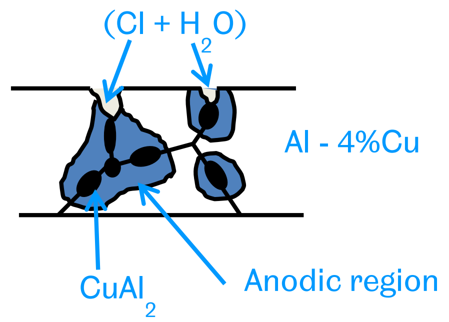
EEE6008 2013-14 Exam Solutions

1) a) Blech effect: Electron wind force = stress induced force. Equate the forces and then rearrange to give:

Gives $L_c = \frac{\Omega\sigma_c}{Z^* q \rho j_e}$ = $(1e^{-23} \times 60)/(1 \times 1.6e^{-19} \times 4e^{-6} \times 1e^{5})$ = 94μm

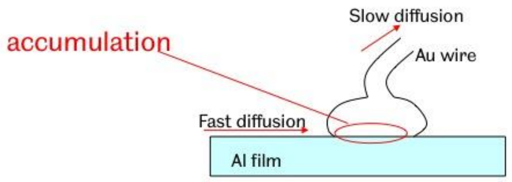
b) atoms can skip along surface, migrate along GBs, ho within dislocation core, swap places with vacancies in the bulk (in order f increasing energy needed)

c)



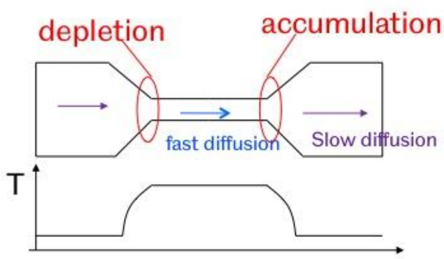
Dissolution around GBs where precipitates have formed

d) i) Bond between Al conductor track and Au wire
E_a(Al) ~0.6eV, E_a(Au)>1eV → GB diffusion faster in Al
GBs in bulk wire < GBs in Al film
Accumulation under joint → cracking



Au wire/Al film contact

ii) Regions where conductor width changes
Joule heating increases along narrow part of track increasing GB diffusion rate
Accumulation at anode, depletion at cathode.



e) Electromigration under oxide observed using IR. Light reflected from metals show contrast. SAM could be used but would not have the required resolution for the narrow conductor lines so wouldn't be appropriate in this case. Don't need SEM for any of these methods or methods requiring packaging removal.

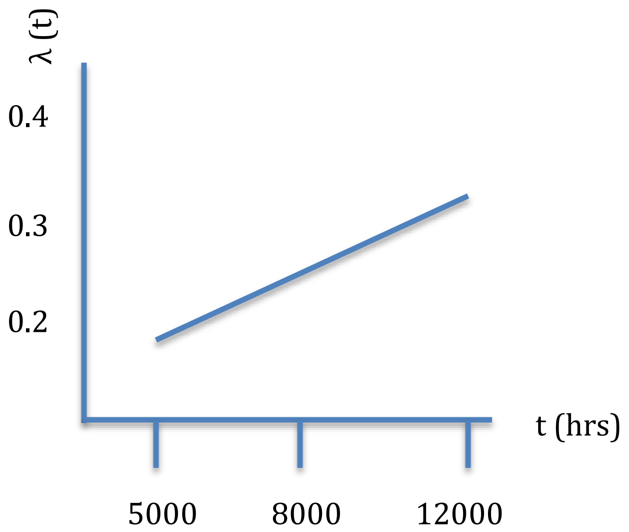
2)
a)
i) MTTF = 8,100 hours
ii) shape parameter = 1.6
iii)

$$/ \left(t\right) = \frac{bt^{b-1}}{h^{b}}$$

Read η on timescale axis when F(t) = 63.2% and hence ln[-ln(1-F(t))] ~0
Here, ln(t) ~4.5, so t ~ 90 hrs

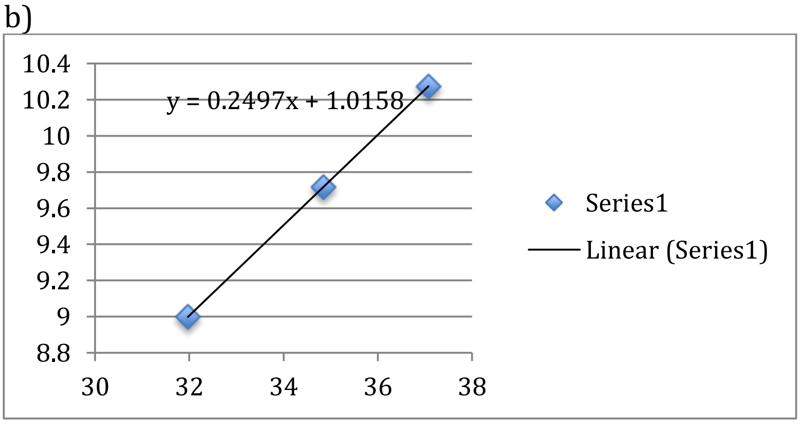
So, $/ \left(t\right) = \frac{1.6t^{0.6}}{90^{1.6}} = \frac{1.6t^{0.6}}{1339}$

