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TECHNICAL SPECIFICATION

Nanomanufacturing – Key control characteristics – Part 8-4: Metal-oxide interfacial devices – Activation energy of electronic trap states: Low-frequency-noise spectroscopy

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IEC TS 62607-8-4 has been prepared by IEC technical committee 113: Nanotechnology for electrotechnical products and systems. It is a Technical Specification.

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

Draft	Report on voting
113/865/DTS	113/876/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.

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.

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.

Future subparts of IEC 62607-8 will carry the new general title *Metal-oxide interfacial devices* as cited above. Titles of existing subparts in this series will be updated at the time of the next edition.

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

- reconfirmed,
- withdrawn, or
- revised.

INTRODUCTION

Nano-enabled metal-oxide interfaces, such as an oxide nanolayer sandwiched by metal electrodes, are the essential components of IoT and AI 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. 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. It is known that the analogue resistance change occurs electronically in oxide interfacial layers regardless of the filamentary conductance. Since the electrical resistance is affected by electrons scattering in a material, it is extremely important to standardize the technique for evaluating electron traps in that material. Low-frequency-noise spectroscopy (LFNS) measurement is the powerful and unique tool to evaluate the activation energy of the electron trap states, which is one of the most essential electronic properties – especially in devices with the nano-scaled conductive path.

This document specifies a measurement protocol to evaluate the electronic trap states by LFNS in nano-enabled metal-oxide interfacial devices.

NANOMANUFACTURING – KEY CONTROL CHARACTERISTICS –

Part 8-4: Metal-oxide interfacial devices – Activation energy of electronic trap states: Low-frequency-noise spectroscopy

1 Scope

This part of IEC 62607 specifies a measurement protocol to determine the key control characteristic

- activation energy of electronic trap states

for metal-oxide interfacial devices by

- low-frequency-noise spectroscopy

The noise spectra peak temperatures are obtained within a designated temperature range. Activation energies are then calculated based on the frequency dependence of the peak temperatures to analyse the energy levels associated with the electronic trap states. The activation energy is determined by the temperature dependence of the capture time at electron traps under the assumption that it is described by an Arrhenius function.

– In metal-oxide interfacial devices, electrical conductance is observed through an oxide nanolayer sandwiched between metal electrodes.

– The size of the conductive path in metal-oxide interfacial devices is dependent on the current value and is usually nanoscale in diameter, taking the form of a filamentary wire. This evaluation method is useful for analysing the electronic trap states in nanowires and other miniaturized devices that have nanolayers.

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/TS 80004-1, *Nanotechnologies – Vocabulary – Part 1: Core terms*

3 Terms, definitions, and abbreviated terms

3.1 Terms and definitions

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

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

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

3.1.1 General terms

3.1.1.1
device under test
DUT
sample attached to an apparatus for evaluation of a specific physical property such as electrical resistance or current–voltage behaviour

3.1.2 Terms specific to this document

3.1.2.1
electronic trap state
state which traps a carrier, for example, an electron, in the nanoscale metal-oxide interface and the oxide nanolayer

3.1.2.2
metal-oxide interfacial device
electronic component that consists of metal electrodes and an oxide nanolayer

EXAMPLE Non-volatile and volatile memories, and metal-oxide-semiconductor field-effect transistors (MOSFETs).

Note 1 to entry: The oxide layer is located between the metal electrodes, and the electrical conductance is observed through this layer.

Note 2 to entry: Metal-oxide interfacial devices play an important role in various electronic applications and are commonly used in various fields such as electronics, electrical engineering, and energy storage.

3.1.2.3
activation energy
measure of the minimum energy required to initiate a thermally activated electronic, physical, or chemical process

Note 1 to entry: The activation energy is an important parameter that is often described by the Arrhenius equation, which models the temperature dependence of chemical reaction rates and other thermally activated processes.

3.1.2.4
low-frequency-noise spectroscopy
technique used to measure and analyse low-frequency fluctuations in electrical signals in electronic devices to gain information about the underlying physical mechanisms causing the noise

Note 1 to entry: The fluctuations are analysed in the frequency domain to determine the spectral distribution of the noise and to obtain information about the underlying physical mechanisms causing the noise.

Note 2 to entry: Low-frequency-noise spectroscopy is commonly used to study the properties of materials and devices at the nanoscale, including the behaviour of electrons, the distribution of energy levels, and the dynamics of charge transport. The mechanism of noise is evaluated in terms of the number of charge carriers fluctuating due to the capture and emission processes of carriers at electron traps with certain activation energies.

Note 3 to entry: The information obtained from low-frequency-noise spectroscopy can be used to improve the performance and reliability of electronic devices, as well as to gain insights into the fundamental physics of materials and systems.

3.2 Abbreviated terms

AI	artificial intelligence
IoT	Internet of Things
LFNS	low-frequency-noise spectroscopy