

# IPC-4921A

2017 - May

## Requirements for Printed Electronics Base Materials (Substrates)

*An international standard developed by IPC*

Association Connecting Electronics Industries



**The Principles of Standardization**

In May 1995 the IPC's Technical Activities Executive Committee (TAEC) adopted Principles of Standardization as a guiding principle of IPC's standardization efforts.

**Standards Should:**

- Show relationship to Design for Manufacturability (DFM) and Design for the Environment (DFE)
- Minimize time to market
- Contain simple (simplified) language
- Just include spec information
- Focus on end product performance
- Include a feedback system on use and problems for future improvement

**Standards Should Not:**

- Inhibit innovation
- Increase time-to-market
- Keep people out
- Increase cycle time
- Tell you how to make something
- Contain anything that cannot be defended with data

**Notice**

IPC Standards and Publications are designed to serve the public interest through eliminating misunderstandings between manufacturers and purchasers, facilitating interchangeability and improvement of products, and assisting the purchaser in selecting and obtaining with minimum delay the proper product for his particular need. Existence of such Standards and Publications shall not in any respect preclude any member or nonmember of IPC from manufacturing or selling products not conforming to such Standards and Publication, nor shall the existence of such Standards and Publications preclude their voluntary use by those other than IPC members, whether the standard is to be used either domestically or internationally.

Recommended Standards and Publications are adopted by IPC without regard to whether their adoption may involve patents on articles, materials, or processes. By such action, IPC does not assume any liability to any patent owner, nor do they assume any obligation whatever to parties adopting the Recommended Standard or Publication. Users are and are wholly responsible for protecting themselves against all claims of liabilities for patent infringement.

**IPC Position Statement on Specification Revision Change**

It is the position of IPC's Technical Activities Executive Committee that the use and implementation of IPC publications is voluntary and a part of a relationship entered into by customer and supplier. When an IPC publication is updated and a new revision is published, it is the opinion of the TAEC that the use of the new revision as part of an existing relationship is not automatic unless required by the contract. The TAEC recommends the use of the latest revision. Adopted October 6, 1998

**Why is there a charge for this publication?**

Your purchase of this document contributes to the ongoing development of new and updated industry standards and publications. Standards allow manufacturers, customers, and suppliers to understand one another better. Standards allow manufacturers greater efficiencies when they can set up their processes to meet industry standards, allowing them to offer their customers lower costs.

IPC spends hundreds of thousands of dollars annually to support IPC's volunteers in the standards and publications development process. There are many rounds of drafts sent out for review and the committees spend hundreds of hours in review and development. IPC's staff attends and participates in committee activities, typesets and circulates document drafts, and follows all necessary procedures to qualify for ANSI approval.

IPC's membership dues have been kept low to allow as many companies as possible to participate. Therefore, the standards and publications revenue is necessary to complement dues revenue. The price schedule offers a 50% discount to IPC members. If your company buys IPC standards and publications, why not take advantage of this and the many other benefits of IPC membership as well? For more information on membership in IPC, please visit [www.ipc.org](http://www.ipc.org) or call 847/597-2872.

Thank you for your continued support.



IPC-4921A

# 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

Supersedes:  
IPC-4921 - June 2012

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

Contact:

IPC  
3000 Lakeside Drive, Suite 105N  
Bannockburn, Illinois  
60015-1249  
Tel 847 615.7100  
Fax 847 615.7105

This Page Intentionally Left Blank

Currently in preview, click buy full version

## Acknowledgment

Any document involving a complex technology draws material from a vast number of sources across many continents. While the principal members of the Printed Electronics Base Material/Substrates Subcommittee (D-62) of the Printed Electronics Committee (D-60) are shown below, it is not possible to include all of those who assisted in the evolution of this standard. To each of them, the members of IPC extend their gratitude.

