IEC 60749-17

Edition 2.0 2019-03

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Semiconductor devices – Mechanical and climatic test methods –
Part 17: Neutron irradiation

Dispositifs à semiconducteurs – Méthodes d'essais mécaniques et climatiques –
Partie 17: Irradiation aux neutrons

IEC 60749-17:2019-03(en-fr)

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Semiconductor devices – Mechanical and climatic test methods – Part 17: Neutron irradiation

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

ICS 31.080.01

ISBN 978-2-8322-6702-8

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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 60749-17 has been prepared by IEC technical committee 47: Semiconductor devices.

This second edition cancels and replaces the first edition published in 2003. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) updates to better align the test method with MIL-STD 883J, method 1017, including removal of restriction of use of the document, and a requirement to limit the total ionization dose;
b) addition of a Bibliography, including US MIL- and ASTM standards relevant to this test method.

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

FDIS	Report on voting
47/2538/FDIS	47/2553/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.

A list of all parts in the IEC 60749 series, published 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 document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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- withdrawn,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

SEMICONDUCTOR DEVICES – MECHANICAL AND CLIMATIC TEST METHODS –

Part 17: Neutron irradiation

1 Scope

The neutron irradiation test is performed to determine the susceptibility of semiconductor devices to non-ionizing energy loss (NIEL) degradation. The test described herein is applicable to integrated circuits and discrete semiconductor devices and is intended for military- and aerospace-related applications. It is a destructive test.

The objectives of the test are as follows:

a) to detect and measure the degradation of critical semiconductor device parameters as a function of neutron fluence, and

b) to determine if specified semiconductor device parameters are within specified limits after exposure to a specified level of neutron fluence (see Clause 6).

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

4 Test apparatus

4.1 Test instruments

Test instrumentation to be used in the radiation test shall be standard laboratory electronic test instruments such as power supplies, digital voltmeters, and pico-ammeters, etc., capable of measuring the electrical parameters required.

4.2 Radiation source

The radiation source used in the test shall be a well characterized neutron source that produces either a broad neutron energy spectrum (such as a TRIGA®[1] reactor or a fast burst reactor) or a monoenergetic neutron spectrum such as available from deuterium-tritium or deuterium-deuterium accelerators) provided that the output can be converted to a 1 MeV equivalent spectrum.

[1] TRIGA is the trade name of a product supplied by General Atomics. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the product named. Equivalent products may be used if they can be shown to lead to the same results.

4.3 Dosimetry equipment

The following dosimetry equipment shall be used (as required):

a) fast-neutron threshold activation foils such as ^{32}S, ^{54}Fe, and ^{58}Ni;

b) CaF2 thermoluminescence dosimeters (TLDs);

c) appropriate activation foil counting and TLD readout equipment.

4.4 Dosimetry measurements

4.4.1 Neutron fluences

The neutron fluence used for device irradiation shall be obtained by measuring the amount of radioactivity induced in a fast-neutron threshold activation foil such as ^{32}S, ^{54}Fe, or ^{58}Ni, irradiated simultaneously with the device.

A standard method for converting the measured radioactivity in the specific activation foil employed into a neutron fluence is given in national and international standards (examples are given in the Bibliography).

The conversion of the foil radioactivity into a neutron fluence requires a knowledge of the neutron spectrum incident on the foil. If the spectrum is not known, it shall be determined by use of a recognised national standard or equivalent (examples are given in the Bibliography).

Once the neutron energy spectrum has been determined and the equivalent monoenergetic fluence calculated, then an appropriate monitor foil (such as ^{32}S, ^{54}Fe, or ^{58}Ni) should be used in subsequent irradiations to determine the neutron fluence. Thus, the neutron fluence is described in terms of the equivalent monoenergetic neutron fluence per unit monitor response. Use of a monitor foil to predict the equivalent monoenergetic neutron fluence is valid only if the energy spectrum remains constant.

4.4.2 Dose measurements

If absorbed dose measurements of the gamma-ray component during the device test irradiations are required, then such measurements shall be made with CaF2 thermo-luminescence dosimeters (TLDs), or their equivalent. These TLDs shall be used in accordance with the recommendations of recognised national standards or their equivalent (examples are given in the Bibliography).

5 Procedure

5.1 Safety requirements

Neutron irradiated devices may be radioactive. Handling and storage of test specimens or equipment subjected to radiation environments shall be governed by the procedures established by the local Radiation Safety Officer or Health Physicist.

5.2 Test samples

A test sample shall be randomly selected and consist of a minimum of 10 devices, unless otherwise specified. All sample devices shall have met all the requirements of the relevant specification for that device. Each device shall be serialised to enable pre- and post-test identification and comparison.

