



ASSOCIATION CONNECTING  
ELECTRONICS INDUSTRIES®

---

# IPC-4101A

## Specification for Base Materials for Rigid and Multilayer Printed Boards

### **IPC-4101A**

December 2001

A standard developed by IPC

---

Supersedes IPC-4101  
December 1997

2215 Sanders Road, Northbrook, IL 60062-6135  
Tel. 847.509.9700 Fax 847.509.9798  
[www.ipc.org](http://www.ipc.org)

---

## The Principles of Standardization

In May 1995 the IPC's Technical Activities Executive Committee 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 also 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 (TAEC) that the use and implementation of IPC publications is voluntary and is part of a relationship entered into by customer and supplier. When an IPC standard/guideline 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 standard?

Your purchase of this document contributes to the ongoing development of new and updated industry standards. 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 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 in order to allow as many companies as possible to participate. Therefore, the standards revenue is necessary to complement dues revenue. The price schedule offers a 50% discount to IPC members. If your company buys IPC standards, 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 847/790-5372.

Thank you for your continued support.



ASSOCIATION CONNECTING  
ELECTRONICS INDUSTRIES®

IPC-4101A

# Specification for Base Materials for Rigid and Multilayer Printed Boards

Developed by the Laminate/Prepreg Materials Subcommittee (3-11) of  
the Printed Board Base Materials Committee (3-10) of IPC

***Supersedes:***

IPC-4101 - December 1997  
IPC-L-108  
IPC-L-109  
IPC-L-112  
IPC-L-115  
IPC-AM-361

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

Contact:

IPC  
2215 Sanders Road  
Northbrook, Illinois  
60062-6135  
Tel 847 509.9700  
Fax 847 509.9798

This Page Intentionally Left Blank

## Acknowledgment

Any Standard involving a complex technology draws material from a vast number of sources. While the principal members of the Laminate/Prepreg Materials Subcommittee (3-11) of the Printed Board Base Material Committee (3-10) 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 the IPC extend their gratitude.

<b>Printed Board Base Material Committee</b>	<b>Laminate/Prepreg Materials Subcommittee</b>	<b>Technical Liaison of the IPC Board of Directors</b>
Chair Erik Bergum Polyclad Laminates, Incorporated	Chair Douglas Sober Essex Technologies Group Incorporated	Dr. William Beckenbaugh Sanmina
<b>Laminate/Prepreg Materials Subcommittee</b>		
Wolfgang Alberth, Isola	Walter Christiansen, Resolution Performance Products	Mahendra Gandhi, Space Systems/ Loral
Bernard Alzua, Bernard Alzua & Associates	John Christmas, U.S. Air Force	Rick Gargus, Neltec, Incorporated
JoAnne Andrews, Sanmina Corporation	Jennifer Chung, Resolution Performance Products	Joseph Gibson, Sanmina Corporation
Masamitsu Aoki, Toshiba Chemical Company	Christine Coapman, Delphi Automation	Richard Grannells, United Technologies
Bruce Ballert, Borden Chemical	Eric Collis, PPG Industries	Lisa Greenleaf, Teradyne Connection Systems
Richard Barnett, Compaq Computer	David Coppens, Isola Laminate Systems Corporation	Jason Gretton, Matsushita/Aromat
Keith Bendyk, JPS Glass	Michael Davis, GE Electromaterials	Chester Guiles, Arlon MED
Gerald Bouska, Isola Laminate Systems Corporation	John DeBrita, Sanmina Corporation	William Hall, Oak-Mitsui
James Brady, Isola Laminate Systems Corporation	Nitin Desai, Motorola, Incorporated	Robert Hearn, Dow Chemical USA
Jack Bramel, Jack Bramel & Associates	William Dieffenbacher, BAE Systems Controls	Adam Hen, Celestica International
Thomas Bresnan, Sanmina Corporation	Paul DuFresne, Yates Foil USA Incorporated	Rocky Hilburn, Gould Electronics Incorporated
Carl Brooks, Northrup Grumman Corporation	Robert Dunnagan, BGF Industries	Philip Hinton, Hinton PWB Engineering
Judy Brown, Winonics, Incorporated	Theodore Edwards, Honeywell Incorporated	David Ho, Unique Interconnect Incorporated
Michael Bryant, BGF Industries	Douglas Eng, PPG Industries	David Iguchi, Park/Nelco
Victor Brzozowski, Northrup Grumman Corporation	Werner Engelmaier, Engelmaier Associates, LC	Steven Ising, Borden Chemical
Thomas Burke, Polyonics Corporation	Steven Ethridge, Sanmina Corporation	John Jephson, Circuit Foil Trading
John Callahan, Gould Electronics Incorporated	Thomas Farrell, Underwriters Laboratories Incorporated	Lawrence Johnson, LGJ Technologies
H. Landis Carter, JPS Glass	Peter Fiedler, BFGoodrich	Albert Jones, University of Alabama
Gerard Cave, Pacific Testing Laboratories	Terry Fischer, Hitachi Chemical Company America	Yvonne Julian-Hargrove, Dow Chemical USA
Clifton Cavin, Motorola SSTG	Kent Fujiwara, Sumitomo Plastics America	Richard Kajander, Johns Manville
Philip Chen, Intel Corporation	Lionel Fullwood, WKK Distribution Limited	Joan Karner, Holaday Circuits
		Hideo Kato, Nitto Boseki Co., Limited
		Stephen Keller, Trace Labs-East
		Thomas Kemp, Rockwell Collins

---

Patricia Klein, Tyco Printed Circuit Group	Scott Opperhauser, Trace Labs-East	Scott Sharot, AIL Systems Incorporated
Robert Konsowitz, GIL Technologies	Daniel Osenbaugh, Multiline Technologies	William Shaw, FiberMark, Incorporated
John Kozuch, 4DI Inc.	Raul Pabon, Resolution Performance Products	Lowell Sherman, Defense Supply Center Columbus
Raymond Lavallee, Borden Chemical	Deepak Pai, General Dynamics Information Systems	Michael Shin, Pacific Testing Laboratories
James Legein, Raytheon Company	John Penc, Taconic Advanced Dielectric Division	Hans Shin, Pacific Testing Laboratories
Katie Lehnert, Dow Chemical USA	John Pfinney, Matsushita/Aromat	Edward Skorupski, Oak-Mitsui
Joseph Leibowitz,	Morris Pfinney, Pfinney Associates	Andrew Slade, Sanmina Corporation
Edward Lewis, Isola Laminate Systems Corporation	Thierry Philbert, Hexcel Fabrics S.A.	Joseph Slanina, Honeywell Incorporated
David Lowery, Summit Products & Services	Miguel Rincon, Electroply, Incorporated	Clark Smedstad, BGF Industries
P. Douglas Lyle, Advanced Glassfiber Yarns	Paul Rose, Lockheed Martin Electronics & Missles	George Stoddart, Canadian Standard Association
Alfred Macha, Sanmina Corporation	Craig Ruggeri, Yates Foil USA Incorporated	Kurt Summa, Young Electronics
Thomas Martin, Owens-Corning Fiberglass Corporation	Visa Ruuhonen, Nokia Networks	Valetin Tereshkin, Elma Limited
Renee Martinez, TRW Electronics & Technology Division	David Salerno, Advanced Interconnection Technology	Roger Tietze, Vantico Incorporated
Brian McCrory, Delsen Testing Labs	Jerome Sallo, Sallo Consulting Services	Christopher Totten, Gividi USA Incorporated
David McGowan, DRM Consulting	Joseph Salvini, Underwriters Laboratories Incorporated	James Tracy, GE Electromaterials
David McGregor, E. I. Du Pont de Nemours and Company	Rolland Savage, Gould Electronics Incorporated	Kenneth Trude, Sanmina Corporation
Darryl McKenney, Parlex Corporation	Fabio Scari, Gividi Italia S.p.A.	James (Tom) Turner, Isola Laminate Systems Corporation
Bill Mercer, Dow Chemical USA	Marco Scari, Gividi USA Incorporated	Antti Vaisanen, Nokia Networks
Nicholas Mescia, Ciena Corporation	Fredrich Schlitter, Ruwel-Werke GmbH	Crystal Vanderpan, Underwriters Laboratories Incorporated
Renee Michalkiewicz, Trace Labs-East	Steven Sekanina, Neltec, Incorporated	David Wagner, Flex-Link Products
Keita Miyasota, Nitto Boseki Co., Limited	Kenneth Selk, TRW Electronics & Technology Division	Daniel Welch, Arlon MED
Cameron Murray, 3M Company	Suzanne Seymour, Taconic Advanced Dielectric Division	Dewey Whittaker, Honeywell Incorporated
Joel Murray, Hexcel Schwebel		Xie Xiaoyan, Guangdong Shegyi Sci. Tech Co., Limited
Michael Musich, Underwriters Laboratories Incorporated		Roman Zotman, Gould Electronics Incorporated
Robert Neves, Microtek Laboratories		
Thomas Nowak, Nowak & Associates		
Gerard O'Brien, Photocircuits Corporation		