| <b>Printed Electronics Committee</b>   | <b>Printed Electronics Base Material/Substrates Subcommittee</b>         | <b>Technical Liaison of the IPC Board of Directors</b>                        |
|--|--|---|
| Co-Chairs<br>Neil Bolding<br>MacDermid Enthone<br>Electronics Solutions        | Chair<br>Scott E. Gordon<br>DuPont Teijin Films                          | Bob Neves<br>Microtek (Changzhou) Laboratories                                |
| Daniel Gamota<br>Printovate Technologies, Inc.                                 | Vice Chair<br>Neil Bolding<br>MacDermid Enthone<br>Electronics Solutions |   |
| <b>Printed Electronics Base Material/Substrates Subcommittee</b>               |  |   |
| Leonard Allison, Engineered<br>Materials Systems, Inc.                         | Mahendra S.Gandhi, Northrop<br>Grumman Aerospace Systems                 | Tom Rogers, Polyonics, Inc.   |
| John Andresakis, Park<br>Electrochemical Corp.                                 | Ken Gann, Lab Tech   | Hardeep Sarma, GO 2 Scout 4 R&T   |
| Lance Auer, Raytheon Missile<br>Systems  | MaryAlice Gill, Jabil Circuit, Inc.                                      | Joseph Schmidt, Raytheon Missile<br>Systems                                   |
| Sai Avuthu, Jabil Circuit, Inc.  | Josh Goldberg, Taiyo America Inc.  | Jeff Shubrooks, Raytheon Company  |
| Anirban Basu   | Scott E. Gordon, DuPont Teijin Films                                     | Michael Slocum, Coast to Coast<br>Circuits, Inc.                              |
| Andy Behr, Panasonic Industrial<br>Devices Sales Company of<br>America (PIDSA) | Mary K. Herndon, Raytheon<br>Company                                     | Richard C. Snogren, Bristlecone LLC   |
| Todd Boedecker, GM Nameplate   | Abbas Hosseinzadeh, Coast to Coast<br>Circuits, Inc.                     | David Sommervold, The Bergquist<br>Company/Henkel Electronic<br>Materials LLC |
| Neil Bolding, MacDermid Enthone<br>Electronics Solutions                       | Nizamudin Jaffer, Kimoto Tech  | Mamoru Takahashi, Asahi Glass Co.,<br>Ltd.                                    |
| Alan Brown, Engineered Materials<br>Systems, Inc.                              | Michael J. Javitz, Orbital ATK   | Brian J. Toleno, Microsoft<br>Corporation                                     |
| Alan M. Burk, ALMAX  | Wolfgang Jiu, Flextronics International                                  | Hector A. Valladares, Honeywell<br>Aerospace                                  |
| Antonio Caputo, Massachusetts<br>Institute of Technology                       | Jason Marsh, Nextflex  | Crystal Vanderpan, UL LLC   |
| P. Marc Carter, SAIC   | Daniel McCormick, NSWC Crane   | Steve Vetter, NSWC Crane  |
| Hikmat Chammass, Honeywell Inc.<br>Air Transport Systems                       | Marty Medvetz, Chromaline<br>Corporation                                 | Michael Wagner, Butler<br>Technologies, Inc.                                  |
| John Crumpton, DuPont - RTP  | Roger J. Miedico, Raytheon<br>Company                                    | Diane H. Williams, Corning<br>Incorporated                                    |
| Daniel Gamota, Printovate<br>Technologies, Inc.                                | Dean A. Miner, 3M  | Mobin Yahyazadehfar, DuPont<br>Engineering Polymers                           |
|  | Jeffrey Parker, Insulectro   |   |
|  | Sujatha Ramanujan  |   |
|  | German Rivera, Coast to Coast<br>Circuits, Inc.                          |   |
|  | Cassandra Rocha, Boeing Company  |   |

