Keep it tight: understanding hermeticity

Craig Hillman

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One of the great ways to make it in the electronics industry is to realize that everything old is new again. About every five years, almost like clockwork, manufacturers seem to forget how to make the most basic of technologies. Wire bonds. Electrolytic capacitors. Flame retardants. Underfills. Etc.

Hermetic packages are a great example. The very first semiconductor devices, going back to the commercialization of the transistor in the early 1950's, were hermetically sealed. TI even highlighted the value of their moisture-proof glass-to-metal packaging in an advertisement in 1953. (For a great treatise on the early days of semiconductors, go to *https://sites.google.com/site/transistorhistory/Home/us-semiconductor-manufacturers/ti*). And yet, even though this technology is one of the oldest in the microelectronics industry, it is amazing how poorly hermeticity is understood and how often devices fail due to issues with their hermetic environment.

As a first step in this discussion, we need to define where hermeticity is needed. Hermetic packages are required in the small portion of electronic parts that cannot be potted/encapsulated with resin. These include

- Parts that have mechanical movement (crystals, MEMS, relays)
- Parts that function using light (opto-electronics)
- Parts that operate at high frequency (microwave)
- Parts that cannot outgas (space applications)
- Parts that must operate at elevated temperatures (above 125C)
- Parts that must be high reliability (some military applications)[Note: This can sometimes be based on the incorrect assumption that hermetic parts are more reliable than plastic parts]

While hermetic packages are classified by their ability to prevent the escape or entry of air, there is actually a wide range of materials used to endow hermeticity. The housing can be fabricated from a variety of metals or ceramics, with the most common being Kovar and Alumina. The seam can be created through a welding, brazing, or soldering process. And the feedthroughs can incorporate variety of designs and materials, depending upon geometries, performance requirements, and, most importantly, cost targets.

To have a successful hermetic package requires not just the ability to keep out the 'bad' air but also to make sure there is 'good' air inside the package and that 'good' air does not change over time.

For keeping out the 'bad' air, a significant amount of effort has been expended by the electronics community in developing techniques and specifications. The oldest and most popular are the methods defined in three US military standards:

- MIL-STD-202, Test Method for Electronic and Electrical Component Parts – Method 112E Seal
- MIL-STD-750, Test Methods for Semiconductor Devices – Method 1071.9 Hermetic Seal
- MIL-STD-883, Test Method for Microcircuits – Method 1014.13 Seal

For the purposes of this article, we are going to skip past the gross leak tests defined in the standard and focus primarily on fine leak detection (less than 10^{-5} atm cm^3/s). Within the realm of fine leak detection, the dominant technique is still the helium leak test (also known as helium mass spectrometry), even as tracer gas and interferometry have demonstrated superior performance at the increasingly smaller volumes of today's wafer-level and MEMS devices.

The major difficulty with leak rate standards is the problem with almost all standards and specifications: a strong desire by the majority of users to do the least amount of work possible (which is understandable, as time is money). That means they quickly look for THE NUMBER (typically in a table). For the three military standards that means using the Fixed Conditions procedure, where the hermetic device is 'bombed' in a helium environment for a period of time and the device is then rejected if it a certain rate is detected escaping from the device (assuming it had no helium to begin with).

The MIL-STD-202G (2002) and MIL-STD-883H (2010) provide similar reject limits. For example, the helium leak rate must be less than 5 x 10^{-8} atm cm^3/second for small packages (volumes less than 0.4 cc). This basic leak rate has become gospel and is pervasive among numerous part manufacturers and independent labs. In fact, what is kind of funny is that commercial component industry has pretty much thrown out the volume and specs 5 x 10^{-8} atm cm^3/second for almost everything (what did I tell you about looking for the easy way out?).

MIL-STD-750, however, is different.

In response to concerns about insufficient leak rates for smaller packages and a misreading of requirements, the newer MIL-STD-750F (2012) has changed the conversation from helium leak rates to air leak rates (that is, how the device will actually perform in the real environment). See, air leaks at a much lower rate than helium (larger molecule). This and other attributes need to be considered when correlating the results of the helium leak rate test to time to failure in the actual use environment.

