

Package Hermeticity and Gas Analysis

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Package Hermeticity and Gas Analysis

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BOTH PACKAGE HERMETICITY and residual gas analysis testing are the focus of this article. Each is described separately.

Hermeticity Testing

Failure mechanisms identified in micro-electronic devices are, to a large degree, triggered by excessive moisture in the package cavity. Results vary from a subtle electrical leakage to severe corrosion and electrical failure. Although this internal water vapor may be sealed in the package during processing or may be generated internally after seal from material outgassing or decomposition, a primary source is the ingress of moisture that occurs because of a non-hermetic package seal.

Usually, to evaluate overall package integrity, both fine and gross leak tests are required to test the full leak rate range of interest, as indicated in Table 1. Most test methods cited use a pressurization cycle with a tracer gas or fluid, followed by a measurement of the amount of tracer entrapped in the package, or its rate of flow from the package (per unit time).

Test Methods

Fine Leak Tests. The operational range of fine leak testing provides the measurement of leak rates from 10^{-6} to 10^{-10} atm · cm³/s. Fine leak testing must be performed prior to gross leak testing because gross leak tracer fluids may plug capillary leak channels, preventing the influx of a tracer gas for accurate fine leak measurement.

The two most commonly used fine leak tests are helium mass spectrometry leak detection and the radioisotope leak test. For the helium leak test, devices are placed in a pressurization tank, which is evacuated and then pressurized with helium (He) at a spec-

ified pressure for a specified period of time. At the conclusion of the pressurization cycle, the devices are removed and placed into a mass spectrometer, where the rate at which helium is leaking from the device is measured in atm · cm³/s. In an effort to bypass the pressurization cycle prior to fine leak testing, some devices are sealed in an atmosphere containing up to 25% He. In such cases, devices are transferred directly to the mass spectrometer for leak measurement without any preconditioning.

Determination of the appropriate time and pressure values for the pressurization cycle is based on the internal volume of a device and may be assigned using a fixed or flexible method. The fixed method, as outlined in Table 2 (Ref 1, test condition A1) utilizes specified time and pressure values for given package volume ranges, which will ensure the test sensitivity for the required measured leak rate, R_1 . The flexible method allows a variance in test conditions to detect the specified equivalent leak rate, L , at a predetermined leak rate, R_1 , in accordance with Eq 1:

$$R_1 = \frac{LP_E}{P_0} \left(\frac{M_A}{M} \right)^{1/2} \cdot \left\{ 1 - e^{- \left[\frac{Lt_1}{VP_0} \left(\frac{M_A}{M} \right)^{1/2} \right]} \right\} \cdot e^{- \left[\frac{Lt_2}{VP_0} \left(\frac{M_A}{M} \right)^{1/2} \right]} \quad (\text{Eq 1})$$

where R_1 = measured leak rate of the tracer gas, He, through the leak in atm · cm³/s He; L = equivalent standard leak rate in atm · cm³/s air, as determined by:

Internal volume of package cm ³ / in. ³		Reject limit leak size (L), atm · cm ³ /s air
≤ 0.01	≤ 0.0006	5 × 10 ⁻⁸
0.01 ≤ V ≤ 0.4	≤ 0.0006 ≤ V ≤ 0.024	1 × 10 ⁻⁷
≥ 0.4	≥ 0.024	1 × 10 ⁻⁶

P_E = pressure of exposure in atmospheres absolute; P_0 = atmospheric pressure in atmospheres absolute (1); M_A = molecular weight of air in grams (28.7); M = molecular weight of the tracer gas, He, in grams (4); t_1 = time of exposure to P_E in seconds; t_2 = dwell time between release of pressure and leak detection in seconds; and V = internal volume of device package cavity in cubic centimeters.

Another variation of the leak test, which, although not quantifiable, can serve to identify the location of the leak site, is the mass spectrometry probe, or so-called sniffer, method. In this case, following pressurization, a probe attached to the mass spectrometer inlet is passed over the device to identify the leak site and source of outgassing helium.