# Table of Contents

<b>1 SCOPE</b> .....	1	3.4.1	Qualification Testing of Laminate .....	7
1.1 Classification .....	1	3.4.2	Qualification Testing of Prepreg .....	7
1.1.1 Specification Sheet Description .....	1	3.5	Verification of Manufacturer's Quality System .....	9
1.1.2 Nominal Laminate Thickness .....	1	3.6	Conflict .....	9
1.1.3 Metal Cladding Type and Nominal Weight/Thickness .....	1	3.7	Materials .....	9
1.1.3.1 Metal Cladding Type.....	1	3.7.1	Metal Cladding.....	9
1.1.3.2 Nominal Weight/Thickness .....	1	3.7.2	Reinforcement Fabric.....	9
1.1.4 Thickness Tolerance (Laminate).....	1	3.7.3	Resin Systems .....	9
1.1.5 Surface Quality Class.....	2	3.8	General Requirements.....	9
1.1.6 Reinforcement Style.....	2	3.8.1	Fabricated Sheets and Panels .....	9
1.1.7 Prepreg Parameters.....	2	3.8.1.1	Fabricated Laminate Sheet Material.....	9
1.1.8 Color .....	2	3.8.1.2	Fabricated Laminate Panel Material.....	9
1.1.8.1 Contrast Agents .....	2	3.8.1.3	Fabricated Prepreg Panels.....	9
1.2 Dimensions and Tolerances .....	3	3.8.1.4	Fabricated Prepreg Rolls.....	9
1.2.1 Metric and Imperial Measurements.....	3	3.8.2	Inspection Lot .....	9
<b>2 APPLICABLE DOCUMENTS</b> .....	3	3.8.2.1	Inspection Lot for Laminate .....	9
2.1 IPC .....	3	3.8.2.2	Inspection Lot for Prepreg.....	9
2.2 National Conference of Standards Laboratories (NCSL) .....	4	3.8.2.3	Preparation of Samples .....	9
2.3 International Standards .....	4	3.8.2.4	Etching Process and Etchant Removal for Copper Foil Specimens.....	10
2.4 Underwriters Laboratories (UL) .....	4	3.8.2.5	Standard Laboratory Conditions .....	10
<b>3 REQUIREMENTS</b> .....	4	3.8.3	Visual Properties .....	10
3.1 Terms and Definitions .....	4	3.8.3.1	Laminate Visual Properties .....	10
3.1.1 Qualification Assessment .....	4	3.8.3.1.1	Foil Indentations.....	10
3.1.2 Quality Conformance Testing .....	5	3.8.3.1.2	Wrinkles.....	10
3.1.3 Manufacturer's Quality System .....	5	3.8.3.1.3	Scratches.....	10
3.1.4 Process Control Testing .....	5	3.8.3.1.4	Plastic Surface Finish of Metal-Clad Single-Sided Base Material.....	10
3.1.5 Self Declaration.....	5	3.8.3.1.5	Surface Finish of Foil after Curing – Except Double Treat .....	10
3.1.6 Quality Assessment Data .....	5	3.8.3.1.6	Surface and Subsurface Imperfections .....	10
3.1.7 Sample Qualification.....	5	3.8.3.2	Prepreg Visual Properties .....	11
3.1.8 Production Data.....	5	3.8.3.2.1	Inclusions.....	11
3.1.9 Customer Test Data.....	5	3.8.3.2.2	Impregnation Imperfections .....	11
3.1.10 Internal Assessment.....	5	3.8.4	Dimensional.....	11
3.1.11 Individual Customer Audit.....	5	3.8.4.1	Length and Width.....	11
3.1.12 Independent Third Party Assessment .....	5	3.8.4.1.1	Length and Width of Laminate.....	11
3.1.13 Epoxy, Multifunctional.....	5	3.8.4.1.2	Length and Width of Prepreg .....	11
3.1.14 Epoxy, Difunctional .....	5	3.8.4.1.3	Prepreg Roll Width.....	11
3.1.15 AABUS.....	7	3.8.4.1.4	Prepreg Roll Length.....	11
3.1.16 Filler.....	7	3.8.4.2	Thickness .....	11
3.2 Specification Sheets.....	7	3.8.4.2.1	Class A, B, and C Laminate Materials.....	11
3.3 Manufacturer Quality Profile .....	7	3.8.4.2.2	Class D Laminate Materials.....	11
3.4 Qualification Testing .....	7			





# Specification for Base Materials for Rigid and Multilayer Printed Boards

## 1 SCOPE

This specification covers the requirements for base materials, herein referred to as laminate or prepreg, to be used primarily for rigid or multilayer printed boards for electrical and electronic circuits.

**1.1 Classification** The system shown below identifies clad and unclad laminate or prepreg base materials. The specification sheets serve as a cross-reference connecting the outlined callout system in this document to previously used systems.

Example for laminate base materials where this specification is referenced:

L	Material Designator (see 1.1.1)
25	Specification Sheet Number (see 1.1.1)
1500	Nominal Laminate Thickness (see 1.1.2)
C1/C1	Metal Cladding Type and Nominal Weight/Thickness (see 1.1.3)
A	Thickness Tolerance Class (see 1.1.4)
A	Surface Quality Class (see 1.1.5)

Example for prepreg base materials where this specification is referenced:

P	Material Designator (see 1.1.1)
25	Specification Sheet Number (see 1.1.1)
E7628	Reinforcement Style (see 1.1.6)
TW	Resin Content Method (see 1.1.7)
RE	Flow Parameter Method (see 1.1.7)
VC	Optional Prepreg Method (see 1.1.7)

**1.1.1 Specification Sheet Description** At the end of this document is a series of specification sheets. Each specification sheet outlines requirements for both laminate and prepreg for each product grade. The specification sheets are organized by a specific reinforcement type, resin system, and/or construction and are provided with a specification sheet number for ordering purposes. For convenience, the laminate and prepreg requirements for materials of the like composition are on the same specification sheet. Material Designator “L” indicates laminate material and Material Designator “P” indicates prepreg material as shown in designation examples in 1.1. When certifying to multiple specification sheets, the strongest performance requirements **shall** apply.

The headings for each specification sheet include reference definitions for the material, which cover the reinforcements, resin systems, flame retardants, and fillers used, as well as its other known identifications and glass transition temperature,  $T_g$ . The specific line items within the specification sheets are the requirements that material **shall** meet in order to be certified to this specification.

**1.1.2 Nominal Laminate Thickness** The nominal thickness is identified by four digits. For all substrates covered by this document, thicknesses may be specified or measured either over the cladding or over the dielectric (see 1.1.4 and 3.8.4.2). For metric specification, the first digit represents whole millimeters, the second represents tenths of millimeters, etc. For orders requiring Imperial units, the four digits indicate the thickness in ten-thousandths of an inch (tenths of mils). In the example shown in 1.1, 1500 is designated for the Imperial unit usage of 0600 for a laminate with thickness of 1.5 mm [59.1 mil].

**1.1.3 Metal Cladding Type and Nominal Weight/Thickness** The type and nominal weight or thickness of the metallic cladding for laminate base material is identified by five designators. The first and fourth designators indicate the type of cladding; the third designator is a slash mark that differentiates sides of the base material; the second and fifth designators indicate the nominal weight or thickness of the metallic cladding.

**1.1.3.1 Metal Cladding Type** The types of metallic cladding and the designators representing them are shown in Table 1-1. Table 1-1 is provided as a reference only. The referee document is the latest version of IPC-CF-148, IPC-4562, or IPC-CF-152 as appropriate. Cladding types C and R, and cladding types H and S, may be used interchangeably as agreed upon between user and supplier. Cladding type H can be used for type C and type S can be used for type R. Cladding type R may be substituted for type C, and cladding type S may be substituted for type H.

**1.1.3.2 Nominal Weight/Thickness** The weight or thickness of metallic cladding and the designators representing them are listed in Table 1-2. Table 1-2 is provided as a reference only. The referee document is the latest version of IPC-CF-148, IPC-4562, or IPC-CF-152 as appropriate.

