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TECHNICAL SPECIFICATION

colour inside

Measurement procedures for materials used in photovoltaic modules – Part 8-1: Electrically conductive adhesive (ECA) – Measurement of material properties

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

Draft	Report on voting
82/2200/DTS	82/2241/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 62788 series, published under the general title *Measurement procedures for materials used in photovoltaic modules*, can be found on the IEC website.

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- reconfirmed,
- withdrawn, or
- revised.

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INTRODUCTION

Electrically conductive adhesive (ECA) is a material composed of conductive fillers blended with an organic adhesive polymer matrix. Already widely used as an interconnect material in electronic packaging and interconnection technologies for electronic devices, ECA is beginning to replace metallic solders as an innovative interconnection method in recent designs of photovoltaic (PV) modules. In a typical shingled PV module, solar cells are cut into strips and these solar cell strips overlap each other. ECA is applied in between the top electrode of one cell strip and the bottom electrode of the adjacent cell strip to form the electric interconnection. In some back-contact PV module designs, ECA allows the interconnection of solar cells' rear busbars to a conductive backsheet. In some PV modules where the solar cells are sensitive to high soldering temperatures, ECA is used to connect PV ribbons to the electrodes of the solar cells. The solar cell interconnections based on ECA can effectively reduce mechanical stress, shading loss and interconnect ohmic loss, and have been profiled as a promising alternative to traditional soldering process.

ECA can be used for wiring and surface assembly in PV modules. Initial performance and environmental endurance in application are highly dependent on its inherent material characteristics. For instance, adhesive properties are the primary requirement for ECA. Good adhesion between ECA and the adherends enables the structural integrity and long-term durability of the bonded joint over its service lifetime. Furthermore, the electrical performances of ECA, including volume resistance and contact resistance, are essential for the output performance and field durability of PV modules. Other characteristics such as viscosity, fineness, and conditions of use have a significant impact on the process conditions in manufacturing.

It is impractical to perform all the tests on ECA at the PV module level. Evaluation of the inherent material characteristics of ECA is highly desirable for pre-qualification of materials. This document defines test methods for key characteristics of ECA intended for use in photovoltaic modules.

The material property tests in this document cover general characteristics, mechanical characteristics, adhesion characteristics, electrical characteristics, thermal characteristics and the conditions of use.

MEASUREMENT PROCEDURES FOR MATERIALS USED IN PHOTOVOLTAIC MODULES –

Part 8-1: Electrically conductive adhesive (ECA) – Measurement of material properties

1 Scope

This document defines test methods and datasheet reporting requirements for key characteristics of ECA used in photovoltaic modules, involving mechanical characteristics, adhesive characteristics, electrical characteristics, thermal characteristics, etc.

The object of this document is to offer a standard test procedure to ECA manufacturers for product design, production and quality control, and to PV module manufacturers for the purpose of material screening, material inspection, process control, and failure analysis.

This document is intended to be applied to ECA used in solar PV modules.

For non-conductive adhesives or tapes used in PV modules, the applicable test methods except for electrical characteristics in this document may be used.

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 60068-1, *Environmental testing – Part 1: General and guidance*

IEC TS 61836, *Solar photovoltaic energy systems – Terms, definitions and symbols*

IEC TS 62788-2, *Measurement procedures for materials used in photovoltaic modules – Part 2: Polymeric materials – Frontsheets and backsheets*

ISO/IEC Guide 98-3:2008, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

ISO 37:2017, *Rubber, vulcanized or thermoplastic – Determination of tensile stress-strain properties*

ISO 291, *Plastics – Standard atmospheres for conditioning and testing*

ISO 1524:2020, *Paints, varnishes and printing inks – Determination of fineness of grind*

ISO 2393, *Rubber test mixes – Preparation mixing and vulcanization – Equipment and procedures*

ISO 2811-1, *Paints and varnishes – Determination of density – Part 1: Pycnometer method*