For the radioisotope leak test, as described in Ref 1, test condition B, the test sequence is essentially the same as the helium leak test with the devices being pressurized in a radioactive isotope (krypton-85) and nitrogen mixture. Measurement of the penetration of tracer gas into the nonhermetic device is accomplished by measuring (with a radiation detector) gamma rays emitted through the walls of the package. The count rate acquired from the detector is applied in a conversion equation to calculate the leak rate.

A comparison of the helium and radioisotope leak tests shows that each is specific to a given application; the final choice of technique depends on device size, configuration, and the ultimate objective of the failure analysis. One potential problem that may be encountered with the helium leak test is the "one-way leaker" phenomenon. Occasionally, during the helium pressurization cycle, physical stress in the intergranular oxide in glass-to-metal feed-through seals may form temporary cracks, forcing helium into an otherwise hermetic package. After pressure has been removed, these minute cracks can reseal, resulting in an acceptable hermeticity reading. However, subsequent testing of the package cavity gas by residual gas analysis (RGA) will result in conflicting data. Residual gas analysis will confirm the presence of the fine leak tracer

Table 1 Fine and gross leak tests

Leak test	Operational range	Test method	Tracer
Fine leak	10^{-6} to 10^{-10} atm · cm ³ /s	Helium leak detection	Helium
		Radioisotope	Krypton-85
		Bubble test	Fluorocarbon
		Weight gain	Fluorocarbon
		Dye penetrant	Fluorescent dye
Gross leak	10^{-1} to 10^{-5} atm · cm ³ /s		

Table 2 Fixed conditions for helium fine line leak test

Volume of package, cm ³ (in. ³)	Pressure		Bomb condition		Reject limit (R ₁), atm · cm ³ /s He
	kPa	psia (±2)	Exposure time (t ₁), h (+1, -0)	Maximum dwell (t ₂), h	
<0.05 (<0.003)	520	75	2	1	5 × 10 ⁻⁸
≥0.05 to <0.5 (≥0.003 to <0.03)	520	75	4	1	5 × 10 ⁻⁸
≥0.5 to <1.0 (≥0.03 to <0.006)	310	45	2	1	1 × 10 ⁻⁷
≥1.0 to <10.0 (≥0.06 to <0.61)	310	45	5	1	5 × 10 ⁻⁸
≥10.0 to <20.0 (≥0.61 to <1.2)	310	45	10	1	5 × 10 ⁻⁸

gas, indicating a nonhermetic package. The radioisotope method overcomes this problem, because detection of the radioactive tracer gas in the package interior does not depend on outflow through a leak channel, but on the detection of radiation through the package walls.

Although the radioisotope leak test provides better sensitivity than the helium leak test, it cannot be used to identify the location of leak sites. Moreover, for devices that fail the radioisotope leak test, further analyses on the device should be suspended for several days to allow radioactive decay and safe handling.

Note that for all fine leak testing, any heavy contamination, polymeric materials, or highly modeled surfaces on the exterior of the device may lead to the absorption and adsorption of tracer gas, which will be detected in the final measurement and will compromise the accuracy of the test. If possible, foreign material should be physically removed prior to the pressurization cycle. Chemical removal should be avoided, because this may result in plugging existing leak channels. If the material cannot be removed, an air or nitrogen (N) wash or a brief bake-out following the pressurization cycle may be applied.

Gross Leak Tests. The operational range of gross leak testing provides the measurement of leak rates from 10⁻¹ to 10⁻⁵ atm · cm³/s. Depending on the device size, configuration, and design, one of three gross leak tests may be applied: the fluorocarbon bubble test, the fluorocarbon weight gain test, or the dye penetrant test.

In the fluorocarbon bubble test, devices are pressurized with a low boiling point tracer fluid, typically FC-72, FC-84, or

equivalent, at a specified pressure for a specified period of time. The devices are then immersed in a bath of indicator fluid, typically FC-43, FC-40, or equivalent, at a temperature above the boiling point of the tracer fluid. Increased pressure in the cavity of the device from the vaporized tracer fluid will force gas out through the leak channels, resulting in bubble formation at egress points.

