

TECHNICAL SPECIFICATION



Measurement procedures for materials used in photovoltaic modules – Part 2: Polymeric materials – Frontsheets and backsheets

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 27.160

ISBN 978-2-8322-4673-3

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

CONTENTS

FOREWORD.....	6
INTRODUCTION.....	8
1 Scope.....	10
2 Normative references	10
3 Terms and definitions	13
4 Test procedures	16
4.1 General.....	16
4.2 Mechanical characteristics	17
4.2.1 General	17
4.2.2 Thickness	17
4.2.3 Area weight	18
4.2.4 Tensile strength / elongation at break	19
4.2.5 Curling.....	22
4.3 Adhesion testing	22
4.3.1 Purpose.....	22
4.3.2 General	22
4.3.3 Sample preparation	23
4.3.4 Sample conditioning	24
4.3.5 Apparatus and procedure	24
4.3.6 Adhesion tests for interfaces of backsheet and frontsheet	24
4.3.7 Reporting requirements	27
4.4 Thermal characteristics	28
4.4.1 Thermal endurance.....	28
4.4.2 Dimensional stability.....	28
4.4.3 Relative thermal expansion (CTE)	30
4.4.4 Thermal conductivity.....	31
4.5 Electrical characteristics	31
4.5.1 Breakdown voltage	31
4.5.2 Distance through insulation (dti)	32
4.5.3 Comparative Tracking Index (CTI)	37
4.5.4 Volume resistivity	38
4.6 Optical characteristics.....	39
4.6.1 General	39
4.6.2 Specimen preparation.....	40
4.6.3 Visual Inspection	40
4.6.4 Optical transmittance of frontsheets and backsheets	41
4.6.5 Optical reflectance of backsheets	42
4.6.6 Yellowness index (YI)	42
4.6.7 Colour measurement (L*, a*, b*)	43
4.6.8 Surface gloss.....	44
4.7 Diffusion characteristics	45
4.7.1 Permeability of water vapour	45
4.7.2 Permeability of oxygen	46
4.8 Chemical characteristics	46
4.8.1 Resistance to solvents.....	46

4.9	Other characteristics	48
4.9.1	Ignitability – Purpose	48
4.9.2	Flammability – Purpose	48
4.10	Accelerated ageing tests	48
4.10.1	Purpose	48
4.10.2	Damp Heat (DH) testing at elevated heat and moisture	49
4.10.3	Weathering at elevated levels of temperature and moisture	50
5	Uniform characterization form (UCF)	55
5.1	General	55
5.2	Layer stack description	55
5.3	Material test results and reporting requirements	56
6	Data sheet	58
6.1	Purpose	58
6.2	Reporting requirements	58
7	Product identification sheet (label)	58
Annex A (informative) Overview of adhesion testing of frontsheet and backsheet		59
A.1	Type of adhesion failure	59
A.2	Characteristics of adhesion peel tests	60
A.3	Characteristics of pluck and lap-shear tests	60
A.4	Cross-hatch tape testing	61
A.5	Other caveats	61
A.6	Overview	61
Annex B (normative) Adhesive bond strength test procedures in PV context		64
B.1	180° peel adhesion test	64
B.1.1	Specimens	64
B.1.2	Procedure	64
B.1.3	Measurement	65
B.2	T-peel adhesion test	66
B.2.1	Sample preparation	66
B.2.2	Procedure	67
B.2.3	Measurement	67
B.3	Dynamic tensile (T-pluck)	68
B.3.1	Purpose	68
B.3.2	Principle	68
B.3.3	Specimens	68
B.3.4	Measurement procedure	69
B.3.5	Final measurements	69
B.4	Dynamic overlap shear	70
B.4.1	Purpose	70
B.4.2	Principle	70
B.4.3	Specimens	70
B.4.4	Measurement procedure	72
B.4.5	Final measurements	72
B.5	Cross-hatch tape test	73
B.5.1	Apparatus	73
B.5.2	Procedure	74
B.5.3	Final measurements	74

