Hybrid Memory Products Ltd

Hermeticity Testing

TECHNICAL NOTE

Summary

A large portion of the failure mechanisms which are most active in electronic packages are either initiated or accelerated by the presence of moisture. In hermetic packages (ceramic or metal) this moisture can be locked inside the case during sealing or can outgas from materials inside, such as the die attach.

The largest problem, however, is improper sealing of the package. Seals are important because they prevent moisture and other contaminants from reaching the die. Therefore, the reliability effects of defects in the seal deal mainly with contamination and corrosion mechanisms.

Poor Seals in Hermetic Packages

There are several sealed areas to consider in a typical cavity package: leads at the case wall and lid, pins at the case bottom or wall, the lid to package interface, and often there is a wall to case bottom seal. These seals are commonly made with glass, solder, or brazing techniques. Poor seals can be caused by errors in any of these processes.

Leaks arising from poor seals or micro-cracks can allow moisture and contaminants to enter packages freely. When the device is switched on it warms up. This causes a pressure increase in the gas within the cavity. Gas is forced out through the leak until the internal and external pressures have equalized. When the device is switched off it cools down and there is a corresponding drop in internal pressure which causes damp ambient air to be drawn in. This breathing effect on intermittently used components has a major impact on their long-term reliability.

The size of a leak is measured by the volume of air which would pass through the leak each second with a pressure difference of 1 atmosphere (atm.cc / sec) Expressing commonly mentioned leak rates in every day terms gives an understanding of the scale involved.

Sample leak rates (atm.cc/sec)

10^{-1}	1 cc leaks every 10 seconds
10^{-3}	1 cc leaks every 17 minutes
10^{-5}	1 cc leaks every 28 hours
10^{-8}	1 cc leaks every 3 years
10^{-11}	1 cc leaks every 3000 years

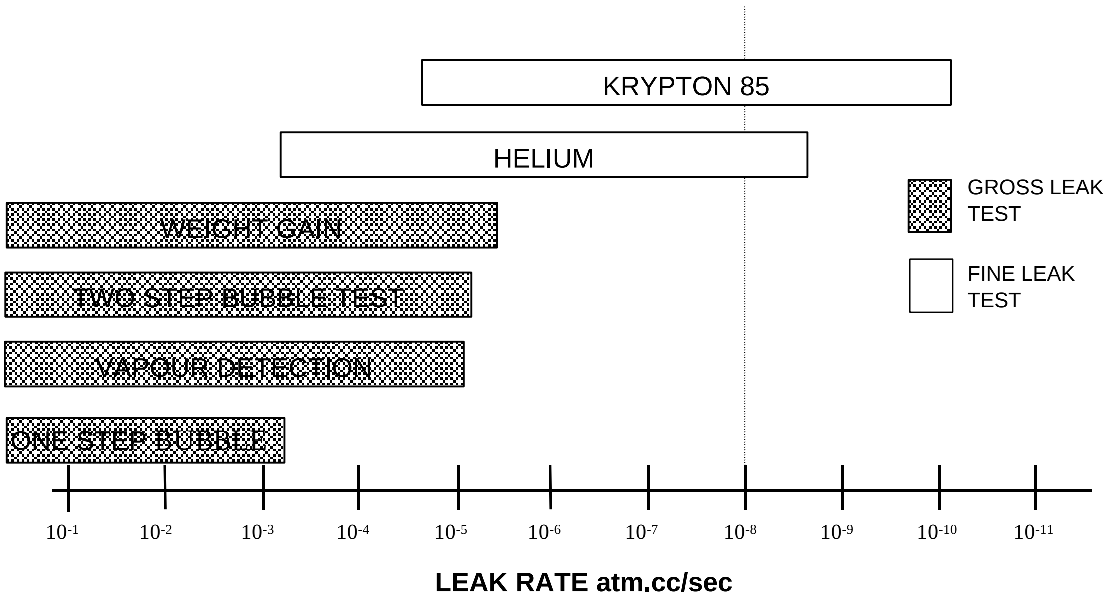
Most specifications for hermeticity testing define leak rates larger than 10^{-5} as being ***GROSS*** and smaller than 10^{-5} as being ***FINE***.