As in the helium leak test, time and pressure values for the pressurization cycle are based on the internal volume of the device and may be assigned using either a fixed or flexible method. The fixed method, as outlined in Table 3 (Ref 1, test condition C1), uses specified time and pressure values for given package volume ranges. The flexible method (Ref 1, test condition C2) allows the devices to be pressurized at 205, 415, 520, or 620 kPa (30, 60, 75, or 90 psig) for a minimum time, determined by Eq 2:

$$T_p = \frac{0.1VF_1}{6 \times 10^{-4} \text{ cm}^3} \quad (\text{Eq 2})$$

where T_p = minimum time of pressurization in minutes, V = internal volume of device package cavity in cubic centimeters, and F₁ = filling time, as determined by:

Pressure	Filling time, min	
	kPa	psig
207	30	45
415	60	15
517	75	12
620	90	10

For the fluorocarbon weight gain test (Ref 1, test condition 3), devices are cleaned, baked, and weighed on a microbalance prior to pressurization in a low-viscosity, low

vapor pressure fluorocarbon tracer fluid. As seen in fine leak testing, the exterior of the device should be cleaned; if possible, materials should be removed before testing to prevent inaccurate readings caused by tracer fluid retention. Following an air dry, the devices are reweighed to determine weight gain from entrapped tracer fluid. Depending on package volume, a 1 to 2 mg (3.5 × 10⁻⁵ to 7.0 × 10⁻⁵ oz) increase in weight typically is cause for rejection. Unlike the bubble test and the dye penetrant test, this technique cannot be used to identify the location of the actual leak.

The dye penetrant test (Ref 1, test condition D) uses a fluorescent dye as a tracer fluid and is most effectively used on devices with transparent walls. The devices are pressurized in a fluorescent dye, washed with a suitable solvent, and then visually inspected under an ultraviolet (UV) light source for evidence of dye penetration.

Inherent to all of the described gross leak tests is the fact that true gross leakers may be damaged from the influx of tracer fluid, inhibiting further analyses.

Characterization of Hermeticity Test Failures.

By leak measurement and identification using fine and gross leak testing, coupled with inspection via optical microscopy and/or a scanning electron microscope, the mechanism that caused the loss of package hermeticity can typically be characterized. Excluding overall breakage, cracks, or chip-outs caused by mishandling or physical or thermal stress during operation, the two most common production-related hermeticity failure sites are in the lid-to-package seal and around glass-to-metal feed-through seals.

The integrity of the lid-to-package seal, whether a solder, weld, or glass seal, is a function of the package materials and the applicable time/temperature/pressure sealing parameters. A discontinuity in the application of the sealing materials or in the process often accounts for some of the most severe gross leaks encountered.

Radial cracking is the most common cause of failure in glass-to-metal feed-through seals. Such cracks originate at the pin-glass interface and radiate outward toward the perimeter of the glass seal. In addition to mishandling, pin size and shape with respect to the diameter of the feed-through, as well as its placement within the glass, should be considered in determining the cause of radial cracking. Other causes of failure in glass-to-metal seals include weakness in the intergranular oxide at the pin-glass interface and poor glass meniscus formation at pin egress points.

Residual Gas Analysis

A complete quantitative analysis of the ambient gases in the package cavity can verify elevated internal moisture in suspect-

Table 3 Fixed conditions for fluorocarbon gross leak test

Cavity volume, cm ³ (in. ³)	Vacuum(a)	Minimum bomb pressure		Minimum bomb duration, h
		kPa	psig	
≥0.1	Optional	415	60	2
≥0.1	Optional	205	30	10(b)
≥0.1	Optional	310	45	6(b)
≥0.1	Not required	310	45	10(b)
<0.1	Required	415	60	2
<0.05	Required	520	75	1

(a) At ≥665 Pa (±5 torr) for ≥1 h when required. (b) This condition may be used only for packages that cannot withstand the standard conditions.