**1.1.4 Thickness Tolerance (Laminate)** The class of thickness tolerance for laminate base material is identified by either A, B, C, D, K, L, M, or X (as agreed upon

**Table 1-1 Metal Cladding Types**

A	Copper, wrought, rolled (IPC-4562, grade 5)
B	Copper, rolled (treated)
C	Copper, electrodeposited (IPC-4562, grade 1)
D	Copper, electrodeposited, double treat (IPC-4562, grade 1)
G	Copper, electrodeposited, high ductility (IPC-4562, grade 2)
H	Copper, electrodeposited, high temperature elongation (IPC-4562, grade 3)
J	Copper, electrodeposited, annealed (IPC-4562, grade 4)
K	Copper, wrought, light cold rolled (IPC-4562, grade 6)
L	Copper, wrought, annealed (IPC-4562, grade 7)
M	Copper, wrought, rolled, low temperature annealable (IPC-4562, grade 8)
N	Nickel
O	Unclad
P	Copper, electrodeposited, high temperature elongation, double treat (IPC-4562, grade 3)
R	Copper, reverse treated electrodeposited (IPC-4562, grade 1)
S	Copper, reverse treated electrodeposited, high temperature elongation (IPC-4562, grade 3)
T	Copper, copper foil parameters as dictated by contract or purchase order
U	Aluminum
V	Copper, reverse treated electrodeposited, high temperature elongation (IPC-4562, grade 3) for buried capacitance applications
X	As agreed between user and supplier (AABUS)
Y	Copper Invar Copper
Z	Copper, electrodeposited, high temperature elongation, double-treat (IPC-4562, grade 3) for buried capacitance applications

between user and supplier) as described in 3.8.4.2. Material certified to tighter tolerances can be used to meet lower tolerance requirements without recertification (i.e., Class C material can be used for Class B).

**1.1.5 Surface Quality Class** The class of surface quality is identified by either A, B, C, D, or X (as agreed upon between user and supplier) as described in 3.8.3. Material certified to a higher surface quality can be used to meet lower surface quality requirements without recertification (i.e., Class B material can be used for Class A).

**1.1.6 Reinforcement Style** The reinforcement type and style of the prepreg is indicated by five digits, based on the chemical type and style. Typical examples of reinforcement designators are shown below:

- a) E7628 represents E-glass reinforcement style 7628 per IPC-4412.
- b) S0313 represents S-glass reinforcement style 313 per IPC-SG-141.

- c) A3080 represents aramid reinforcement style 3080 per IPC-A-142.
- d) Q0525 represents quartz reinforcement style 525 per IPC-QF-143.

Reinforcement properties such as thickness, construction, and weight are established in accordance with the reinforcement style designations of the appropriate material specification.

**1.1.7 Prepreg Parameters** A variety of test procedures can be used to specify and determine fitness for use of prepreg in multilayer printed board applications. The amount of resin and how much that resin will flow under specified conditions are the two critical performance characteristics. The specification for prepreg **shall** consist of one test from Group A and one test from Group B, as shown below with the corresponding designators. The use of a test from Group C is optional. If no test is chosen from Group C, zero-zero (00) **shall** be the designator. The choice of the tests **shall** be as agreed upon between user and supplier and supplied as part of the ordering information. The nominal value and tolerances for the individual tests **shall** be as specified on the purchase order or by other agreement between user and supplier. Additional test(s) can be specified by agreement between user and supplier but the additional test(s) will not be part of the designator.

#### **Group A**

##### Resin Content Tests

- RC – Resin Content Percent
- TW – Treated Weight Total
- 00 – None Specified

#### **Group B**

##### Flow Parameter Tests

- MF – Resin Flow Percent
- SC – Scaled Flow Thickness
- NF – No Flow
- RE – Rheological Flow
- DH – Delta H
- PC – Percent Cure
- 00 – None Specified

#### **Group C**

##### Optional Prepreg Tests

- VC – Volatile Content
- DY – Dicy Inspection
- GT – Gel Time
- 00 – None Specified

**1.1.8 Color** Unless otherwise specified, all laminate and prepreg are supplied in the natural (undyed/unpigmented) color. If the user requires another color, it **shall** be specified on the purchase order.

**1.1.8.1 Contrast Agents** Contrast agents, which may be added to a natural color resin system to enhance processing, such as tinting agents for contrast in automatic optical

Table 1-2 Copper Foil Weight and Thickness

Foil Designation	Common Industry Terminology	Metric		English		
		Area Weight (g/m <sup>2</sup> )	Nominal Thickness (µm)	Area Weight (oz./ft. <sup>2</sup> )	Area Weight (g/254 in <sup>2</sup> )	Nominal Thickness (mils)
E	5 µm	45.1	5.1	0.148	7.4	0.20
Q	9 µm	75.9	8.5	0.249	12.5	0.34
T	12 µm	106.8	12.0	0.350	17.5	0.47
H	1/2 oz	152.5	17.1	0.500	25.0	0.68
M	3/4 oz	228.8	25.7	0.750	37.5	1.01
1	1 oz	305.0	34.3	1	50.0	1.35
2	2 oz	610.0	68.6	2	100.0	2.70
3	3 oz	915.0	102.9	3	150.0	4.05
4	4 oz	1220.0	137.2	4	200.0	5.40
5	5 oz	1525.0	171.5	5	250.0	6.75
6	6 oz	1830.0	205.7	6	300.0	8.10
7	7 oz	2135.0	240.0	7	350.0	9.45
10	10 oz	3050.0	342.9	10	500.0	13.50
14	14 oz	4270.0	480.1	14	700.0	18.90

For nominal weights not listed in this table the nominal thickness is calculated as follows:

Thickness (mils) = 1.35 x Area Wt. (oz/ft<sup>2</sup>)

Where 1.35 is a factor determined from the density of copper foil assumed to be 8.93 g/cm<sup>3</sup> [5.16 oz/in<sup>3</sup>].

This factor is within 1% for all densities from 8.81 g/cm<sup>3</sup> to 8.99 g/cm<sup>3</sup>.

For any alloy or other metals outside this density range the appropriate factor must be used to calculate the foil thickness.

**Caution:** Nominal thickness values in the table are not representative of mechanical thickness of the foil. An allowance for the roughness of the treated side must be added to all values.

inspection (AOI), **shall** not adversely affect the performance, properties, or functionality of the laminate or prepreg and **shall** be considered as the natural color.

**1.2 Dimensions and Tolerances** All dimensions and tolerances specified herein are applicable to only the end product. Dimensions are expressed in millimeters. Reference information is shown in parentheses.

**1.2.1 Metric and Imperial Measurements** IPC policy is that documents be published in hard metric units with soft imperial units in brackets.

## 2 APPLICABLE DOCUMENTS

The following documents of the issue in effect at the time of the order form a part of this specification to the extent specified herein.

### 2.1 IPC<sup>1</sup>

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

**IPC-SG-141** Specification for Finished Fabric Woven from "S" Glass for Printed Boards

**IPC-A-142** Specification for Finished Fabric Woven from Aramid for Printed Boards

**IPC-QF-143** Specification for Finished Fabric Woven from Quartz (Pure Fused Silica) for Printed Boards

**IPC-CF-148** Resin Coated Metal Foil for Printed Boards

**IPC-CF-152** Composite Metallic Material Specification for Printed Wiring Boards

**IPC-TM-650** Test Methods<sup>2</sup>

2.1.5 Surface Examination, Unclad and Metal-Clad Material

2.1.9 Surface Scratch Examination Metal-Clad Foil

2.1.10 Visual Inspection for Undissolved Dicyandiamide

2.2.19.1 Length, Width and Perpendicularity of Laminate and Prepreg Panels

2.3.1.1 Chemical Cleaning of Metal-Clad Laminate

2.3.4.2 Chemical Resistance of Laminates, Prepreg and Coated Foil Products, by Solvent Exposure

2.3.6 Etching, Ammonium Persulfate Method

2.3.7 Etching, Ferric Chloride Method

2.3.7.1 Cupric Chloride Etching Method

2.3.10 Flammability of Laminate

2.3.16 Resin Content of Prepreg, by Burn-Off

2.3.16.1 Resin Content of Prepreg, by Treated Weight

1. IPC, 2215 Sanders Road, Northbrook, IL 60062

2. Current and revised IPC Test Methods are available through IPC-TM-650 subscription and on the IPC Web site ([www.ipc.org/html/testmethods.htm](http://www.ipc.org/html/testmethods.htm)).

