The University Of Sheffield.

Data Provided: Lognormal probability graph paper

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Autumn Semester 2007-2008 (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. Explain the key differences between electrical overstress and electrostatic discharge (ESD). **(4)**

b. A pulse of 2500 V is discharged from a person into a pn diode with a resistance of 10Ω. Assume negligible voltage drop across the photodiode and the human-body model is valid.

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

ii) Calculate the time constant of the discharge and estimate the time span over which the discharge occurs. **(3)**

ii) Calculate the average power dissipated by the diode over the discharge period. **(6)**

c. Consider a MOSFET with a gate oxide area of $1\mu m^2$. The gate is connected to a square antenna with an area of $1600\mu m^2$. In a subsequent fabrication stage using plasma etching a current density of $10mA/cm^2$ was induced in the antenna. What current is supplied to the gate oxide? Discuss the effect of this current on the MOSFET? **(5)**

2. **a.** Al can provide very good ohmic contact on Si devices. However depositing Al directly on Si is not acceptable in IC manufacturing. Describe the main reliability issue and provide examples of failure mechanisms at the Al-Si interface. **(4)**

b. It is a common practice to use Al-Cu-Si metallisation scheme on Si devices.

i) Explain the reasons for incorporating Si and Cu in this metallisation scheme. **(2)**

ii) Discuss the disadvantages of using this metallisation scheme. **(4)**

c. SiO_2 is used as a protective layer to minimise corrosion and to prevent mechanical damage to the metal contacts and interconnects in ICs.

i) What are the advantages and disadvantages of adding phosporus into SiO_2, in terms of reliability of ICs? **(2)**

ii) Give another example of failure mechanism of metal contacts and interconnects that is related to SiO_2. Provide your reasons. **(3)**

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

3. **a.** High energy particles such as α-particles, x-rays and gamma rays can cause damage to semiconductors and insulators. An example of failure is soft errors in memory chips, in which the writing and erasing functions are not possible but reading is still possible.

i) Describe how radioactive elements in materials used in packaging and cosmic rays can affect the memory chips. **(6)**

ii) Identify the main challenge faced in designing reliability test for soft errors and outline two methods adopted to obtain reliability data for soft errors. **(5)**

b. Radiation damage is also known to occur in MOSFETs, GaAs FETs and laser diodes. Provide examples of failure in these devices and explain how high energy particles cause these failures. **(9)**

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

$$f(t) = \frac{1}{t\sigma\sqrt{2\pi}} \exp\left[-\frac{(\ln(t) - \mu)^2}{2\sigma^2} \right],$$

where σ and μ are constants. A batch of 60 laser diodes was tested at 250°C. After 1000 hours 7 of the laser diodes were found to have failed at 110, 90, 67, 160, 230, 180 and 45 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 Lognormal probability paper provided. **(4)**

iii) Obtain the values for σ and the mean time to failure. **(2)**

iv) Sketch the failure rate of these laser diodes. Suggest the most likely failure mechanism in these diodes. Provide reasons for your suggestion. **(5)**

b. A reliability test on a batch of transistors yielded a mean time to failure of 250,000 hours.

i) Based on an exponential distribution, predict the probability of failure after 1 year. **(3)**

ii) What is the probability of device failure between 8 and 10 years. **(2)**

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