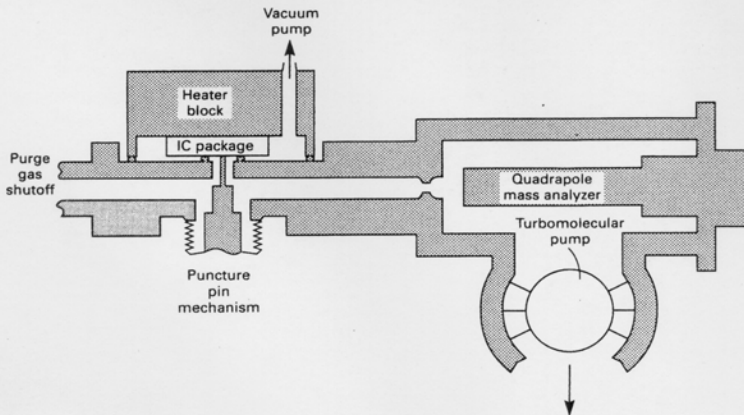


Fig. 1 Cross section of sample block and analyzer in rapid cycle RGA system

ed moisture-related failures and can provide invaluable information on the source of moisture and other potentially corrosive gases, as well as information on the processing history of the device. The most widely accepted method for evaluating ambient gas content is RGA by mass spectrometry.

Test Method

The mass spectrometric method for RGA involves ionization and separation of gas molecules as they flow from the package cavity, followed by a measurement of their relative abundance as a function of their mass-to-charge (m/e) ratio. Most commercially available RGA systems employ quadrupole mass spectrometers and are configured for either batch or rapid cycle testing. Batch systems use a larger test chamber, which can accommodate several samples on one central carousel. Once loaded, the test chamber is vacuum baked for 12 to 24 h to reduce background levels before testing. Rapid cycle systems are designed to load and test one device at a time; because of the reduced size of the test chamber, they require only a 10 min vacuum bake-out for achieving suitable background levels before testing. A cross section of a rapid cycle RGA system is shown in Fig. 1.

The minimum requirements for the measurement of internal water vapor content (Ref 2, procedure 1) are outlined in Table 4. As applied to a rapid cycle RGA system, the test sequence begins by loading a single sample into the test chamber, where the lid of the sample is sealed against a Viton O-ring. The puncture pin will be driven through the center of this Viton O-ring to pierce the package lid. This mounting procedure places most of the sample outside the realm of the mass spectrometer analyz-

er, thus minimizing the effect of the exterior of the package as one of the major adsorption variables. The mount is sealed against the wall of the inlet block, leaving a hermetic cavity around the sample, where a vacuum may be maintained. Once the test chamber is sealed, the sample is allowed to reach thermal equilibrium at 100 °C (212 °F) for a minimum of 10 min, while a turbomolecular pump maintains the mass spectrometer inlet and analyzer at 133×10^{-8} Pa (1×10^{-8} torr). After the 10-min bake (assuming an adequate background level is achieved), a background scan is collected, and the package lid is punctured, releasing the ambient gases into the mass spectrometer analyzer. The relative ionic abundance or intensity is acquired during several 1 to 100 atomic mass unit (AMU) (m/e units) scans. Raw data is corrected for background, interfering spectral peaks, and instrument sensitivity to individual ambient gases. The final quantification is calculated in percent or ppmv concentration.

The key to accuracy in measuring the moisture level in such relatively small volumes of gas lies in a calibration system that closely simulates a sample burst into the mass spectrometer inlet. To accomplish this, multiple or single volume calibrators are mounted on the sample test chamber and are used to simulate sample bursts using various calibration gases. The volume sizes used during a full-scale calibration range from 0.01 to 20.0 cm^3 (0.0006 to 1.2 in^3), allowing the operator to simulate sample bursts for several package sizes.

For the calibration of moisture, a general-purpose humidifier is used to generate a known moisture level, which is confirmed by a dew point hygrometer. Air and special gas mixtures are used to calibrate other gases.

Table 4 Minimum requirements for internal water vapor content measurement

Per MIL-STD-883C, method 1018.2, procedure 1

Parameter	Value or description
Accuracy at 5000 ppm, %	± 10
Volume range, cm^3 (in^3)	0.01–20.0 (0.0006–1.2)
Temperature for 10 min	
Sample, °C (°F)	100 (212)
Mass spectrometer inlet, °C (°F)	125 (255)
Package puncturing	Puncture a hole without breaking hermetic seal
Sample preparation	Prebake at 100 °C (212 °F) for 12 to 24 h if device contains desiccants or organics; ceramics lids can be thinned by abrasion to facilitate localized piercing
Measure	Chamber pressure, moisture content, all other gases
Failure criteria	Water vapor content greater than the specified maximum value (maximum value per MIL-STD-883C, method 5005, is 5000 ppmv). Abnormally low total gas content (device may be replaced)

Interpretation of RGA Data

The interpretation of RGA data requires an understanding of the source and implications of the individual constituents that comprise an RGA spectrum. The following sections are an overview of the gases measured in RGA and are followed by an interpretation of several RGA data sets.