ISO 4587, *Adhesives – Determination of tensile lap-shear strength of rigid–to–rigid bonded assemblies*

ISO 4664-1:2022, *Rubber, vulcanized or thermoplastic – Determination of dynamic properties – Part 1: General guidance*

ISO 5893, *Rubber and plastics test equipment – Tensile, flexural and compression types (constant rate of traverse) – Specification*

ISO 7500-2, *Metallic materials – Verification of static uniaxial testing machines – Part 2: Tension creep testing machines – Verification of the applied force*

ISO 7886-1, *Sterile hypodermic syringes for single use – Part 1: Syringes for manual use*

ISO 8510-2, *Adhesives – Peel test for a flexible-bonded-to-rigid test specimen assembly – Part 2: 180 degree peel*

ISO 10365, *Adhesives – Designation of main failure patterns*

ISO 11358-1, *Plastics – Thermogravimetry (TG) of polymers – Part 1: General principles*

ISO 11358-2, *Plastics – Thermogravimetry (TG) of polymers – Part 2: Determination of activation energy*

ISO 11359-1, *Plastics – Thermomechanical analysis (TMA) – Part 1: General principles*

ISO 11359-2:2021, *Plastics – Thermomechanical analysis (TMA) – Part 2: Determination of coefficient of linear thermal expansion and glass transition temperature*

ISO 16525-1:2014, *Adhesives – Test methods for isotropic electrically conductive adhesives – Part 1: General test methods*

ISO 16525-2:2014, *Adhesives – Test methods for isotropic electrically conductive adhesives – Part 2: Determination of electrical characteristics for use in electronic assemblies*

ISO 17212, *Structural adhesives – Guidelines for surface preparation of metals and plastics prior to adhesive bonding*

ISO 23529:2016, *Rubber – General procedures for preparing and conditioning test pieces for physical test methods*

ASTM D1337-10, *Standard practice for storage life of adhesives by viscosity and bond strength*

ASTM D4287-00, S*tandard Test Method for High – Shear Viscosity Using a Cone/Plate Viscometer*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC TS 61836, together with 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
contact resistivity
electrical resistance that is generated on the contact surface between the isotropic electrically conductive adhesive and the adherend

Note 1 to entry: It is expressed in $\Omega \cdot mm^2$.

Note 2 to entry: Contact resistivity is the resistance times the contact area.

[SOURCE: ISO 16525-2:2014, 3.3, modified – deleted <electronic assembly> and interfacial.]

3.2
coefficient of linear thermal expansion
K^{-1}
reversible increase in length of a material per unit length per degree change in temperature

[SOURCE: ISO 11359-2:1999, 3.2]

3.3
electrically conductive adhesive
adhesive consisting of conductive fillers that provide electrical conduction and resin that serves for adhesion

Note 1 to entry: The resin can either be thermoplastic or cross-linked.

[SOURCE: ISO 16525-1:2014, 3.1, modified – deleted isotropic, added note.]

3.4
elongation at break
E_b
tensile strain in the test length at breaking point

[SOURCE: ISO 37:2017, 3.5]

3.5
four-probe method
method for measuring resistance that consists of two terminals for current application and two terminals for voltage measurement

[SOURCE: ISO 16525-2:2014, 3.4]

3.6
fineness
reading obtained on a standard gauge under specified conditions of test, indicating the depth of the groove(s) of the gauge at which discrete solid particles in the product are readily discernible

Note 1 to entry: It is expressed in µm.

[SOURCE: ISO 1524:2020, 3.1, modified – fineness of grind was changed to fineness.]

3.7
lap shear strength
force per unit surface area necessary to bring an adhesive joint to the point of failure by means of stress applied in the longitudinal mode, parallel to the plane of the bond-line

[SOURCE: EN 923:2015, 2.7.18]

3.8
loss normal modulus
loss Young's modulus
E″
component of the applied normal stress, which is 90 degree out of phase with the normal strain, divided by the strain

$$E'' = |E^*| \sin\delta$$

Note 1 to entry: It is expressed in Pa.