5.3 Pre-exposure

5.3.1 Electrical tests

Pre-exposure electrical tests shall be performed on each device as required. Where delta parameter limits are specified, the pre-exposure data shall be recorded.

5.3.2 Exposure set-up

Each device shall be mounted unbiased and have its terminal leads either all shorted or all open. For MOS devices or any microcircuit containing an MOS element, all leads shall be shorted. An appropriate mounting fixture shall be used. The mounting fixture shall accommodate the units-under-test as well as any required dosimeters. The configuration of the mounting fixture will depend on the type of facility used and should be discussed with facility personnel. Test devices shall be mounted such that the total variation of fluence over the entire sample does not exceed 20 %.

5.4 Exposure

The test devices and dosimeters shall be exposed to the neutron fluence as specified. If multiple exposures are required, the post-radiation electrical tests shall be performed (see 5.5.1) after each exposure. A new set of dosimeters is required for each exposure level. Since the effects of neutrons are cumulative, each additional exposure will have to be determined to give the specified total accumulated fluence. All exposures shall be made at 24 °C ± 6 °C and shall be correlated to a 1 MeV equivalent fluence. To avoid confounding NIEL effects with total ionizing dose (TID) damage effects, units-under-test shall not be exposed to a neutron fluence that causes the unit-under-test to receive a TID in excess of 10 % of its rated value. If necessary, the use of shielding to reduce the accompanying gamma TID exposure is acceptable.

5.5 Post-exposure

5.5.1 Electrical tests

Test items shall be removed only after clearance has been obtained from the Health physicist at the test facility. The temperature of the sample devices shall be maintained at 20 °C ± 10 °C from the time of the exposure until the post-electrical tests are made. The post-exposure electrical tests as specified shall be made within 24 h after the completion of the exposure. If the residual radioactivity level is too high for safe handling – this level to be determined by the local Radiation Safety Officer –, the elapsed time before post-test electrical measurements may be extended to one week. Alternatively, provisions may be made for remote testing. All required data shall be recorded for each device after each exposure.

5.5.2 Anomaly investigation

Devices which exhibit previously defined anomalous behaviour (e.g., non-linear degradation of 0,125) shall be subjected to failure analysis, in accordance with national and international standards (an example is given in the Bibliography, [10]).

5.6 Reporting

As a minimum, the report shall include the device type number, serial number, manufacturer, controlling specification, the date code and other identifying numbers given by the manufacturer. Each data sheet shall include radiation test date, electrical test conditions, radiation exposure levels, ambient conditions as well as the test data. Where other than specified electrical test circuits are employed, the parameter measurement circuits shall accompany the data. Any anomalous incidents during the test shall be fully explained in footnotes to the data.

6 Summary

The following details shall be specified in the request for test or, when applicable, the relevant specification:

a) device types (see 5.6);
b) quantities of each device type to be tested, if other than specified in 5.2;
c) electrical parameters to be measured in pre- and post-exposure tests (see 5.3.1 and 5.5.1);
d) criteria for pass, fail, record actions on tested devices (see 5.3.1, 5.5.1 and 5.6);
e) criteria for anomalous behaviour designation (see 5.5.2);
f) radiation exposure levels (see 5.4);
g) test instrument requirements (see Clause 4);
h) radiation dosimetry requirements, if other than 4.3;
i) ambient temperature, if other than specified herein (see 5.4 and 5.5.1);
j) requirements for data reporting and submission, where applicable (see 5.6).

Bibliography

[1] ASTM E 263, *Standard test method for measuring fast-neutron reaction rates by radioactivation of iron*

[2] ASTM E 264, *Standard test method for measuring fast-neutron reaction rates by radioactivation of nickel*

[3] ASTM E 265, *Standard test method for measuring fast-neutron reaction rates by radioactivation of sulfur*

[4] ASTM E 720, *Standard guide for selection of a set of neutron-activation foils for determining neutron spectra used in radiation-hardness testing of electronics*

[5] ASTM E 721, *Standard method for determining neutron energy spectra with neutron-activation foils for radiation-hardness testing of electronics*

[6] ASTM E 722, *Standard practice for characterizing neutron energy fluence spectra in terms of an equivalent monoenergetic neutron fluence for radiation-hardness testing of electronics*

[7] ASTM E 1018, *Standard guide for application of ASTM evaluated cross section data file*

[8] ASTM E 668, *Standard practice for application of thermoluminescence-dosimetry (TLD) systems for determining absorbed dose in radiation-hardness testing of electronic devices*

[9] ASTM E 2450, *Standard practice for application of CaF2(Mn) thermoluminescence dosimeters in mixed neutron-photon environments*

[10] MIL-STD-883 Method 5003, *Failure analysis procedures for microcircuits*

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