Moisture. For any hermetically sealed device, there are three primary sources of internal moisture: a loss of package hermeticity, internal outgassing after sealing, and a poor sealing atmosphere. The most easily identified source is a loss of hermeticity, resulting in an ingress of moisture from the surrounding environment. In such cases, the presence of a leak can usually be confirmed by evaluating the levels of oxygen (O) and argon (A) and, if applicable, by the presence of residual helium and/or fluorocarbons from previously performed hermeticity testing.

A second source of internal moisture is post-seal outgassing from package materials as a result of chemical reactions, thermal degradation, or desorption. Moisture may be released as a by-product of a chemical reaction activated by available reactive species, as well as the physical parameters of time, temperature, and pressure. For example, in some ceramic packages that incorporate a glass frit seal with dry air as a sealing gas, moisture and carbon dioxide may be generated by the oxidation of carbonaceous species in the sealing glass. This reaction is activated at high temperatures such as those achieved during the sealing process. Moisture and carbon dioxide are also generated

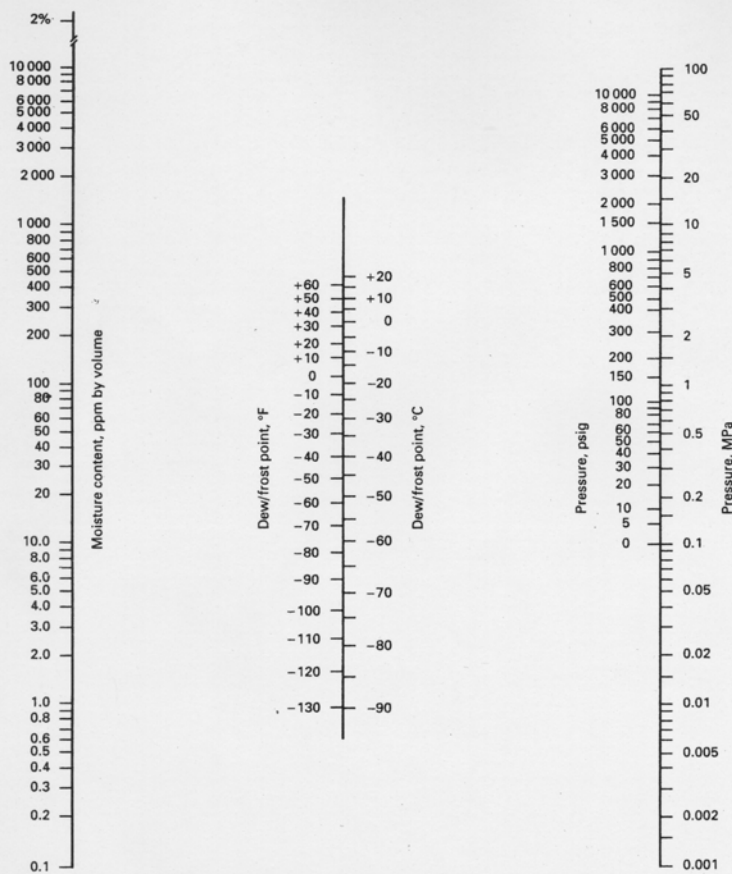


Fig. 2 Nomograph for dew point and ppmv as a function of pressure

during the thermal degradation of organic die and substrate attach materials, as a result of overcuring. A simple desorption of moisture from organic, ceramic, and metal package materials may also occur. Considering all of the potential sources for post-seal outgassing, the package ambient should never be viewed as a static system.

The third and least common source of internal moisture is an extremely poor sealing atmosphere where the moisture essentially is present in the sealing gas and enters the device at the time of seal. This can result from a faulty sealing line or from poor quality control of sealing gases.

