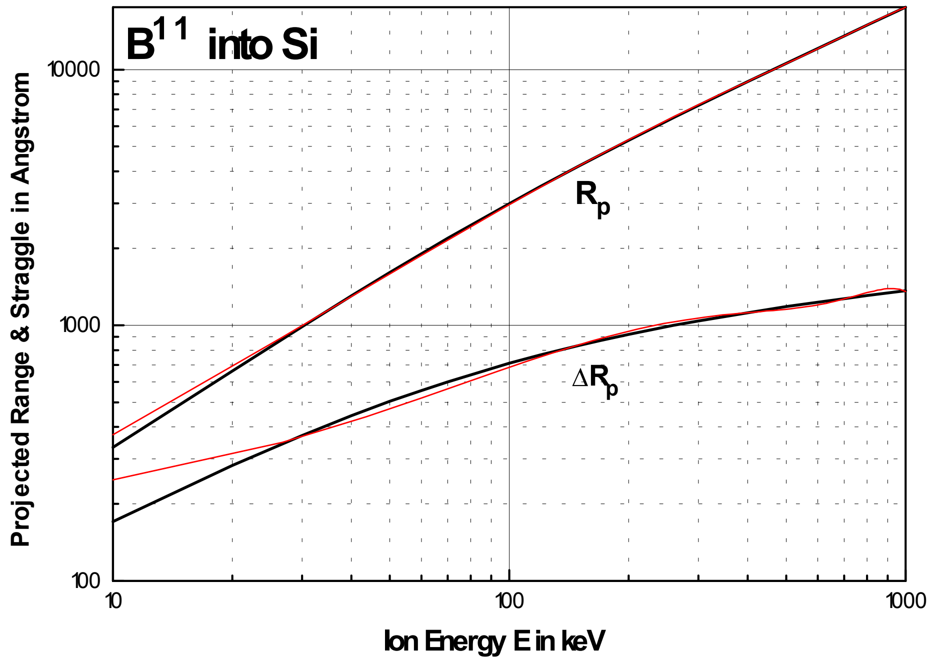


Figure 1.15 Electron and hole mobilities in silicon at 300 K as functions of the total dopant concentration. The values plotted are the results of curve fitting measurements from several sources. The mobility curves can be generated using Equation 1.2.10 with the following parameter values:[3]



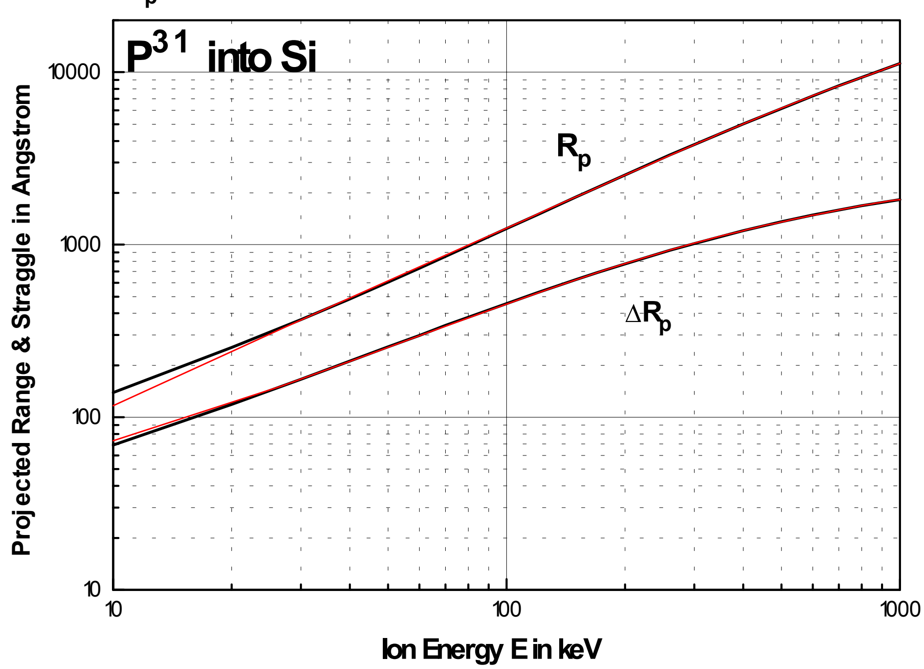
$$R_p = 51.051 + 32.60883\, E - 0.03837\, E^2 + 3.758e{-}5\, E^3 - 1.433e{-}8\, E^4$$

$$\Delta R_p = 185.34201 + 6.5308\, E - 0.01745\, E^2 + 2.098e{-}5\, E^3 - 8.884e{-}9\, E^4$$



$$R_p = -7.14745 + 12.33417\, E + 0.00323\, E^2 - 8.086e{-}6\, E^3 + 3.766e{-}9\, E^4$$

$$\Delta R_p = 24.39576 + 4.93641\, E - 0.00697\, E^2 + 5.858e{-}6\, E^3 - 2.024e{-}9\, E^4$$



Irvin Curves