Hermetic Seal Test

Seal tests are undertaken to ensure that moisture cannot get into ceramic, metal or glass packages which have an internal cavity. There are many different methods available for fine and gross leak testing. However the methods appropriate for gross leak testing cannot be used for fine leak testing and vice versa. Gross leak tests tend to use liquids for detection while fine leak tests use a tracer gas.

Leak detection is covered by a wide variety of specifications including Mil 883, BS9000, IEC749 and Mil 202F.

All of these specifications allow manufacturers a choice between the available fine and gross leak test methods as shown below:



All international specifications agree that the sensitivities of fine and gross leak tests must overlap. This is because many of the leaks which occur in semiconductor packages occur beyond the detection range of commonly used test methods.

The most commonly used hermeticity test is MIL-STD-883 Method 1014. This test is often run after the thermal shock test or the high temperature storage test. There are two classifications of this test: fine and gross leak testing (Table 1).

Table 1: Fine and Gross Leak Testing

TEST	OPERATIONAL RANGE (atm*cc/s)	METHOD	TRACER
Fine Leak	10^{-6} to 10^{-10}	Helium leak Radioisotope	Helium Krypton-85
Gross Leak	10^{-1} to 10^{-5}	Bubble test Weight Gain Dye Penetrant	Fluorocarbon Fluorocarbon Flourescent

Fine Leak Test

For a helium leak test, the package is placed in a pressurization tank, which is pressurized with helium at a given temperature for a given amount of time. The package is then removed and placed into a mass-spectrometer so that the amount of helium coming out of the case can be observed. The test parameters are based on the internal volume of the case. A fixed condition chart can be used (Table 2) or the parameters can be calculated.

Table 2: Fine Leak Test Parameters

PACKAGE VOLUME (cc)	PRESSURE (kPa)	EXPOSURE TIME (hours)	DWELL (hour)	REJECT LIMIT (atm*cc/s He)
<0.05	520	2	1	5E-8
0.05 < V <0.05	520	4	1	5E-8
0.5 < V < 1.0	310	2	1	1E-7
1.0 < V < 10	310	5	1	5E-8
10 < V < 20	310	10	1	5E-8

Flexible calculations are used to determine the equivalent leak rate (helium vs air):

$$R_1 = \frac{LP_E}{P_o}\left(\frac{M_A}{M}\right)^{\frac{1}{2}}\left[1 - \exp\left(\frac{Lt_1}{VP_o}\left(\frac{M_A}{M}\right)^{\frac{1}{2}}\right)\right]\exp\left(\frac{Lt_2}{VP_o}\left(\frac{M_A}{M}\right)^{\frac{1}{2}}\right)$$

where R_1 is the measured leak rate of the tracer, L is the equivalent leak rate of air (as determined in Table 3), P_E is the pressure of exposure (atm absolute) P_o is atmospheric pressure, M_A is the molecular weight of air (28.7g), M is the molecular weight of helium (4g), V is the internal case volume (cc), t_1 is time of exposure to P_E (seconds), and t_2 is the dwell time (between pressure release and spectrometer inspection).

Table 3: Determining the Equivalent Leak Rate of Air

PACKAGE VOLUME (cc)	REJECT LIMIT (L) (atm*cc/s Air)
< 0.01	5E-8
0.01 < V < 0.4	1E-7
> 0.4	1E-6

One disadvantage of the helium leak test is the "one way leaker" phenomenon. This occurs when the pressure from the test causes helium to enter through microcracks caused by the stress. However, when the pressure is removed these cracks can reseal, locking the helium inside the case. This will cause conflicting results if a residual gas analysis is performed on the case cavity contents after the helium has been sealed inside.

In a radioisotope test, the test procedures are the same as for the helium test just described. The only difference is the tracer; krypton-85 (radioactive) and nitrogen are used here. Emission rates can therefore be measured through gamma ray detection. This rate can be converted into a corresponding air leak rate.

While the "one way leaker" problem does not exist for this method, it may not be chosen because of its inability to point out the location of the leak. In addition, the use of radioactive materials can be hazardous and may delay the failure analysis process.

