Getters:

How getters improve reliability of hermetically sealed electronic packages

HERMETIC SOLUTIONS GROUP
Enabling Technology

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Electronic components may fail if they are exposed to corrosive agents or chemical attack by moisture or other reactive gases that may be present within an electronic package or enclosure. The reliability of sensitive electronic components can be improved by hermetically sealing them within a protective enclosure and self-contained atmosphere. While hermetic sealing may be effective, outgassing of the package materials or materials within the enclosure may be a source of reactive moisture or other gases that could contribute to early device failure. Generally speaking, an assembled package is baked out before hermetically sealing the enclosure under specific temperatures for a duration of a few hours to a few hundred hours in order to drive potential contaminants from the package materials or components prior to the final hermetic sealing process. While this pre-bakeout process is most effective for metallic material, its efficiency to devolve all of the potential contaminants present within the device is less effective for polymeric based components, which may include epoxies and circuit boards. This may result in contaminants being outgassed into the sealed device during their operational life. In such cases, it may be necessary to install getters, which are passive materials that can remove moisture (H2O), hydrogen (H2), oxygen (O2), carbon dioxide (CO2), hydrocarbons (HCs), volatile organic compounds (VOCs) or other products of outgassing within these hermetically sealed electronic enclosures.

“Hermetic Solutions Group has developed a full line of getter products for several different applications that are available in a variety of materials, sizes and form factors.”

ELECTRONIC SYSTEM FAILURE MODES

Sensitive electronic components may be subject to numerous failure modes if they are not hermetically sealed. The process of hermetic sealing ensures that there are no leak paths or channels by which external atmospheric gases or vapors may be transported into the enclosure over long periods of time, for example, 10 to 20 years. Additional protection is added by evacuating the atmospheric air within the enclosure and replacing it with an inert atmosphere, such as pure nitrogen gas or nitrogen gas mixed with helium gas during the hermetic sealing process.

While hermetic sealing can be effective in many applications, certain package materials within the electronic system, such as polymers, epoxies, printed circuit boards and metal plating layers may outgas a variety of potential contaminants when subjected to operating temperature extremes. These contaminants may react with internal electronic components resulting in corrosion and oxidation, or they may interfere with the regular operation of the electronic system, leading to reduced service life and premature failure of the electronic system. Outgassing products that are of primary concern include H2O, H2, O2, CO2, HCs and VOCs, each with different failure modes; some of which are discussed below.

H2O or water vapor in the electronic enclosures can condense onto electronic components if the temperature falls below the dew point temperature. The moisture, together with surface contamination, such as sodium or chloride, or with sour gas CO2, can cause an electrochemical reaction resulting in corrosion of the electronic components. Moisture can also cause a variety of other problems, such as electrical leakage, arcing, or short-circuiting, and contamination or fogging of electro-optical devices.

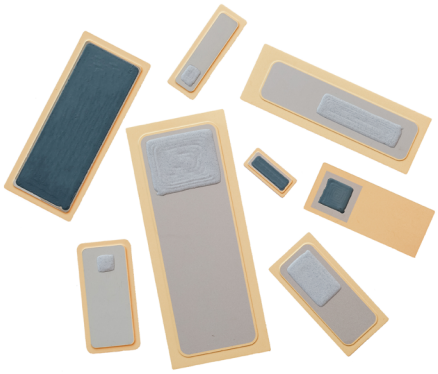
Outgassed H2 in hermetically sealed packages that contain gallium arsenide (GaAs) and indium phosphide (InP) semiconductors (for example, FETs, MMICs, MOSFETs and HEMTs) has been identified as one of the common failure modes in microwave module packages. It is thought that the outgassed H2 can diffuse into the titanium/platinum/gold (Ti/Pt/Au) and Ti/palladium (Pd)/Au device gate structure and cause performance deterioration by reacting with silicon dopants within the material or forming hydride.

O2 gas could be outgassed from any package materials that make up an electronic device or module package. O2 mainly prompts the oxidation of the metal surface especially under an elevated operating temperature that turns an electric conductive component or wire bonding into an electrically insulated one. The metal oxide formation may also cause low thermal conduction between the components and enclosure that often leads to thermal management challenges.

HCs are mainly outgassed from polymers and epoxies that could be thermoplastic or thermoset materials. The long-chain molecules may emit from these materials and contaminate various component surfaces. HCs also have low thermal conductivity that may cause low thermal conduction between the components and enclosure that often leads to thermal management challenges. HC deposits may degrade transmission performance of a laser optics or mirror and other optical components in the module package.

CO2 could emit from a polymer package or epoxy materials by elevated operating temperature. The emitted CO2 sour gas could interact with outgassed moisture to form acidic vapor that can corrode electronic components.

The potential presence of these harmful contaminants within electronic enclosures underscores the need to not only hermetically seal sensitive electronic components, but to also install getters for reducing water vapor and other outgassed species to within acceptable levels.



