SOLUTIONS EEE 6008, 205-06 (CHT)

Q1.a.i) F(t) = 1-exp(-0.003t)

At t = 100 hrs, F(100) = 1- exp (-0.003 (100)) = 0.259

t = 200 hrs, F(200) = 1-exp (-0.003 (200)) = 0.451

Probability of failure between 100 hours and 200 hours = F(200) – F(100)

= 0.451 – 0.259

= 0.192

ii) $\lambda(t) = \dfrac{f(t)}{1 - F(t)}$ f(t) is the PDF

$$f(t) = \frac{dF(t)}{dt} = \frac{d}{dt}[1 - \exp(-0.003t)] = 0.003\exp(-0.003t)$$

$$\lambda(t) = \frac{0.003\exp(-0.003t)}{1 - [1 - \exp(-0.003t)]} = 0.003 \quad \text{failure/ hour}$$

$\therefore$ $\lambda(t)$ is independent of time.

MTTF = $\dfrac{1}{\lambda_o}$ for exponential distribution.

$\therefore$ MTTF = $\dfrac{1}{0.003} = 333.33$ hrs.

b. i) The failure rate is given by $\lambda_p = \lambda_b \pi_T \pi_A \pi_Q \pi_E$ failures/10^6 hours

From specifications, $\lambda_b = 0.012$, $\pi_T = 1.4$, $\pi_Q = 8.0$, $\pi_A = 0.7$, $\pi_E = 0.5$.

$\therefore$ $\lambda_p = 0.012 \times 1.4 \times 0.7 \times 8 \times 0.5 = 0.047/10^6$ hours

(Any of)

iii)

<u>Advantages</u>

- Low cost
- Covers 19 major electronic devices categories
- Used successfully on thousands of military development efforts
- Readily available to system designers
- Military quality

<u>Disadvantages</u>

- Based on pessimistic failure rate assumption
- May be outdated
- Limited recognition with Telecommunication industry

(Any of)

Q.2.a) <u>Chemical Vapour Deposition</u>

- Thin film deposits deposited onto wafer.
- Oxidation and flaking of heaters.
- Impurities from precursor gases
- Particulars from gas-phase environment
- Poor adhesion dielectrics
- Roughened film topologies

<u>Ion Implantation</u>

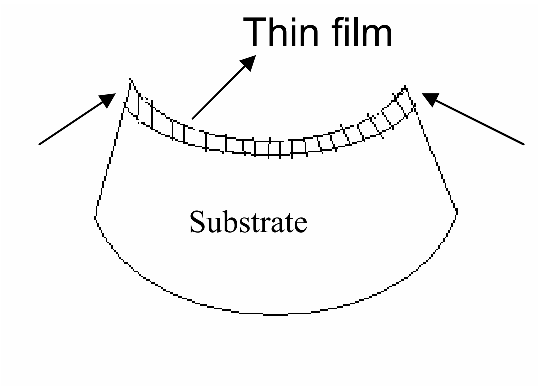
- Contamination due to ion species, Fe, Ni, Cr and Mo.

- Ion-beam-sputtered atoms from photoresists, vacuum hardware,
- Wrong ion may be implanted. Selection of ion species is based on m/q variations.
- Variation in the depth implantations leading to junction depth variations.

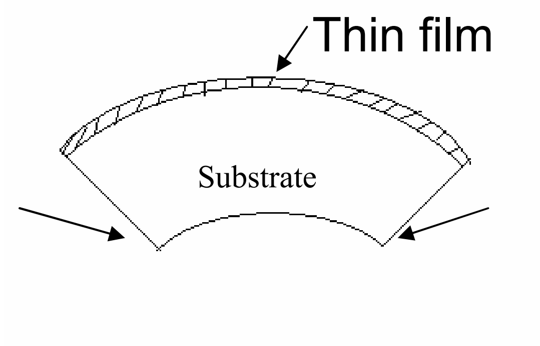
Plasma processing
- Build up of charge produced by plasma that leads to large current flowing through the dielectric causing wearout damage.
- Build up of charge leads to charge trapping.
- Film adhesion damage due to photon and chemical attacks.
- Damage to surface of semiconductor.

Lithography
- Defective mask, e.g., scratches, cracks.
- Leftover chemicals or photoresists.
- Clean room residues.
- Dust, water marks on mask.
- Contamination from photoresists/ etchants (if wet etching used).

