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Title: Hermetic vs. "Near Hermetic" Packaging - a Technical Review

Abstract: Hermetic cavity packages have long been the standard for military and space applications. On one hand the hermeticity specs are getting tighter, on the other hand the question that is now being poised is; Do I need to be hermetic? "Near hermetic" or "non-hermetic" packages hold the promise of reliability at a greatly reduced cost…maybe…download now!

What is hermeticity?

The dictionary definition of the term "hermetic" means a seal that is gas tight or impervious to gas flow. In the context of microelectronics it implies an airtight seal that will keep moisture and other harmful gases from penetrating the sealed package. Metals, ceramics and glasses are the materials used to form the hermetic seal and prevent water vapor from accessing components inside the package. A properly made hermetic seal with a sufficiently low leak rate can keep a package dry and moisture free for many years.

Mil -STD -883 Test Method 1014 is the universally accepted test designed to determine the effectiveness or hermeticity of the seal. There are several techniques for testing hermeticity, but the most common method is to measure the rate at which helium escapes from a package that has been pressurized or backfilled with helium (the tracer gas). The exact definition of hermetic is defined in TM 1014 para. 3.1.1.2.1, which lists the failure criteria for a given package volume in terms of an air equivalent leak rate. When a cavity sealed microelectronic package passes both gross and fine leak test per TM 1014 the part is deemed "hermetic". When it fails it's known as a "leaker". Download a Practical Guide to TM 1014.

Polymeric materials such as silicones and epoxies do not provide a hermetic seal and cannot be used to improve or fix a hermetic seal. Cavity packages made from polymers (e.g. LCP) or molded/potted microelectronics are known in the industry as "near-hermetic" or "non-hermetic". These two similar terms are used interchangeably in this document. A "near" or "non" hermetic configuration may provide enhanced resistance to moisture entry into a package, but they are not hermetic as defined by the military specs.

A Reason to Seal

If liquid droplets form on the surface of an IC or other active devices sensitive to moisture, then corrosion or other electrochemical reactions may occur and degrade the performance of the device and lead to failure. Moisture droplets can form as the package is cooled below the dew point. This surface water (H_2O) combines with any available surface ionic contamination, particularly sodium (Na) or chlorine (Cl), and along with a bias will chemically attack and corrode exposed aluminum metal at the wirebond pad. The conductor metallization beneath defects, such as, cracks or pinholes in device passivation, or thin film resistor networks are also susceptible to this type of failure mechanism. Three monolayers of moisture on the surface is all that is needed to sustain surface conduction and facilitate electrochemical reactions.

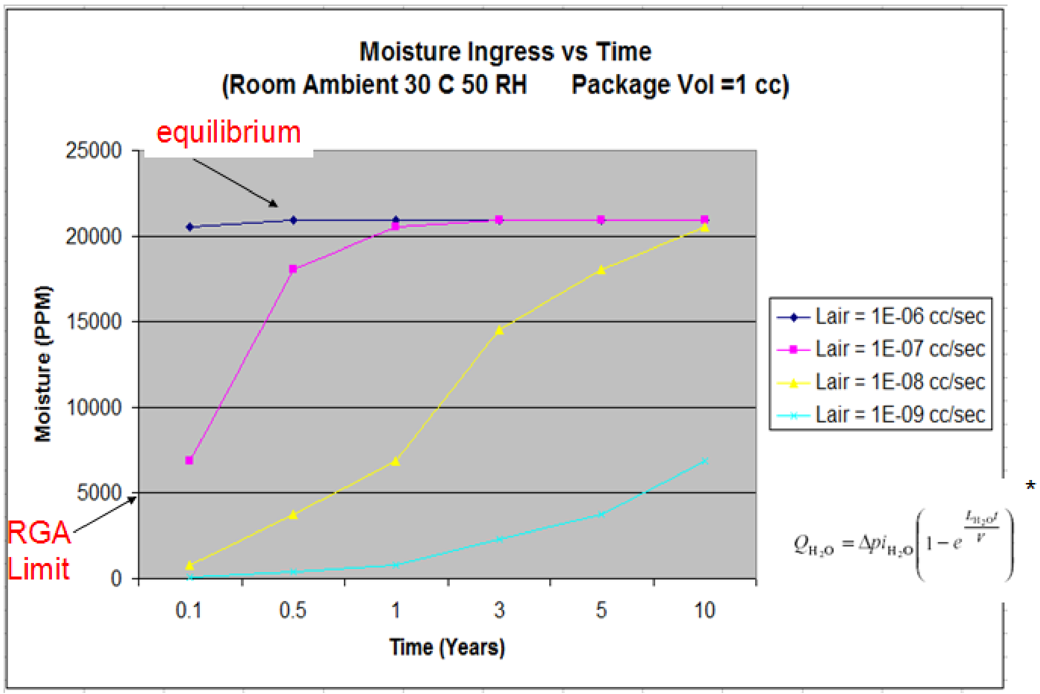
Other problems caused by moisture inside a package include: electrical leakage across pins, damage to the doped layers on a silicon chip if there are pinholes in the surface passivation, arcing in a high voltage device, fogging of optical components, and "stiction" of moving parts in a MEMS component. Moisture related problems over the years have been well chronicled in technical journals and discussed at length at conferences such as the International Reliability Physics Symposium (IRPS) and a series of workshops conducted by National Institute of Standards and Technology (NIST). In addition, every year since the early 1980s the Minnowbrook conference is held in upstate NY at the town of Blue Mountain Lake to discuss hermeticity and the associated problems with moisture in a package. Contact the author for more information on the Minnowbrook Conference.

