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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Semiconductor devices – Mechanical and climatic test methods – Part 7: Internal moisture content measurement and the analysis of other residual gases

Dispositifs à semiconducteurs – Méthodes essais mécaniques et climatiques – Partie 7: Mesure de la teneur en humidité interne et analyse des autres gaz résiduels

IEC 60749-7:2011

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FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 60749-7 has been prepared by IEC technical committee 47: Semiconductor devices.

This second edition cancels and replaces the first edition published in 2002 and constitutes a technical revision. This second edition has been completely re-written so as to align it with the text of the latest versions of MIL-STD-750, method 1018 and MIL-STD-883, method 1018.

The main change is the removal of the two alternative methods formerly designated method 2 and method 3.

The text of this standard is based on the following documents:

FDIS	Report on voting
47/2087/FDIS	47/2098/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60749 series, under the general title *Semiconductor devices – Mechanical and climatic test methods*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

SEMICONDUCTOR DEVICES – MECHANICAL AND CLIMATIC TEST METHODS –

Part 7: Internal moisture content measurement and the analysis of other residual gases

1 Scope

This International Standard specifies the testing and measurement of water vapour and other gas content of the atmosphere inside a metal or ceramic hermetically sealed device. The test is used as a measure of the quality of the sealing process and to provide information about the long-term chemical stability of the atmosphere inside the package. It is applicable to semiconductor devices sealed in such a manner but generally only used for high reliability applications such as military or aerospace. This test is destructive.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

None

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
parts per million by volume
ppmv
the concentration of one substance in another substance expressed as a ratio of parts of the one substance in a million parts of the other substance, measured by volume

4 Test apparatus

4.1 Mass spectrometer method

This method measures the water vapour content of the device atmosphere by mass spectrometry. The apparatus is detailed below.

4.2 Mass spectrometer

The mass spectrometer shall be capable of meeting the requirements of 4.2.1 to 4.2.2 and shall be calibrated in accordance with 4.2.3 to 4.2.8.

4.2.1 Spectra range

The mass spectrometer shall be capable of reading a minimum spectra range of 1 AMU to 100 AMU (atomic mass units).

4.2.2 Detection limit

The mass spectrometer shall be capable of reproducibly detecting the specified moisture content for a given volume package with a signal-to-noise ratio of 20:1 (i.e. for a specified limit of 5 000 ppmv, 0,01 ml, the mass spectrometer shall demonstrate a 250 ppmv minimum detection limit to moisture for a package volume of 0,01 ml). The smallest volume shall be considered the worst case.

4.2.3 System calibration

The mass spectrometer shall be calibrated annually with a moisture level in the 4 500 ppmv to 5 500 ppmv range, with a moisture level in the 2 000 ppmv to 3 000 ppmv range and with a moisture level in the 7 000 ppmv to 8 000 ppmv range using the same sensitivity factor. This calibration needs to be performed for each calibrator volume to demonstrate a linear response and to detect offset. A minimum of three data points for each moisture level shall be collected. Package simulators which have the capability of generating at least three known volumes of gas ±10 % on a repetitive basis by means of a continuous sample volume purge of known moisture content ±5 % shall be used. Moisture content shall be established by the standard generation techniques (i.e. double pressure, divided flow, or cryogenic method). The dew point hygrometer shall be recalibrated a minimum of once a year using equipment traceable to national standards or by a suitable commercial calibration services laboratory using equipment traceable to national standards. The dew point hygrometer shall be capable of measuring the dew point temperature to within an accuracy of ±0,2 °C. The system shall have a pressure sensor to measure the pressure in line with the temperature dew point sensor to an accuracy of ±300 Pa for the range of pressure being used. In addition, the test laboratory shall have a procedure to calculate the concentration of moisture, in units of parts per million by volume, from the dew point temperature measurement and the pressure measurement. Gas analysis results obtained by this method shall be considered valid only in the moisture range or limit bracketed by at least two (volume or concentration) calibration points (i.e. 5 000 ppmv between 0,01 ml to 0,1 ml or 1 000 ppmv to 5 000 ppmv between 0,01 ml to 0,1 ml). A best fit curve shall be used between volume calibration points. Systems not capable of bracketing may use an equivalent procedure as approved by the customer or certifying body. Corrections of sensitivity factors deviating greater than 10 % from the mean between calibration points shall be required.