- 2.3.16.2 Treated Weight of Prepreg
- 2.3.17 Resin Flow Percent of Prepreg
- 2.3.17.2 Resin Flow of “No Flow” Prepreg
- 2.3.18 Gel Time, Prepreg Materials
- 2.3.19 Volatile Content of Prepreg
- 2.4.4 Flexural Strength of Laminates (at Ambient Temperature)
- 2.4.4.1 Flexural Strength of Laminates (at Elevated Temperature)
- 2.4.8 Peel Strength of Metallic Clad Laminates
- 2.4.8.2 Peel Strength of Metallic Clad Laminates at Elevated Temperature (Hot Fluid Method)
- 2.4.8.3 Peel Strength of Metallic Clad Laminate at Elevated Temperature (Hot Air Method)
- 2.4.13.1 Thermal Stress of Laminates
- 2.4.22.1 Bow and Twist, Laminate
- 2.4.24 Glass Transition Temperature and Z-Axis Thermal Expansion by TMA
- 2.4.25 Glass Transition Temperature and Cure Factor by DSC<sup>3</sup>
- 2.4.38 Prepreg Scaled Flow Testing
- 2.4.39 Dimensional Stability, Glass Reinforced Thin Laminates
- 2.4.41 Coefficient of Linear Thermal Expansion of Electrical Insulating Materials
- 2.4.41.1 Coefficient of Thermal Expansion by the Vitreous Silica (Quartz) Dilatometer Method
- 2.5.1 Arc Resistance of Printed Wiring Material
- 2.5.5.2 Dielectric Constant and Dissipation Factor of Printed Wiring Board Material - Clip Method
- 2.5.5.3 Permittivity (Dielectric Constant) and Loss Tangent (Dissipation Factor) of Materials (Two Fluid Cell Method)
- 2.5.5.9 Permittivity and Loss Tangent, Parallel Plate, 1 MHz to 1.5GHz
- 2.5.6 Dielectric Breakdown of Rigid Printed Wiring Material
- 2.5.6.2 Electric Strength of Printed Wiring Material
- 2.5.17.1 Volume and Surface Resistivity of Dielectric Materials
- 2.6.1 Fungus Resistance, Printed Wiring Materials
- 2.6.2.1 Water Absorption, Metal Clad Plastic Laminates
- 2.6.16 Pressure Vessel Method for Glass Epoxy Laminate Integrity

**IPC-QL-653** Qualification of Facilities that Inspect/Test Printed Boards, Components, and Materials

**IPC-1730** Laminator Qualification Profile

**IPC-4110** Specification and Characterization Methods for Nonwoven Cellulose Based Paper for Printed Boards

**IPC-4121** Guidelines for Selecting Core Constructions for Multilayer Printed Wiring Board Applications

**IPC-4130** Specification and Characterization Methods for Nonwoven “E” Glass Mat

**IPC-4411** Specification and Characterization Methods for Nonwoven Para-Aramid Reinforcement

**IPC-4412** Specification for Finished Fabric Woven from “E” Glass for Printed Boards

**IPC-4562** Metal Foil for Printed Wiring Applications

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

**J-STD-003** Solderability Test for Printed Boards

## 2.2 National Conference of Standards Laboratories (NCSL)<sup>4</sup>

**ANSI/NCSL Z540-1-1994** General Requirements for Calibration Laboratories and Measuring and Test Equipment

## 2.3 International Standards<sup>5</sup>

**ISO 10012-1** Quality Assurance Requirements for Measuring Equipment, Part 1 - Metrological Confirmation System for Measuring Equipment

## 2.4 Underwriters Laboratories (UL)<sup>6</sup>

**UL 94** Flammability

## 3 REQUIREMENTS

**3.1 Terms and Definitions** The definition of terms **shall** be in accordance with IPC-T-50 and as stated in 3.1.1 through 3.1.15.

**3.1.1 Qualification Assessment** Qualification assessment is a form of risk reduction between a buyer and a source for laminates and prepregs. The laminator **shall** produce an assessment of capabilities and sources of verification for the buyer to evaluate. The buyer must then review this assessment and determine whether the information and

3. Test Method 2.4.25 also describes the delta glass transition temperature test (Delta T<sub>g</sub>)

4. NCSL, 1800 - 30th Street, Suite 305B, Boulder, Colorado 80301-1032, 303-440-3339, www.ncsl-hq.org

5. ANSI, 11 West 42nd St., New York, NY 10036, 212-642-4900, www.ansi.org

6. Underwriters Laboratories, Inc., 1285 Wait Whitman Road, Melville, Long Island, NY 11746

verification provided constitute an acceptable level of risk. The more verification of self-declaration parameters provided, the lower the risk factor associated with utilizing a new laminator. There is no minimum level of qualification assessment verification required by this specification, and it is between the buyer and laminator to determine the extent of verification applicable to their requirements. If the risk assessment is determined to be unacceptably high, the risk may be reduced by increasing the verification requirements. The cost associated with reducing this risk varies with the type of verification determined to be necessary.

**3.1.2 Quality Conformance Testing** Quality conformance testing is performed on a regular basis following qualification testing as determined by the manufacturer's quality system. This is done to demonstrate the supplier is continually meeting the finished product requirements of this specification and the applicable specification sheet for each base material. In the absence of a documented manufacturer's quality system, the conformance testing **shall** be conducted in accordance with the frequency as specified in Table 3-1 for laminates and Table 3-2 for prepregs.

**3.1.3 Manufacturer's Quality System** The manufacturer's quality system is an organized entity within the laminator's operation that administers the documentation system, steering committee, lines of responsibilities, etc., as described in IPC-9191.

Any equipment for inspection or testing in accordance with this document **shall** meet ANSI/NCSL Z540-1-1994 or ISO 10012-1.

**3.1.4 Process Control Testing** Process control testing is performed for the purpose of nominalizing the critical steps of the manufacturers' internal process.

**3.1.5 Self Declaration** The first level of qualification assessment is self declaration. A completed IPC-1730 contains a profile of a manufacturer's site capability, processing and test equipment, technology specifics, quality program, manufacturing history, company information, and data verification sources. Self declaration is the laminator's view of its products and process capabilities to meet the customer's requirements, the requirements of this specification, and the applicable associated specification sheet(s) (see 3.3).

**3.1.6 Quality Assessment Data** The data contained in the self assessment is compiled and analyzed for performance characteristics of laminates or prepregs. The performance data may be based on information from a variety of both internal and external sources.

**3.1.7 Sample Qualification** Verification by sample qualification signifies a manufacturer is capable of producing a product with a given set of parameters at the time when the qualification sample is manufactured. Sample qualification testing of laminate and prepreg performance characteristics **shall** be performed at a facility that demonstrates compliance with IPC-QL-653.

**3.1.8 Production Data** Production data is normal performance data from manufacturing runs generated as a quality assurance function. This data can be compiled, analyzed, and reported as support for product compliance to this specification by the laminator.

**3.1.9 Customer Test Data** Customer test data is normal performance data generated at incoming inspection by the customer. This data can be compiled, analyzed, and reported as support for product compliance to this specification by the laminator.

**3.1.10 Internal Assessment** Internal assessments consist of periodic supplier verification of data contained in the quality profile section of the self declaration.

**3.1.11 Individual Customer Audit** The individual customer audit is an evaluation of the laminator's facility to compare the current management quality system against the self declaration and the requirements of this specification. The analysis, summary, and necessary corrective actions may become part of the laminator's self declaration at the discretion of the customer.

**3.1.12 Independent Third Party Assessment** Assessments are performed by a third party assessor, which is generally procedural in nature. Examples of third party assessors are International Organization for Standardization (ISO) Registrars, Malcom Baldrige (BNQP), Underwriters' Laboratories (UL), Canadian Standards Agency (CSA), International Electrotechnical Commission Quality Assessment (IECQ), etc.

**3.1.13 Epoxy, Multifunctional** Any epoxy polymer, monomer, or oligomer with three or more potentially reactive epoxy functional groups.

**3.1.14 Epoxy, Difunctional** Any epoxy polymer, monomer, or oligomer with two potentially reactive epoxy functional groups.



