The University Of Sheffield.

**Data Provided: Weibull probability graph paper**

## DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

**Spring Semester 2006-2007 (2 hours)**

**Reliability and Failure 6008**

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 list of dielectric parameters is provided in the table 1.

| Materials | Young's modulus, E (GPa) | Coefficient of thermal expansion, $\alpha$ ($\times 10^{-6}$/K) | Poisson ratio, $\upsilon_f$ |
|---|---|---|---|
| $SiO_2$ | 94 | 0.5 | 0.25 |
| PSG | 79 | 2 | 0.2 |
| BPSG | 120 | 2 | 0.2 |
| SiN | 158 | 2 | 0.25 |
| Al-Si | 60 | 27 | 0.33 |
| Si | 160 | 4 | 0.22 |

**Table 1**

A chemical vapour deposition system was used to deposit epitaxial Si films, using a reaction of a chlorinated silane, on substrates heated to 1100$^o$C. However the substrate heater is non-uniform and was found to lead to the wafer edge being 195$^o$C higher in temperature than the wafer centre. Calculate the amount of stress developed at the edge relative to the centre. Is the stress tensile of compressive? **(4)**

**b.** In the fabrication of ICs SiN film is deposited on a Si wafer as a dielectric layer. SiN is usually deposited at 300$^o$C and allowed to cool to room temperature.

i) Calculate the thermal stress developed in the SiN film. **(3)**

ii) Is the SiN film under tensile or compressive stress? Sketch and label the film/wafer interface under stress. **(3)**

**c.** i) Describe the origin of electromigration in conductors and give two examples of conductor degradation caused by electromigration. **(5)**

ii) What is the Blech effect? Discuss how the Blech effect can influence electromigration in conductors. **(5)**

**2.** **a.** i) List two Scanning Electron Microscope (SEM) techniques that can be used to characterise atomic species and explain how each technique works. **(6)**

ii) Explain how a SEM can be used to locate short-circuits or open circuits in interconnects. **(3)**

**b.** In the fabrication of a Si diode, a gold bond pad is deposited on a 0.03 cm thick Si substrate. A layer of 0.1 cm thick polymer is deposited on top of the bond pad as a protective layer. As part of a failure analysis the diode is irradiated with a 20 keV x-ray beam. The absorption coefficients at 20 keV for the polymer, Si and gold are 5 $cm^{-1}$, 10.2 $cm^{-1}$ and 1510 $cm^{-1}$ respectively.

i) Outline the principles of x-ray radiography. **(4)**

ii) Give two examples of failure mechanisms that can be identified using the x-ray radiography. **(2)**

iii) Using a sensible value for the thickness of the gold bond pad, show how the x-ray radiography can be used to detect an open circuit in the bond pad. **(5)**

**3.** **a.** i) What are the possible failure mechanisms during the die attachment stage of IC packaging? **(3)**

ii) Suggest 3 possible types of wire bonding failure mechanism and provide one possible cause for each failure mechanism suggested. **(6)**

**b.** i) Describe the origin of popcorn cracking in plastic encapsulation. **(5)**

ii) Suggest two ways of detecting failure mechanisms caused by popcorn cracking. **(2)**

iii) List four other failure mechanisms in plastic encapsulated ICs. **(4)**

**4. a.** The Weibull probability density function is given by

$$f(t) = \frac{\beta t^{\beta-1} \exp\left[-\left(\frac{t}{\eta}\right)^{\beta}\right]}{\eta^{\beta}},$$

where $\eta$ and $\beta$ are constants. A batch of 70 transistors was tested and 7 of the transistors were found to fail after 120, 800, 920, 1150, 649, 395 and 705 hours, respectively.

i) Rank the data and calculate the median ranking percentage using $F_i(t) = \frac{i-0.3}{N+0.4} \times 100$, where *i* is the rank and *N* is the total number of samples. **(4)**

ii) Plot and label the time to failure data on the Weibull probability paper provided. **(4)**

iii) Determine the values for $\eta$ and $\beta$. **(2)**

iv) Find the mean time to failure of the transistors and predict the percentage of transistors that will have failed after 3000 hours. **(2)**

v) What is the trend of the failure rate of these transistors? Given this trend, suggest two possible failure mechanisms in these transistors. **(3)**

**b.** A value of $\beta = 0.5$ was extracted from the failure data for a batch of photodiodes which can be described using the Weibull distribution. Discuss the trend of the failure rate for these photodiodes and suggest possible reasons for this type of failure mode. Outline possible strategies for these photodiodes to reduce or prevent the observed failures. **(5)**

**CHT- / PJP-**