Ex/BBSUS/ ET-403/10

B.E. (ETC) Part-II 4th Semester Examination, 2010

Microelectronics

(ET-403)

Time : 3 hours **Full Marks : 70**

Answer any FIVE questions.

1. a) Discuss the Czocharlski technique for crystal growth. What is the significance of segreggation coefficient in such growth processes? Derive the expression for doping concentration in the solid at any instant of time during the growth process.

   b) Assuming that a 10 kg pure silicon charge is used, what is the amount of boron that must be added to get the boron-doped silicon to have a resistivity of 0.010 cm when one-half of the ingot is grown? Atomic weight of boron is 10.8 and density of silicon is 2.53 g/cm^3.

   c) Obtain the expression for the equilibrium density of vacancy at a temperature T. Calculate the vacancy density in silicon at 27°C and 1000°C if the energy of formation is 2.3 ev. [**8**+2**+4)**

2. a) Why is four probe essential to measure the resistivity of silicon?

   b) How can one estimate the type of a semiconductor? Explain the principle of operation. Can it be applied to any doping concentration of the semiconductor? Explain.

   c) If two metal contacts are placed acrose a p-n junction, such that the metal with the p-type semiconductor makes a non-ohmic contact and that with the n-type semiconductor makes an ohmic contact, plot the nature of the I-V characteristics of such a structure. Explain with the help of an equivalent circuit diagram.

   d) In silicon, the lattice constant is 5.43 A. Considering silicon to be a diamond cubic lattice structure

      (i) calculate the radius of a silicon atom,

      (ii) determine the density of silicon atoms in atom/cm^3,

      (iii) use the Avogadro constant to find the density of silicon. |2+2**+4**+6|

3. a) Prove that for small time of oxidation, the oxide growth rate is directly proportional to time and for larger times, the oxide growth rate varies with square root of time.

b) A bar and undoped (100) silicon sample is oxidized for 1 hour at 1200°C in dry 0_2. It is then covered and has the oxide removed over half the wafer. Next, it is re-oxidized in wet oxygen at 1200°C for 30 minutes. What is the thickness of the oxide in both the regions?
[For dry oxidation at 1200°C, A = 0.04 um, B = 0.045 um^2/hr, x = 0.027h.
For wet oxidation at 1200°C, A = 0.05 um, B = 0.72 um^2/hr]

c) Discuss the impact of segreggation coefficient in the redistribution of impurities during oxidation.

d) How is oxide thickness measured? What factors affect the quality of thermal oxide? [5+3+3+31

4. a) How dust particles interfere with the photo lithographic pattern transfer in IC technology?
If one exposes a 6-inch wafer for 5 minutes to an air stream under a laminar-flow condition at 30m/min, how many dust particles will land on the wafer in a class 100 clean room?

b) Discuss the relative advantages and disadvantages of contact printing and proximity printing technique.

c) What are the significances of contrast ratio and threshold energy of a photo resist in the lithography process? Conventional resists cannot be used for 248 mm or 193 mm lithography. Why?

d) Find the final yield for a nine-mask level process in which the average fatal defect density per cm^2 is 0.1 for four levels, 0.25 for the next four levels and 1.0 for the last level. The chip area is 50 sq. mm.

e) An optical lithographic system has an exposure power of 0.3 mW/cm^2. The required exposure energy for a positive photoresist is 140mJ/cm^2 and the negative photoresist is 9 **mj**/cm^2. Compare the wafer throughput for positive photoresist and negative photoresist. **|4+2+3+2+3|**

5. a) Obtain the expression of impurity distribution for drive-in diffusion.

b) Arsenic was predeposited by arsine gas and the resulting total amount of dopant per unit area was 10^{14} atom/cm^2. How long would it take to drive the arsenic in to a junction depth of I **um?** Assume a background doping of C_B - 10^{15} atoms/cm^3 and a drive-in temperature of 1200°C. For As diffusion, D_0 = 24 cm^2/sec and E_a = 4.08 eV.

c) What is epitaxy? What is the significant difference between diffusion and epitaxial growth?

d) Discuss briefly the epitaxial growth of a phosphorus doped silicon layer on a p-type substrate. |6+3+3+**2|**

6. a) What is the basic mechanism of ion implantation? Why it is preferred over diffusion? Explain with an example from the VLSI technology.

   b) What are the mechanisms of ion stopping?
   If a 100 keV boron implants on a 100 mm silicon wafer at a dose of 5 x 10^{14} ions/cm^{2}, calculate the peak concentration and the required ion bean current for 1 minute of implantation [The projected range and straggle are 0.31 and 0.07 um respectively].

   c) If a 50keV boron ion is implanted into the silicon substrate calculate the damage density. Assume silicon atom density is 5 x 10^{22} atoms/cm^{3}, the silicon displacement energy is 15eV, the range is 2.5 mm and the spacing between silicon lattice plane is 0.25 mm. The projected range and straggle are 0.2 and 0.05 um respectively. |**4+4**+6|

7. a) Prove that the mean free path of a molecule in a plasma environment is inversely proportional to the pressure.
   Why the pressure in the chamber cannot be made too low or high in plasma assisted etching or deposition?

   b) The electron densities in RIE and HDP systems range from 10^{9} to I0^{,0}cm~^{3} and 10^{11} to 10^{12} cm^{-3} respectively. Assuming the RIE chamber pressure is 200mTorr and HDP chamber pressure is 5mTorr, calculate the ionization efficiency in RIE reactors and HDP reactors at room temperature.

   c) What is junction spiking effect? How it can be reduced?

   d) Why high current densities cause device failure due to electromigration? To avoid electromigration problems, the maximum allowed current density in an aluminium runner is about 5 x 10^{5} A/cm^{2}. If the runner is 2mm long, 1 um wide and 1 um thick, and if 20% of the runner length passes over steps and is only 0.5 urn thick there, find the total resistance of the runner if the resistivity is 3x I0~^{6} *Clem.* Find the maximum voltage that can be applied across the runner. **[3+3+3+5]**

8. a) Why is surface micromachining more IC compatible compared to bulk micromachining?

   b) Discuss with process flowchart the steps for fabrication of a standard piezoresistive pressure sensor by bulk micromachining.

   c) Define gage factor and piezoresistive coefficient and derive the relationship between them. **[2+8+4]**