Table 3-1 Reference Information and Test Frequency of Laminate

Tests	Requirement Paragraph	Test <sup>1</sup> Method	Qualification Testing	Conformance Testing	Conformance Testing Frequency	Specimens per Sheet Sampled
<b>General</b>						
Visual Properties	3.8.3.1	2.1.5	✓	✓	Audit <sup>2</sup>	-
Surface Finishes	3.8.3.1.1 - 3.8.3.1.5	2.1.5 2.1.9	✓		Audit <sup>2</sup>	
Surface/Sub-Surface Imperfections	3.8.3.1.6		✓	✓	Lot	3
<b>Dimensional</b>						
Length/Width	3.8.4.1	2.2.19.1	✓	✓	Audit <sup>9</sup>	-
Squareness	3.8.4.1.1	2.2.19.1	✓	✓	Audit <sup>9</sup>	-
Thickness	3.8.4.2	2.2.18 2.2.18.1	✓	✓	Audit <sup>9</sup>	-
Bow/Twist	3.8.4.3	2.4.22.1	✓	✓	Lot	1
<b>Physical</b>						
Peel Strength After Thermal Stress	3.9.1.1.1	2.4.8	✓	✓	Lot	4 <sup>5</sup>
Peel Strength at Elevated Temperature <sup>4</sup>	3.9.1.1.2	2.4.8 2.4.8.2 2.4.8.3	✓	✓	3 Months	4 <sup>5</sup>
Peel Strength After Exposure to <sup>3,4</sup> Process Solutions	3.9.1.1.3	2.4.8	✓	✓	3 Months	4 <sup>5</sup>
Dimensional Stability <sup>11</sup>	3.9.1.2	2.4.39	✓	✓	1 Month	3
Flexural Strength <sup>13</sup>	3.9.1.3	2.4.4	✓	✓	12 Months	6 <sup>7</sup>
Flexural Strength at Elevated Temperatures <sup>4</sup>	3.9.1.4	2.4.4.1	✓	✓	3 Months	3 <sup>8</sup>
<b>Chemical</b>						
Flammability <sup>10,12</sup>	3.10.1.1	UL94	✓	✓	1 Month	5
Thermal Stress Etched	3.10.1.2	2.4.13.1	✓	✓	Lot	2
Thermal Stress Unetched	3.10.1.2	2.4.13.1	✓	✓	Lot	2
Solderability	3.10.1.3	J-STD-003 Edge Dip	✓	✓	3 Months	3
Chemical Resistance <sup>3</sup>	3.10.1.4	2.3.4.2	✓	✓	Lot	1
Metal Surface Cleanability <sup>3</sup>	3.10.1.5	2.3.1.1	✓	✓	Lot	1
T <sub>g</sub> <sup>3</sup>	3.10.1.6	2.4.24 2.4.25	✓	✓	Lot	1
Delta T <sub>g</sub> <sup>3</sup>	3.10.1.7	2.4.25	✓		Lot	1
X/Y CTE <sup>3</sup>	3.10.1.8	2.4.41 2.4.41.1	✓		Lot	1
<b>Electrical</b>						
Permittivity <sup>4</sup> (1 MHz)	3.11.1.1	2.5.5.2 2.5.5.3 2.5.5.9	✓	✓	1 Month	3
Loss Tangent <sup>4</sup>	3.11.1.2	2.5.5.2 2.5.5.3 2.5.5.9	✓	✓	1 Month	3
Volume Resistivity	3.11.1.3	2.5.17.1	✓	✓	12 Months	6
Surface Resistivity	3.11.1.4	2.5.17.1	✓	✓	12 Months	6
Arc Resistance	3.11.1.5	2.5.1	✓	✓	12 Months	3
Dielectric Breakdown	3.11.1.6	2.5.6	✓	✓	3 Months	3 <sup>6</sup>
Electric Strength	3.11.1.7	2.5.6.2	✓	✓	3 Months	3

**Table 3-1 Reference Information and Test Frequency of Laminate (continued)**

Tests	Requirement Paragraph	Test <sup>1</sup> Method	Qualification Testing	Conformance Testing	Conformance Testing Frequency	Specimens per Sheet Sampled
<b>Environmental</b>						
Moisture Absorption	3.12.1.1	2.6.2.1	✓	✓	3 Months	4
Fungus Resistance	3.12.1.2	2.6.1	✓			1
Pressure Vessel <sup>3,4</sup>	3.12.1.3	2.6.16	✓		Lot	3
Total Halogen Content <sup>4</sup>	3.10.1.9	TBD	✓			
CAF Growth Resistance <sup>4</sup>	3.12.1.4	TBD	✓			

<sup>1</sup> All methods are from IPC-TM-650 unless otherwise noted.

<sup>2</sup> The following are audit requirements for visual properties.

Lot Size	Sample Size	Acceptance Number
2 to 50	5	0
51 to 90	7	0
91 to 150	11	0
151 to 280	13	0
281 to 500	16	0
501 to 1,200	19	0
1,201 to 3,200	23	0
3,201 to 10,000	29	0

<sup>3</sup> Optional tests as agreed upon between user and supplier.

<sup>4</sup> Applicable to specific material only.

<sup>5</sup> One lengthwise and one crosswise specimen for each side; four total for double sided.

<sup>6</sup> One additional sample will be prepared for initial voltage reading for step-by-step testing.

<sup>7</sup> Three lengthwise and three crosswise specimen.

<sup>8</sup> All lengthwise specimens.

<sup>9</sup> The supplier **shall** use a statistical sampling plan to assure conformance to dimensional requirements.

<sup>10</sup> Flammability qualification testing is to be conducted on cured 0.80 mm [0.0315 in] and 1.60 mm [0.0630 in] samples, which automatically qualifies prepreg and thin laminate. Flammability conformance testing is to be conducted on cured samples >0.5 mm [0.020 in].

<sup>11</sup> Nominal value to be agreed upon between user and supplier.

<sup>12</sup> The UL94 test for flammability is to be used with the optional conditioning of 24 hours at 125°C allowed.

<sup>13</sup> Note that a minimum laminate thickness requirement of 0.79 mm [0.0311 in] exists in Method 2.4.4 to correctly measure the flexural strength. This thickness requirement takes precedence over the ≥0.50 mm callout in all specifications sheets for the flexural strength measurements.

**3.1.15 AABUS** Acronym defines “as agreed upon between user and supplier.”

**3.1.16 Filler** A substance that is added to a material to improve its solidary, bulk or other properties.

**3.2 Specification Sheets** The individual item requirements **shall** be as specified herein and in accordance with the applicable specification sheets. Where there is no specification sheet available, the individual requirements **shall** be as specified in complementary documents such as master drawings or ordering data sheets (see 6.1). In the event of any conflict between requirements of this specification sheet and a complementary document, the latter **shall** govern.

**3.3 Manufacturer Quality Profile** Suppliers of laminates and prepregs **shall** assess their manufacturing capability and complete IPC-1730. The laminator qualification profile **shall** be reviewed and updated on a two-year basis at a minimum. The laminator qualification profile **shall** be made available for review upon request.

**3.4 Qualification Testing** Laminate and prepreg base materials furnished under this specification **shall** be qualified as described in Table 3-1 for laminates and Table 3-2 for prepregs. The supplier **shall** retain on file supporting data that the materials meet the requirements of this speci-

fication using the test methods described herein. Qualification testing **shall** be performed to demonstrate the supplier’s ability to meet all of the requirements of each applicable specification sheet for each base material. Materials listed on a Qualified Products List (QPL) for MIL-S-13949 as of November, 30 1998 are considered to be qualified to the extent of the original qualification and consistent with 3.4.1, provided the test information is available for review.

**3.4.1 Qualification Testing of Laminate** Qualification of laminates **shall** require test data for both thin and thick materials. One set of test information for laminate 0.10 mm [0.004 in] or thinner **shall** qualify all laminate thicknesses up to and including 0.50 mm [0.0197 in]. If the thinnest thickness tested is >0.10 mm [0.004 in], but <0.50mm [0.0197 in], all laminates from that thickness up to and including 0.50 mm [0.0197 in] **shall** qualify all laminates included in that range. One set of test information for a laminate ≥0.8 mm [0.0315 in] **shall** qualify the manufacturer for thick laminate materials.

**3.4.2 Qualification Testing of Prepreg** Qualification of the prepreg comprised of the thinnest reinforcement style automatically qualifies by extension all the thicker reinforcement styles for a given specification sheet.

Table 3-2 Reference Information and Test Frequency of Prepreg

Tests	Requirement Paragraph	Test <sup>1</sup> Method	Qualification Testing	Conformance Testing	Conformance Testing Frequency	Specimens per Unit sampled
<b>General</b>						
Visual Properties	3.8.3.2	2.1.5	✓	✓	Lot	1
<b>Dimensional</b>						
Length/Width	3.8.4.1.2	2.2.19.1	✓	✓	Audit <sup>6</sup>	
Squareness	3.8.4.1.2	2.2.19.1	✓	✓	Audit <sup>6</sup>	
<b>Physical</b>						
Resin Content Percent by Treated Weight <sup>2</sup>	3.9.2.1.1	2.3.16.1		✓	Lot	1
Resin Content Percent by Burn-Off <sup>2</sup>	3.9.2.1.2	2.3.16	✓	✓	Lot	1
Treated Weight Total <sup>2</sup>	3.9.2.1.3	2.3.16.2		✓	Lot	1
Resin Flow Percent <sup>3</sup>	3.9.2.2.1	2.3.17	✓	✓	Lot	1
Scaled Flow Thickness <sup>3</sup>	3.9.2.2.2	2.4.38	✓	✓	Lot	1
No Flow	3.9.2.2.3	2.3.17.2	✓	✓	Lot	1
Rheological Flow	3.9.2.2.4	AABUS <sup>7</sup>		✓	Lot	1
Delta H	3.9.2.2.5	AABUS <sup>7</sup>		✓	Lot	1
Percent Cure	3.9.2.2.6	AABUS <sup>7</sup>		✓	Lot	1
Gel Time <sup>4</sup>	3.9.2.2.7	2.3.18	✓	✓	Lot	1
Volatile Content <sup>4</sup>	3.9.2.2.8	2.3.19	✓	✓	Lot	1
<b>Chemical</b>						
Flammability <sup>8,9,10</sup>	3.10.2.1	UL94	✓	✓	1 Month	5
Chemical Resistance <sup>4,9</sup>	3.10.2.2	2.3.4.2		✓	Lot	
Presence of Dicy <sup>4</sup>	3.10.2.3	2.1.10	✓	✓	Lot	1
<b>Electrical</b>						
Permittivity <sup>5,9</sup>	3.11.2.1	2.5.5.2 2.5.5.3 2.5.5.9	✓		1 Month	3
Loss Tangent <sup>5,9</sup>	3.11.2.2	2.5.5.2 2.5.5.3 2.5.5.9	✓		1 Month	3
Electric Strength <sup>9</sup>	3.11.2.3	2.5.6.2	✓	✓	3 Months	3
<b>Environmental</b>						
Fungus Resistance <sup>9</sup>	3.12.2.1	2.6.1	✓			
CAF Growth Resistance <sup>4,9</sup>	3.12.2.2	TBD	✓			

