Data Provided: graph paper

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Autumn Semester 2012-13 (2.0 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. Suggest the most appropriate characterisation method for investigation of the following degradation processes in plastic encapsulated electronic devices. Your answers should provide justification for using this method rather than potential alternatives:

i) Gold wire displacement
ii) Intermetallic formation under ball bonds
iii) Popcorn cracking
iv) Electromigration of conductor tracks under a SiO_2 layer **(10)**

b. Evaluate the relative merits of two possible methods for characterising crystal defects in pn junctions using a scanning electron microscope (SEM), and outline their operation. **(5)**

c. Starting with initial optical microscope observations, descibe a potential process flow for detecting and characterising an unknown failure in a packaged electronic component such as plastic encapsulated ICs or laser diodes in a hermetically sealed butterfly package. **(5)**

2. a. Describe what is meant by Frenkel and Schottky defects and how they might form in a compound structure (you may use diagrams to help). **(4)**

b. An experiment was performed in order to determine the concentration of point defects in a pn diode. The leakage current was recorded as function of device temperature in Table 2.1.

Temperature (K)	Leakage current (A)
500	3.35×10^{-4}
400	4.54×10^{-5}
300	2.26×10^{-6}
200	5.60×10^{-9}
100	6.31×10^{-16}

Table 2.1 Leakage current recorded as a function of temperature

i) Extract the activation energy from the data presented in Table 2.1. Graph paper is provided for your use. **(2)**

ii) Use this value to deduce the concentration of vacancies at 1000K. **(2)**

c. Describe how impurities differ to dopants, and how such species can influence the electronic properties of semiconductor materials. Please use bandgap diagrams to help your discussion. **(6)**

d. Outline why extrinsic interstitial impurities are typically less prevalent than substitutional impurities. **(2)**

e. Metal impurities can be introduced during the fabrication of electronic devices.

i) List 3 origins of metal impurities in electronic devices.

ii) Choosing one origin of metal impurity from your list in i), briefly outline how the impurity can be introduced, what its effects can be and how such impurities might be avoided. **(4)**

3. The following figure plots the results taken from reliability analysis of a set of diodes operated under accelerated life-test at 80°C:

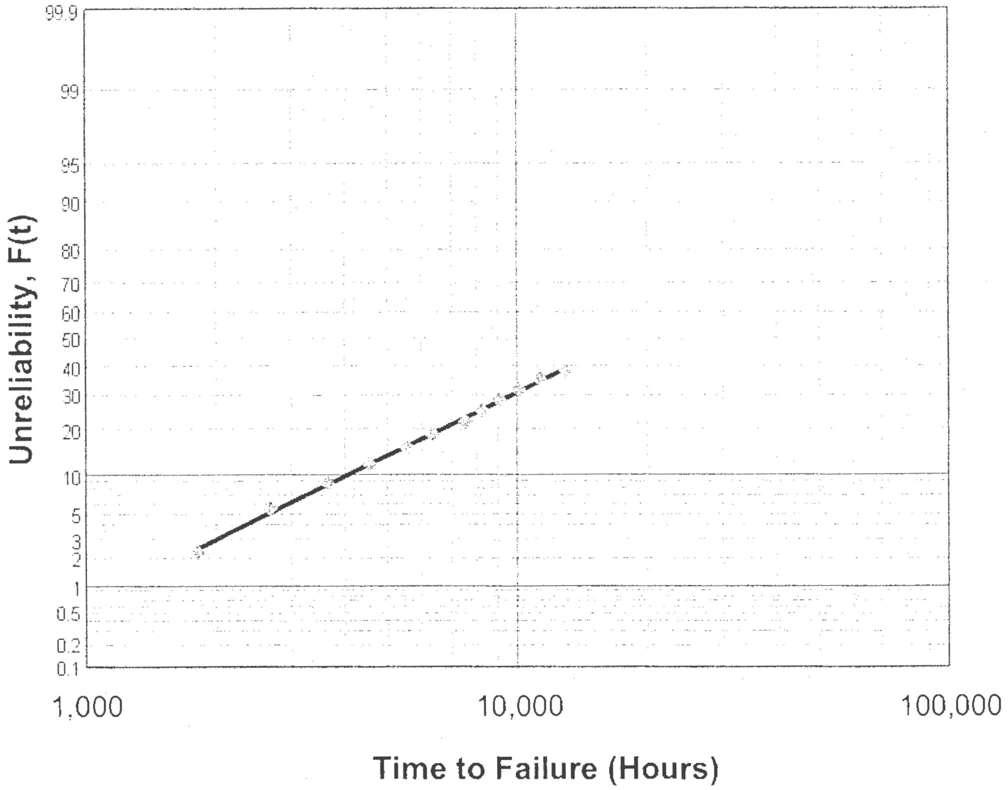

Figure 3.1 Failure probability plot for a batch of diodes at 80°C

From Figure 3.1 above,

a. Estimate the MTTF (time to 50% cumulative failures). **(1)**

b. What is the probable cause of failures in these devices? **(3)**

c. It is hoped that the diodes could operate at 100°C for >8,000 hours for use in a particular application. Given the life-test data shown and the MTTF of 32,000 hours at 60°C:

 i) Deduce the acceleration factor and use this to show that the activation energy, $E_a \sim 0.29$eV. **(4)**

 ii) Use this value of E_a to determine the MTTF at 100°C and discuss the probability that diodes will still work after 8,000 hours operation at this temperature. Use k=8.617 × 10^{-5} eVK^{-1} and assume a scaling factor, A=1. **(4)**

d. Using your estimation of MTTF in part c, predict the probability of device failure between 8,000 and 10,000 hours at 100°C if you were to now base your calculations on an exponential distribution. **(4)**

e. Parallel systems can be used to improve overall system reliability. Evaluate the trade-off between cost and reliability for a parallel system by demonstrating the percentage comparative reliability over a single component as a function of component number for 5 identical components with 75% reliability. **(4)**

4. a. Aluminium can be used as an Ohmic contact to silicon. Describe the main reliability issue resulting from direct deposition of Al onto Si, using a sketch, or sketches, to demonstrate the failure mechanism at the Al-Si interface. **(4)**

b. Explain why use of an Al-Cu(4wt%)-Si(1.7wt%) metallisation scheme could offer improved contacts to Si over the basic Al-Si contact above. **(2)**

c. Discuss the additional reliability issues that might arise instead when using this metallisation scheme. **(4)**

d. Electromigration is a major failure mechanism in interconnects when large current densities are applied. Give two examples of interconnect degradation due to electromigration and outline four possible strategies to minimise electromigration in ICs. **(5)**

e. Describe the process of electrolytic electromigration and explain what conditions are necessary for it to occur. **(3)**

f. Explain how reduced temperatures can lead to atmospheric corrosion without the presence of a bulk electrolyte. **(2)**

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