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INTERNATIONAL STANDARD

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Semiconductor devices – Micro-electromechanical devices – Part 37: Environmental test methods of MEMS piezoelectric thin films for sensor application

Dispositifs à semiconducteurs – Dispositifs microélectromécaniques – Partie 37: Méthodes d'essai d'environnement des couches minces piézoélectriques MEMS pour les applications de type capteur

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SEMICONDUCTOR DEVICES – MICRO-ELECTROMECHANICAL DEVICES –

Part 37: Environmental test methods of MEMS piezoelectric thin films for sensor application

FOREWORD

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The text of this International Standard is based on the following documents:

FDIS	Report on voting
47F/355/FDIS	47F/357/RVD

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

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

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INTRODUCTION

Piezoelectric MEMS technology belongs to an interdisciplinary field founded on a wide range of element technologies including piezoelectric thin film materials, thin film deposition and microfabrication processes, device design, and system formulation. Along with the increased sophistication of MEMS functionality, research on MEMS applications for piezoelectric thin films, such as Pb(Zr,Ti)O_3 (PZT) or AlN, has become increasingly popular in recent years. MEMS piezoelectric thin films have the capability of configuring simple compact devices that have a lower power consumption, higher sensitivity, and quicker response than conventional bulk-type, electrostatic, or electromagnetic thin films. However, their device performance is greatly affected by the properties of the thin film materials.

Several test methods for thin film materials have been established to date. Among these, the overriding property that determines device performance is the material's piezoelectric property. Standardization of IEC 62047-30 (*Semiconductor devices – Micro-electromechanical devices – Part 30: Measurement methods of electro-mechanical conversion characteristics of MEMS piezoelectric thin film*) has been promoted for the purpose of precisely measuring and evaluating MEMS piezoelectric thin films using simply structured test pieces and inexpensive equipment.

In order to realize a viable MEMS piezoelectric thin film, it is essential to gain a clear understanding of how its piezoelectric properties change as a result of the environmental stress of temperature and humidity, and degradation in the piezoelectric material over time at its surfaces and interfaces.

The following summarizes the features of this standard.

- The degree of degradation in a device under test (DUT) is evaluated by measuring the piezoelectric properties of the DUT before and after applying the environmental stress of temperature and humidity using the measurement methods in IEC 62047-30.
- Test conditions for moist heat and dielectric withstand tests are derived from existing standards for semiconductor devices and fixed capacitors of ceramic dielectric.

SEMICONDUCTOR DEVICES – MICRO-ELECTROMECHANICAL DEVICES –

Part 37: Environmental test methods of MEMS piezoelectric thin films for sensor application

1 Scope

This part of IEC 62047 specifies test methods for evaluating the durability of MEMS piezoelectric thin film materials under the environmental stress of temperature and humidity and under mechanical stress and strain, and test conditions for appropriate quality assessment. Specifically, this document specifies test methods and test conditions for measuring the durability of a DUT under temperature and humidity conditions and applied voltages. It further applies to evaluations of direct piezoelectric properties in piezoelectric thin films formed primarily on silicon substrates, i.e. piezoelectric thin films used as acoustic sensors, or as cantilever-type sensors.

This document does not cover reliability assessments, such as methods of predicting the lifetime of a piezoelectric thin film based on a Weibull distribution.

2 Normative references

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IEC 62047-30, *Semiconductor devices – Micro-electromechanical devices – Part 30: Measurement methods of electro-mechanical conversion characteristics of MEMS piezoelectric thin film*

3 Terms and definitions

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4 Testing procedure

4.1 General

The degree of degradation in a device under test (DUT) is evaluated by measuring the piezoelectric properties of the DUT before and after applying the environmental stress of temperature and humidity. Figure 1 shows the general flow of the testing procedure.

