The University Of Sheffield.

**Data Provided: List of Reliability Models**

**DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING**

**Autumn Semester 2008-2009 (2 hours)**

**Reliability and Failure EEE6008**

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.** **i)** Describe the drain avalanche hot carrier effect in MOSFETs and the associated degradation in device characteristics. **(4)**

**ii)** Why is this effect an important reliability issue in modern integrated circuits? **(2)**

**iii)** Discuss two methods of controlling hot carrier effects in MOSFETs. **(4)**

**b.** Breakdown of dielectric in MOSFETs is an equally important reliability issue in integrated circuits.

**i)** Describe how this occurs. **(3)**

**ii)** Briefly describe the most common failure mechanisms in thin oxide layers. **(2)**

**c.** In a reliability test of a batch of MOS capacitors the failure distribution was found to be bimodal, as illustrated in Figure 1.1. Discuss a possible failure mechanism in these capacitors and propose two prevention methods. **(5)**

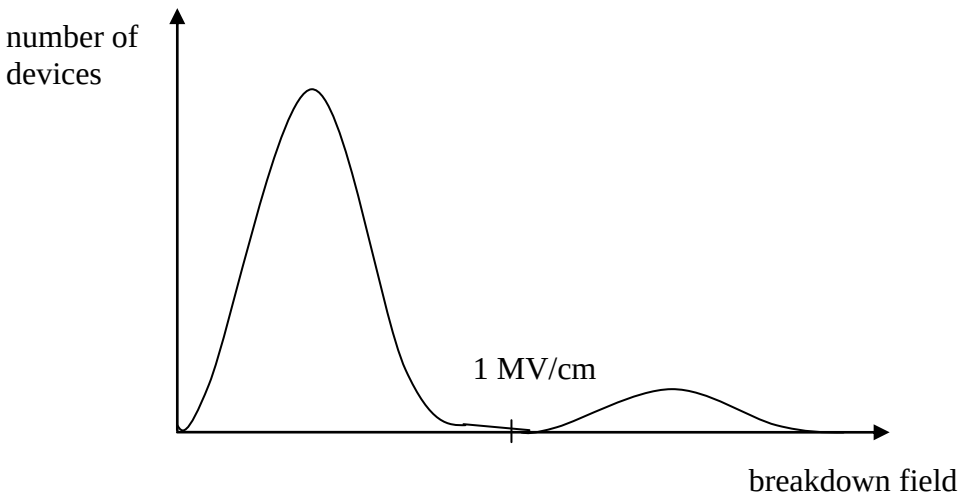


**Figure 1.1**

**2.**

**2. a.** **i)** Describe how a Scanning Electron Microscope (SEM) works. **(4)**

**ii)** Energy dispersive X-rays and catholuminescence are two possible SEM techniques that can be used for failure analysis. Explain how each of them works and provide an example of a failure mechanism that can be identified using these techniques. **(6)**

**b.** **i)** Briefly explain key stages in IC packaging using a plastic DIP. **(4)**

**ii)** Provide two failure mechanisms that can occur during wire bonding. What are the possible causes for the failure mechanisms provided? **(2)**

**iii)** Give a brief description of flip-chip bonding. Discuss the main advantages of using flip-chip bonding. **(4)**

**3. a.** List and explain three types of failure mechanism in lasers. **(6)**

**b.** Describe the key characteristics of electrostatic discharge (ESD) and explain how ESD occurs. **(4)**

**c.** Metal spiking was found to occur in a laser diode when the current density reaches $5\times10^{7}$ $Am^{-2}$. The laser diode has an area of $4\times10^{-8}$ $m^{2}$ and a resistance of 20Ω. Assume negligible voltage drop across the laser diode and that the human-body model is valid.

**i)** Describe how the human body model works. **(2)**

**ii)** What is magnitude o the human body voltage pulse required to cause the metal spiking? **(3)**

**d.** A number of laser diodes, manufactured under similar conditions to the laser diode in part (c), were subjected to further Human Body Model tests under forward and reverse bias. Diodes that failed showed short circuit behaviour. The results are shown in Figure 3.1.