NOTE It is recommended that the percentage of water vapour contained in a gas flowing through the gas humidifier be compared to the dew point sensor reading for accuracy of the sensor. The following equation may be used to calculate the per cent of water vapour contained in a gas flowing through the gas humidifier.

$$\%H_2O = \frac{100\,(P_\mathrm{v})}{P_\mathrm{g} + P_\mathrm{a}} \tag{1}$$

where

P_v is the vapour pressure of water in the GPH based on water temperature in degrees celsius (°C);

P_g is the gauge pressure;

P_a is the atmospheric pressure.

4.2.4 Calibration for other gases

Calibration shall be required for all gases found in concentrations greater than 0,01 % by volume. As a minimum, this shall include all gases listed in Item b) of Clause 5. The applicable gases shall be calibrated at approximately 1 % concentrations requirements, with the exception of the following:

– fluorocarbons, which may use a concentration of approximately 200 ppmv;
– ammonia, which may use a concentration of approximately 200 ppmv;
– hydrogen, which may use a concentration of approximately 200 ppmv;
– nitrogen, which may use a concentration of approximately 80 %;
– helium, which may use a concentration of approximately 10 %; and

– oxygen, which may use a concentration of approximately 20 %.

4.2.5 Daily calibration check

The system calibration shall be checked on the day of test prior to any testing. This shall include checking the calibration by admitting a sample with a moisture level in the 4 500 ppmv to 5 500 ppmv range at the required volumes and comparing the result with the dew point hygrometer. The resulting moisture reading shall be within 250 ppmv of the moisture level in the calibration sample. Calibration performed on the day of test prior to any testing may be substituted for this calibration check. Calibration records shall be kept on a daily basis.

NOTE Equipment error needs to be determined and subtracted from the allowed maximum deviation of 250 ppmv. The calibration check shall be performed using the same conditions used for testing devices (e.g. background pressure, background environment, time between sample inlets, package simulator volume, etc.).

4.2.6 Substitution

Any calibration performed on the day of test, and prior to any testing may be substituted for this calibration check.

4.2.7 Precision tuning

Precision tuning shall be performed following significant maintenance or repair of the ion source.

4.2.8 Record keeping

A record of all changes made to the sensitivity factors shall be maintained.

4.3 Vacuum opening chamber

The test apparatus shall incorporate a vacuum opening chamber which can contain the device and a vacuum transfer passage connecting the device to the mass spectrometer according to 4.2. A vacuum transfer passage shall efficiently (without significant loss of moisture from adsorption) transfer the gas from the device to the mass spectrometer ion source for measurement.

For initial certification of systems or extension of suitability, device temperature on systems using an external fixture shall be characterized by placing a thermocouple into the cavity of a blank device of similar mass, internal volume, construction, and size. This shall be a means for proving the device temperature that has been maintained at 100 °C ± 5 °C for the minimum 10 min. This also applies to devices prebaked in an external oven but tested with the external fixture to adjust for any temperature drop during the transfer. These records shall be maintained by the test laboratory.

4.4 Piercing arrangement

The test apparatus shall contain a piercing arrangement functioning within the opening chamber or transfer passage according to 4.3, which can pierce the specimen housing (without breaking the mass spectrometer chamber vacuum and without disturbing the package sealing medium), thus allowing the specimen's internal gases to escape into the chamber and mass spectrometer.

NOTE A sharp-pointed piercing tool, actuated from outside the chamber wall via a bellows to permit movement is used to pierce both metal and ceramic packages. For ceramic packages, or devices with thick metal lids, the package lid or cover should be locally thinned by abrasion to facilitate localized piercing.

4.5 Pressure-sensing device

A pressure-sensing device shall be located in the transfer passage to measure the pressure rise in the transfer passage during the test. This pressure sensor is used to read a relative pressure change when the device is punctured. This relative pressure change indicates the

relative quantity of gas in the device when comparing the test results of one device to another device. The significance of the reading is not intended to be absolute. Although the pressure gauge reading is reported, the pressure gauge is for indication only.

5 Procedure

All devices shall be pre-baked for 16 h to 24 h at 100 °C ± 5 °C prior to the test. Ovens shall have a means to indicate if a power interruption occurs during the pre-baking period and for how long the temperature drops below 100 °C ± 5 °C. Devices whose temperature drops below 100 °C ± 5 °C for more than 1 h shall undergo another pre-bake to begin a minimum of 12 h later.