<sup>1</sup> All methods are from IPC-TM-650 unless otherwise noted.

<sup>2</sup> For qualification purposes, resin content **shall** be in accordance with Resin Content Percent by Burn Off. For conformance testing, resin content may be determined using IPC-TM-650, Test Methods 2.3.16, 2.3.16.1 or 2.3.16.2.

<sup>3</sup> For prepreg types other than no flow prepreg, either resin flow percent or scaled flow thickness may be specified for qualification and conformance testing.

<sup>4</sup> Optional tests are agreed upon between user and supplier.

<sup>5</sup> Applicable to specific material only.

<sup>6</sup> Supplier **shall** use a statistical sampling plan to assure conformance to dimensional specifications.

<sup>7</sup> AABUS = As Agreed Upon Between User and Supplier.

<sup>8</sup> For flammability see Footnote 10 of Table 3-1. Prepreg conformance is satisfied by testing laminate samples from the same specification sheet.

<sup>9</sup> Tests to be conducted after pressing the prepreg into a laminate.

<sup>10</sup> The UL94 test for flammability is to be used with the optional conditioning of 24 hours at 125°C allowed.

**Note:** If the same glass style of prepreg is used to make thin core laminate, testing of the laminate only is required.



**3.5 Verification of Manufacturer's Quality System** The verification of the manufacturer's quality system, as outlined in the self declaration in IPC-1730, may be conducted to reduce risk to the buyer. The verification can be accomplished via several methods, including internal assessment, individual customer audit, and/or third party assessment.

**3.6 Conflict** In the event of conflict, the following order of precedence **shall** apply:

1. Purchase order
2. Master drawing (see 6.1.1-D or 6.1.2-D)
3. This specification (specification sheets take precedence over body of text)
4. Applicable documents (see Section 2)

### 3.7 Materials

**3.7.1 Metal Cladding** Metal cladding **shall** meet the requirements of IPC-4562, IPC-CF-148, IPC-CF-152, or as agreed upon between user and supplier. For alternate metal claddings not covered by industry standards, requirements **shall** be as agreed upon between user and supplier.

**3.7.2 Reinforcement Fabric** Construction of reinforcement fabrics **shall** be in accordance with IPC-4412, IPC-SG-141, IPC-A-142, IPC-4411, IPC-4110, IPC-4130 and IPC-QF-143. For alternate reinforcement types not covered by industry standards, requirements **shall** be as agreed upon between user and supplier.

**3.7.3 Resin Systems** Resin systems used to produce laminate and prepreg base materials under this specification **shall** be as specified in the individual specification sheets (see 1.1.1). For alternate resin systems not covered by this specification, requirements **shall** be as agreed upon between user and supplier.

**3.8 General Requirements** Laminate or prepreg base materials **shall** be considered acceptable if they meet the requirements listed below and in the applicable specification sheet, or as agreed upon between user and supplier. Requirements only apply to the working area defined in 3.8.1.1 through 3.8.1.4, unless otherwise specified. Both sides of double-sided laminate base material **shall** be evaluated for those requirements that are impacted by the metal/base material relationships. See specific test methods for applicability.

**Note:** When tests are performed by the procuring activity, prepreg should be properly stored per 3.17 and tested as soon as possible after receipt (not to exceed five days).

#### 3.8.1 Fabricated Sheets and Panels

**3.8.1.1 Fabricated Laminate Sheet Material** A fabricated sheet **shall** be any size  $\geq 0.55 \text{ m}^2$  [5.92 ft<sup>2</sup>]. The

working area of a fabricated sheet is considered to be the area inside a 25 mm [0.984 in] border around the perimeter of the sheet.

**3.8.1.2 Fabricated Laminate Panel Material** A fabricated panel **shall** be any size  $< 0.55 \text{ m}^2$  [5.92 ft<sup>2</sup>]. The working area of a fabricated panel is considered to be the area inside a 13 mm [0.512 in] border around the perimeter of the panel.

**3.8.1.3 Fabricated Prepreg Panels** Fabricated panels are cut-to-size pieces of prepreg that are nominally (length x width, excluding considerations of tooling holes or other cut-outs)  $< 0.55 \text{ m}^2$  [5.92 ft<sup>2</sup>]. The working border **shall** be the area excluding a  $15 \pm 3 \text{ mm}$  [0.591  $\pm$  0.118 in] border.

**3.8.1.4 Fabricated Prepreg Rolls** Prepreg rolls are continuous lengths of prepreg that are rolled for the purpose of inventory and custom fabrication by the user. The working area **shall** exclude the outer  $25 \pm 5 \text{ mm}$  [0.984  $\pm$  0.197 in] edge.

No more than 5% of the nominal roll length **shall** be unsuitable for panel fabrication, which includes splices, areas sampled for testing, and non-splice breaks in the continuous length of the prepreg. The length of the roll may be compensated to replace that prepreg unsuitable for panel fabrication as agreed upon between user and supplier.

#### 3.8.2 Inspection Lot

**3.8.2.1 Inspection Lot for Laminate** An inspection lot of laminate **shall** meet the following criteria:

- a) Material covered by a single specification sheet and the same metal cladding type
- b) One press load or 200 sheets, whichever is greater. The 200 sheets must be comprised of consecutive press loads of the same material covered by a single specification sheet and the same metal cladding type.

**3.8.2.2 Inspection Lot for Prepreg** An inspection lot of prepreg **shall** be one master roll of reinforcement as provided by the supplier. Splices provided by the reinforcement supplier are not considered to be a change in the master roll. Each master roll **shall** be inspected at the beginning and end as a minimum. A significant parameter change to the impregnation process as agreed upon by user and supplier **shall** require an additional prepreg inspection point.

**3.8.2.3 Preparation of Samples** Unless otherwise specified herein, samples and test specimens **shall** be prepared in accordance with standard in-house procedures. If a referee method is required, it **shall** be as agreed upon between user and supplier.

**3.8.2.4 Etching Process and Etchant Removal for Copper Foil Specimens** Unless otherwise specified, any standard procedure may be used; however, IPC-TM-650, Methods 2.3.6, 2.3.7, or 2.3.7.1 **shall** be used as a referee.

**3.8.2.5 Standard Laboratory Conditions** Unless otherwise specified herein, all inspections **shall** be performed in accordance with the test and laboratory conditions specified in IPC-QL-653.

### 3.8.3 Visual Properties

**3.8.3.1 Laminate Visual Properties** The specimen **shall** be tested in accordance with Table 3-1 for laminates. Unless otherwise specified, the working area of the specimen **shall** be examined with normal or corrected 20/20 vision. The worst 50 mm x 50 mm [1.97 in x 1.97 in] **shall** be examined at 10X magnification. Visual inspection may be carried out under ambient temperature and humidity conditions.

**3.8.3.1.1 Foil Indentations** Indentations **shall** be located visually using normal or corrected 20/20 vision. The longest dimension of each foil indentation in a specimen **shall** be measured with a suitable reticule on a minimum 4X magnifier, with referee inspections at 10X. A point value **shall** be allocated according to the longest dimension as specified in Table 3-3.

**Table 3-3 Point Value for Longest Dimensions of Indentation**

Longest Dimension (mm) [in]	Point Value
0.13 to 0.25 [0.005 to 0.009]	1
0.26 to 0.50 [0.009 to 0.019]	2
0.51 to 0.75 [0.019 to 0.029]	4
0.76 to 1.00 [0.029 to 0.039]	7
>1.00 [0.039]	30

The surface quality class (see 1.1.5 and 6.1.1-F) **shall** be determined by the total point count of foil indentations within 300 mm x 300 mm [11.81 in x 11.81 in] as specified in Table 3-4.

