N.Cheung, Spring 99

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

EECS143 Midterm Exam #1

Family Name ________________________ First name____________________________

Signature____

Instructions: DO ALL WORK ON EXAM PAGES
This is a 90-minute exam (open reader materials and homework).

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 (30 points)________________

Problem 2 (20 points)_______________

Problem 3 (25 points) ________________

Problem 4 (25 points) ________________

TOTAL (100 points) __________________

Problem 1 Oxidation (30 points total)

(a) (15 points) A lightly doped Si wafer was processed by some unknown IC processing steps. After these unknown steps, you performed a thermal oxidation experiment [fixed temperature and fixed oxidizing ambient] with this wafer and observed the following results:

Oxidation Time	**SiO2 Thickness**
0 hour	0
1 hour	2000 Å
4 hours	2500 Å

Are the following conjectures TRUE or FALSE ? You have to give brief explanations to justify your answers.

Conjecture 1 **:** The processed Si wafer was oxidized first to an oxide thicknes of 100 Å and then have the oxide dissolved in HF.

Conjecture 2 : The processed Si wafer has a highly doped surface layer (doping > $10^{19}/cm^3$) which is less than 1000 Å thick.

Conjecture 3 : The processed Si wafer has a thin layer of poly-Si layer on top surface.

Problem 1 continued

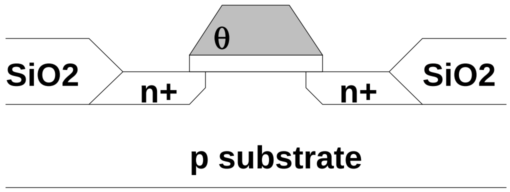
(b)(7 points) A pure Si spherical particle of radius 1µm is oxidized completely, what is the radius of the SiO_2 sphere formed ?

(c) (8 points) Discuss the advantages and disadvantages of using the Local Oxidation (LOCOS) process

ADVANTAGES

DISADVANTAGES

Problem2 Ion Implantation (20 points total)



(a) (10 points) Self-aligned source and drain of a MOSFET is formed by ion implantation of phosphorus. If the gate has a tapered sidewall with angle θ , indicate in the following table whether the electrical channel length L will increase or decrease or no change (↑= increase, ↓ = decrease, 0 = no change) when one of the parameters changes while the others remain constant.

Parameter	**Electrical Channel Length L**
Implant Dose ↑	
Substrate conc. N_B ↑	
Sidewall Angle θ ↑	
Gate material changed from poly-Si to Tungsten	
Implant ions changed from Phosphorus to Arsenic (same energy)	

(b) (5 points) Explain why we need an additional annealing step at >900C after implantation of dopants.

(c) (5 points) We would like to form ultra-shallow junctions, discuss two methods used in IC processing to minimize the ion channeling effect

Problem 3 Diffusion (25 points total)

(A) (15 points) Boron is diffused into a Si substrate having a background phosphorus concentration of 10^{16}/cm^3 . The measured junction depth (x_j) is 0.7 μm and the sheet resistance is 5 Ω/square.

Since we do not have information about the boron depth profile, we make up two approximations:

Profile 1: The profile is an erfc function with $(Dt)^{1/2}$ =0.1μm
Profile 2: The profile is a rectangular profile with constant concentration from surface to x_j.

Calculate the surface concentration of boron for both profiles. The hole mobility can be taken as constant (= 60 cm^2 /V-s) for all depths. Based on the surface concentration values, which profile is a better approximation ?

(b) During the initial stage of diffusion, the doped region is intrinsic (n = p) so we won't expect to see any high concentration diffusion effect. However, Boron diffuses faster than As and the near surface region becomes highly n-doped and the deeper region becomes p-doped. Since the **net** carrier concentration can still be higher than n_i. we will start to observed high concentration diffusion effects in both regions.

(B)(10 points) The surface region of a Si wafer contains **two identical concentration depth profiles** of Boron and Arsenic. Both profiles can be considered as having high concentration (~10^{20}/cm^3 near the peak region)

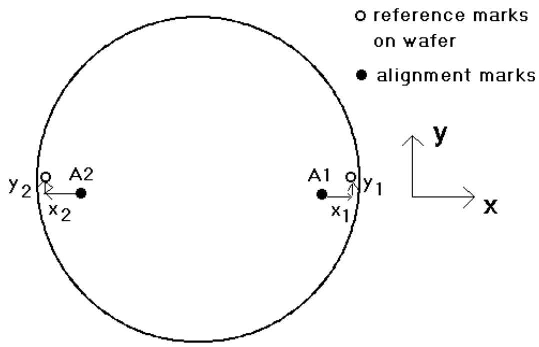
(i) Do you expect to observe ***high concentration diffusion effects*** when the wafer is heated at 1000 °C for short diffusion times? Explain with a sketch.

(i) Do you expect to observe ***high concentration diffusion effects*** when the wafer is heated at 1000 °C for long diffusion times ? Explain with a sketch.

Problem 4 Lithography (25 points total)

(a) (15 points) Two diagonal alignment marks A1 and A2 along the x-axis near the edge of a wafer with 4-inch diameter have overlay errors (x_1, y_1) and (x_2, y_2) respectively.

x_1, x_2, y_1 and y_2 are defined as + along the positive x and y directions.



(x_1, y_1) and (x_2, y_2) are measured to be (+0.2, +0.2) um and (+0.4, +0.4) um.Calculate numerical values of :

(i) Run in/out misalignment.

(ii) Rotational misalignment.

(iii) Translational misalignment.

(B) For a particular lithography process based on projection printing, the minimum resolution (l_m) is 0.5um and the depth of focus (DOF) is 1um. By placing a smaller aperture over the projection lens, the numerical aperture (NA) is reduced by a factor of 2, calculate the new values of l_m and DOF.