[SOURCE: ISO 4664-1:2022, 3.2.7]

3.9
peel strength
force per unit width necessary to bring an adhesive joint to the point of failure or to maintain a rate of failure by means of a stress applied in the peeling mode

[SOURCE: EN 923:2015, 2.7.16]

3.10
pot life
maximum period of time during which the properties of ECA in working conditions could maintain within the specified tolerances

[SOURCE: EN 923:2015, 2.4.24]

3.11
shelf life
time of storage under stated conditions during which an adhesive can be expected to retain its working properties

[SOURCE: EN 923:2015, 2.4.33]

3.12
shingled PV module
solar cell module comprising solar cell strips arranged in a shingled manner

3.13
solids content
percentage by mass of non-volatile matter in a product determined under specified test conditions

[SOURCE: EN 923:2015, 2.4.3]

3.14
elastic normal modulus
storage normal modulus
elastic Young's modulus
E'
component of the applied normal stress, which is in phase with the normal strain, divided by the strain

$$E' = \left|E^*\right| \cos\delta$$

Note 1 to entry: It is expressed in Pa.

[SOURCE: ISO 4664-1:2022, 3.2.6]

3.15
tensile strength
maximum tensile stress recorded in extending the test piece to breaking point

[SOURCE: ISO 37:2017, 3.3]

3.16
test length of a dumb-bell
initial distance between reference points within the length of the narrow portion of a dumb-bell test piece used to measure elongation

[SOURCE: ISO 37:2017, 3.10]

3.17
thixotropic index
ratio of viscosities measured at two shear rates

[SOURCE: ASTM D2556-14:2018, 3.2.2]

3.18
viscosity
property of resistance to steady flow exhibited within the body of the material

Note 1 to entry: It is expressed in mPa·s.

[SOURCE: ASTM D4092-07:2013, 3]

3.19
volume resistivity
electrical resistance of the isotropic electrically conductive adhesive for a given cross-sectional area or given length

Note 1 to entry: It is expressed in Ω·mm.

Note 2 to entry: Volume resistivity is the volume resistance times the cross-sectional area divided by the length of the sample.

[SOURCE: ISO 16525-2:2014, 3.2]

4 Test procedures

4.1 General

Tests shall be carried out under standard atmospheric conditions as described in IEC 60068-1.

ECA is usually stored at a low temperature, and it shall be returned to the experimental ambient temperature before test.

Specimens shall be pre-conditioned under 23 °C ± 2 °C and 50 % ± 10 % RH for at least 4 h, as specified/recommended in ISO 291.

4.2 General characteristics

4.2.1 Visual inspection

4.2.1.1 Purpose

To identify and document visual defects in an ECA.

4.2.1.2 Sampling

ECA is normally supplied in tubular or canned containers. To obtain uniform specimens which are adequately representative of the ECA being sampled, the following procedures shall be applied:

a) For tubular package, the ECA shall be squeezed on a substrate with flat and smooth surface.
b) For canned packaging, open and stir well before visual inspection.

4.2.1.3 Procedure

Inspect the specimens under an illumination of not less than 1 000 lux at a 15 cm to 30 cm viewing distance for the following:

a) colour inhomogeneity;
b) impurities;
c) bubbles;
d) any other phenomenon.

4.2.1.4 Reporting requirements

Report the following information:

a) Note and report the presence or absence of any phenomenon described in the procedure.
b) A photograph is recommended for documentation.

4.2.2 Density

4.2.2.1 Purpose

This test is performed to characterize the density of an ECA.

The density of an ECA can be measured according to ISO 2811-1. The test method consumes a lot of samples and is not suitable for the daily inspection. In this subclause, a test method using a small volume measuring tool, such as a syringe, is described.