**Table 3-4 Surface Quality Classification**

Surface Quality Class	Maximum Point Count	Other Requirements
Class A <sup>1</sup>	29	
Class B	17	
Class C	5	Longest Dimensions ≤380 µm [14.96 mil]
Class D <sup>2</sup>	0	Longest Dimensions <125 µm [4.92 mil] Resin spots = 0
Class X	AABUS	

<sup>1</sup> Class A requirements **shall** apply, unless otherwise specified.

<sup>2</sup> If Class D is specified, other quality related features are also required of this quality class per IPC-4562.

There **shall** be no adherent material in an indentation or exposure of base laminate. Requirements for foil indentations do not apply to copper that has been treated on both sides. Class A applies, unless otherwise specified.

**3.8.3.1.2 Wrinkles** There **shall** be no metal-clad wrinkles, as seen under normal or corrected 20/20 vision of the sheet or panel.

**3.8.3.1.3 Scratches** Scratches are not permitted where any part of the defect is ≥20% of the nominal foil thickness (i.e., 3.4 µm [0.134 mil] for 17 µm [0.669 mil] copper) or have more than five occurrences per 300 mm x 300 mm [11.81 in x 11.81 in]. Any scratch with a depth <5% of the nominal foil thickness **shall** not be counted, regardless of length. The maximum allowable scratch length is 100 mm [3.937 in] for any scratch with a depth ≥5% and <20% of the nominal foil thickness.

**3.8.3.1.4 Plastic Surface Finish of Metal-Clad Single-Sided Base Material** The plastic surface on the unclad side of base materials **shall** be as produced by the curing process. There **shall** be no evidence of resin-starved or scorched areas.

**3.8.3.1.5 Surface Finish of Foil after Curing – Except Double Treat** Unless otherwise specified (see 6.1.1-J), discoloration of the copper surface as a result of the curing process **shall** be acceptable.

**3.8.3.1.6 Surface and Subsurface Imperfections** Etched panels **shall** be inspected to verify no subsurface imperfections in excess of those shown below are present. The panels **shall** be inspected using an optical apparatus or aid that provides a minimum magnification of 4X. Referee magnification **shall** be accomplished at 10X. Lighting conditions of inspection **shall** be appropriate to the type, grade, and thickness being inspected or as agreed between user and supplier.

Surface and subsurface imperfections (i.e., weave texture, resin saturation, scorching, voids, or foreign inclusions) **shall** be acceptable, provided the imperfections meet the following:

- The reinforcement fiber is not cut or exposed.
- There is not more than one piece of residual surface metal after metal removal per 0.55 m<sup>2</sup> [5.92 ft<sup>2</sup>] of surface examined, and this piece **shall** not have an area greater than that of a circle 0.125 mm [0.0049 in] in diameter.
- Encapsulated metallic particles of any size are not allowed.
- The imperfections do not propagate as a result of thermal stress.

- e. The foreign inclusions are translucent.
- f. Opaque foreign fibers are  $\leq 13$  mm [0.512 in] in length and average no more than one per 300 mm x 300 mm [11.81 in x 11.81 in] inspected.
- g. Opaque foreign matter other than fibers **shall** not exceed 0.50 mm [0.019 in]. Opaque foreign inclusions  $< 0.13$  mm [0.005 in] **shall** not be counted. Opaque foreign inclusions between 0.50 mm [0.019 in] and 0.13 mm [0.005 in] inclusive **shall** average no more than two spots per 300 mm x 300 mm [11.81 in x 11.81 in] inspected.
- h. Voids are  $< 0.075$  mm [0.0029 in] in the longest dimension and do not occur in void clusters any more than three voids in a 3.2 mm [0.125 in] diameter circle.

**3.8.3.2 Prepreg Visual Properties** The specimen **shall** be tested in accordance with Table 3-2 for prepregs. Prepreg visual inspection is conducted with normal or corrected 20/20 vision.

**3.8.3.2.1 Inclusions** Metallic inclusions are not acceptable. Nonmetallic inclusions or foreign material **shall** be acceptable, provided they are  $< 0.50$  mm [0.019 in] in the longest dimension and occur no more frequently than two per 300 mm x 300 mm [11.81 in x 11.81 in] of surface for the panel size inspected or a 610 mm [24.02 in] x width sample.

**3.8.3.2.2 Impregnation Imperfections** Imperfections in impregnation **shall** be acceptable, provided the following criteria are met.

- a. Overall prepreg thickness increases from reinforcement imperfections is 99% maximum.
- b. Dewetted areas (measured in at least two dimensions) are 2.3 mm [0.091 in] maximum.
- c. Pin-holed areas are 0.65 mm [0.026 in] maximum.
- d. Reinforcement distortion (variation in pick line) per 300 mm [11.81 in] distance is 25 mm [0.984 in] maximum.
- e. Creases with exposed reinforcement are 15 mm [0.591 in] maximum.
- f. Silver streaks and cigar voids (non-wetted fibers) are not present.
- g. Brown streaks (binder marks) are not present.

**3.8.4 Dimensional** Length, width, thickness, and other dimensional characteristics **shall** be measured with equipment capable of sufficient accuracy to verify the requirements of this specification.

**3.8.4.1 Length and Width** When tested in accordance with Table 3-1 or Table 3-2 as applicable, the material **shall** meet the length and width requirements specified in 3.8.4.1.1 through 3.8.4.1.4.

**3.8.4.1.1 Length and Width of Laminate** For laminate base materials, the manufacturer's standard sizes between 0.45 m [1.48 ft] and 3.6 m [11.8 ft] in length and 0.45 m [1.48 ft] and 1.5 m [4.92 ft] in width **shall** be acceptable. The length and width may vary no more than  $\pm 25$  mm [0.984 in] from the standard size. Unless specific dimensions are specified, standard size metal-clad laminate from which test specimens have been cut **shall** be acceptable. When smaller sizes are cut from standard sizes, the permissible variations from the specified length or width **shall** be as specified in Table 3-5 or as agreed upon between user and supplier. Adjacent edges must be perpendicular within 0.075 mm [0.0029 in] per 25 mm [0.984 in] for laminate.

**3.8.4.1.2 Length and Width of Prepreg** The length and width of prepreg panels **shall** be as specified in the procurement document (see 6.1.2-H). The permissible variations from the specified length or width **shall** be as specified in Table 3-6 or as agreed upon between user and supplier. Adjacent edges **shall** be perpendicular, within 0.13 mm [0.00512 in] per 25 mm [0.984 in].

**3.8.4.1.3 Prepreg Roll Width** For prepreg base materials, the width of the rolls **shall** be as specified in the procurement document (see 6.1.2-H). The width of the material **shall** be within  $+6.4/-0.0$  mm of the specified value [ $+0.252/-0.000$  in].

**3.8.4.1.4 Prepreg Roll Length** The length of the prepreg rolls **shall** be as specified in the procurement document (see 6.1.2-H). The length **shall** be within  $\pm 1\%$  of the value specified.

#### 3.8.4.2 Thickness

**3.8.4.2.1 Class A, B, and C Laminate Materials** For Class A, Class B, and Class C laminate materials, the thickness of the laminate base material without the metal cladding **shall** be measured with a micrometer (see Figure 3-1).

**3.8.4.2.2 Class D Laminate Materials** For Class D materials, thickness **shall** be determined by microsection in accordance with Table 3-7. Three microsections **shall** be done on each specimen. Each microsection **shall** be located at independent corners of the specimen and no closer than 25 mm [0.984 in] from any edge. The base thickness **shall** be measured in accordance with Figure 3-1 and taken at the closest point between metal claddings (see Figure 3-1).

**3.8.4.2.3 Class K, L, M Laminate Materials** For Class K, Class L, and Class M materials, the thickness of the laminate with the metal cladding **shall** be measured with a micrometer (see Figure 3-1).

