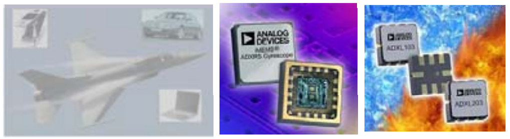
LOMSS

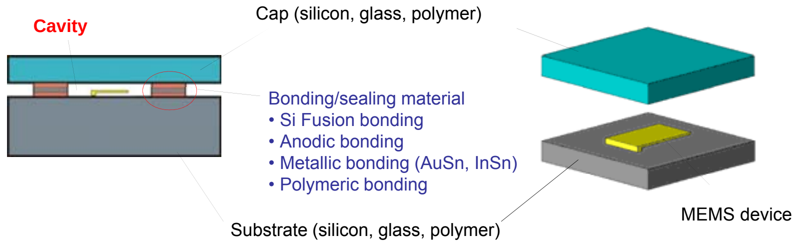
Quantitative Hermeticity Assessment of Micro- to Nano-liter MEMS Packages



http://global.kyocera.com

- MEMS based devices have widespread applications.
- The package provides the device with:
  - a) Mechanical support
  - b) Electrical connections to the outside world.
  - **c) Protection from the external environment**
- **Hermeticity** is the ability of a package to maintain an acceptable level of stable and sometimes inert ambience for the packaged device.

Characteristics of MEMS Packages



Typical cavity volume 10^{-3} cc to 10^{-6} cc

Hermeticity requirement

Maintain a high-vacuum environment in order to obtain a high Q-factor

- e.g. MEMS accelerometers and gyroscopes

Prevent ingress of moisture and contaminants

- e.g. Thin-Film Bulk Acoustic Wave Resonators (FBARs)
- Oxidation of the metal electrode of the FBAR filter can result in a frequency shift.

Hermeticity Measurement

The Helium fine leak test has been used traditionally for measuring leak rates of interest. (< 10^{-4} atm-cc/s)

Specimen with cavity volume, V, is pressurized with high-pressure (P_b) helium in a bombing chamber for several hours (t_b)

↓

Specimen is transferred into a He mass spectrometer.

Dwell time (t_{dwell})

↓

Spectrometer is switched on. It detects the helium ions and outputs the leak rate. This leak rate is called the *measured* (apparent) leak rate, R

Apparent leak rate, R

- The leak rate measured by the spectrometer.
- Dependent on test conditions.
- Dependent on the pressure differential and is hence time variant.

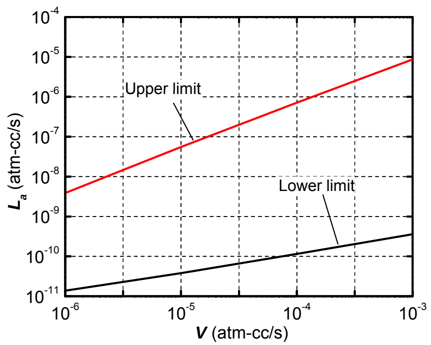
True leak rate, L_a

- Independent of test conditions
- For a given gas it is a characteristic of the package and is hence time invariant.
- Straightforward correlation between true leak rates of different gases

Typically, the apparent leak rate has been used as a hermeticity metric. For small volumes, this can produce erroneous results.

True leak rate facilitates meaningful comparisons.
This warrants the development of a new procedure to extract the true leak rate from the helium leak test data.

Measurable Range of Leak Rates



$$R_i = \frac{L_a P_b}{P_0}\left(\frac{M_a}{M_{helium}}\right)^{\frac{1}{2}} \left\{1 - e^{-\frac{L_a t_b}{V P_0}\left(\frac{M_a}{M_{helium}}\right)^{\frac{1}{2}}}\right\} e^{-\frac{L_a t_{dwell}}{V P_0}\left(\frac{M_a}{M_{helium}}\right)^{\frac{1}{2}}}$$

where $P_o = 1$ atm and M_a = 28.7 g and M_{helium} = 4 g are the molecular weight of air and helium, in grams

Representative test parameters:
P_b = 5 atm
t_b = 6 hours
t_{dwell} = 10 minutes
Spectrometer sensitivity, R_{limit} : 10^{-10} atm-cc/s

Physical meaning of the limits:

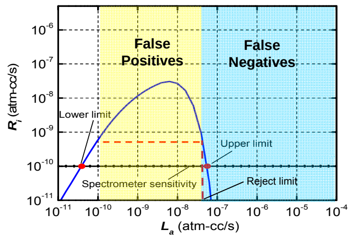
L_a > Upper limit: Nearly all the helium bombed into the specimen leaks out during dwell time

L_a < Lower limit: Less helium is bombed into the specimen for a given bombing time and when the specimen is put in the spectrometer there is not enough helium coming out to be detected.

