IEC TS 62607-8-3

Edition 1.0 2023-10

TECHNICAL SPECIFICATION

colour inside

Nanomanufacturing – Key Control Characteristics –
Part 8-3: Nano-enabled metal-oxide interfacial devices – Analogue resistance change and resistance fluctuation: Electrical resistance measurement

IEC TS 62607-8-3:2023-10(en)

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, …). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch
Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 300 terminological entries in English and French, with equivalent terms in 19 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC TS 62607-8-3

Edition 1.0 2023-10

TECHNICAL SPECIFICATION

colour inside

Nanomanufacturing – Key Control Characteristics – Part 8-3: Nano-enabled metal-oxide interfacial devices – Analogue resistance change and resistance fluctuation: Electrical resistance measurement

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 07.120; 07.030

ISBN 978-2-8322-7640-2

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

NANOMANUFACTURING – KEY CONTROL CHARACTERISTICS –

Part 8-3: Nano-enabled metal-oxide interfacial devices – Analogue resistance change and resistance fluctuation: Electrical resistance measurement

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.

2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.

3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.

4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.

5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.

6) All users should ensure that they have the latest edition of this publication.

7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.

8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.

9) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at https://patents.iec.ch. IEC shall not be held responsible for identifying any or all such patent rights.

IEC TS 62607-8-3 has been prepared by IEC technical committee 113: Nanotechnology standardization for electrical and electronic products and systems. It is a Technical Specification.

The text of this Technical Specification is based on the following documents:

Draft	Report on voting
113/743/DTS	113/767/RVDTS

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

The language used for the development of this Technical Specification is English.

A list of all parts in the IEC 62607 series, published under the general title *Nanomanufacturing – Key control characteristics*, can be found on the IEC website.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

Nano-enabled metal-oxide interfaces, such as an oxide nanolayer sandwiched by metal electrodes, are the essential components of IoT devices for computing. Nano-enabled functions derived from the nanoscale metal-oxide interface and the oxide nanolayer appear, such as a significant change in electrical resistance. The analogue resistance change is the typical characteristic which possesses the large potential for non-von Neumann information processing. More concretely, the metal-oxide interfacial device is an indispensable element in the product-sum circuit that records the learning process as the analogue resistance change. In the research community, however, the analogue change and the fluctuation of the resistance have not yet been systematically investigated. The reason why systematic research and development is not progressing is that the measurement protocol of these characteristics is not quantitative. The bottleneck impedes not only the electrotechnical evaluation of the device but also developments for various applications.

This document offers a measurement protocol of the analogue resistance change and the quantitative index to evaluate the linearity of the analogue resistance change in nano-enabled metal-oxide interfacial devices.

NANOMANUFACTURING – KEY CONTROL CHARACTERISTICS –

Part 8-3: Nano-enabled metal-oxide interfacial devices – Analogue resistance change and resistance fluctuation: Electrical resistance measurement

1 Scope

This part of IEC 62607, which is a Technical Specification, specifies a measurement protocol to determine the key control characteristics

– analogue resistance change, and
– resistance fluctuation

for nano-enabled metal-oxide interfacial devices by

– electrical resistance measurement.

Analogue resistance change as a function of applied voltage pulse is measured in metal-oxide interfacial devices. The linearity in the relationship of the variation of conductance and the pulse number is evaluated using the parameter fitting. The parameter of the resistance fluctuation is simultaneously computed in the fitting process.

– This method is applicable for evaluating computing devices composed of the metal-oxide interfacial device, for example, product-sum circuits, which record the learning process as the analogue resistance change.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

ISO 80004-1, *Nanotechnologies – Vocabulary – Part 1: Core vocabulary*

3 Terms, definitions, acronyms, and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 80004-1 and the following apply.

ISO and IEC maintain terminological databases for the 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

3.1.1
device under test
DUT
sample attached to an apparatus for evaluation of a specific physical property such as electrical resistance or I-V behaviour

3.1.2
DC, qualifier
pertaining to time-independent electric quantities such as voltage or current, to devices operated with direct voltage and current, or to quantities associated with these devices

Note 1 to entry: The notation "DC" is preferred in English to the notation "d.c." which is an abbreviation of "direct current".

[SOURCE: IEC 60050-151:2001, 151-15-02, modified – Notes 2, 3 and 4 to entry have been deleted.]

3.2 Terms specific to this document

3.2.1
analogue resistance change
continuous variation of resistance as a function of applied voltage pulse

Note 1 to entry: When a voltage is applied to a metal-oxide interfacial device, for example, a resistive memory device, the resistance increases or decreases in an analogue manner based on the sign of the voltage [1].

