

IPC-4921A

2017 - May

Requirements for Printed Electronics Base Materials (Substrates)

An international standard developed by IPC

Association Connecting Electronics Industries



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Requirements for Printed Electronics Base Materials (Substrates)

Developed by the Printed Electronics Base Material/Substrates Subcommittee (D-62) of the Printed Electronics Committee (D-60) of IPC

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Users of this publication are encouraged to participate in the development of future revisions.

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Requirements for Printed Electronics Base Materials (Substrates)

1 SCOPE

This standard establishes the classification system, qualification and quality conformance requirements for printed electronics base materials (substrates).

The standard defines the base material only and should not be used for substrates that have been postprocessed and comprise defined features or structures (e.g., conductive traces).

1.1 Purpose The purpose of this standard is to provide and define key characteristics and test methods used for procuring printed electronics base materials (substrates).

1.2 Classification System The system described in 1.2.1 through 1.2.2.5 identifies printed electronics base materials (substrates).

1.2.1 Designating Materials A materials designation is intended for use by designers on master drawings to designate their base material choice. At the end of this standard is a series of material specification sheets, which are identified by specification sheet numbers. Each specification sheet outlines engineering and performance data for a printed electronics base material type. The designer should select the appropriate base material specification sheet as required to meet the operational specifications of the end product application (e.g., consumer, automotive, aerospace, etc.).

An example base material designation would be IPC-4921/2, for which “/2” refers to the specification sheet detailing Polyester Naphthalate (PEN)/Biaxially Oriented Polyethylene Naphthalate (BOPEN).

If the designer requires further material specification details (e.g., thickness), the designer should highlight those details in cross-sectional views or notes on the master drawing.

If the designer is using a material which is not in one of the approved IPC-4921 specification sheets, the designer **shall** select the material type from 1.2.2.2. Users and suppliers should consider submitting new specification sheets for consideration in this standard (see 1.8).

1.2.2 Adding Details When Designating Materials Designers may add details to the procurement documentation for substrate materials.

The additional details designation **shall** follow this format:

Standard designation / Specification Sheet number or Base Material Type / Base Structure / Base Reinforcement Type / Base Material Thickness

Where:

- Standard designation is IPC-4921.
- Specification Sheet number is an approved IPC-4921 specification sheet.
- If no specification sheet exists, the designer **shall** select a Base Material Type designation from 1.2.2.2. If the material type is not included in 1.2.2.2, the designer **shall** create a designator for the material.
- Base Structure is selected from 1.2.2.3.
- Base Reinforcement Type is selected from 1.2.2.4.
- Base Material Thickness is selected from 1.2.2.5.

The following is an example of a detailed designation using an IPC-4921 Specification Sheet as the Base Material Type:

IPC-4921 / 2 / 2 / F / 7 would be PEN/BOPEN in sheet form, nonreinforced, with a thickness range of ≥ 0.250 mm to < 0.400 mm.

The following is an example of a detailed designation using a material which is not represented in an IPC-4921 specification sheet:

IPC-4921 / OR3 / 1 / F / 7 would be Fluorinated Ethylene-Propylene (FEP) in film form, nonreinforced, with a thickness range of ≥ 0.250 mm to < 0.400 mm.

The detailed designation is intended for use on material purchase orders by fabricators (see Section 6). Designers should not use the detailed designation on master drawings to indicate their material selection. Designers **shall** specify on master drawings only the material type, because the detailed designation is lengthy and requires fabricator-level knowledge in making the detailed selections.

1.2.2.1 Base Material Family Utilizing the base material family designation prefix in Table 1-1, the type of printed electronics base material **shall** be designated per 1.2.2.2.

Table 1-1 Base Material Family Designation

Designation	Family
C	Ceramic
M	Metal
OR	Organic
G	Glass
O	Other

1.2.2.2 Base Material Type The printed electronics base material type **shall** be designated per Table 1-2.

Table 1-2 Base Material Type Designation

Designation	Base Type
C1	Alumina (Al_2O_3)
C2	Aluminum Nitride (AlN)
CO	Ceramic, Other
M1	Aluminum (Al)
M2	Copper (Cu)
M3	Copper-Tungsten
M4	Stainless Steel
MO	Metal, Other
OR1	Biaxially Oriented Polypropylene (BOPP)
OR2	Epoxy
OR3	Fluorinated Ethylene-Propylene (FEP)
OR4	Polycarbonate (PC)
OR5	Polyetheretherketone (PEEK)
OR6	Polyethylene Naphthalate (PEN)
OR7	Biaxially Oriented Polyethylene Terephthalate (BOPET, PET)
OR8	Polyethylene Terephthalate w/Glycol (PETG)
OR9	Polyetherimide (PEI)
OR10	Polyimide (PI)
OR11	Polytetrafluoroethylene (PTFE)
OR12	Polyvinyl Chloride (PVC)
OR13	Silicone
OR14	Cellulose
OR15	Cellulose Blend
ORO	Organic – Other
G	Borosilicate (Alkali-Free) Glass
GO	Glass – Other
TPU	Thermoplastic Polyurethane
TPE	Thermoplastic Elastomer
PEF	Polyethylene Furanoate (PEF)

1.2.2.3 Base Structure The base structure **shall** be designated per Table 1-3.

Table 1-3 Base Structure Designation

Designation	Base Structure
1	Film
2	Sheet
3	Composite - Woven
4	Composite - Nonwoven (e.g., fillers)
5	Laminate
6	Other

1.2.2.4 Base Reinforcement Type The base reinforcement type **shall** be designated per Table 1-4.

Table 1-4 Base Reinforcement Type Designation

Designation	Base Reinforcement Type
A	Ceramic
B	Metal
C	Organic
D	Glass
E	Composite
F	Nonreinforced

1.2.2.5 Base Material Thickness The base material thickness designation using Table 1-5 **shall** be reported on the specification sheet.

Table 1-5 Nominal Base Material Thickness Designation

Designation	Base Reinforcement Type (Thickness)
1	< 0.020 mm [< 787 µin]
2	≥ 0.020 mm to < 0.025 mm [≥ 787 µin to < 984 µin]
3	≥ 0.025 mm to < 0.075 mm [≥ 984 µin to < 2953 µin]
4	≥ 0.075 mm to < 0.100 mm [≥ 2953 µin to < 3937 µin]
5	≥ 0.100 mm to < 0.150 mm [≥ 3937 µin to < 5906 µin]
6	≥ 0.150 mm to < 0.250 mm [≥ 5906 µin to < 9843 µin]
7	≥ 0.250 mm to < 0.400 mm [≥ 9843 µin to < 15748 µin]
8	≥ 0.400 mm [≥ 15748 µin]
X	Specified in document

1.3 Surface Treatments This specification recognizes that printed electronics base materials may be subjected to various surface treatments to improve hardness, optical enhancement, wetting and adhesion by the functional material. Additionally, these treatments may provide functionality such as gas barrier, liquid barrier or planarization.

Example surface treatments include:

- Chemical
 - Acid-etched
 - Alkali-etched
 - Anodic oxide

- Corona
- Plasma
- Mechanical
 - Sandblasting
 - Calendering
 - Mechanical galvanizing
 - Cast-coated
 - Extruded
- Coating
 - Adhesion primer
 - Epoxy primer
 - Pigmented
 - Film form
 - Antistatic

1.4 Manufacturing Temperature Classification This specification recognizes that printed electronics base materials will be subjected to different processing temperature conditions during manufacturing of the printed electronics product. The following are manufacturing classifications.

Class 1 – 0 °C to 50 °C*

Class 2 – 50 °C to 125 °C*

Class 3 – 125 °C to 200 °C*

Class 4 – 200 °C to 250 °C*

Class 5 – 250 °C to 300 °C*

Class 6 – > 300 °C

*Maximum dwell time(s) at temperature extremes **shall** be AABUS.

1.5 Quality Conformance This standard establishes a quality conformance system for the suppliers to demonstrate the continual conformance of the printed electronics base material to the quality requirements of the standard. See 4.9 for quality conformance inspection requirements.

1.6 Procurement Documentation The procurement documentation **shall** provide sufficient information to the supplier so the supplier can fabricate the printed electronics base material and ensure the user receives the desired product. The procurement documentation should specify the requirements that can be selected from within this standard.

1.7 Material Characteristics Printed electronics base materials made to this standard use established requirements to enable the material to be applied in a broad range of applications. The printed electronics base materials made to this standard may have characteristics that provide specific enhanced performance (e.g., oxygen/moisture permeation rate). Both the user and supplier should review these enhancements. These enhancements may meet or exceed the specification requirements and will be designated in the purchasing documentation as agreed upon between user and supplier (AABUS) (see 1.7.1).

1.7.1 As Agreed Upon Between User and Supplier (AABUS) AABUS indicates additional or alternate requirements to be decided between the user and the supplier in the procurement documentation. Examples include contractual requirements, modifications to purchase documentation and information on the drawing. Agreements can be used to define test methods, conditions, frequencies, categories or acceptance criteria within a test, if not already established.

1.8 New Materials The printed electronics base materials specification sheets in this standard represent known materials. As new materials become available, they can be added to future revisions.

Users and material developers are encouraged to supply information for printed electronics base materials using the blank specification sheet included at the end of this standard for review by the IPC Printed Electronics Base Material/Substrates Subcommittee (D-62).

The IPC Printed Electronics Base Materials/Substrates Subcommittee (D-62) will consider new or revised specification sheets independent from revision of this standard. Approved new or revised specification sheets **shall** become part of the standard, issued as an Amendment and/or in a full revision of the standard.

1.9 Interpretation of “Shall” The imperative form of the verb “shall” is used throughout this standard whenever a requirement is intended to express a provision that is mandatory. Deviation from a “shall” requirement may be considered if sufficient data are supplied to justify the exception. To assist the reader, the word “shall” is presented in bold characters.

The words “should” and “may” are used whenever it is necessary to express nonmandatory provisions.

“Will” is used to express a declaration of purpose.

1.10 Presentation of Dimensions and Tolerances All dimensions and tolerances in this specification are expressed in hard SI (metric) units and bracketed soft imperial [inch] units. Users of this specification are expected to use metric dimensions. All dimensions ≥ 1.0 mm [0.0394 in] will be expressed in millimeters and inches. All dimensions < 1.0 mm [0.0394 in] will be expressed in micrometers and microinches.

2 APPLICABLE DOCUMENTS

The following documents of the issue currently in effect form a part of this standard to the extent specified herein.

2.1 IPC¹

IPC-T-50 Terms and Definitions for Interconnecting and Packaging Electronic Circuits

IPC-TM-650 Test Methods Manual²

- 2.1.13 Inspection for Voids in Flexible Printed Wiring Materials
- 2.2.4 Dimensional Stability, Flexible Dielectric Materials
- 2.3.2 Chemical Resistance of Flexible Printed Board Materials
- 2.3.38 Surface Organic Contaminant Detection Test
- 2.3.39 Surface Organic Contaminant Identification Test (Infrared Analytical Method)
- 2.4.16 Initiation Tear Strength, Flexible Insulating Materials
- 2.4.17.1 Propagation Tear Strength, Flexible Insulating Material
- 2.4.18.3 Tensile Strength, Elongation, and Modulus
- 2.4.19 Tensile Strength and Elongation, Flexible Printed Wiring Materials
- 2.4.24 Glass Transition Temperature and Z-Axis Thermal Expansion by TMA
- 2.5.5.3 Permittivity (Dielectric Constant) and Loss Tangent (Dissipation Factor) of Materials (Two Fluid Cell Method)
- 2.5.5.5 Stripline Test for Permittivity and Loss Tangent (Dielectric Constant and Dissipation Factor) at X-Band
- 2.5.5.8 Low Frequency Dielectric Constant and Loss Tangent, Polymer Films
- 2.5.5.9 Permittivity and Loss Tangent, Parallel Plate, 1 MHz to 1.5 GHz
- 2.5.5.10 High Frequency Testing to Determine Permittivity and Loss Tangent of Embedded Passive Materials
- 2.5.17 Volume Resistivity and Surface Resistance of Printed Wiring Materials
- 2.6.1 Fungus Resistance Printed Wiring Materials
- 2.6.2 Moisture Absorption, Flexible Printed Wiring
- 2.6.4 Outgassing, Printed Boards

IPC-6013 Qualification and Performance Specification for Flexible Printed Boards

IPC-6903 Terms and Definitions for the Design and Manufacture of Printed Electronics

IPC-9191 General Guidelines for Implementation of Statistical Process Control (SPC)

2.2 ASTM International³

ASTM C623 Standard Test Method for Young’s Modulus, Shear Modulus, and Poisson’s Ratio for Glass and Glass-Ceramics by Resonance