Research task 1: Evaluating applicability of MIL-STD Based Guidelines to Small Packages

According to Method 1014.11 of MIL-STD-883F*:

- Reject limit is established in terms of the true air leak rate (L_a).
- Reject limit in terms of the apparent leak rate (R_i) is calculated using this value and the Howl Mann equation.
- The package is rejected if the apparent leak rate is higher than R_i



Plot of R_i versus L_a for a representative volume

Simulated test parameters:

P_b = 5 atm
t_b = 6 hours
t_{dwell} = 10 minutes
V : 10^{-5} cc

Application of the MIL-STD guidelines to small packages can result in:

- False positives: Good packages that will be failed.
- False negatives: Bad packages that are passed.

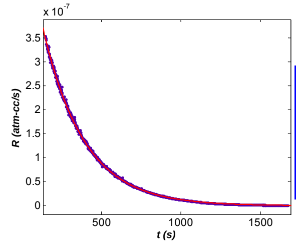
* MIL-STD-883F, Method 1014.11, Test method standard microcircuits, US Department of Defense, 2004.

Research task 2: Quantitative Measurement of Hermeticity

New procedure for determining the true leak rate from the helium fine leak test

Regression based over deterministic approach to analyze the time dependant apparent leak rate data generated by the test.

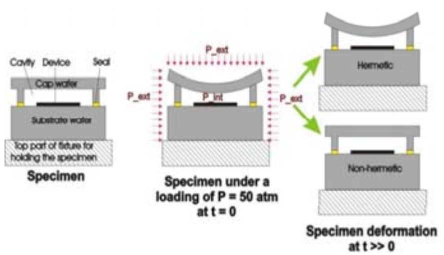
Fitting function	Inputs	Output (unknown parameter)
$R = Ae^{-Lt/VP_o}$	R, P_b, t_b , t_{dwell}, t, V	A, L

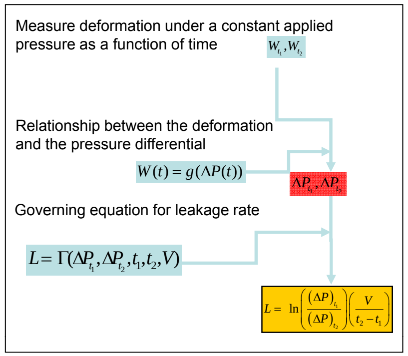


- **Application of the technique to the apparent leak rate data yielded $L = 9 \times 10^{-7}$ atm-cc/s**
- **Robustness of the analysis was proven by testing same specimen with different test conditions.**

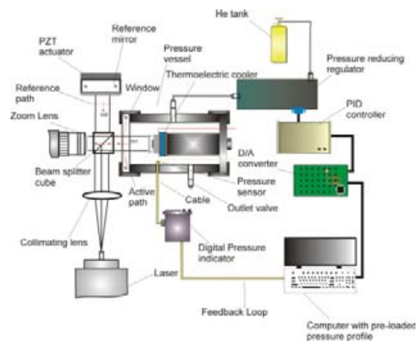
Research task 3: Extending Hermeticity Measurement Capability

- New technique for measuring leak rates beyond the measurable range of the helium leak test
- Principle: True leak rate is calculated by measuring time dependant cap deformation under an applied invariant pressure differential

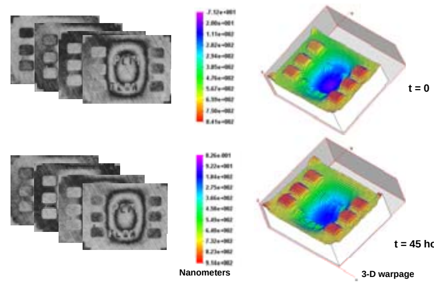




Experimental setup



Results



Cap thickness	Applied pressure	Observation
30 μm	15 atm	Deformation change after 45 hours: < 30 nm

Leakage rate is less than 3×10^{-12} atm-cc/s