

Birla Institute of Technology and Science, Pilani
MEL G611 IC Fabrication Technology
Mid Sem Test Closed Book

Time: 1.5 hrs

Date: 13.10.2017

M.M: 60

You may need: Atomic weight of Si = 28.09 g/mol, Atomic radius of Si = 0.118 nm, density of Si = 2.33 g/cm³, atomic weight of SiO₂ = 60.08 g/mol, density of SiO₂ = 2.21 g/cm³, gas constant R = 8.31 J/mol.K, Distribution coefficient (k₀) of B = 0.8, P = 0.35, As = 0.3, Ga = 8*10⁻³, Sb = 0.023, Al = 2.8*10⁻³

Q-1

(a) You have two lightly doped Si wafers as shown in the figure 1. You have performed a thermal oxidation on both wafers under identical conditions and then measure the oxide thickness. Which wafer will have a thicker oxide? Explain.

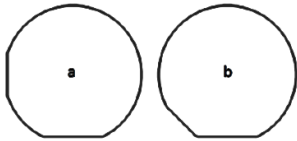


Figure 1: Silicon Wafers

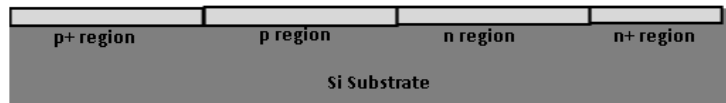


Figure 2: Si substrate

(b) Give the definition of a Clean room. What do you mean by a Class 100 clean room?

(c) Draw the thermal oxidation profile for the Si substrate shown in the figure 2. Assume that grown oxide follows the linear rate constant of the Deal-Grove model.

(d) If the shape drawn in the figure 3 was used as a mask for Si etching, draw a top and side view of what the hole would look like if allowed to go until only (111) planes are exposed. Assume that the Si wafer is (100) oriented.



Figure 3: Mask for Si etching

(e) One micron of silicon dioxide is grown on a wafer. You subsequently determine that the oxidation step has caused the doping concentration near the surface to rise (compared to the bulk). Explain why this has happened, and what this means about the segregation coefficient and the diffusion of this dopant in SiO₂. [Q-1(a-e) each 2M]

(f) Two identical p-type Si wafers ($N_A = 10^{17} \text{ cm}^{-3}$) have a phosphorus pre-deposition of Q_0 applied by ion implantation.

(i) A junction is created at a depth of 0.4 μm by heating the first wafer for 40 min at 1000°C. You want the junction depth at 0.2 μm . How long a time would you heat treat your second wafer if you used the same temperature?

(ii) Now, sketch the carrier concentration vs depth from part a) and label all the curves. [4M]

(g) Suppose you have to meet a fairly tight resistivity specification during CZ crystal growth under rapid stirring condition. (a) Would you prefer to grow N type or P type crystals? Why? (b). What dopant would you use in growing N-type crystals? Why? [4 M]

PTO

Q-2 Suppose we perform a solid solubility-limited predeposition which introduces a total of Q impurities per square cm.

(a). If this predeposition was performed for a total of t minutes, how long would it take (total time) to predeposit a total of $3Q$ impurities into a wafer if the predeposition temperature remained constant?

(b). Derive a simple expression for the drive-in (Dt) which would be required to drive the initial predeposition of Q impurities sufficiently deep so that the final surface concentration is equal to 1% of the solid solubility concentration. This can be expressed in terms of (Dt) predeposition and the solid solubility concentration C_s . Final relation should be in terms of drive-in (Dt) and (Dt) predeposition. [10M]

Q-3 The graph shown in the figure 4 is available for Wet thermal oxidation of $\langle 100 \rangle$ Si wafers. Suppose Si wafer has an initial oxide thickness of $0.5 \mu\text{m}$. With Wet-Oxidation at 1000°C , what is the required oxidation time to obtain a total thickness of $1 \mu\text{m}$? [5M]

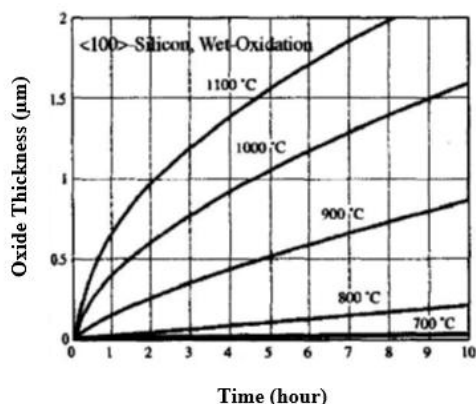
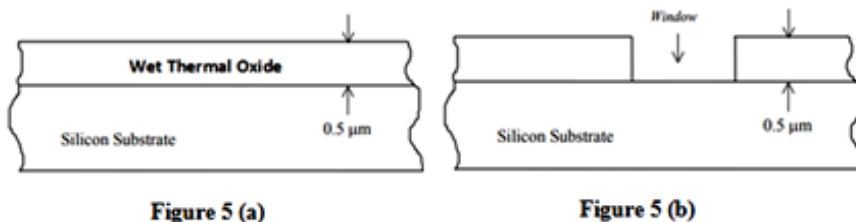


Figure 4: Wet oxidation graph



Q-4 You have grown a $0.50 \mu\text{m}$ thick field oxide on a lightly doped (100) silicon substrate through wet oxidation as shown in the figure 5 (a). Suppose that in a later processing step, by means of some unspecified patterning and etching process a window is opened in the specific area as shown in the figure 5 (b). Then an additional $0.05 \mu\text{m}$ of oxide is grown in the open area. If dry oxidation is used and the oxidation temperature is 1000°C to obtain a higher quality Si/SiO₂ interface, how long will this process take and how much will the thickness of the field oxide be changed due to the additional oxidation?

Assume that the Deal-Grove rate constants at 1000°C are given by: $B/A = 1.244 \times 10^{-5} \mu\text{m}/\text{sec}$ and $B = 2.890 \times 10^{-6} \mu\text{m}^2/\text{sec}$. [7M]

Q-5 (a) Derive the expression density of atomic packing in (111) plane of Si crystal.

(b) A resistor is to be fabricated using p+ diffusion on a lightly doped n-type $\langle 100 \rangle$ Si wafer. Describe your process flow and draw the cross-sectional view of the device after each process steps. [10M]

Q-6 Consider a CZ crystal growing process:

(a) A boron doped crystal is required to have a resistivity of $25 \Omega \text{ cm}$ approximately when 50% of the crystal is grown, i.e., halfway down the ingot from the top or seed end. Assuming that a 100 kg charge of pure silicon is used and neglecting any silicon added to the melt by the seed, what is the required initial concentration of boron in the melt? Assume that the melt is well stirred, the distribution coefficient for boron is 0.72, and that the hole mobility is $480 \text{ cm}^2/\text{volt-sec}$ and the electron mobility is $1250 \text{ cm}^2/\text{V sec}$. Note [$\rho = 1/q\mu_n n$ for a n-type semiconductor]

(b) If an unknown dopant has the same concentration as boron at the top of the ingot, but the concentration is 16.5% higher when 50% of the crystal is grown, i.e., halfway down the ingot, then assuming rapid stirring conditions, what is the segregation coefficient for the unknown dopant? [10M]