Q.2.b) i)



Film under residual tensile stress



Film under residual compressive stress

ii) If $\alpha_f > \alpha_s$

$\alpha_f =$ Coefficient of thermal expansion of film

$\alpha_s =$ Coefficient of thermal expansion of substrate

Assume that film is stress free when deposited at a temperature T. When film cools to room temperature T_o, it contracts more than the substrate. In order to achieve mechanical equilibrium, the film stretches while the substrate contracts by equal amount to keep the overall length same in each. The film/substrate pair also needs to bend the substrate concave upward due to the tensile stress.

In analogous fashion compressive stress causes the substrate to bow (convex downward)

c) Vacancy defect occurs when an atom is missing from one of the lattice sites.

Interstitial defect occurs when an atom resides in a non-lattice site within the crystal.
In Si ICs these defects are few and therefore unlikely to cause failures. Defects introduced during processing are much grosser in scale and more likely to cause failures.

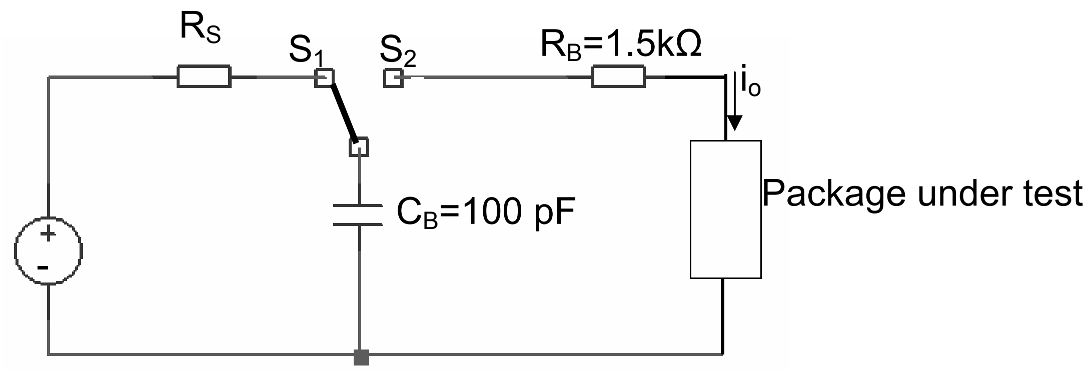
Q.3 a)

Electrical Over Stress (EOS)	Electrical Discharge (ESD)
• Voltage involved is usually tens to hundreds of volts.	• Voltage is usually thousands of volts
• Caused by excessive applied field, mishandling or voltage pulses	• Generated by static charge, signal
• Millisecond to microsecond	• nanosecond

b) i) High voltage pulses produced by electrostatic discharge can reduce large current of short duration. This large current leads to electromigration that causes spiking or shorting.

(Any of)
ii)
- Wear metal wrist straps, antistatic gloves and smocks.
- Use workbenches with table tops and mats that dissipate charge
- Use grounded tools, stool, and chairs
- Use antistatic bags, shielded or protective containers for ICs,
- Control humidity and suppress ionization at air.
- To connect damping elements/ over voltage protection between critical points and ground of devices
- Incorporate shunt capacitors or series inductor filters

c)