Tighter hermeticity specs …but why?

Recently, the hermeticity specification requirement in Mil-STD-750 TM 1071 was tightened, or lowered, by two orders of magnitude. TM 1071 is the cousin of the more broadly referenced MIL-STD-883 TM 1014 spec. This spec change in TM 1071 forced companies to purchase new leak test equipment, since the conventional HMS (helium mass spectrometry) leak test followed by the beloved bubble test no longer provided the test sensitivity to meet the new requirements. The TM 1071 spec change in my estimation was driven by two factors; an awareness of the problem on the part of the government spec writers and availability of enhanced-sensitivity leak detection equipment from the equipment suppliers.

Spec writers gained an understanding and awareness that the previous TM 1071 specification level was too lenient. In other words, given the spec limits one can expect to change over the atmosphere inside a sealed package in a relatively short timeframe. We're talking months, maybe years, but nothing close to what one would expect from a product with a 10 to 30 year mission life. In terms of moisture ingress the graphic below shows how quickly a device sitting out on a desk, in ambient air, might accumulate moisture inside for various air equivalents leak rates. The equation is based on gas flowed into a sealed package. Room air at 30 C and 50% RH is equivalent to .0209 atm of water vapor. As one can see from the chart a 1 cc package is near equilibrium in about a month or so if leaking right at the specification of 1E-06 cc/sec air.
Fortunately, the vast majority of parts hermetically sealed and subjected to TM 1014 are in reality sealed to a much tighter level. The hermeticity specs are essentially a go/no-go check on the seal process.

The recent TM 1071 spec change was not in response to field failures or an overwhelming mandate from OEMs to tighten the hermeticity specs in order to fix a reliability problem. At the same time nobody would argue that moisture inside a package is a good thing. So, should the hermeticity spec limits in TM 1014 be tightened? The jury is still out.



*Ref: Hermeticity of Electronic Packages, H. Greenhouse Eq.5-8

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Experts have always known this and some recommended tighter leak rates in the past. In my view leak test is a one time check on the seal process done under idealized conditions on the factory floor. It's difficult and risky to extrapolate that single leak rate data point to an expected lifetime based on moisture ingress theories with the associated assumption of molecular flow and a single cylindrical leak path. Also, one cannot discount the possibility of pressure and temperature dependent leaks. A measured helium leak rate coming from a package may not be helium escaping through a single simple pathway, but is most probably the culmination of helium escaping the many small, torturous leak pathways peculiar to that package construction and hermetic feedthough materials and technology. Helium leak testing is problematic and there is a great need to educate the industry on hermeticity testing.

Near hermetic…what is that?