Note 2 to entry: This kind of resistive device can be used to mimic a neural synapse wherein the resistance acts like a weight that modulates the voltage applied to it [1].

3.2.2
resistance fluctuation
least-squares error obtained during parameter fitting of analogue resistance changes

3.3 Abbreviated terms

SMU source measure unit

4 Measurement of resistance

4.1 General

The reliable test protocol of analogue resistance measurement is standardized. A schematic diagram of the typical resistance measurement is shown in Figure 1. Figure 2 is a set of example photos showing how the DUT is set onto a sample stage.

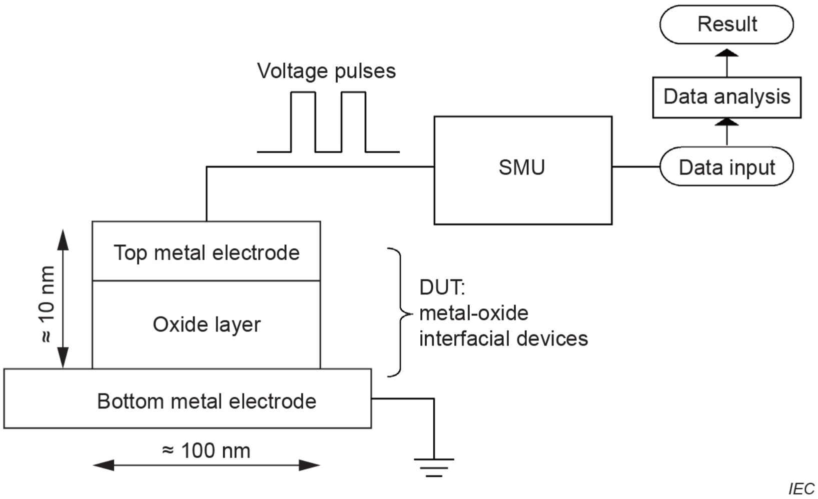
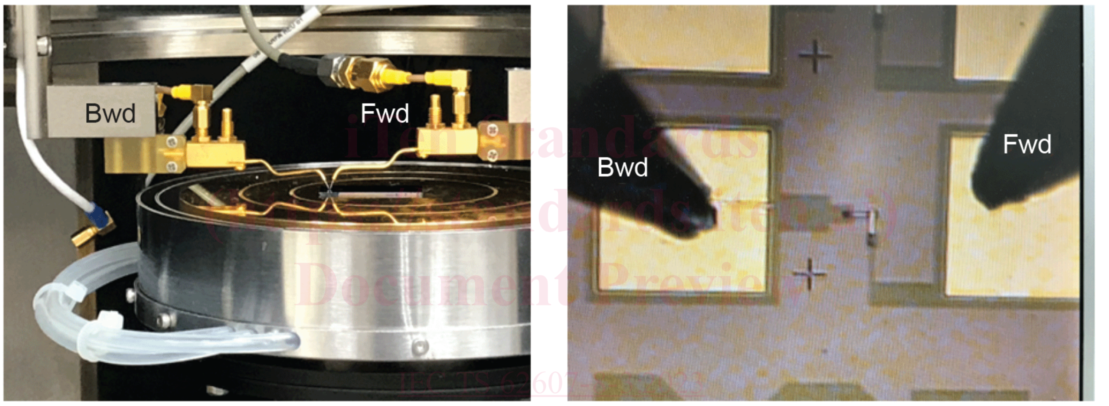


Figure 1 – Example of the experimental schematic diagram for the resistance measurement



Forward (Fwd) and backward (Bwd) contacts are shown.

Figure 2 – Photos of the sample stage

4.2 Method for processing and fabrication of DUT

Report the stacking structure of DUT, such as the material and the thickness of the metal-oxide interfacial device. In addition, the fabrication process information is important to be reported, such as the method of deposition, the shape of the DUT, and the electronic contact to SMU.

In order to avoid resistance measurement artifacts, the electric resistance of the substrate (R_{sub}) should be higher than that of the DUT (R_{dut}). The parallel current path in the substrate becomes smaller with the ratio of R_{dut}/R_{sub}. This value should be smaller than the error bar of the data. The electronic contact resistance, for example between the contact pad and the probe, should be minimized.

4.3 Experimental procedures

- Step 1. Recording of measurement conditions: temperature, humidity, and measurement setup, such as the probe specifications.
- Step 2. Sample setting: the DUT is mounted on the stage to connect to SMU electrically.
- Step 3. DC I-V measurement: from the result of DC I-V measurement, the ranges of current and voltage sweeps are decided.