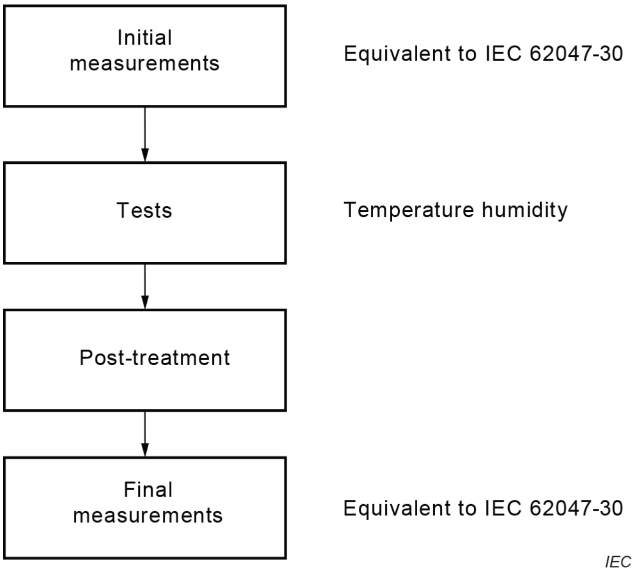

Figure 1 – Flow of the testing procedure

4.2 Initial measurements

The methods of measurement used in the environmental tests shall conform to the methods described in IEC 62047-30. The ambient conditions for measurements shall include an ambient temperature of 25 °C ± 3 °C, a relative humidity of 45 % to 75 %, and an atmospheric pressure of 86 kPa to 106 kPa.

4.3 Tests

4.3.1 DUT setup and environmental conditions

For tests requiring continuous operation of the DUT, the DUT is placed in a test bed that can be adjusted to the prescribed temperature and humidity to conditions. The test conditions are monitored to verify that no abnormalities occur when the chamber environment reaches the prescribed conditions. For tests that do not require continuous operations of the DUT, the DUT may be placed in the test bed and the test bed may be deposited in the chamber, but the test bed need not be put in the chamber. When depositing and removing the DUT and test bed for either test, the operator shall ensure that:

- water does not drip onto the DUT;
- the DUT is not directly immersed in water.

4.3.2 Test duration

Test duration is described in 5.1.1 to 5.1.7.

4.3.3 Number of tests and number of DUTs

Specifications for the number of tests and the number of DUTs shall take the failure mechanism, failure distribution, and other factors anticipated in each test into account. When intermediate measurements are required, such measurements may be performed in accordance with the following timetable:

- 24 h (+8 h, −0 h);
- 48 h (+8 h, −0 h);
- 96 h (+24 h, −0 h);
- 168 h (+48 h, −0 h);

- 480 h (+72 h, −0 h).

Here, the time spent removing the DUT and conducting the intermediate measurements shall be omitted from the test duration.

4.4 Post-treatment

After completion of the tests, first the application of mechanical stress and strain, or vibration, is halted, and then the DUT is removed from the chamber and returned to standard conditions. However, this shall not apply to cases in which the DUT clearly recovers from its degraded state after the application of mechanical stress and strain, or vibration, is halted at the testing temperature because a correct result is not possible.

4.5 Final measurements

The methods of measurement used in moist heat tests shall conform to the methods set forth in IEC 62047-30. The degraded state of a DUT is evaluated by comparing the final measurements to the initial measurements. The environmental conditions for measurements shall include:

- ambient temperature: 25 °C ± 3 °C;
- relative humidity: 45 % to 75 %;
- atmospheric pressure: 86 kPa to 106 kPa.

As a general rule, final measurements shall be conducted within 48 h from the completion of tests after verifying that the surface of the DUT is dry. When conducting intermediate measurements prior to the final measurements, the DUT shall be deposited back into the testing chamber within 96 h after being removed for measurements. Final measurements are preferably completed within 96 h after halting voltage application to the DUT.

5 Environmental and dielectric withstand testing

5.1 Environmental testing

5.1.1 General

Equipment used in these experiments includes:

- a chamber or a room capable of maintaining predetermined test temperature and humidity and allowable temperature and humidity;
- a vibrator or an external actuator for generating a predetermined deflection of the unimorph beam;
- a mechanical stress and strain, or vibration, application equipment having sufficient resistance for withstanding the test temperatures and humidity.

The chamber shall be capable of maintaining its entire interior at the set temperature ±2 °C and the set humidity ±5 % during the test. The applied mechanical stress and strain, and the operating method shall be established with consideration for the limits of the DUT. The application circuit shall be considered to account for load conditions and other factors in order that the operating state of the DUT be suitably maintained.