$\lambda(5{,}000) = 0.2\ hr^{-1}$
$\lambda(8{,}000) = 0.26\ hr^{-1}$
$\lambda(12{,}000) = 0.33\ hr^{-1}$



iv) Wearout
v) 20,000 hours reads ln(t) ~9.9, so ln[-ln(1-F(t))] = 1.1 and therefore F(t) = 0.95 = 95%

b)



$E_a = 0.25$, MTTF (23 degreesC) = 49856 hours = 5.7yrs

c) When the applied electric field across the gate oxide approaches the breakdown field of the oxide, impact ionisation leads to generation of electron-hole pairs in the oxide. Low mobility holes are usually trapped in the oxide further increase the electric field leading to more impact ionisation events and hence higher current flowing through the oxide. The large current produces heat that damages the oxide layer. ii) In thin oxide film with imperfections (pin holes), current tends to flow through these localised spots. This increases the heat which in turn allow more current to flow, leading to a thermal runaway that causes oxide failure/rapture at these local spots. Metal filament growth at these localised spots typically cause short circuit. In more uniform films, the dielectric breakdown causes accumulation of charges in the gate oxide that shift the threshold voltage and reduce the gain.

3) a) 4 from fracture due to differing CTEs, contamination, blow hole, dewetting, component lifting, excess solder, holes not filled, wicking.

b)

$$\gamma = (\alpha_{sub} - \alpha_{Si})\frac{\Delta T}{\Delta t}\frac{l_c}{h_s}$$

plug the numbers in and get 1.8E-5

c) match CTEs, increase solder height, smaller chips, increase contact area, hermetically seal, avoid flux contamination, change hardness of solder used (control degree of deformation allowed)

d) i) AlN for telecoms as InP CTE matched to AlN, doesn't matter too much about thermal conductivity

ii) Very high thermal conductivity is required (such as Cu), but addition of W lowers this slightly but allows improved reliability from better-matched CTEs.

e) see p.19 of Packaging lecture notes to describe the schematic drawn in class.

f) moisture and Cl ions lead to galvanic corrosion between metal bumps in IC and Sn on metal pads. Presence of various other metals directly in contact or in close proximity also increases potential for galvanic corrosion.
Mass transport can form intermetallics leading to brittle cracking
Shear distortion at solder post depending on CTE mismatch – debonding.

4) a) MOSFET radiation damage: Radiation particles can easily produce e^--h^+ pairs in SiO_2.
Ionization energy of SiO_2 = 17eV.
1 rad generates 10^{13} pairs/cm^2.
Mobile electrons extracted, holes are trapped at the Si/SiO_2 interface.
Positive charge reduce the threshold voltage by $\Delta V_t = Q_{ox}/C_{ox}$ causing MOSFETs to turn on at lower applied voltage and large leakage currents. V_t can be large before irradiation, but thick oxide suffers large ΔV_t.

b) Outer space: broad spectrum of energetic particles trapped in Earth's magnetic field (~keV-GeV), cosmic rays generated by heavy ions (>TeV), Solar winds
Nuclear reactors
Industrial radiation processing (sterilization, food preservation, polymer modification)

c) packaging materials themselves may contain small traces of radioactive materials Uranium U^{238} and Thorium Th^{232} which produce energetic particles through decay within the shielded module.

d) i) moist environment: Surface etching → new defects has been suggested as possible cause for fatigue "knee". Possibly dissolution or etching in which silica is removed in the form of $Si(OH)_4$ - causing surface damage. Hydrogen is reported to increase loss at the wavelengths of 1.07-1.24μm .

ii) Radiation creates e^--h^+ pairs which are trapped in defect sites in the fibre creating new energy levels that absorb light. This ↑ optical loss which can be observed from darkening of fibre. Amount of loss depends on dose, temperature, composition and uniformity of fibre.

e) i) To prevent hydrogen permeation and mechanical degradation, fibres are commonly coated using hermetic carbon/metal coatings.

ii) Transient losses can be reduced by defect annealing or exposure to light.

f) i) COD: Surface states created by defects on facet with $E<E_g$
→ Non-Rad.-Rec. and breaking of surface bonds
→ heating further E_g↓ (absorption↑) and point defects ↑ → thermal runaway
→ melting
→ mechanical damage over whole facet area.
Photoenhanced oxidation. As intensity ↑, oxidation rate ↑.
Coat with Al_2O_3, SiO_2 and SiN_x passivation films (λ/2 thick). Also use non-absorbing mirrors (intermixing or window facets).

ii) AlGaAs more susceptible than InP because E_g of InP is smaller -> reduces E released to lattice by each NRRec event.