Gross Leak Test

The three types of gross leak test are listed in Table 1 above. The choice of which test should be used is based on device size, configuration, and design. Before using these tests it must be known that all gross leak test are not always non-destructive.

In the bubble test, the device is immersed in a bath of indicator fluid (FC-43 or FC-40) at a temperature above the boiling point of the tracer fluid (FC-72, FC-84, or equivalent). The device must first be pressurised with the tracer fluid at a given temperature and pressure, which are determined in a way similar to fine leakage tests. The fixed condition chart (Table 4) can be used, or the conditions can be calculated.

Table 4: Gross Leak Test Conditions

CAVITY VOLUME (cc)	VACUUM	MIN PRESSURE (kPa)	MIN DURATION (h)
> 0.1	Optional	415	2
> 0.1	Optional	205	10
> 0.1	Optional	310	6
> 0.1	Not Required	310	10
< 0.1	Required	415	2
< 0	Required	520	1

Condition calculations can be performed for 205, 415, 520, or 620 kPa for a minimum time:

$$T_P = \frac{.1\,VF_1}{6 * 10^{-4} cm^3}$$

where T_P is minimum pressurization time (min), V is the internal volume (cc), and F_1 is the filling time, found in Table 5.

Table 5: Filling Time

PRESSURE (kPa)	FILLING TIME(min)
207	45
415	15
517	12
620	10

The weight gain test involves cleaning and weighing the package before pressurizing it in a fluorocarbon tracer. The tracer material should have low viscosity and a low vapour pressure. The device is then dried and re-weighed. An increase in weight (typically around 1 to 2 mg) causes the package to be rejected.

This test will not indicate the location of the defect, as other gross leak test can.

The dye penetrant test utilizes a dye as a tracer, hence it is mostly used on transparent packages. Again, the device is pressurized in the tracer. The next stage, after washing, is to visually inspect (using a UV light) the interior to find dye inside of the cavity.

APPENDIX #1

MIL STD 883D METHOD 1014 TEST CONDITION A2 - FLEXIBLE METHOD

Values for bomb pressure, exposure time and dwell time shall be chosen such that actual measured trace gas leak rate readings obtained for the devices under test will be greater than the minimum detection sensitivity of the mass spectrometer. The devices must be subjected to a minimum of 2 atmospheres absolute of helium pressure If the chosen dwell time (t_2) is >60 minutes, graphs shall be plotted to determine an R_1 value which will ensure overlap with the selected Gross leak test conditions.

Flexible calculations are used to determine the equivalent leak rate (helium vs air):

$$R_1 = \frac{LP_E}{P_o}\left(\frac{M_A}{M}\right)^{\frac{1}{2}}\left[1 - \exp\left(\frac{Lt_1}{VP_o}\left(\frac{M_A}{M}\right)^{\frac{1}{2}}\right)\right]\exp\left(\frac{Lt_2}{VP_o}\left(\frac{M_A}{M}\right)^{\frac{1}{2}}\right)$$

Where:

R_1 is the measured leak rate of the tracer gas (He) through the leak in atm.cc/sec

L is the equivalent leak rate of air in atm.cc/sec (cavity volume dependant see table below)

P_E is the pressure of exposure atm absolute

P_o is atmospheric pressure atm absolute (1)

M_A is the molecular weight of air (28.7g),

M is the molecular weight of helium (4g),

V is the internal case volume(cc),

t_1 is time of exposure to P_E (seconds),

t_2 is the dwell time between pressure release and spectrometer inspection (seconds)

PACKAGE VOLUME (cc)	REJECT LIMIT (L) (atm*cc/s Air)
< 0.01	$5x10^{-8}$
0.01 < V < 0.4	$1x10^{-7}$
> 0.4	$1x10^{-6}$

If it is assumed that the worst case dwell time between pressure release and testing is 30 minutes (1800 seconds) the only variables in the equation are P_E, t_1 and V. If the dwell time is fixed at 2 or 4 hours and pressures of 30,45 and 75 PSI are used as standards it is possible to create a set of graphs of cavity volume against measured leak rate. It is also safe to assume that all HMP products have cavity volumes greater than 0.01cc. The following graphs show leak rate plotted against cavity volume for cavities between 0.01 and 0.4cc and for cavities between 0.4 and 5cc.