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Semiconductor devices – Flexible and strechable semiconductor devices – Part 3: Evaluation of thin film transistor characteristics on flexible substrates under bulging

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CONTENTS

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SEMICONDUCTOR DEVICES –
FLEXIBLE AND STRECHABLE SEMICONDUCTOR DEVICES –

Part 3: Evaluation of thin film transistor characteristics on flexible substrates under bulging

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

FDIS	Report on voting
47/2492/FDIS	47/2511/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 62951 series, published under the general title *Semiconductor devices – Flexible and stretchable semiconductor devices*, 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,
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INTRODUCTION

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SEMICONDUCTOR DEVICES –
FLEXIBLE AND STRECHABLE SEMICONDUCTOR DEVICES –

Part 3: Evaluation of thin film transistor characteristics on flexible substrates under bulging

1 Scope

This part of IEC 62951 specifies the method for evaluating thin film transistor characteristics on flexible substrates under bulging. The thin film transistor is fabricated on flexible substrates, including polyethylene terephthalate (PET), polyimide (PI), elastomer and others. The stress is applied by applying a uniformly-distributed pressure to the flexible substrate using the equipment.

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.

IEC 62047-17, *Semiconductor devices – Micro-electromechanical devices – Part 17: Bulge test method for measuring mechanical properties of thin films*

IEC 60747-8, *Semiconductor devices – Discrete devices – Part 8: Field-effect transistors*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62047-17, in IEC 60747-8 and the following apply.

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

3.1
flexible substrate
substrate with flexibility onto which a thin film transistor is fabricated

4 Test piece

4.1 General

The test piece shall be prepared using the thin film transistor fabrication process on flexible substrates. The mechanical and electrical properties of thin film transistors may depend on the fabrication processes. Thin film transistors shall be prepared to prevent formation of cracks or flaws and delamination from the substrate.

4.2 Size of a test piece

As long as the size of a test piece is larger than that of the chamber open area, any test piece will suffice. Since the change in electrical characteristics is related to strain or stress, it is recommended that the thin film transistors be fabricated in a central region, where the strain is uniform. To measure the electrical characteristics, attach lead wires to the source, drain and gate pads of thin film transistors of the test piece.

4.3 Measurement of dimensions

The thickness and dimension of the thin film transistors and flexible substrate shall be accurately measured respectively, because they are used to determine the mechanical and electrical properties of thin film transistors. It is recommended that the thickness of thin film transistors be smaller than that of the substrate in order to keep the deformation of the thin film transistors uniform. The substrate material should be in-plane isotropic in order to keep the stress and strain applied on the thin film transistor equibiaxial. There can be some combinations of thin film transistor and substrate where it is difficult to fulfil the tolerance of thickness measurement. In this case the average and the standard deviation of the thickness measurement should be reported.

4.4 Storage prior to testing

In the case of thin film transistors, the storage environment may affect the electromechanical properties of the thin film transistors. For example, oxidation on the test piece surface will deteriorate the electrical and mechanical properties of the test piece. If there is an interval between final preparation and testing, particular care should be taken in storing the test pieces, and the specimens should be examined by appropriate means to ensure that the surface has not deteriorated during the storage period. If any deterioration is observed that was not present after the specimens were prepared, testing shall not be performed. However, if the damage was introduced during the preparation processes, the test shall be performed.

5 Test apparatus and procedure

5.1 General

The test is performed by bulging a test piece at a specified temperature. To measure the change in electrical characteristics along with the change in mechanical strain, carefully select the measuring section. The section for measuring mechanical strain shall be coincident with or scalable to that for measuring electrical characteristics. There are several types of bulging equipment by which to measure the electromechanical property of thin film transistors. It is not necessary that a certain type of bulging test method be preferred. As examples, absorption-type electrical and mechanical test equipment with a heating system and bulging-type electrical and mechanical test equipment with a halogen lamp heating system are described in Annex A.

5.2 Test apparatus

5.2.1 General

By applying pressure to the specimen, the deformation response, i.e. the change in bulge height as well as the electrical response of the thin film transistor on flexible substrate, shall be measured. In general, test apparatus can be composed of pressuring device, pressure chamber, pressure chamber open window, heating device (optional), bulging height measurement unit and electrical measurement units as shown in Figure 2. Exemplary schematics of pressure chamber, pressure chamber open window and wire bonding are given in Figure 3 and Figure 4.

5.2.2 Apparatus

5.2.2.1 Pressuring device

The pressuring device should be equipped to apply a specified continuous pressure with a controlled rate or a certain level of pressure to the pressure chamber open window to be stressed. Pressure media can be oil, gas and distilled water. In general, the device can be composed of a pressure sensor and pressure controller. The controller should show an accuracy of 1 % in the full test scale.

NOTE At the pressures encountered in the tests, gas is over a million times more compressible than typical liquids such as oil and distilled water.

5.2.2.2 Pressure chamber

The pressure chamber should be as compact as possible, to reduce the compliance of the test system. The volume, which has to be pressurized and which potentially contributes to the compliance, would be minimized.

In case liquid is used to pressurize the test system, the system shall contain as little air as possible because even a small air bubble trapped inside the test system can dominate the system's compliance. It is recommended that the system including the chamber be designed so that there are no places where air bubbles can hide and that the liquid can be refilled easily. It is necessary that special care be taken not to introduce air bubbles when the test piece is mounted and removed.