Annex C (normative) DC breakdown voltage	75
C.1 Apparatus	75
C.2 Surrounding medium	76
C.3 Procedure	76
C.4 Criteria of breakdown	77
C.5 Other characterization methods	77
Annex D (informative) Abrasion testing	79
D.1 Purpose	79
D.2 Methods	79
Annex E (normative) Sampling of films	82
E.1 Purpose	82
E.2 Procedure	82
Annex F (normative) Sample preparation	83
F.1 Purpose	83
F.2 Sample constructions	83
F.2.1 General considerations	83
F.2.2 Materials and procedures	83
Bibliography	87
Figure 1 – Specimen type	20
Figure 2 – Specimen before and after shrinkage	29
Figure 3 – Examples of lamination cycles	34
Figure 4 – Schematics of test specimen for distance for insulation before and after lamination	34
Figure 5 – Directions for sectioning (perpendicular to solder wire position)	35
Figure 6 – Example of dti cross-section of a backsheet with an E-layer as inner side material	37
Figure A.1 – Adhesive and cohesive failure type schematics for lap-shear (top) and T-pluck (bottom)	59
Figure B.1 – Example test panel (70 mm x 150 mm) and test specimen	64
Figure B.2 – Fixation of the sample for 180° peel (for use with flexible/flexible samples) and cross-section of the sample	65
Figure B.3 – Single and multiple failure modes in a peel test	66
Figure B.4 – Sheet sandwich (above) from which test specimens for T-peel are prepared	67
Figure B.5 – Dynamic tensile (pluck) schematic	68
Figure B.6 – Schematic of pluck sample (in cross-section) for a laminated backsheet test	69
Figure B.7 – Dynamic tensile variables	69
Figure B.8 – Overlap shear force schematics	70
Figure B.9 – Schematic of overlap shear specimen shown in cross-section, for a laminated backsheet coupon	71
Figure B.10 – Details of overlap shear specimens (ISO 4587:2003, Figure 1)	71
Figure B.11 – Overview of overlap shear test conditions	72
Figure B.12 – Dynamic overlap shear schematic	73
Figure B.13 – Illustration of area removal by tape in cross-hatch test, with classification from 0 to 5 (from left to right)	74

Figure C.1 – Equal electrodes for dielectric strength test (taken from Figure 1b of IEC 60243-1:2013).....	76
Figure D.1 – Number size distributions of saltation particles at the dune site, 30 cm height, and the Gobi sites, 20 cm and 30 cm height, from 1223 to 1320 UT, 5 April 2002 [13]	80
Figure D.2 – Particle size distribution of sand from different heights	81
Figure D.3 – Grain size distribution of surface sand and drifting sand captured at 20 cm high above the crest of dune [14]	81
Table 1 – Overview of adhesion tests	25
Table 2 – Overview of sample preparation for exposure of sun-facing side of backsheet depending on intended post evaluation (see Table F.1)	52
Table 3 – Uniform characterization form (UCF) for polymeric PV frontsheet or backsheet	57
Table A.1 – Overview of various adhesion tests and their general capability of testing polymeric frontsheet and backsheet	62
Table F.1 – Overview of sample preparation suitable for material tests	85

INTERNATIONAL ELECTROTECHNICAL COMMISSION

MEASUREMENT PROCEDURES FOR MATERIALS USED IN PHOTOVOLTAIC MODULES –

Part 2: Polymeric materials – Frontsheets and backsheets

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) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a technical specification when

- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 62788-2, which is a technical specification, has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
82/1189/DTS	82/1243A/RVDTS

Full information on the voting for the approval of this technical specification can be found in the report on voting indicated in the above table.

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.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

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

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

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication 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

Backsheets provide the electrical insulation at the backside of a PV module under the environmental stress factors and use conditions encountered during the intended lifetime of the module. Frontsheets have the same function at the front side of the module facing towards the sun. Both can be made from glass or polymeric material.

Polymeric backsheets and frontsheets are typically compositions of layered materials, such as films, adhesives or coatings, in which at least one material layer delivers the relied-upon insulation (RUI) for electrical safety. Other layers may provide extended protection of the RUI against the environmental factors or adhesive functionality. As an integral part of the PV module, backsheet and frontsheet shall provide their durable electrical insulating function in presence of the other components of the PV module, such as light-to-current conversion element (the “cell”), electrical circuits and connectors, frontsheet and encapsulant, sealing material, junction boxes, etc. These elements may introduce additional stresses on the backsheet or frontsheet (e.g. by chemical interactions or introducing thermal load or mechanical stress) or alter environmental stresses (e.g. filtering of UV radiation reaching the sun-facing side of the backsheet).

It is impractical to conduct all endurance tests for frontsheet or backsheet component on module level. Instead, testing is performed directly on these components for pre-qualification of the materials as such, as e.g. given by the thermal endurance test required for material intended for use as relied-upon-insulation, that is qualified by IEC 60216 (see IEC 61730-1:2016, 5.5.1.3.3) and results in RTE/RTI/TI ratings of ≥ 90 °C or maximum operating temperature (whichever is greater). In the case of thermal pre-qualification of backsheet and frontsheet only dielectric and mechanical material tests apply for RTE/RTI/TI assessment.