Although not always the sole cause of failure, moisture is typically a key contributor. As an ionizable species that will migrate under bias, moisture may serve to mobilize electric charge or corrosive ionic contaminants. In measuring internal wa-

ter vapor content, the ultimate concern is internal surface moisture available at operational temperatures that may serve as this carrier medium. The package moisture concentration, as reported in RGA in ppmv, may be converted to a dew point measurement, the temperature at which moisture condenses from the vapor state. Using the total internal package pressure and the RGA moisture reading, the nomograph in Fig. 2 may be used to determine the dew point.

Common moisture-related failure mechanisms include electrical instability, corrosion, and electromigration of metallization. Identifying moisture-induced electrical instability is an interesting problem because the instability sometimes disappears when the package is opened for inspection. Corrosion will occur when biased metallizations behave as electrodes in an electrolytic

environment created by adsorbed moisture and ionic impurities. In both corrosion and metal migration, the level of moisture required to trigger these mechanisms is variable and depends on the availability of reactive contaminants as well as operating time and bias.

Nitrogen. Nitrogen (N) is typically the major constituent reported in RGA, because most hermetically sealed devices incorporate dry nitrogen, dry air, or a nitrogen-oxygen mix as a sealing gas. Reported levels may range from 78%, in the case of dry air, to 99%, which represents a pure nitrogen sealing atmosphere.

Oxygen is typically required in the sealing atmosphere of ceramic dual-in-line packages at levels ranging from 10 to 20% for an effective glass frit seal. Oxygen can be highly reactive and may be consumed in a reaction with available carbon (C) from the glass frit or ceramic case during the high-temperature sealing process, resulting in the generation of moisture and carbon dioxide. In solder-sealed devices, surface oxidation of the sealing solder, which jeopardizes the integrity of the metal-to-metal seal, prohibits the use of oxygen in the sealing atmosphere.

Argon may be detected as a residual in a nitrogen sealing atmosphere in levels of less than 500 ppmv; in a dry-air atmosphere, it is typically present at a level of approximately 9200 ppmv. In identifying a suspected leaker, an evaluation of the level of argon, the ratio of oxygen to argon (~20/1 in air), and the presence of other gaseous constituents (such as He and/or fluorocarbons), can confirm the presence and perhaps time of occurrence of a nonhermetic seal.

Carbon dioxide in the package ambient is commonly an end product of post-seal outgassing. It may be generated during the thermal degradation of organic die and substrate attach materials when temperature stressed, as a result of the oxidation of available hydrocarbons present in package materials, or from contamination under normal processing and operating conditions. The level of carbon dioxide can vary from as low as 100 ppmv to several percent, depending on the amount of hydrocarbons available for reaction. Extremely high levels of carbon dioxide and moisture can ultimately have corrosive effects on exposed metallization.

Hydrogen. The presence of hydrogen (H) indicates either a package sealed in a reducing atmosphere or post-seal outgassing from electroplated coatings. Hydrogen values that are consistently reported at greater than 10% typically indicate the use of a reducing atmosphere during package seal. This forming gas may be used to stabilize certain device types or to prevent the oxidation of sealing surfaces. By comparison, hydrogen that has outgassed from electroplated coatings after seal is extremely vari-

Table 5 RGA results for standard CERDIP and side-braze packages

Parameter	1		
	16-pin CERDIP	24-pin CERDIP	16-pin side braze
Pressure, kPa (torr)	24 (0.18)	55 (0.41)	40 (0.30)
Nitrogen, %	78.2	84.5	99.8
Oxygen, %	20.6	15.1	ND
Argon, ppm	9120	340	350
Carbon dioxide, ppm	2030	1920	410
Moisture, ppm	850	1740	460
Hydrogen, ppm	ND	ND	780

able and may reach levels up to several percent, depending on the ratio of electroplated surface area to package cavity volume.

Helium and Fluorocarbons. The presence of helium indicates either a leak test escape or the use of helium in the sealing atmosphere as a tracer gas for subsequent fine leak testing. Leak test escapes may occur when the leak is beyond the detection limits of the leak test equipment or when a one-way leaker has prevented the detection of the tracer gas. In both cases, reported levels of helium will be extremely variable and will range from as low as a few hundred ppmv for an undetected fine leaker to 20% for a one-way leaker. Helium sealed in the package as a tracer gas is typically reported at levels as high as 25% and when hermetic conditions exist, shows consistency from package to package.