The material of the chamber should be chosen considering the pressure media for the test, testing pressure range, measurement temperature range and interference with the electrical measurements.

In case liquid is used to pressurize the test system, it is recommended that the testing apparatus be made out of transparent plexiglass (polymethyl methacrylate) in order to see air bubbles and then to minimize them trapped within the chamber.

The pressure chamber is connected to the pressuring device and thus allows a test piece to be deformed with fine control. The test piece is mounted on the pressure chamber by mechanical clamping or the epoxy gluing method, etc.

NOTE In the case of a capacitance measurement type, the pressure chamber has an electrode and a mechanical spacer. The electrode, which measures the height change of a test specimen due to deformation, is made of Cu-coated polychlorinated biphenyl (PCB). A mechanical spacer that is located between the specimen and the electrode controls a sensitivity of capacitance change by adjusting the thickness of the spacer.

The pressure inside the chamber shall be monitored and measured through a suitable pressure sensor, which can be installed directly in the chamber or connected though the tube transporting the pressure without loss of the pressure to be measured.

It is recommended that exposition of the area of the pressure sensor to the pressure media be minimized and that the area have no indentation or internal cavities trapping air.

It is recommended that the nonlinearity and hysteresis of the pressure sensor be less than 0,5 % and be calibrated according to the national standard.

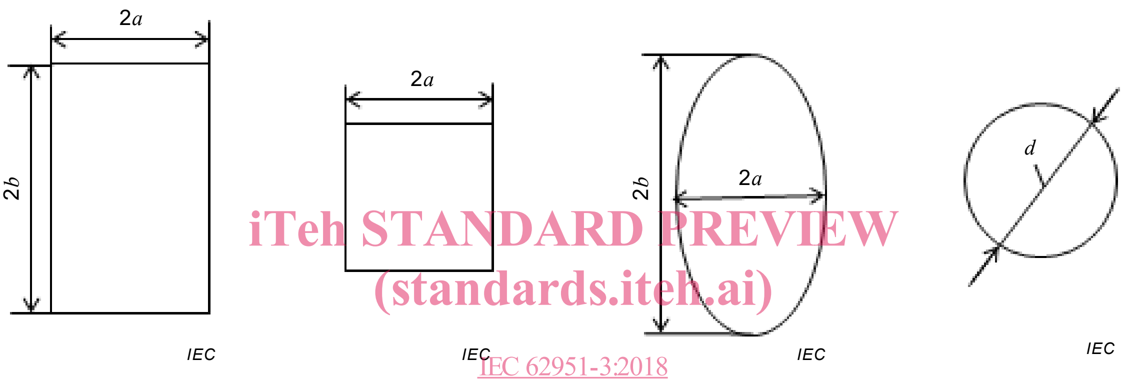
5.2.2.3 Heating device (optional)

When a very large pressure is needed to deform a flexible substrate, an optional heating device such as a hot plate or a halogen lamp can be added to increase the temperature of the device under testing. A heating device can be used when a large elastic or plastic deformation is needed through a reasonable pressuring device, since the elastic modulus of flexible substrates such as PET or PI becomes smaller at a higher temperature. When a plastic deformation is effected, the flexible substrate is deformed permanently and cannot be recovered to its initial non-stressed state. When a heating device is used, the pressure chamber should be designed with materials that conduct heat easily from the heating device to the flexible substrate under testing. The materials used for the pressure chamber should be able to withstand the supplied heat.

5.2.2.4 Pressure chamber open window

5.2.2.4.1 Pressure chamber open window shapes

Pressure chamber open windows can be in the shape of a rectangle, square, circle or ellipse, as shown in Figure 1. In case of a square or circle shape, the stress state of the sample is biaxial, while in case of a rectangle or ellipse, the stress state may be uniaxial. In case of measuring transistor characteristics, a square or circle shape is recommended, since the alignment of the thin film transistor under test is not necessary with biaxial stress. The pressure chamber open window is surrounded with a thick substrate frame or frame jig, which is not deformed by pressure. It is recommended that the half width, a, of the rectangular, square and elliptic chamber open window and the diameter, d, of the circular window be in the range of 1 mm to 50 mm.



a) rectangular b) square c) ellipse d) circle

Figure 1 – Pressure chamber open window shapes

5.2.2.4.2 Measurement of pressure chamber open window dimension

To analyze the test results, the accurate measurement of the pressure chamber open window dimension and pressure is required since the dimensions are used to extract mechanical properties of the test piece. The dimension of the window (width and length or diameter) should be measured with very high accuracy within less than ±1 %. Special care should be taken to measure the window size with clear division of the window boundary.

Special care should also be taken to avoid damage to the test piece during the measurement.

5.2.2.5 Height measurement unit

The height measurement unit should be installed in a position suitable to measure the deformation of the flexible substrate and perform the function of continuous measurement, which is needed to determine the maximum deformation of the flexible substrate bulged with applying pressure. The maximum deformation of the flexible substrate can be determined from the measurement in full-field or on top of the bulged area using the laser interferometric system or capacitance type measurement system, which is described in detail in Annex B of IEC 62047-17:2015.

The resolution of the measurement device for the deflection measuring a bulged flexible substrate by pressure should be in units of micrometers. A fine resolution of less than 0,1 % in full scale is very important for an accurate measurement.