In analogy to RTE/RTI/TI, it is desirable to also obtain pre-qualification of backsheet and frontsheet films to provide durable electrical insulation after exposure to additional environmental factors, such as:

- a) Elevated moisture and temperature (damp heat), or
- b) UV-weathering in a manner representative of the field conditions. These tests can either be conducted direct on the backsheet or frontsheet films or on dedicated test coupons as engineering type specimens, which are prepared from the same materials and produced under comparable processing conditions (i.e. lamination) as the PV modules.
 - The portion of the backsheet that contributes to the relied upon insulation should be evaluated for d.c. voltage (V) breakdown strength according to IEC 60243-1 and IEC 60243-2, and meet the requirements as described in 5.6.4.3 of IEC 61730-1:2016. In this document a suitable choice of test parameters for the assessment of polymeric frontsheet and backsheet is defined.
 - The relied upon insulation material shall have a minimum thickness, also known as distance through insulation (dti) defined in the “thickness in thin layers” rows of Tables 3 and 4 in 5.6 of IEC 61730-1:2016.
 - Materials relied upon for insulation are further categorized into Materials Groups I, II, or III, according to CTI values describing potential tracking along interfaces that may get in contact with live parts.
 - Durable adhesion between components of the backsheet or frontsheet is needed to preserve the integrity of the sheet material in field conditions. Also, preservation of adhesion to other components of the module such as encapsulant and edge seal or adhesion to the junction box adhesive are important. Different test geometries may apply depending on the interface under test and construction of the sheet material.

Other characteristics of frontsheet or backsheet might be relevant for the electrical yield (e.g. optical transmittance or reflectance) or module producibility (e.g. lamination process).

This document defines test methods required for reporting of properties of polymeric frontsheet and backsheet in a datasheet. Those properties are related to safety and yield of the assembled PV module and may be applied to backsheet/frontsheet before and after specific ageing tests as mentioned before.

In analogy to RTE/RTI/TI testing, the test methods in this document are intended to be used in procedures for pre-qualification and/or quality assurance of frontsheet and backsheet components with respect to their endurance under damp-heat and UV weathering stresses – once these pre-qualification procedures are agreed on and implemented in alignment with the pertinent standards IEC 61730 and IEC 61215, in which the safety requirements on PV module level are defined.

NOTE At the time of writing this TS, an amendment project for IEC 61730-1 is in preparation, in which requirements for measurement of dti (distance through insulation) and resistance against weathering are planned based on methods defined in this document IEC TS 62788-2 as well as IEC TS 62788-7-2.

The test methods in these TS provide additional information on material properties and endurance of backsheet and frontsheet components that cannot be assessed in the tests on PV module alone.

Furthermore, optional characterization test methods are defined, addressing properties of backsheet and frontsheet that are of informative nature, e.g. in the context of PV module design, but which are not directly safety, yield or processing related.

Test methods for characterization of components of backsheet and frontsheet are described, which are useful in R&D context.

All of these test methods are set into perspective by indicating their use and limitations.

MEASUREMENT PROCEDURES FOR MATERIALS USED IN PHOTOVOLTAIC MODULES –

Part 2: Polymeric materials – Frontsheets and backsheets

1 Scope

This part of IEC 62788 defines test methods and datasheet reporting requirements for safety and performance related properties (mechanical, electrical, thermal, optical and chemical) of non-rigid polymeric materials intended for use in terrestrial photovoltaic modules as polymeric frontsheets and backsheets.

The test methods in this document define how to characterize backsheet and frontsheet materials and their components in a manner representative of how they will be used in the module, which eventually includes combination with other matched components such as encapsulant or adhesives. The methods described in this document support the safety and performance related tests defined on PV module level as defined in the series IEC 61730 and IEC 61215.

This document also defines test methods for assessment of inherent material characteristics of polymeric backsheets and frontsheets or their components, which may be required in datasheet reporting or may be useful in the context of product development or design of PV modules.

Rigid polymeric sheet materials (also providing mechanical support) may require further consideration.

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 60050-581, *International Electrotechnical Vocabulary – Part 581: Electromechanical components for electronic equipment*

IEC 60050-826, *International Electrotechnical Vocabulary – Part 826: Electrical installations*

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

IEC 60112:2003, *Method for the determination of the proof and the comparative tracking indices of solid insulating materials*

IEC 60212, *Standard conditions for use prior to and during the testing of solid electrical insulating materials*

IEC 60216-1, *Electrical insulating materials – Properties of thermal endurance – Part 1: Ageing procedures and evaluation of test results*

IEC 60216-2:2005, *Electrical insulating materials – Thermal endurance properties – Part 2: Determination of thermal endurance properties of electrical insulating materials – Choice of test criteria*