NOTE 1 The degree of degradation in a device under test (DUT) is evaluated by measuring the piezoelectric properties of the DUT before and after applying the environmental stress of temperature and humidity.

NOTE 2 The degree of degradation in a DUT is evaluated using the measurement methods in IEC 62047-30.

NOTE 3 A test circuit for testing a plurality of DUT simultaneously is designed so that failure of one DUT during a test does not affect the other DUT.

5.1.2 High-temperature bias test

The objective of this test is to evaluate the ability of MEMS piezoelectric thin film to operate at a high temperature. Mechanical stress and strain (beam deflection) is applied to the piezoelectric film under a high temperature to evaluate the effects of these conditions over a long duration. The conditions applied to the DUT, including the vibration mode (resonant mode or non-resonant mode), input waveform, the frequency, and the like shall be determined based on the expected application of the sensor. The following test conditions shall be applied:

- test temperature: 85 °C or higher;
- test duration: 96 h or longer.

The example of this test result is provided in Annex A.

NOTE 1 Sample test temperatures can include 85 °C, 105 °C and 125 °C.

NOTE 2 Sample test durations can include 96 h, 480 h and 960 h.

5.1.3 High-temperature and high-humidity bias test

The objective of this test is to evaluate the ability of MEMS piezoelectric thin film to operate under high temperature and high humidity. Mechanical stress and strain (beam bending) is applied to the piezoelectric thin film under high temperature and humidity and the effects of these conditions are assessed over a long duration. The humidity test determines whether electronic products have sufficient electrical and mechanical properties to withstand heavy conditions with high relative humidity, regardless of whether condensation is present. The humidity test may also be used to inspect the resistance of the DUT to various corrosive actions. Based on the expected application of the sensor, the measurement parameters shall be determined as follows:

- resonant mode or non-resonant mode;
- input waveform;
- frequency.

Table 1 shows the selectable test conditions.

Table 1 – Selectable test conditions

Condition	Temperature (°C)	Humidity (%)
A	40 ± 2	90 ± 5
B	60 ± 2	90 ± 5
C	85 ± 2	85 ± 5

The test parameters shall be determined as follows:

- test strain: maximum strain of piezoelectric thin films applied by bending beam (operation max.);
- test duration: 96 h or longer.

NOTE Sample test durations include 96 h, 480 h and 960 h.

5.1.4 High-temperature storage

The objective of this test is to evaluate the ability of MEMS piezoelectric thin film to withstand storage at a high temperature. The piezoelectric thin film is kept under a high temperature for a long duration, and the effects of these conditions are evaluated. The following test conditions shall be applied:

- test temperature: 85 °C or higher;
- test duration: 96 h or longer.

NOTE 1 Sample test temperatures include 85 °C, 105 °C and 125 °C.

NOTE 2 Sample test durations include 96 h, 480 h and 960 h.

5.1.5 Low-temperature storage

The objective of this test is to evaluate the ability of MEMS piezoelectric thin film to withstand storage at a low temperature. The piezoelectric thin film is kept under a low temperature for a long duration, and the effects of these conditions are evaluated. The following test conditions shall be applied:

- test temperature: −20 °C or lower;
- test duration: 96 h or longer.

NOTE Sample test durations include 96 h, 480 h and 960 h.

5.1.6 High-temperature and high-humidity storage

The objective of this test is to evaluate the ability of MEMS piezoelectric thin film to withstand storage under a high temperature and high humidity. The piezoelectric thin film is maintained under high temperature and high humidity conditions for a long duration, and the effects of these conditions are evaluated. Table 2 shows the selectable test conditions.

Table 2 – Selectable test conditions

Condition	**Temperature** (°C)	**Humidity** (%)
A	40 ± 2	90 ± 5
B	60 ± 2	90 ± 5
C	85 ± 2	85 ± 5

The test parameters shall be determined as follows:

- test duration: 96 h or longer.

NOTE Sample test durations include 96 h, 480 h and 960 h.

5.1.7 Soldering heat test

The objective of this test is to evaluate the resistance of MEMS piezoelectric thin film to heat generated during soldering. The temperature and time required for replicating thermal conditions expected in reflow soldering are specified in Table 3.

Table 3 – Soldering heat test condition

	Specified temperature (°C)	**Hold time** (s)
Test conditions	265 ± 5	30 ± 5