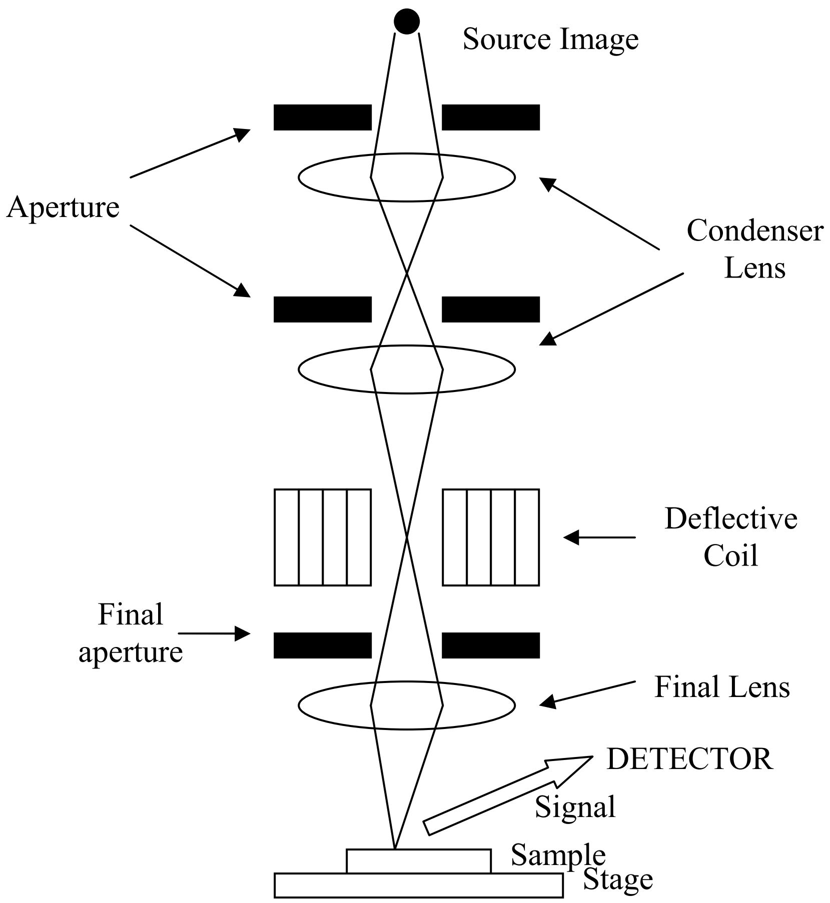


d) i) V_{BHM} = 3000V R_d =20Ω
The time constant is given by
$\tau = (R_B + R_d)C_B = (1500+20)100\times10^{-12} = 0.152$ µs
The discharge occurs over ~ $5\,\tau = 0.76$ µs

ii) Maximum current = $i_o = \frac{v_{BHM}}{R_B + R_d} = \frac{3000}{1500+20} = 1.97 \text{ A}$

$\therefore$ Maximum current density = $\frac{1.97}{4\times10^{-8}} = 49.3\times10^{6} \text{ Am}^{-2}$

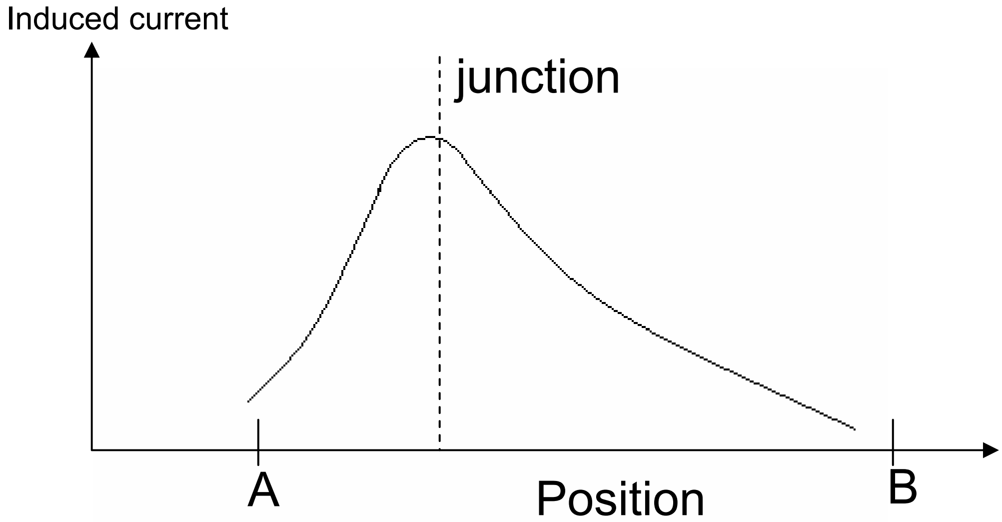
Q.4. a) i)



ii) Electrons thermionically emitted from tungsten filaments (1-50kV potential difference)
After passing through the condenser and objective lenses, the electron beam is demagnified to ~ 1nm spot.
This beam is then raster scanned over the sample.
The bombarding electrons (primary electrons) dislodge electrons (secondary electrons) from the sample.
The electrons are attracted and collected by a positively biased detector to form signal.
More secondary electrons are emitted from sharp corners, edges and sloped regions than planner surface.

Q.4.b) An electron beam is injected into a semiconductor to generate minority carriers. These carriers then diffuse from their generation points. They recombine at a rate determined by their minority carrier lifetimes and diffusion lengths. Therefore the signal/current induced by the minority carriers is small in the absence of electric field.

c)i) In the p-n junction, electrons and holes generated within the depletion region are separated by the electric field. As they drift, external current is induced at the contacts. This induced current is largest at the junction and decays with distance away from the p-n junction as the carrier collection drops.
Therefore the variation in the currents can be translated into variations of contrast in EBIC image.
ii)



d) In the presence of defects that serve as non-radiative recombination centres, current induced is smaller. Therefore areas with defects correspond to smaller currents and will appear darker in the EBIC image.