This Page Intentionally Left Blank

Currently in preview, click buy full version

## Table of Contents

|  |   |  |    |
|--|---|--|----|
| <b>1 SCOPE</b> .....   | 1 | 3.4.4 Storage Conditions .....                       | 9  |
| 1.1 Purpose .....  | 1 | 3.4.5 Chemical Compliance .....                      | 9  |
| 1.2 Classification System .....  | 1 | 3.5 Visual Requirements .....                        | 9  |
| 1.2.1 Designating Materials .....                                      | 1 | 3.5.1 Marking .....                                  | 9  |
| 1.2.2 Adding Details When Designating Materials .....                  | 1 | 3.5.2 Wrinkles, Creases, Streaks and Scratches ..... | 9  |
| 1.3 Surface Treatments .....   | 3 | 3.5.3 Inclusions .....                               | 9  |
| 1.4 Manufacturing Temperature Classification .....                     | 4 | 3.5.4 Voids .....                                    | 10 |
| 1.5 Quality Conformance .....  | 4 | 3.5.5 Holes, Tears and Delaminations .....           | 10 |
| 1.6 Procurement Documentation .....                                    | 4 | 3.6 Dimensional Requirements .....                   | 10 |
| 1.7 Material Characteristics .....                                     | 4 | 3.6.1 Sheet Width and Length .....                   | 10 |
| 1.7.1 As Agreed Upon Between User and Supplier (AABUS) .....           | 4 | 3.6.2 Roll Width .....                               | 10 |
| 1.8 New Materials .....  | 4 | 3.6.3 Roll Length .....                              | 10 |
| 1.9 Interpretation of “Shall” .....                                    | 5 | 3.6.4 Thickness .....                                | 10 |
| 1.10 Presentation of Dimensions and Tolerances .....                   | 5 | 3.7 Mechanical Requirements .....                    | 10 |
| <b>2 APPLICABLE DOCUMENTS</b> .....                                    | 5 | 3.7.1 Bend .....                                     | 10 |
| 2.1 IPC .....  | 5 | 3.7.2 Coefficient of Thermal Expansion (CTE) .....   | 10 |
| 2.2 ASTM International .....   | 5 | 3.7.3 Coefficient of Hygroscopic Expansion (CHE) ..  | 10 |
| 2.3 UL .....   | 7 | 3.7.4 Dimensional Stability .....                    | 10 |
| 2.4 NCSL International .....   | 7 | 3.7.5 Edge Strength .....                            | 10 |
| 2.5 International Organization for Standardization (ISO) .....         | 7 | 3.7.6 Initiation Tear Strength .....                 | 10 |
| 2.6 American Society of Mechanical Engineers (ASME) .....              | 7 | 3.7.7 Propagation Tear Strength .....                | 10 |
| 2.7 Technical Association of the Pulp and Paper Industry (TAPPI) ..... | 7 | 3.7.8 Tensile Strength, Elongation and Modulus ..... | 11 |
| 2.8 British Standards Institution (BSI) .....                          | 7 | 3.7.9 Density .....                                  | 11 |
| 2.9 International Electrotechnical Commission (IEC) .....              | 8 | 3.7.10 Poisson’s Ratio .....                         | 11 |
| 2.10 Japanese Standards Association .....                              | 8 | 3.8 Surface Requirements .....                       | 11 |
| <b>3 GENERAL REQUIREMENTS</b> .....                                    | 8 | 3.8.1 Coefficient of Friction .....                  | 11 |
| 3.1 Terms and Definitions .....  | 8 | 3.8.2 Surface Energy .....                           | 11 |
| 3.1.1 Coefficient of Hygroscopic Expansion (CHE) ....                  | 8 | 3.8.3 Surface Hardness .....                         | 11 |
| 3.1.2 Skew .....   | 8 | 3.8.4 Surface Roughness .....                        | 11 |
| 3.1.3 Poisson’s Ratio .....  | 8 | 3.9 Optical Requirements .....                       | 11 |
| 3.1.4 Surface Gloss .....  | 8 | 3.9.1 Color .....                                    | 11 |
| 3.1.5 Dielectric Constant (Dk) .....                                   | 8 | 3.9.2 Luminous Transmittance and Haze .....          | 11 |
| 3.1.6 Thermal Conductivity .....                                       | 8 | 3.9.3 Refractive Index .....                         | 11 |
| 3.2 Specification Sheets .....   | 8 | 3.9.4 Surface Gloss .....                            | 11 |
| 3.3 Conflict .....   | 8 | 3.10 Chemical Requirements .....                     | 11 |
| 3.4 Material Requirements .....  | 8 | 3.10.1 Chemical Resistance .....                     | 11 |
| 3.4.1 Preferred Side for Printing .....                                | 9 | 3.10.2 Oxygen Gas Transmission .....                 | 11 |
| 3.4.2 Sheet Material .....   | 9 | 3.10.3 Water Vapor Transmission .....                | 11 |
| 3.4.3 Roll Material .....  | 9 | 3.11 Electrical Requirements .....                   | 11 |
|  |   | 3.11.1 Permittivity (Dielectric Constant) .....      | 11 |
|  |   | 3.11.2 Loss Tangent (Dissipation Factor) .....       | 12 |
|  |   | 3.11.3 Volume Resistivity (Damp Heat) .....          | 12 |
|  |   | 3.11.4 Surface Resistance (Damp Heat) .....          | 12 |

