RELIABILITY ISSUES AND FAILURE MECHANISMS-Hermetic package failure

Early active devices needed a hermetic package to prevent junction leakage and degradation of transistor gain caused by moisture and contamination. Nowadays, this approach is more commonly seen in devices such as crystals, where it is important to protect internal surfaces from contamination without making direct contact with them.

'Hermetic' means gas-tight – such packages use ceramic-glass or glass-metal feed-throughs and soldered or welded seals to produce a package whose walls are at least in theory impervious to the outside atmosphere. However, if a package is not properly gas-tight, moisture and contaminants can equally well end up partially sealed in! The consequence is that these packages are usually tested for hermeticity.

Testing involves two stages:

A 'gross leak' test, for major defects. In the bubble test (or 'dunk test') method most commonly used, the package is immersed in hot liquid and the operator (or automatic equipment) looks for bubbles emerging from the package as the trapped air expands. Typical equipment uses high boiling point perfluorocarbons such as Fluorinert FC-40 and FC-43, held at 125ºC in a back-lit bath with a magnifying front panel. If a large leak is present, a stream of bubbles will be seen rising from the device. This test not only detects a hermeticity failure, but also identifies the location of the leakage site.

A 'fine leak' test for minor defects. A preliminary is to pressurise the package within a 'bomb' containing an inert tracer gas, usually helium. This forces the tracer gas through any small leaks. Immediately afterwards, the package under test is transferred to a vacuum chamber connected to a 'helium sniffer'. This test can detect leaks1 of as little as 10−8std.cc/sec−1 for the average package.

1 MIL-STD-883 defines a standard leak rate as 'that quantity of dry air at 25ºC in atmosphere cubic centimetres flowing through a leak or multiple leak paths per second when the high pressure side is at one atmosphere and the low side pressure side is at a pressure of not greater than 1mm Hg. Standard leak rate should be expressed in units of atmosphere cubic centimetres per second (atm.cc.s−1)'.

Normal practice is to carry out the tests on sealing after all mechanical tests have been carried out, thus ensuring that handling and any environmental testing has not damaged the integrity of the seal. Because fine-leak testing will expose the package to stress, this is carried out first, followed by the gross leak test.

The fundamental requirement is that the moisture inside the package should not be able to form a layer of surface water which is thick enough to allow sufficient current flow to sustain corrosion. Lau showed this thickness to be 3 molecular layers of condensed or absorbed water. However, it has been calculated that a standard leak rate of 10−8 atm.cc.s−1 would allow the equivalent of nearly 100,000 layers of water on a chip in ten years, implying that a leak rate of 10−13 atm.cc.s−1 is really what would be needed to limit the exposure in the same time to safe levels!

Two practical observations must be made about this:

The MIL-STD-883 requirements are based on what is practicable within a reasonable test schedule, and rely on the fact that hermetic seals are mostly either very much better than the limit or are substantially defective and present definite failures.

This 10−13 atm.cc.s−1 leak rate is about 10−7 times smaller than the lowest permeability observed for polymers – although polymer seals may appear to pass the gas leak-tightness tests, they cannot be regarded as truly hermetic.

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