Data Provided: None

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Autumn Semester 2013-2014 (2 hours)

Integrated Circuit Technology

Answer **THREE** questions. **No marks will be awarded for a solution to a fourth question.** Solutions will be considered in the order that they are presented in the answer book. Trial answers will be ignored if they are clearly crossed out. **The number given after each section of a question indicates the relative weighting of that section.**

1. a. Explain what is meant by ionisation energy. Draw a diagram that indicates a deep state in the bandgap of a semiconductor. **(2)**

b. Show by means of a 3D diagram a wurtzite structure. Name two semiconductors which have the wurtzite structure. Explain if they are polar or not. Indicate the atoms in the stacking sequence of this structure on the 3D diagram above. **(5)**

c. What is an *E-k* diagram ? How can you tell a direct from an indirect semiconductor based on the *E-k* diagram? How would you use this knowledge to practically determine if a semiconductor is direct or indirect ? **(3)**

d. How would you differentiate the behaviour of the resistivity of a metal and a semiconductor ? Explain two methods to measure the resistivity of a sample: **(3)**

e. Explain the Hall effect. Name one use of the Hall effect. **(2)**

f. How would you expect defect concentration to be distributed in an ingot of high purity silicon ? Explain Why. **(5)**

2. a. Describe 3 key differences between the Czochralski and floatzone techniques for crystal growth. Show diagrams as necessary **(6)**

b Explain the key features of epitaxial growth via CVD and MOCVD. Give the main difference between these two techniques with an example of a key reaction in each case. **(8)**

c A silicon ingot is grown by the Czochralski technique. The ingot is doped with Arsenic whose segregation coefficient in Si is 0.3. If C_0 is the initial concentration of the impurity in the melt, C_s is the final concentration of the impurity in the crystal, x is the fraction of melt solidified and k_0 is the impurity segregation coefficient, then, given that

$$C_S = k_0 C_0 (1-x)^{k_0 - 1}$$

Calculate the fraction of the melt solidified when the concentration of Arsenic in **(6)**

the ingot has risen by a factor of 30 from its initial value.

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3. **a.** State what is meant by dry and wet oxidation. Explain the reaction kinetics of an oxidation process. How is it possible to modify the reaction rates of oxidation? **(5)**

b Starting from a basic p-type substrate, show diagrammatically the most important steps in a CMOS process flow consisting of adjacent p and n MOS devices. **(10)**

c Explain diagrammatically what is meant by lift-off technique. **(5)**

4. **a** CVD is used to grow a silicon epitaxial layer upon a silicon substrate at a temperature of 1250 ºC. If the layer growth rate is 0.5 µm/min and the substrate is heavily doped with boron, deduce by calculation whether autodoping of the layer would be expected to be a problem? You can assume that the activation energy for boron diffusion in silicon (E_a) is 3.46 eV, the boron diffusion pre-exponential factor (D_0) is 0.76 cm^2/s and Boltzmann's constant (k) is 8.62×10^{-5} eV/K. **(6)**

b Transition element impurities are detected in a batch of wafers after epitaxial layer growth. Describe how the unwanted impurities may be removed from device regions by the process of external gettering. **(9)**

c Give 5 minimum requirements of the kind of material which will be required to replace Silicon in future microelectronics. **(5)**