The University Of Sheffield.

Data Provided: Lognormal probability plotting paper, graph paper

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Autumn Semester 2010-2011 (2 hours)

EEE6008 Reliability and Failure

Answer **THREE** questions. **No marks will be awarded for solutions 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 numbers given after each section of a question indicate the relative weighting of that section.**

1. a. A number of defects and contaminants can be incorporated during the fabrication of electronic and optoelectronic devices. Briefly describe two examples of defect or contaminant that can be introduced during:

i) Photolithography **(2)**

ii) Plasma processing **(2)**

iii) Ion implantation **(2)**

b. Describe two effects of metal contamination in semiconductor devices. **(2)**

c. Provide an example of a [0D], [1D], [2D] and [3D] defect. **(2)**

d. Draw and label a basic schematic diagram of a scanning electron microscope (SEM). **(4)**

e. Describe three methods that can be employed within SEM to characterise defects in semiconductor devices. **(6)**

2. **a.** State what is meant by reliability and why it is important in electronic devices **(2)**

b. Plot the bathtub failure rate curve and label the three distinct regions, giving two likely reasons for failure in each region. **(4)**

c. State which distributions can be used to model each of the three regions of the curve. **(2)**

d. A reliability qualification exercise was conducted applying accelerated aging at 60, 70 and 85ºC. 10 devices were life-tested at each temperature.

Failure times determined for the 10 devices operating at 85ºC are shown in Table 1.

Device number	Lifetime (hours)
1	16,200
2	13,000
3	9,500
4	24,500
5	14,750
6	11,200
7	7,500
8	20,500
9	30,000
10	18,500

Table 1. Lifetime of 10 devices at 85ºC.

i) Rank the data using Bernard's approximation **(2)**

ii) Plot and label the reliability data on the lognormal probability plotting paper provided. **(3)**

iii) Extract the shape parameter, σ, and suggest the main cause of failure in these devices. **(2)**

iv) Extract the MTTF (50% cumulative failure) **(1)**

v) Similar analysis was performed at 60 and 70ºC yielding MTTF of 28,300 and 22,000 hours respectively.

Through use of an Arrhenius plot, created on the graph paper provided, determine the activation energy and use it to estimate the MTTF for these devices at 40ºC. In order to accurately display the Arrhenius plot over the region 60 to 85ºC please assume a value of 8.6 for the scaling factor, *A*.

(Use $k = 8.617\times10^{-5}\text{eVK}^{-1}$). **(4)**

3. **a.** Briefly describe what is meant by electrostatic discharge (ESD) and electrical overstress (EOS), and summarise the key differences between them. **(4)**

b. A pulse of 4700V is discharged from a person into a p-n junction. The junction area is $5\times10^{-7}cm^2$ and the resistance is 25Ω. Assume that the voltage across the device is negligible compared with that of the ESD pulse.

i) Draw the equivalent circuit for the human-body model commonly used for simulating ESD. **(2)**

ii) Over what time span does the discharge occur? **(2)**

iii) What is the maximum current? **(2)**

iv) Calculate the power density discharged through the diode **(2)**

c. High-energy particles such as α-particles, x-rays and gamma-rays can cause radiation damage in MOSFETs, GaAs FETs, laser diodes and optical fibres. Explain how each of these failures are caused. **(8)**

4. **a.** Explain how Fick's law can describe the migration of atoms in a matrix under a concentration gradient driving force, and outline the factors influencing the diffusion coefficient. **(3)**

b. Describe how atomic diffusion takes place. In your answer, place diffusion mechanisms in the order of energy required for the process to occur. **(3)**

c. Describe how the Kirkendall effect can cause reliability problems at the interface between two dissimilar materials. **(3)**

d. The Kirkendall effect can lead to the failure of Au bonds made to Al bondpads upon Si. Briefly describe three other possible types of wire bond failure. **(3)**

e. Electromigration describes the migration of metal atoms in a conductor through which large currents flow. Sketch and briefly describe three sites at which electromigration may occur. **(6)**

f. Black's equation describes the relationship between MTTF and both current density and temperature. Draw a schematic plot of the MTTF as a function of current density, labelling important features of the plot. **(2)**

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END OF PAPER