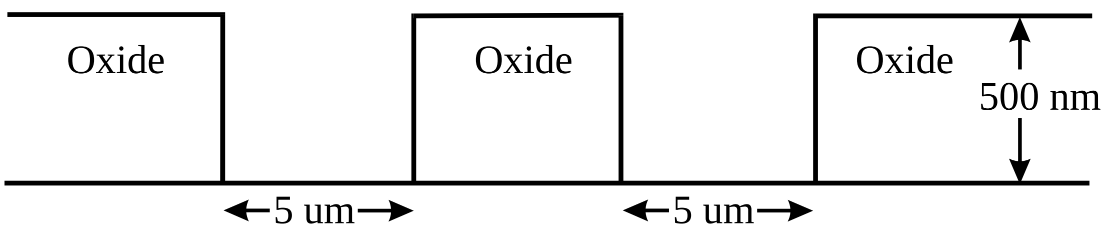
ENSC 495/851 mid Term (Mar. 27, 2012)

This test is OPEN BOOK: Time: 90 minutes
any book, notes and calculator may be used, but not a computer, iphone, itouch.
NOTE: Do 2 questions in part I 25 marks each for a total of 50 marks
Do 1 question in part II for 50 marks.
Test Total is 100 marks.

Section 1: Do 2 of these 3 questions: 25 marks each

(1) A wafer is oxidized and the pattern below is etched into the oxide. Then Boron is diffused into the n <100> wafer which has a uniform substrate doped at 2.5×10^{15} cm^{-3}. For the following calculate the junction depth, the surface concentration and show what you expect the doping pattern in the Si looks like at the point where the doping drops to 3.5×10^{16} cm^{-3}.
(1ai) It is doped with Boron constant source diffusion of 3×10^{18} cm^{-3}.for 40 minutes at 1000°C (13 marks)
(1aii) It is dopend with Boron limited source diffusion of $Q = 1.2 \times 10^{11}$ cm^{-2} also for 40 minutes at 1000°C (12 marks)
Assume the Diffusion coefficients follow the usual formula and have an activation energy of E_a and a D_0. as stated in the notes.
(1b) For the same wafer a 2 mA ion implanter beam of 50 KeV B^+ ions is done instead of the diffusion. For these use the implant charts from your notes or calculations. How long does it take to implant a dose of 10^{16} atoms/cm^2 .
(1bi)What is the peak concentration of dopant?
(1bii) At what depth will the peak occur concentration occur?



Silicon Substrate <100>

(2a) Sketch on three axis plots the following crystal planes:
- (i) (122) (2 marks)
- (ii) $(1\bar{1}1)$ (2 marks)

(2b) Wafers supplied often have the terms CZ and FZ applied to them. What do these mean and explain the difference in production of wafers between them? Give two advantages of each type. Which of these two would appear for the largest size of wafers? (8 marks)
Substrates for sputter deposition are placed 30 cm below the target. Sputtering is performed using argon.
(2c) What type of sputtering is used if the target (and material being deposited) is Aluminum and alternatively if the target is silicon dioxde and why? How does the plasma shape look for each (7 marks each)
(2d) Find the argon pressure in microns at which the mean free path in the gas becomes equal to the target substrate distance (molecular diameter = 0.286 nm for Ar) (6 marks)

(3) Consider an oxide film 1.0 microns thick sitting on a Silicon substrate. You want to etch 4 micron wide oxide lines (width at the top). Etching is to done with BOE at 100 nm/min. Assume also the BOE attacks silicon at 2 nm/min.
(3a) What is the width of resist need for to get that line width? (3 marks)
(3b) What is line width at the substrate? Draw a cross section of the structure after eteching. (7 marks)
Now assume the film thickness varies by ± 10% over the wafer
(3c) What is the width of resist need for to get the desired line width? (3 marks)
(3d) What is line width at the substrate? Draw a cross section of the structure after eteching. (10 marks)
(3e) What colour is photoresist used in the lab and what strips it? (2 marks)

Section 2: Do 1 of these 2 questions: 50 marks each

(4) The illustration below show a process called LOCOS for Local Oxidation of Silicon. In this a thin film of Silicon Nitride is depostied and patterned into protective pads, in this case 20 microns wide. Silicon Nitride does not let the oxide diffuse through it, so that when an oxidation process is done the oxide only grows in the areas not protected by the silicon nitride, and no oxide grows under the nitride.