IEC 60216-5, *Electrical insulating materials – Thermal endurance properties – Part 5: Determination of relative thermal endurance index (RTE) of an insulating material*

IEC 60243-1:2013, *Electrical strength of insulating materials – Test methods – Part 1: Tests at power frequencies*

IEC 60243-2, *Electric strength of insulating materials – Test methods – Part 2: Additional requirements for tests using direct voltage*

IEC 60296, *Fluids for electrotechnical applications – Unused mineral insulating oils for transformers and switchgear*

IEC 60664-1, *Insulation co-ordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60904-3:2016, *Photovoltaic devices – Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data*

IEC 61140, *Protection against electric shock – Common aspects for installation and equipment*

IEC 61189-3, *Test methods for electrical materials, printed boards and other interconnection structures and assemblies – Part 3: Test methods for interconnection structures (printed boards)*

IEC 61215-1:2016, *Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 1: Test requirements*

IEC 61215-2:2016, *Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 2: Test procedures*

IEC 61730-1:2016, *Photovoltaic (PV) module safety qualification – Part 1: Requirements for construction*

IEC 61730-2, *Photovoltaic (PV) module safety qualification – Part 2: Requirements for testing*

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

IEC 62788-1-2, *Measurement procedures for materials used in photovoltaic modules – Part 1-2: Encapsulants – Measurement of volume resistivity of photovoltaic encapsulants and other polymeric materials*

IEC 62788-1-4, *Measurement procedures for materials used in photovoltaic modules – Part 1-4: Encapsulants – Measurement of optical transmittance and calculation of the solar-weighted photon transmittance, yellowness index, and UV cut-off wavelength*

IEC 62788-1-5, *Measurement procedures for materials used in photovoltaic modules – Part 1-5: Encapsulants – Measurement of change in linear dimensions of sheet encapsulation material resulting from applied thermal conditions*

IEC TS 62788-7-2, *Measurement procedures for materials used in photovoltaic modules – Part 7-2: Environmental exposures – Accelerated weathering tests of polymeric materials*

IEC 62790, *Junction boxes for photovoltaic modules – Safety requirements and tests*

IEC 62805-2, *Method for measuring photovoltaic (PV) glass – Part 2: Measurement of transmittance and reflectance*

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

ISO 527 (all parts): *Plastics*

ISO 527-3, *Plastics – Determination of tensile properties – Part 3: Test conditions for films and sheets*

ISO 536:2012, *Paper and board – Determination of grammage*

ISO 2409:2013, *Paints and varnishes – Cross-cut test*

ISO 2808, *Paints and varnishes determination of film thickness*

ISO 2813, *Paints and varnishes – Determination of gloss value at 20 degrees, 60 degrees and 85 degrees*

ISO 4587:2003, *Adhesives – Determination of tensile lap-shear strength of rigid-to-rigid bonded assemblies*

ISO 4593: *Plastics – Film and sheeting – Determination of thickness by mechanical scanning*

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

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

ISO 11664-1, *Colorimetry – Part 1: CIE standard colorimetric observers*

ISO 11664-2, *Colorimetry – Part 2: CIE standard illuminants*

ISO 11664-4, *Colorimetry – Part 4: CIE 1976 L*a*b* Colour space*

ISO 15105-2, *Plastics – Film and sheeting – Determination of gas-transmission rate – Part 2: Equal-pressure method*

ISO 15106-1, *Plastics – Film and sheeting – Determination of water vapour transmission rate – Part 1: Humidity detection sensor method*

ISO 15106-2, *Plastics – Film and sheeting – Determination of water vapour transmission rate – Part 2: Infrared detection sensor method*

ISO 15106-3, *Plastics – Film and sheeting – Determination of water vapour transmission rate – Part 3: Electrolytic detection sensor method*

ISO 17223, *Plastics – Determination of yellowness index and change in yellowness index*

EN 821-2, *Advanced technical ceramics – Monolithic ceramics, thermo-physical properties – Part 2: Determination of thermal diffusivity by the laser flash (or heat pulse) method*

ASTM D374–16, *Standard Test Methods for Thickness of Solid Electrical Insulation*

ASTM D3487-16, *Standard Specification for Mineral Insulating Oil Used in Electrical Apparatus*

ASTM D 5402-06, *Standard Practice for Assessing the Solvent Resistance of Organic Coatings Using Solvent Rubs*

ASTM D7869-17, *Standard Practice for Xenon Arc Exposure Test with Enhanced Light and Water Exposure for Transportation Coatings*

ASTM E1461, *Standard Test Method for Thermal Diffusivity by the Flash Method*

UL 746B, *Standard for Polymeric Materials – Long Term Property Evaluations*