GETTER TECHNOLOGIES

Getters are passive materials that can remove products of outgassing within hermetically sealed electronic enclosures. They are comprised of materials that can adsorb or absorb targeted gases, thereby maintaining a benign atmosphere within the electronic enclosure. Adsorption involves the adhesion of molecules (or ions and atoms) to the surface of a solid or liquid, where the molecules accumulate only at the surface and do not enter the bulk of the adsorbing material. Absorption, on the other hand, is a physical mechanism or chemical reaction where electrons, molecules or ions join the targeted gas. For example, a Pd getter can adsorb hydrogen molecules and absorb hydrogen atoms and form PdH ($x \leq 1.0$) hydrides that effectively remove outgassed hydrogen gas from an electronic enclosure. Getters made from zeolites, a molecular sieve material, have a range of pore sizes from 0.3 nm to 1.0 nm for locking H2O, O2, CO2, HCs and VOCs. Getter materials are selected based on the outgassed species that must be absorbed.

Applications that may require getters include any microelectronic or electronic device, module or package housing with high outgassing materials, and that need to be reliable for long-term operation, especially if they are exposed to elevated operating temperatures. These applications include radio frequency (RF) and microwave (MW) modules used for electronic warfare (EW) applications, image sensing devices, implantable medical devices and telecommunications devices.

Numerous techniques may be employed to determine whether a hermetically sealed electronic enclosure requires a getter. For example, a routine test is residual gas analysis (RGA). This measures constituent gases within an electronic enclosure, thereby quantifying any problematic outgassed species. Visual inspections, such as a rusted surface on any component may indicate high moisture content or a CO2 combined effect induced corrosion issue. The presence of a low transmission optical surface may indicate contamination caused by hydrocarbons emitted from the package materials. The electric signal in voltage, currency and phase may also anomalously drift due to metal oxide or hydride formations.

SELECTION OF THE OPTIMAL GETTER

Getters are suited to specific applications and come in a variety of materials, sizes, form factors, operating temperature ranges, service lifetimes and absorption capabilities. Two common getter materials are zeolites and certain transition metals — each with different capabilities, advantages and limitations.

Zeolites are used for scavenging moisture, CO2, HCs and VOCs. These are customized by use of different zeolite types to capture specific molecules. Palladium oxide (PdO) particles can also be added to the zeolite to form a getter that can simultaneously scavenge H2, H2O, HCs and other VOCs. Metal-based getters (Ti thin films, Pd foil) are used for high-quantity H2 scavenging applications. Owing to their high absorption capacity, the size of such a metal getter could be small enough to easily fit into various small electronics enclosures or packages, such as microwave modules or laser diode modules. These two primary types of getter technologies can be used together in different packages based on the failure modes identified, the volume of outgassing materials that must be neutralized and the size of the electronic enclosure.

To ensure that a device can maintain reliable operation over its lifetime, a safety factor is typically used for getter specifications. The safety factor is defined by the ratio of its maximum absorption capacity to the target absorption quantity. It is normally adjusted according to the type of getter used, the expected quantity of outgassed materials and the operating temperature range. Generally, the desired absorption of a selected getter should have sufficient sorption capacity to scavenge a multiple of the total outgassed harmful material expected over the operational lifetime from a specific electronic enclosure. For example, if a microwave module may outgas total 1 cubic centimeter (cc) volume H2 gas during its 10-year operation, the getter should be sized to have a maximum absorption capacity of 3 cc. If an electronic package is operated at elevated temperatures (greater than 250° C), a much higher safety factor of 30 to 100 may be preferred to ensure long-term reliability. Quantitative specifications for different types of electronic packages may be recommended to provide effective capability in the removal of outgassed contaminants from any hermetically sealed package housing.

HERMETIC SOLUTIONS GROUP

Hermetic Solutions Group (HSG) has developed a full line of getter products for several different applications that are available in a variety of materials, sizes and form factors. The getters fall into two distinct families. Zeolite based materials (developed in conjunction with Johnson Matthey) are available in a number of forms. They can be printed onto the surface of a package component (usually the lid) or other substrate. They can also be formed into tablets where higher capacity is needed on a smaller footprint than is possible with printed materials.

Zeolites are crystalline solid elements made of silicon, aluminum and oxygen that form a regular lattice structure. This zeolite can be designed with specific pore sizes within the lattice, with different pore sizes attracting specific molecules. The zeolites are refined using a proprietary process to remove impurities. This ensures the stability of the lattice thereby giving predictable performance over many years. There is no chemical reaction between the target gas and the zeolite. It is a physical process, meaning that zeolite getters are fully reversible at low temperatures. A standard pre-seal bake is usually all that is required to ensure that the full getter capacity is available at the point of device sealing. Other materials such as palladium oxide can be added to zeolite getters. PdO acts as a hydrogen getter.