When the term "near hermetic" or "non-hermetic" packaging is used it implies the package is made from polymeric materials as opposed to glasses, metals and ceramics. LCP (Liquid Crystal Polymer), PEEK (Polyetheretherketone), Parylene-C coatings come to mind when thinking of "near hermetic" packaging material sets. Naturally, plastics reduce cost, weight, size and if designed, manufactured and tested properly hold the promise of a reliable substitute for a hermetic can. A "near hermetic" package simply put is not hermetic as defined by the military specs.

Do the TM 1014 hermeticity specs apply to a "non-hermetic" cavity package?

Not really. Any old plastic cavity with an epoxy lid glued on will likely pass the TM 1014 hermeticity specifications. Does that mean I can fly it in space? No. The hermeticity specs were designed to test for cracks in glass to metal seals, poor braze joints, insufficient weld seals and the like. They assume the packages are made from glasses, metals or ceramics. In "near hermetic" plastic packages the problem is now one of moisture diffusion through the bulk material, along with the interface of the lid seal and feedthrough to package body interface. In a hermetic can the moisture permeability through the bulk packaging material is rightfully ignored. Moisture permeability in most glasses, metals and ceramics is negligible. But not so with any plastic, it is several orders of magnitude greater and is therefore now an important contributor to moisture uptake inside the package and an important consideration in the package design.

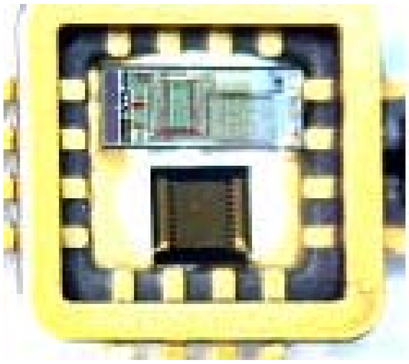
How would I qualify a "non-hermetic" package for use in the military systems?

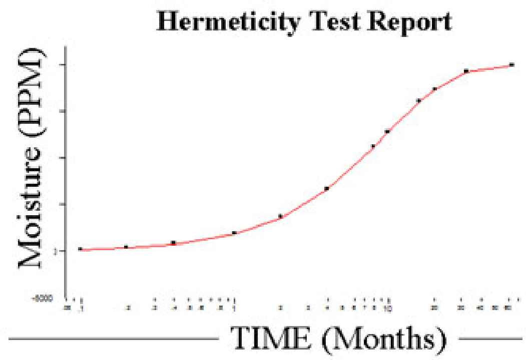
Good luck, you'll be fighting a forty year old paradigm that says it can't be done. But there is hope. Thanks to some forward thinking and market pressures the most recent version of MIL-PRF-38534 (Hybrid Specification) contains an appendix D that details the qualification and testing requirements for "non- hermetic" packages for military and space applications. NASA is also leading an effort to develop a new class of non-hermetic parts (Class Y) for monolithic devices intended for space.

Fick's law of diffusion becomes the dominant theory to explain gas flow through the bulk polymeric material of a near-hermetic package. Michal Tencer published a landmark paper on this vary topic, which serves as a good starting point for evaluation of a "near hermetic" cavity package. In a sense Fick's law replaces the Howl and Mann equation and the theory of gas flow through a defined leak path. New "non hermetic" evaluation test techniques will need to be developed.

How will I know if "Near" is better?

The best way to measure the dynamic rate of moisture into and out of a plastic cavity package, or a supposedly hermetic one for that matter, is to mount a moisture sensor inside the package cavity and directly measure real time the rate of moisture ingress as a function of changing ambient environmental conditions. Moisture sensing technology has come a long way in the past 30 years. It's now possible to mount a small moisture sensor inside the package cavity and measure RH and Temp to a reasonable degree of accuracy real time inside the package.





[Moisture Testing Services]

Going Forward

This debate will no doubt rage on over the next decade, but in my estimation "near hermetic" packaging technology will win out and our trusted hermeticity packaging technology will likely only be used on parts that really need it, e.g. vacuum packed MEMS or extremely moisture sensitive components. As it is with most paradigm shifts it will take some time. The next generation of package designers will likely look at the choices available to them via their mobile devices and conclude the "near hermetic" approach wins on most counts, certainly cost, size and weight and reliability (maybe).

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*The opinions expressed herein are my own thoughts and ideas and are meant to prompt and stimulate open discussion on this important topic

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