The presence of gross leak fluorocarbons always indicates that the package was (or still is) in a nonhermetic state. This is the result of either a one-way leaker created during hermeticity testing or a package that was a marginal leaker prior to testing. These marginal leakers can be from poor assembly procedures or subsequent mishandling.

Other Residual Gases. Other sources of residual gases that may be identified in RGA include organic materials, residual solvents/cleaning agents, and amine-base curing agents. Organic gases are typically associated with polymeric die and substrate attach materials, as well as residuals from etching (photoresist) and bake-out (vacuum pump oils) processes. Their presence may be used to gage processing quality; at this time, there is no known failure mechanism directly linked to their presence. Residual solvents and cleaning agents such as isopropyl alcohol, trichloro ethane, chlorofluoro-

carbons, and methyl ethyl ketone also reflect poor processing procedures.

Epoxy systems employing dicyandiamide as a curing agent will outgas ammonia at levels up to several percent. This decomposition and outgassing can occur after burn-in or high-temperature stress. In combination with moisture, this can create a highly alkaline environment, which will subsequently lead to the corrosion of exposed metallization.

Sample Data Sets. Table 5 shows representative RGA results, with no significant anomalies for standard CERDIP or side-braze packages. The pressure reading, reported in torr, represents the pressure rise in the test chamber that occurs when the package is punctured. This reading is a relative measurement that reflects the quantity of gas in the package cavity and is useful in identifying suspected leakers. Column 1 in Table 5 represents RGA data collected from a CERDIP sealed in dry air. The level of carbon dioxide in dry air can range from 900 to 1200 ppm. The level reported in this data set indicates that some oxidation of available carbon from package materials has occurred. Column 2 in Table 5 represents RGA data collected from a CERDIP sealed in a dry nitrogen-oxygen mixture. Note that the level of argon is approximately at the same level as that shown in column 3, which represents RGA data collected from a side-braze package sealed in a dry nitrogen atmosphere. In column 3 there is some indication of low-level hydrogen outgassing from package materials.

The results of an oxygen depletion reaction in a ceramic package are shown in Table 6. The level of argon indicates that the package was originally sealed in a dry-air atmosphere, where the oxygen level was approximately 20%. A large-scale oxidation of carbonaceous

Table 6 Oxygen consumption with moisture and carbon dioxide generation

Parameter	48-pin ceramic side-braze package	
	1	2
Pressure, kPa (torr)	81 (0.61)	88.1
Nitrogen, %	88.1	1.38
Oxygen, %	1.38	9160
Argon, ppm	9160	7.73
Carbon dioxide, %	7.73	1.87
Moisture, %	1.87	

species from either the sealing glass or the ceramic walls resulted in a substantial drop in the level of oxygen and the generation of moisture and carbon dioxide.

Table 7 presents the RGA results from a hybrid package that was sealed in a dry nitrogen atmosphere, apparently a leak test escape, as indicated by the presence of oxygen, argon, helium, and fluorocarbons. Several percent of ammonia have also been reported and can be expected as a result of outgassing from some amine-cured epoxy systems.

The hybrid package shown in Table 8 was sealed in a dry-nitrogen atmosphere, but shows evidence of a degradation of epoxy attach materials as a result of thermal stress. Levels of both moisture and carbon dioxide are extremely elevated and are the primary by-products from overcured organic materials. Overcuring may occur either through elevated cure temperatures or extended bake time at the recommended cure temperatures.

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Table 7 Leak test escape with outgassed ammonia

Parameter	Hybrid package
Pressure, kPa (torr)	720 (5.43)
Nitrogen, %	86.8
Oxygen, %	3.64
Argon, ppm	1730
Carbon dioxide, ppm	5680
Moisture, ppm	9350
Helium, %	1.66
Fluorocarbons, ppm	3940
Ammonia, %	5.83

Table 8 Thermal degradation of organic material with generation of moisture and carbon dioxide

Parameter	Hybrid package
Pressure, MPa (torr)	1.5 (11.6)
Nitrogen, %	86
Oxygen, %	NL
Argon, ppm	ND
Carbon dioxide, %	8.13
Moisture, %	5.44
Hydrogen, ppm	1240
Hydrocarbons, ppm	1060

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