A maximum 5 min transfer time from pre-bake to hot insertion into apparatus shall be allowed. If 5 min is exceeded, the device shall be returned to the pre-bake oven and pre-bake continued until device reaches 100 °C ± 5 °C.

The system shall be maintained at a stable temperature equal to or above the device temperature. The fixturing in the vacuum opening chamber shall position the specimen as required by the piercing arrangement according to 4.4 and maintain the device at 100 °C ± 5 °C for a minimum of 10 min prior to piercing.

After device insertion, the device and chamber shall be pumped down and baked out at a temperature of 100 °C ± 5 °C until the background pressure level will not prevent achieving the specified measurement accuracy and sensitivity. The background vacuum spectra shall be acquired and shall later be subtracted from the sample spectra. After pump down, the device case or lid shall be punctured and the following properties of the released gases shall be measured using the mass spectrometer.

a) The water-vapour content of the released gases, as a percent by unit volume or ppmv of the total gas content.

b) The proportions (by volume) of the other following gases: nitrogen, helium, Mass 69 (fluorocarbons), oxygen, argon, hydrogen, carbon dioxide, methane, ammonia, and other solvents, if available. Calculations shall be made and reported on all gases present. Data reduction shall be performed in a manner, which will preclude the cracking pattern interference from other gas species in the calculations of moisture content. Data shall be corrected for any system dependent matrix effects such as the presence of hydrogen in the internal ambient.

c) The increase in chamber pressure as the gases are released by piercing the device package. A pressure change of ±25 % from expected for that package volume and pressurization may indicate that

   - the puncture was not fully accomplished,
   - the device package was not sealed hermetically, or
   - does not contain the normal internal pressure.

d) The test laboratory should provide comments describing the spectra of unknowns or gases that are present but not in sufficient concentration to be identified or quantified with reasonable certainty.

e) If the test laboratory has reason to believe that the test results may be invalid due to reasons such as improper puncture of the device or equipment malfunction, the results shall be reported as ‘no test’ with additional comments provided. The device may be replaced with another.

NOTE The device should be hermetic in accordance with IEC 60749-8, and free from any surface contaminants which may interfere with accurate water vapour content measurement. The internal gas analysis laboratory is not required to test for hermeticity in accordance with IEC 60749-8. It is recommended that samples submitted for testing should include information about the manufacturing process, including sealing pressure, sealing gas, free internal cavity volume, lid thickness at puncture site, lid material, and the location of the puncture site.

6 Failure criteria

The failure criteria are as follows.

a) A device shall be considered a failure if the water vapour content exceeds 5 000 ppmv, unless otherwise detailed in the relevant procurement specification;

b) A device shall be considered a failure if the content of other gases exceeds the maximum value detailed in the relevant procurement specification;

c) A device being tested in a batch system which exhibits an abnormally low total gas content, as defined in Item c) of Clause 5, shall constitute a hermeticity failure not an internal gas analysis failure. Such a device may be replaced by another device from the same population; if the replacement device exhibits normal total gas content for its type, neither it nor the original device shall constitute a failure for this cause.

7 Implementation

Suitability for performing analysis using this test method is granted by the qualifying authority for specific limits and volumes. The calibration procedures and the suitability survey of this test method are designed to guarantee ±20 % lab-to-lab correlation in making a determination whether the sample passes or fails the specified limit. Water vapour contents reported either above or below the range of suitability are not certified as correlatable values. This out of specification data has meaning only in a relative sense and only when one laboratory's results are being compared. The specification limit of 5 000 ppmv shall apply to all package volumes (unless otherwise specified), with the following correction factors permitted, to be used by the manufacturer provided they are documented and shown to be applicable:

a) For package volumes less than 0,01 ml internal free volume which are sealed while heated in a furnace:

$$C_T = \frac{T_r + 273}{T_s + 273} \quad (2)$$

where

C_T is the correction factor (temperature);

T_r is the room temperature (°C);

T_s is the sealing temperature (°C).

b) For package volumes of any size sealed under vacuum conditions:

$$C_P = \frac{P_s}{P_a} \quad (3)$$

where

C_P is the correction factor (pressure);

P_s is the sealing pressure;

P_a is the atmospheric pressure.

The correction factor, if used, shall be applied as follows:

Water vapour (corrected) = water vapour (measured) × C_X;

where

C_X is the applicable correction factor.