The second family consists of mechanically mill rolled Pd foil based H2 getters, which can be attached to package lids by heat spot welding or by low-outgassing adhesive. Pd-based getter elements may be one of the most promising solutions in removing H2 gas from a microelectronic package. Unlike reactive metal getters based on titanium, vanadium or zirconium there is no need for thermal activation. Pd is used industrially as a catalyst for hydrogenation reactions and exhaust gas cleaning because it combines a high activity for hydrogen splitting with a high solubility for hydrogen in the bulk. This enables Pd to absorb more than 900 times its own volume of hydrogen.

The challenge in using base/raw palladium in a package as a getter system is the tendency of the material to become less ductile (even embrittled) with the formation of palladium hydride, which primarily limits the uptake of its absorption capacity. HSG recognized this challenge and developed a process whereby the bulk Pd material is mechanically stretched by accumulative forces that effectively reduce the polycrystalline grain sizes and thereby enrich the material's high absorption capacity through increased surface-to-volume ratio of the nanocrystalline grains for highly hydride formation PdH(x) with $0.70 \leq x \leq 1.0$, where the grain boundaries are more allowable for hydrogen atoms being easily bonded to Pd atoms up to a maximum bond number of 1.0.

Gettering Materials	Package Contaminants	Getter Sizes	Max Water Absorption Capacity (wt.%)	Max H_2 Absorption (cc)	H_2 Sorption Capacity (atm.cc/g)	H_2 Sorption Capacity (torr-liter/g)
Silicone Polymer (5-35% Zeolites and 5-25% PdO)	H_2, H_20	1.0”x1.0”x0.010”	>3.5	5.4	45	34.2
		1.0”x1.0”x0.010”	3 to 5	5.5	50.2	38.2
Varnish Polymer (5-60% Zeolites, 0-25% PdO)	H_2, H_20, HCs and other organics	1.0”x1.0”x0.010”	5 to 15	6.7	50	38
Ti film ($TiH_{0.70}$)	H_2	1.0”x1.0”x0.006”	--	79.1	71	54
Mill rolling Pd Foil ($PdH_{0.70}$)	H_2	1.0”x1.0”x0.006”	--	95.1	81	61.5

Table 1. Getter materials and getter types.

Different getters have a wide variety of form factors which can be customized according to the specific application in which they are used. These include foil getters, printed getters, adhesive attached getters and inorganic tablets for ultra-high reliability at elevated operating temperatures. To select a proper getter for scavenging contaminants from a specific electronic package application, Table 1 provides theoretical uptake estimates of several getters, with capacity based on 1.0 inch x 1.0 inch x 0.010 inch getter size for zeolite based getters and 1.0 inch x 1.0 inch x 0.006 inch for metallic getters. This table can be used for tailoring a getter size to fit to any electronic package volume. Application of the materials within the package may vary.

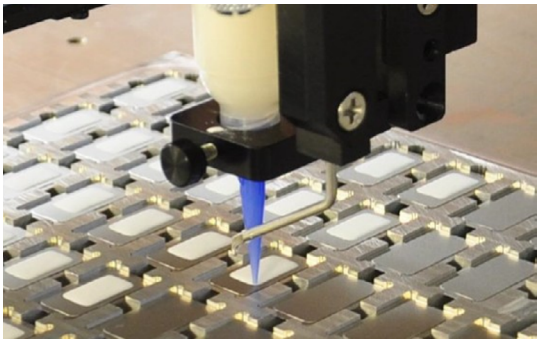


Figure 1: Automated printing of zeolite/PdO getters.

For example, the polymer bound zeolite getter films can be directly deposited onto a package lid surface, while the metallic getters can be attached nearly anywhere into an electronic package interior (walls or lid surface) via the use of either a low-outgassing adhesive or through the use of spot welding the getter onto the package or lid surface. These getter materials may be combined using advanced manufacturing techniques to remove combinations of target gases that may be present inside an electronic package. For example, HSG can apply a getter containing zeolite for the removal of moisture with PdO for the removal of hydrogen through an automated printing process onto metal and ceramic substrates (Figure 1).

HSG provides the broadest offering of getter materials and getter types, with a customized size or form factor for fitting to customer’s package constraints, rather than “one size fits all” products. HSG manufactures electronic packaging components, including a broad range of getters that are ideally suited for specific applications. This ensures optimum cost and performance over the operational lifetime of the protected device.

TALK TO US TODAY

To find out more about HSG’s line of Getters, or any of the products in our portfolio, contact us at info@hermeticsolutions.com.

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ABOUT HERMETIC SOLUTIONS GROUP

At Hermetic Solutions Group, we solve problems. We were formed in 2016 to provide a comprehensive offering that houses and protects microelectronics in the world's most extreme environments to maximize performance and life. We bring six industry leading component manufacturing and service companies together under a single umbrella – Cristek Interconnects, FilConn, Litron, Hi-Rel Group, Pacific Aerospace & Electronics, and Sinclair Manufacturing. With a common focus of putting our customers at the center of everything we do, our companies employ proprietary technologies, best practices engineering and specialized manufacturing to get it right for you the first time, every time and on-time. Visit our website at www.hermeticsolutions.com.

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