But wait! This is not the end of the story (and, yes, I understand the story has been pretty dry up to this point). There are two issues with the new requirements in MIL-STD-750F. First, most mass spectrometers have a detection limit of 1 x 10^{-9} atm cm^3/second. Problem is that there are number of instances where Table 1071-V requires detection limits down to 1 x 10^{-10} and 1 x 10^{-11}. So it looks like the boys in DC want to jump start the economy by requiring everyone to buy new equipment.

Quick sidebar: Have you ever noticed that standards from suppliers are constantly removing requirements and standards from customers are constantly increasing requirements? If the electronics community is not careful, suppliers and customers will soon be talking to each other across a pretty wide chasm.

The second issue is how to calculate time to failure based on the leak rate. Because, really, the only reason to define a maximum leak rate is to make sure the hermetic package will not fail over the desired lifetime. And how do hermetic packages fail if they become leakers? Moisture. Water is the enemy number one to almost all hermetic packages.

And how much moisture is too much moisture? For that, you might refer back to the August issue of Global SMT and Packaging, available in the digital archive at http://digital.trafalgarmedia.com.

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Conflict materials—Continued from p. 30

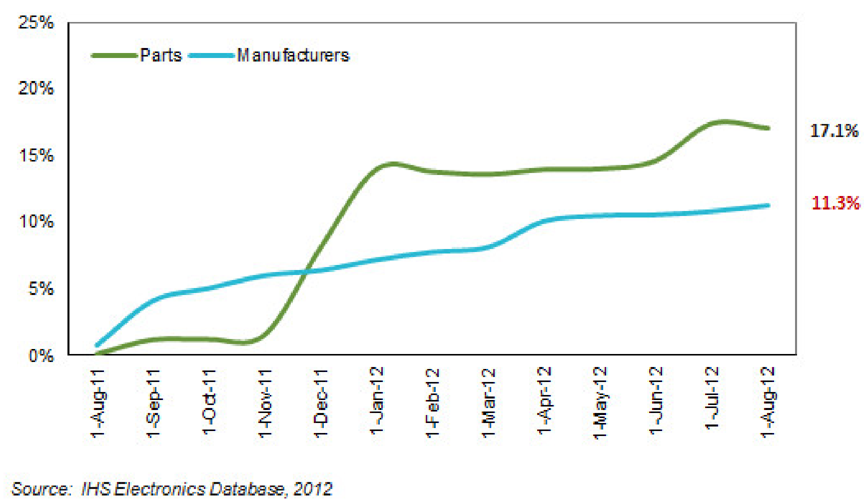

Figure 1. Percentage of companies that have provided documentation and number of parts documented for conflict materials.

companies arises from the rule's widespread impact throughout the supply chain, affecting electronic product makers, their suppliers, their suppliers' suppliers and so on.

"Large electronic original equipment manufacturers (OEM) use tens of thousands of parts that must be examined to determine their conflict mineral content," said Rory King, director, supply chain product marketing at IHS. "The next 19 months really is not very much time to communicate, collect, analyze, and prepare information on mineral sources across a globally diverse, multi tier value chain, in order to determine conflict minerals content and develop reports that comply with the SEC rule."

Journey to compliance

Even after the SEC deadline arrives, the task of reducing or eliminating conflict mineral usage will continue.

"Compliance with the conflict mineral rule is about the journey, rather than the destination," King noted. "Companies will have to arm themselves with information, tools and procedures to continually monitor their supply chains for conflict minerals."

Murphy's law

The arrival of the SEC deadline also could have unintended consequences for the electronics supply chain.

"The Reduction of Hazardous Substances (ROHS) legislation in Europe produced a series of unintended consequences, including shortages, price increases, and large-scale obsolescence of components," King said. "Similar unexpected events could arise from the SEC conflict minerals rule, especially as a pooling of two supply chains materialize where some companies and their supply chains move away from minerals sourced from illegal operations in the DRC and other global supply chains do not."

Sorting out the conflict minerals

IHS has been able to gather detailed and accurate information on the extent of conflict mineral reporting by leveraging data from its electronic component database. The database offers information and tools for more than 300 million electronic, electromechanical and fastener components used in commercial and military applications.

"IHS has been gathering information on conflict minerals for more than two years," said Greg Wood, director, product management for IHS. "Our conflict mineral data is not based on a survey or estimate, but rather was developed using data provided directly from companies, including environmental declarations, part descriptions and compliance documents. IHS has led the way on conflict minerals and has begun to incorporate conflict minerals documents, declarations and descriptions into our innovative solutions."