1. www.ipc.org

2. Current and revised IPC Test Methods are available on the IPC Web site (www.ipc.org/html/testmethods.htm)

3. www.astm.org

- ASTM D149** Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies
- ASTM D150-11** Standard Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation
- ASTM D257** Standard Test Methods for DC Resistance or Conductance of Insulating Materials
- ASTM D374** Standard Test Methods for Thickness of Solid Electrical Insulation
- ASTM D542** Standard Test Method for Index of Refraction of Transparent Organic Plastics
- ASTM D635** Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position
- ASTM D523** Standard Test Method for Specular Gloss
- ASTM D696** Standard Test Method for Coefficient of Linear Thermal Expansion of Plastics Between -30°C and 30°C With a Vitreous Silica Dilatometer
- ASTM D882** Standard Test Method for Tensile Properties of Thin Plastic Sheeting
- ASTM D1003** Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics
- ASTM D1505** Standard Test Method for Density of Plastics by the Density-Gradient Technique
- ASTM D1894** Standard Test Method for Static and Kinetic Coefficients of Friction of Plastic Film and Sheeting
- ASTM D2457-08** Standard Test Method for Specular Gloss of Plastic Films and Solid Plastics
- ASTM D2520** Standard Test Methods for Complex Permittivity (Dielectric Constant) of Solid Electrical Insulating Materials at Microwave Frequencies and Temperatures to 1650°C
- ASTM D5470** Standard Test Method for Thermal Transmission Properties of Thermally Conductive Electrical Insulation Materials
- ASTM D6343-14** Standard Test Methods for Thin Thermally Conductive Solid Materials for Electrical Insulation and Dielectric Applications
- ASTM D7127** Standard Test Method for Measurement of Surface Roughness of Abrasive Blast Cleaned Metal Surfaces Using a Portable Stylus Instrument
- ASTM D7490** Standard Test Method for Measurement of the Surface Tension of Solid Coatings, Substrates and Pigments Using Contact Angle Measurements
- ASTM E96** Standard Test Methods for Water Vapor Transmission of Materials
- ASTM E290** Standard Test Methods for Bend Testing of Material for Ductility
- ASTM E384 - 11e1** Standard Test Method for Knoop and Vickers Hardness of Materials
- ASTM E595** Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials From Outgassing in a Vacuum Environment
- ASTM E831** Standard Test Method for Linear Thermal Expansion of Solid Materials by Thermomechanical Analysis
- ASTM E1356** Standard Test Method for Assignment of the Glass Transition Temperatures by Differential Scanning Calorimetry
- ASTM E1478** Standard Practice for Visual Color Evaluation of Transparent Sheet Materials
- ASTM F1595** Standard Practice for Viewing Conditions for Visual Inspection of Membrane Switches
- ASTM F1683** Standard Practice for Creasing or Bending a Membrane Switch, Membrane Switch Flex Tail Assembly or Membrane Switch Component
- ASTM F2622** Standard Test Method for Oxygen Gas Transmission Rate Through Plastic Film and Sheeting Using Various Sensors

2.3 UL⁴

UL 94 Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances

UL 746B Polymeric Materials - Long Term Property Evaluations

2.4 NCSL International⁵

ANSI/NCSL Z540.1 Calibration Laboratories and Measuring and Test Equipment - General Requirements

2.5 International Organization for Standardization (ISO)⁶

ISO 489 Plastics—Determination of Refractive Index

ISO 1210 Plastics—Determination of the Burning Behaviour of Horizontal and Vertical Specimens in Contact With a Small-Flame Ignition Source

ISO 4287 Geometrical Product Specifications (GPS)—Surface Texture: Profile Method—Terms, Definitions and Surface Texture Parameters

ISO 8295 Plastics—Film and Sheet—Determination of the Coefficients of Friction

ISO 14782 Plastics—Determination of Haze for Transparent Materials

ISO 15105 Plastics—Film and Sheet—Determination of Gas Transmission Rate

ISO 15106 Plastics—Film and sheeting—Determination of Water Vapour Transmission rate

2.6 American Society of Mechanical Engineers (ASME)⁷

ASME B46.1 Surface Texture (Surface Roughness, Waviness and Lay)

2.7 Technical Association of the Pulp and Paper Industry (TAPPI)⁸

TAPPI T 414 Internal Tearing Resistance of Paper (Elmendorf-Type Method)

TAPPI T 448 Water Vapor Transmission Rate of Paper and Paperboard at 23 °C (73 °F) and at 50 % RH

TAPPI T 494 Tensile Testing of Paper

TAPPI T 479 Smoothness of Paper (Bekk method)

TAPPI T 524 Color of Paper and Paperboard (45/0, C/2)

TAPPI T 527 Color of Paper and Paperboard (D/0, C/2)

TAPPI T 538 Roughness of Paper and Paperboard (Sheffield method)

TAPPI T 543 Bending Resistance of Paper (Gurley-Type Tester)

TAPPI T 566 Bending Resistance (Stiffness) of Paper (Taber-Type Tester in 0 to 10 Taber Stiffness Unit Configuration)

TAPPI T 815 Coefficient of Static Friction (Slide Angle) of Packaging and Packaging Materials (Including Shipping Sack Papers, Corrugated and Solid Fiberboard) (Inclined Plane Method)

2.8 British Standards Institution (BSI)⁹

BS EN 14582 Characterization of Waste. Halogen and Sulfur content. Oxygen Combustion in Closed Systems and Determination Methods

4. www.ul.com

5. www.ncsl.org

6. www.iso.org

7. www.asme.org

8. www.tappi.org

9. www.bsigroup.com