|   |    |  |    |
|---|----|--|----|
| 3.11.5 Dielectric Strength .....                    | 12 | 4.8.2 Frequency .....  | 14 |
| 3.12 Environmental Requirements .....               | 12 | 4.9 Quality Conformance Inspection .....                                   | 14 |
| 3.12.1 Fungus Resistance .....                      | 12 | 4.9.1 Inspection of Product for Delivery .....                             | 15 |
| 3.12.2 Moisture Absorption .....                    | 12 | 4.9.2 Sample Unit .....  | 15 |
| 3.12.3 Flammability .....                           | 12 | 4.9.3 Group A Inspection .....   | 15 |
| 3.12.4 Halogens .....                               | 12 | 4.9.4 Group B Inspection .....   | 15 |
| 3.12.5 Relative Thermal Index (RTI) .....           | 12 | 4.10 Statistical Process Control (SPC) .....                               | 16 |
| 3.12.6 Glass Transition ( $T_g$ ) Temperature ..... | 12 | 4.10.1 Reduction of Quality Conformance Testing .....                      | 16 |
| 3.13 Workmanship Requirements .....                 | 12 | <b>5 PREPARATION FOR DELIVERY</b> .....                                    | 16 |
| 3.14 Special Requirements .....                     | 12 | 5.1 Packaging .....  | 16 |
| 3.14.1 Outgassing .....                             | 12 | <b>6 NOTES</b> .....   | 16 |
| 3.14.2 Organic Contamination .....                  | 12 | 6.1 Ordering Data .....  | 16 |
| 3.15 Physical Requirements .....                    | 13 | 6.2 Chemical Resistance .....  | 17 |
| 3.15.1 Thermal Conductivity .....                   | 13 |  |    |
| <b>4 QUALITY ASSURANCE PROVISIONS</b> .....         | 13 |  |    |
| 4.1 Responsibility for Inspection .....             | 13 | <b>Tables</b>  |    |
| 4.2 Test Equipment and Inspection Facilities .....  | 13 | Table 1-1 Base Material Family Designation .....                           | 2  |
| 4.3 Preparation of Samples .....                    | 13 | Table 1-2 Base Material Type Designation .....                             | 2  |
| 4.4 Standard Laboratory Conditions .....            | 13 | Table 1-3 Base Structure Designation .....                                 | 3  |
| 4.5 Tolerances .....                                | 13 | Table 1-4 Base Reinforcement Type Designation .....                        | 3  |
| 4.6 Classification of Inspection .....              | 13 | Table 1-5 Nominal Base Material Thickness Designation .....                | 3  |
| 4.7 Material Inspection .....                       | 13 | Table 4-1 Test Method Frequency .....                                      | 14 |
| 4.8 Qualification Inspection .....                  | 13 | Table 4-2 Sampling Plan for Group A Inspection for<br>Sheet Goods .....    | 15 |
| 4.8.1 Characterization Testing .....                | 13 | Table 4-3 Lot Sampling Plan for Group A Inspection for<br>Roll Goods ..... | 15 |

# 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 Material** 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  $\geq 0.250$  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: