Self Assessment Questions (SAQs) 4

- Briefly outlined the stages involved in semiconductor packaging and provide at least an example of failure mechanism in each stage.

Die preparation, wafer cut into individual die

Die attach, die attached to substrate using epoxy

Wire bonding, provide electrical connection from device to the substrate

Ball bonding and wedge bonding are used

Wire bond tests, visual, pull test, ball shear test, bake test

Moulding, to provide mechanical support and protect from outside environment

Marking, to print corporate and product information

- List potential package reliability issues in plastic encapsulated IC.

1) Wiresweep/short
2) Voids (epoxy and die attach)
3) Wire breakage
4) Passivation or dielectric cracking
5) Bond non-stick and cratering
6) Die cracking
7) Delamination
8) Outgassing
9) Radiation damage

- What is popcorn effect?

One of the most common failure mechanisms in plastic encapsulation is the so-called "popcorn" cracking. This usually occurs during solder reflow of surface mounted packages. The popcorn cracking develops in the following stages.
First the moisture penetrates into the package via metal-plastic interfaces and is absorbed in the moulding compound. During reflow soldering, the condensed moisture rapidly expands to form a pressurized dome of steam.
The pressure dome coupled with reduced strength of the moulding compound at elevated temperature causes the formation of cracks and growth of delamination.

- Briefly discuss the operation principles of x-radiograhy (x-rad), scanning acoustic microscope (SAM) and scanning electron microscope (SEM).

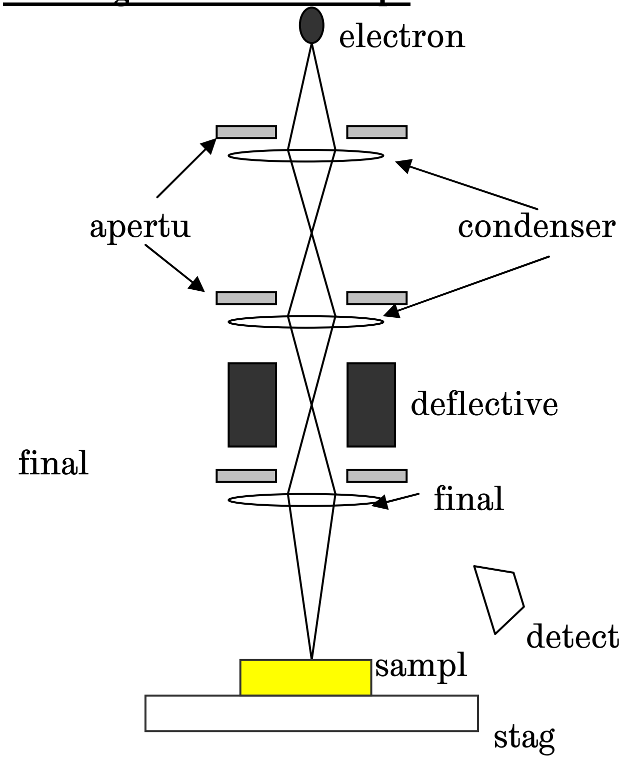
X-radiography

When x-ray beam of intensity I_o is incident on a sample, the intensity decays (due to absorption) with penetration depth, x. The expression is $I(x) = Io \exp(-\mu x)$, where μ is the absorption coefficient and x is the penetration depth.
If two materials have large difference in μ then good contrast can be obtained.

Eg: x-ray at 20keV, μ = 10.2cm-1 in Si but 1510cm-1 in Au.

Scanning acoustic microscope
An acoustic wave is generated in a piezoelectric transducer. This is directed onto the sample under test via a lens and coupling fluid (eg. water). Using raster scanning, the reflected acoustic wave collected is used to construct an image of the sample. Subsurface information is obtained by changing the distance between the sample surface and the lens, i.e. changing the point of focus.

Scanning electron microscope



Tungsten filaments emit electrons thermionically under a potential difference of 1 to 50kV. After passing through a condenser lens, the electron beam is defocus to ~1nm spot and then raster scans over the sample under test.
Electron impingement on the sample produces secondary electrons, Auger electrons and elastic back-scattered electrons. X-ray emission from the sample is also resulted.
Secondary electrons are ejected at the surface. More secondary electrons are emitted at sharp corners, edges and sloped regions than planar surfaces. The emitted electrons are collected by detectors which convert them into images.

- What are the possible operation modes in SEM?

Backscatter mode: Elastically scattered electrons can provide information from depths of a few micrometers. The amount of electrons back-scattered is used to construct images.
This mode can be used to analyse conductor failure beneath dielectric passivation layer without the need for removal of the dielectric.
Formation of voids due to electromigration and delamination are examples of failure mechanisms that can be revealed by this mode.

It is also possible to perform some composition analysis since the amount of back-scattered electrons also depends on the atomic number.

Secondary electron mode: This mode relies on inelastically scattered electrons to form the image. It is most useful for analysis of surface morphology. An example of failure mechanism that can be detected is cracking in passivation layers. Metallization layout and surface profiles can also be studied using this mode.

Electron beam induced current (EBIC): An electron beam is injected into a semiconductor to generate minority carriers. These carriers then diffuse from their generation points and recombine at a rate determined by their minority carrier recombination lengths. Therefore the current induced by the minority carriers is small in the absence of electric field. In a 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 junction as carrier collection efficiency drops. Therefore the variations in the currents can be translated into variations of contrast in an EBIC image. This mode can be used to locate defects that act as non-radiative recombination centers and to locate pn junctions in devices.

Catholumniscence: This is very similar to EBIC except that no electric field is required. In addition the luminescence characteristics can provide composition information not available from EBIC.

Energy dispersive x-ray (EDX): X-ray emitted in this mode contains information of the energy levels of a given atom and therefore can be used for atomic species analysis. This mode can be used to study failure mechanisms such as filament growth, ESD induced short circuit and perform composition analysis.

Voltage contrast mode: When a device is powered up, the surface potentials alter the secondary electron emissions. Electron detector is biased positively to collect the emitted electrons. The more negative the surface potential is, the more the secondary electrons are emitted, leading to a brighter image. This mode can be used to locate short or open circuits in interconnects. It is particularly useful for examination of large complicated devices with many interconnects.

- Discuss how x-radiography, SAM and SEM can be used to characterise failure mechanisms in electronic devices.

The SEM has been discussed above. For x-radiography and SAM see lecture notes.