**i)** Discuss the difference between forward and reverse bias failures that can be observed. **(3)**

**ii)** Have the laser diodes been sufficiently well designed to handle ESD if the largest current expected during operation is <2A? **(2)**

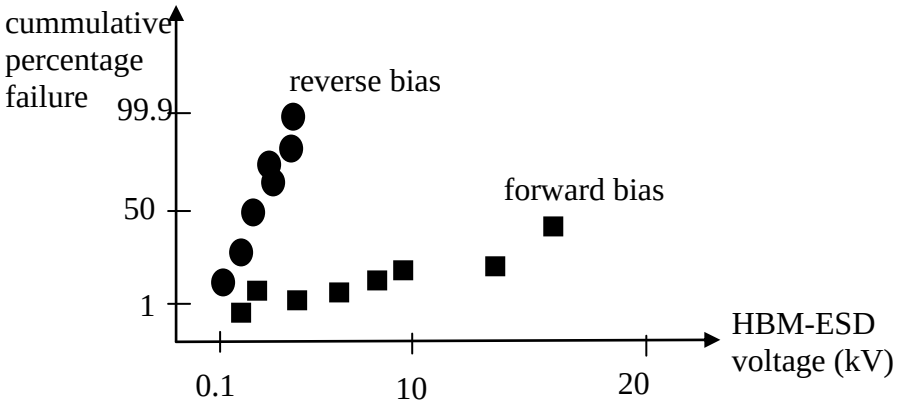


**Figure 3.1**

**4. a.** Consider an amplification system that consists of 3 amplifiers connected in series. The failure rate and mean time to failure (MTTF) for each amplifier are given below.

| Amplifier | Failure rate/$10^6$ hour | MTTF (hours) |
|---|---|---|
| 1 | 10.01 | 49000 |
| 2 | 7.20 | 48050 |
| 3 | 8.10 | 48500 |

**i)** Obtain the total failure rate of the system.

**ii)** Assuming an exponential distribution, find the reliability of this amplification system after 1000 hours.

**iii)** Compare the reliability of the system to that for an individual amplifier. **(4)**

**b.** A reliability test on a group of MOSFETs at 70°C has produced the failure data summarised in figure 4.1.

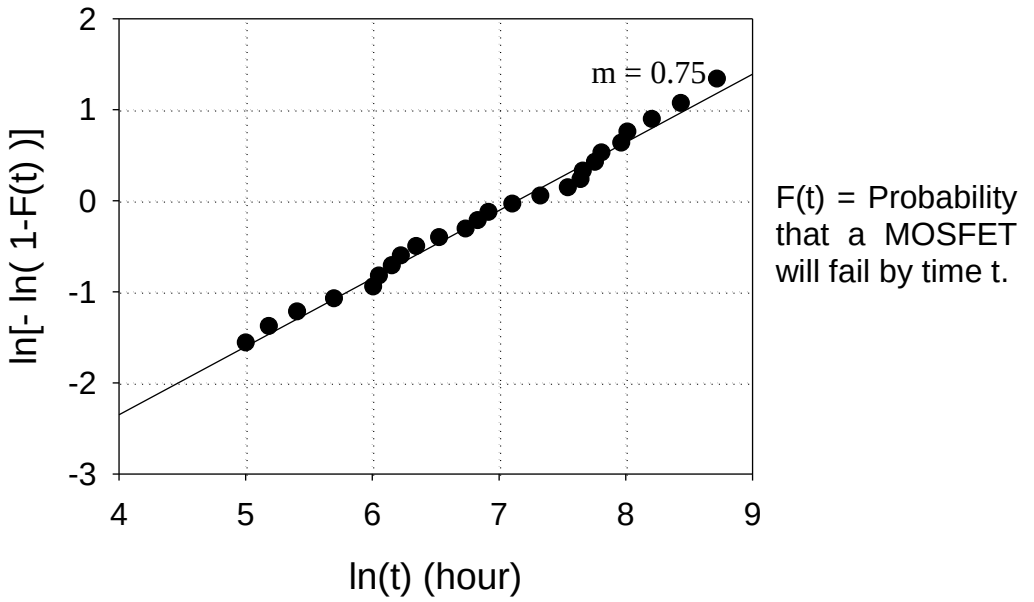


**Figure 4.1**

**i)** Estimate the percentage of devices that failed after 1000 hours and the median time. **(4)**

**ii)** The failure data can be fitted using a straight line with gradient of m = 0.75, as shown in Figure 4.1. Calculate the failure rate at 150 hours, 750 hours, 1000 hours and 3000 hours. **(6)**

**iii)** Based on your calculation in part (ii) sketch and label the failure rate. **(2)**

**iv)** Suggest a possible failure mechanism for the photodiodes that failed before the median time and provide a characterisation technique to analyse the mechanism suggested. **(4)**