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INTERNATIONAL STANDARD

colour inside

Semiconductor devices – Flexible and stretchable semiconductor devices – Part 8: Test method for stretchability, flexibility, and stability of flexible resistive memory

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

Draft	Report on voting
47/2786/FDIS	47/2793/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.

The language used for the development of International Standard 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/standardsdev/publications.

A list of all parts in the IEC 62951 series, published under the general title *Semiconductor devices – Flexible and stretchable semiconductor devices*, can be found on the IEC website.

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- withdrawn,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

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SEMICONDUCTOR DEVICES –
FLEXIBLE AND STRETCHABLE SEMICONDUCTOR DEVICES –

Part 8: Test method for stretchability, flexibility, and stability of flexible resistive memory

1 Scope

This part of IEC 62951 defines terms and specifies the test method for evaluating the stretchability, flexibility, and stability of flexible resistive memory. The test method descriptions include experimental procedures and the equipment to be used. It also includes general requirements for test conditions such as the temperature and relative humidity of the testing environment. The test method described in this document focuses on stability evaluation rather than reliability.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

ISO and IEC maintain terminological 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
flexible resistive memory
flexible device that works by changing the resistance between dielectric materials

3.2
bending radius
measured to the inside curvature, is the minimum radius one can bend a pipe, tube, sheet, cable or hose

3.3
resistance of low resistance state
LRS
one of stable resistance states induced by applying higher voltage (unipolar switching) or positive bias (bipolar switching)

3.4
resistance of high resistance state
HRS
one of stable resistance states induced by applying lower voltage (unipolar switching) or negative bias (bipolar switching)

3.5
set voltage
V_{set}
voltage for switching to low resistance state

3.6
reset voltage
V_{reset}
voltage for switching to high resistance state

4 Test method

4.1 General

This document applies to flexible resistive memory in order to evaluate its stretchability, flexibility, and stability. This type of semiconductor device is used mostly in products related to flexible or wearable electronics, which are often stretched or bent when used. Hence, it is critical that the main performance parameters of the device be maintained under mechanical deformation. Detailed performance parameters and characterisation procedures are described in IEC 62951-1, and Table 1 in this document summarises them as applicable to resistive memory. This document focuses on experimental methods for testing stretchability, flexibility and stability, and includes a description of the experimental setup.

One of the most problematic issues in the reliability of resistive memory is its increased performance degradation rate under mechanical deformation. This deterioration is caused by cracks in electrodes and the resistive materials used in these types of semiconductor devices. In particular, degradation is accelerated when cracks occur in the encapsulation layer due to the stress caused by bending. Therefore, this evaluation suggests an experimental method for observing the deterioration of an organic semiconductor while flat and bent and while held at a specified humidity and temperature higher than room temperature.

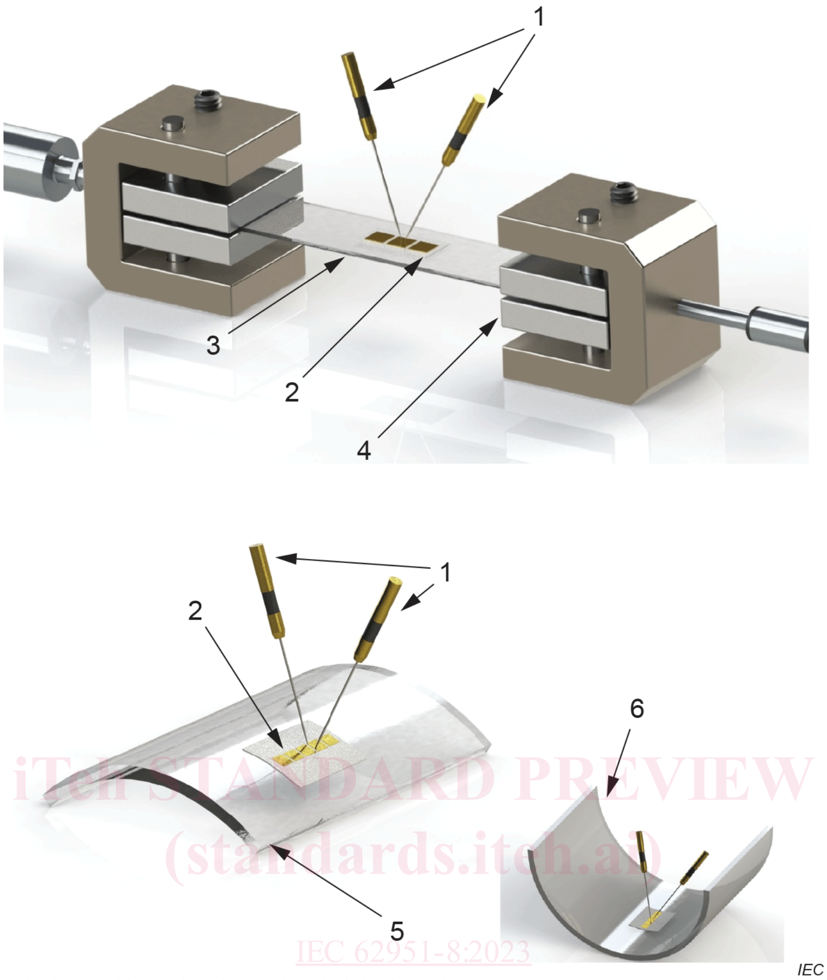
In order to evaluate the performance and its change or degradation, below performance parameters need to be evaluated before and after bending and stretching.

Table 1 – Performance parameters of resistive type memory

Characteristics	Performance parameters
I-V characteristics (switching behaviour)	V_{set}, V_{reset}
Switching endurance	Resistance change as a function of cycle time
Retention test	Current change as a function of time

4.2 Test equipment and tools

A variety of experimental approaches have been employed to test the stretchability and flexibility of flexible devices. Each has advantages and disadvantages, requiring a user to decide which type is appropriate to their application. If a setup from a similar application is considered, care should still be taken to consider the device size or material used to make it. In this evaluation of resistive memory, the experimental setup shown in Figure 1 should be used. Details of each experimental setup and test procedure are explained in 4.3.



Key

1 Probe for characterisation;

2 Specimen (resistive memory);

3 Substrate used in device fabrication;

4 Jig for stretchability test;

5 Jig for flexibility test (tensile stress);

6 Jig for flexibility test (compressive stress).

Figure 1 – Examples experimental setup for testing stretchability (top) and flexibility (bottom)

For stability tests, an environmental chamber shall be used in order to maintain a test environment at a suggested temperature and relative humidity such as those listed in Table 2 of 4.3.3.

4.3 Test procedures

4.3.1 Stretchability test

Stretchability testing is carried out in order to investigate whether the performance of resistive memory is maintained while under the tensile stress induced by stretching. In particular, tensile stress in resistive memory can induce changes in resistivity, voltage, mobility and drain current. Figure 2 shows schematics of stretchability testing and denotes key parameters that should be reported following a test. Note that the grip shall be longer than the substrate, as explained in Annex A. The amount of stretching can be determined based on strain, stress or force, but of these, strain is the only geometry-dependent parameter and is independent of other factors such as the dimension of the substrate or material type. Moreover, strain is easy to measure without additional equipment. The strain (ε) induced by stretching is determined by

$$\varepsilon = \frac{L_0 - L_1}{L_0} \times 100 \ (\%) \qquad (1)$$

where L_0 and L_1 are the substrate length prior to stretching and after stretching, respectively. W_0 and W_m are the length prior to stretching and after stretching, respectively, measured from the middle of the sample.