(4a) Choose a time, temperature combination that will grow 500 nm of wet oxide in the uncovered Si areas in under 80 minutes. Use the chart from the notes for this. (5 marks)

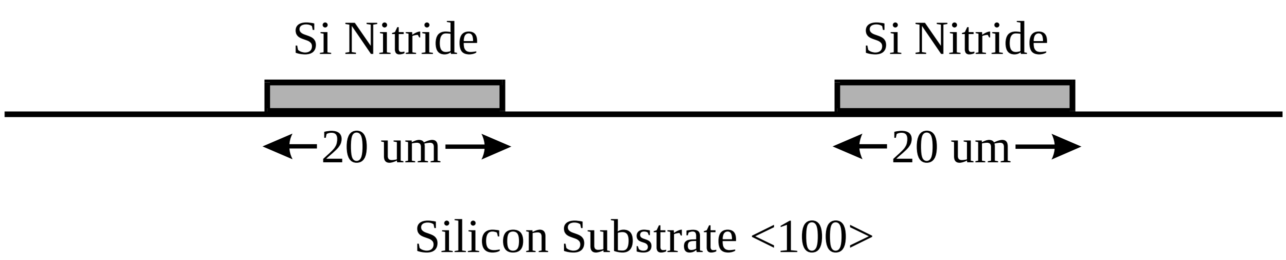
(4b) Sketch what the resulting structure looks like in cross section, assuming that oxide does not grow under the nitride area. Be sure to show where the Si/oxide and nitride/Si boundries are (5 marks)

(4c) Now assume the nitride is stripped leaving bare silicon there, without affecting the other oxide. Now choose a time, temperature combination that will grow 250 nm of wet oxide in the uncovered Si areas in under 80 minutes. Use the chart from the notes for this. (5 marks)

(4d) What is the resulting oxide thickness of the field area (outside the etched area). Now do the same calculations using both A & B coefficents from the notes. (10 marks)

(4e) Sketch the resulting structure, showing the oxide/Si interface position at each point, and oxide surface. Note thickness and positions of one layer relative to the other. Show the original Si surface position on the same drawing. (15 marks)

(4f) If the same structure had instead been exposed to 1.5 hours of dry oxidation at $1100^{o}C$ what would be the oxide thicknesses in the field and opened areas. Sketch the resulting structure as in part (e). Assume the continued growth of an oxide is not affected by whether the original oxide was wet or dry. (10 marks)



(5a) In IC fabrication name the type of optical photolithographic equipment is used most often for structures larger than 3.0 microns? What type is used for structures 2 microns or less? In which type will the masks last longer and why? (7 marks)

(5b) Name the two types of photoresist. What is the basic process that causes the image to be developed in each case. Do not give details, just a one sentence description of how the resist is changed during exposure and what happens the exposed/unexposed areas during development. (11 marks).

(5c) Sketch how the 1st and 2nd layer alignment structures are aligned to each other when the 2nd mask is a light field one. Do the same for a 2nd mask of the dark field type. (7 marks)

(5d) Photoresist is spun on a wafer and lines are to be defined that are 0.7 microns wide. The photoresist is 1 micron thick. If the development rate of this photoresist is 15 nm/sec when exposed to 100 mJ/sq cm, and 0.2 nm/sec unexposed. What is the exposure time for perfect development. Calculate the width of the photoresist line at the Si surface and the resist surface for this exposure. How much is the surface of the resist removed during this time? Sketch the expected profile. (10 marks)

(5e) Assume there is a 15% variation in the resist thickness across the wafer and a 20% variation in the development rate, what is the exposure time you then want to use? Repeat part (d) but for the worst case conditions with this new development condition. (15 marks).