**3.8.4.2.4 Thickness Tolerance of Laminate Materials** The thickness of the laminate within the working area **shall**

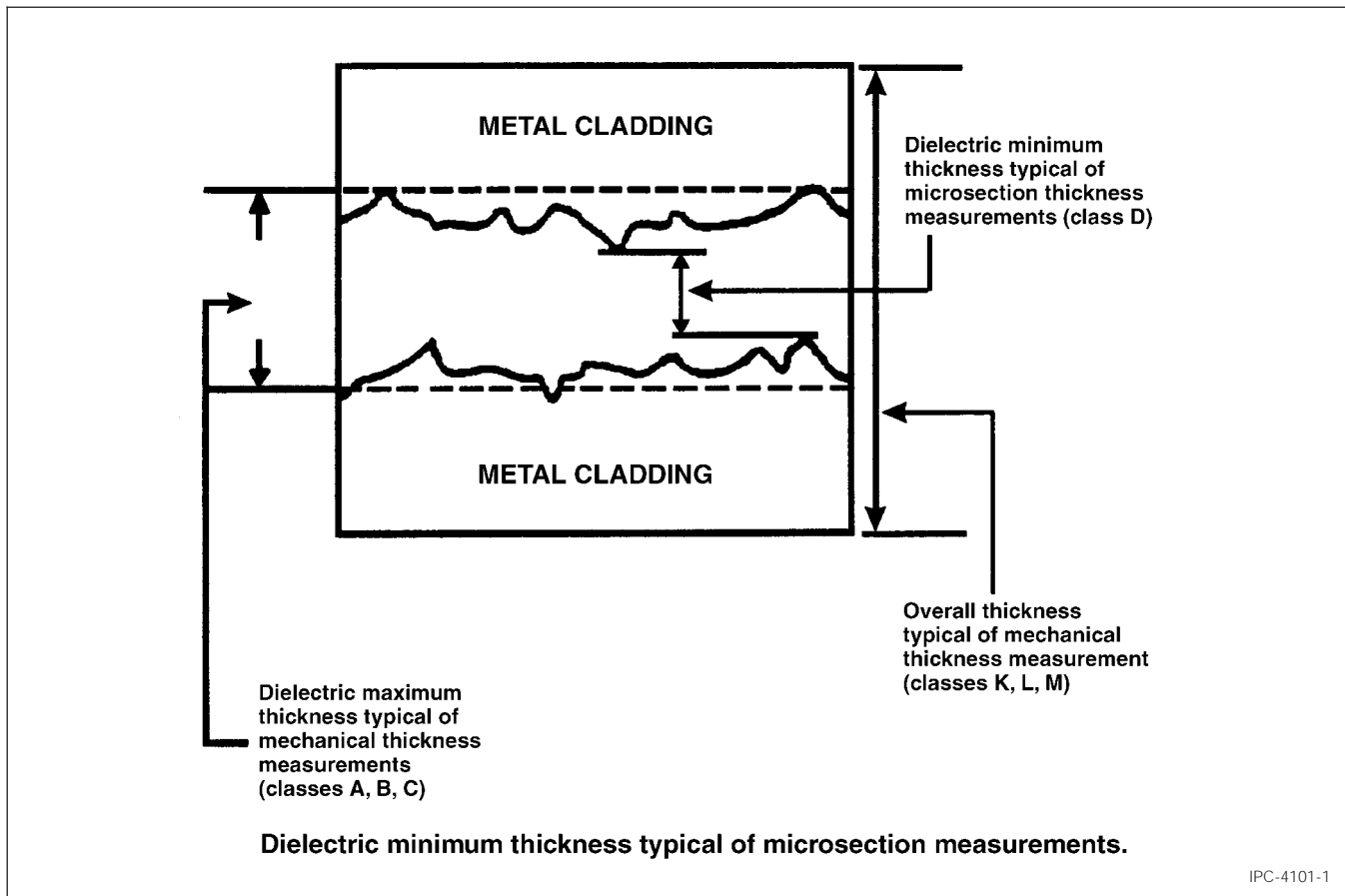
**Table 3-5 Permissible Variation in Length and Width of Laminates**

Panels	
<300 mm [11.81 in]	± 0.8 mm [0.031 in]
300 to 600 mm [11.81 to 23.62 in]	± 1.6 mm [0.063 in]
>600 mm [23.62 in]	± 3.2 mm [0.126 in]
Manufacturer's standard size with 0.45 m ≤ Width ≤ 1.5 m [1.48 ft ≤ Width ≤ 4.92 ft] 0.45 m ≤ Length ≤ 3.6 m [1.48 ft ≤ Length ≤ 11.8 ft]	+25.0/-0.0 mm [+0.984/-0.000 in]

**Table 3-6 Permissible Variation in Length and Width of Prepregs**

Panels	Grade A <sup>1</sup>	Grade B
<300 mm [11.81 in]	± 1.6 mm [0.063 in]	± 0.8 mm [0.031 in]
300 to 600 mm [11.81 to 23.62 in]	± 3.2 mm [0.126 in]	± 1.6 mm [0.063 in]
>600 mm [23.62 in]	± 6.4 mm [0.252 in]	± 3.2 mm [0.126 in]
<b>Rolls</b>		
Width	+6.4/-0.0 mm [+0.252/-0.000 in]	
Length	± 1% of specified value	

<sup>1</sup> Grade A requirements shall apply, unless otherwise specified.



**Figure 3-1 Thickness Measurements for Laminates**

be in accordance with Table 3-7 . The thickness outside the working area of the laminate sheet or cut-to-size panel supplied by the supplier **shall** not vary from the nominal by a value >125% of the specified tolerance. Unless otherwise specified, Class A/K requirements **shall** apply.

**3.8.4.3 Bow and Twist of Laminate Materials** When specimens are tested in accordance with Table 3-1, permissible bow and twist **shall** be as defined in Table 3-8, or as agreed upon between user and supplier. This requirement does not apply to double-sided laminate with a dielectric thickness <0.50 mm [0.019 in] or with unequal cladding of >0.065 mm [0.0025 in] thickness between the two sides.

**3.8.4.3.1 Sheets and Panels with Both Dimensions ≥300 mm [11.81 in]** Fabricate a 300 mm x 300 mm [11.81 in x 11.81 in] specimen from a sheet or panel in a manner that

will not impart additional bow or twist to the specimen (i.e., when shearing, test specimen sheared edges **shall** be those on the shear deck side of each cut).

**3.8.4.3.2 Panels with One or Both Dimensions <300 mm [11.81 in]** If both dimensions are <300 mm [11.81 in], use an as-received panel as the test specimen. If one dimension is >300 mm [11.81 in], cut back to 300 mm [11.81 in].

**3.9 Physical Requirements**

**3.9.1 Physical Requirements of Laminate Materials**

**3.9.1.1 Peel Strength** When specimens are tested in accordance with Table 3-1, peel strength for all copper types **shall** meet the requirements of 3.9.1.1.1 through 3.9.1.1.3. For non-copper metallic foils, adhesion test

**Table 3-7 Thickness and Tolerances for Laminates**

Nominal Thickness of Laminate (mm) [in]	Class A/K (mm) [in]	Class B/L (mm) [in]	Class C/M (mm) [in]	Class D (mm) [in]
0.025 to 0.119 [0.0009 to 0.0047]	± 0.018 [± 0.0007]	± 0.018 [± 0.0007]	± 0.013 [± 0.0005]	-0.013 [-0.0005] + 0.025 [+ 0.0009]
0.120 to 0.164 [0.0047 to 0.0065]	± 0.038 [± 0.0015]	± 0.025 [± 0.0009]	± 0.018 [± 0.0007]	-0.018 [-0.0007] + 0.030 [+ 0.0012]
0.165 to 0.299 [0.0065 to 0.0118]	± 0.050 [± 0.0019]	± 0.038 [± 0.0015]	± 0.025 [± 0.0009]	-0.025 [-0.0009] + 0.038 [+ 0.0015]
0.300 to 0.499 [0.0118 to 0.0196]	± 0.064 [± 0.0025]	± 0.050 [± 0.0019]	± 0.038 [± 0.0015]	-0.038 [-0.0015] + 0.050 [+ 0.0019]
0.500 to 0.785 [0.0197 to 0.0309]	± 0.075 [± 0.0029]	± 0.064 [± 0.0025]	± 0.050 [± 0.0019]	-0.050 [-0.019] + 0.064 [+ 0.0025]
0.786 to 1.039 [0.0309 to 0.04091]	± 0.165 [± 0.0065]	± 0.10 [± 0.004]	± 0.075 [± 0.0029]	N/A
1.040 to 1.674 [0.04091 to 0.06594]	± 0.190 [± 0.0075]	± 0.13 [± 0.005]	± 0.075 [± 0.0029]	N/A
1.675 to 2.564 [0.06594 to 0.10094]	± 0.23 [± 0.009]	± 0.18 [± 0.007]	± 0.10 [± 0.004]	N/A
2.565 to 3.579 [0.10094 to 0.14091]	± 0.30 [± 0.012]	± 0.23 [± 0.009]	± 0.13 [± 0.00512]	N/A
3.580 to 6.35 [0.14094 to 0.250]	± 0.56 [± 0.022]	± 0.30 [± 0.012]	± 0.15 [± 0.006]	N/A

**Table 3-8 Permissible Bow and Twist for Laminates, %**

<b>For Laminate with Thickness, 0.50 mm ≤ t ≤ 0.78 mm [0.0197 in ≤ t ≤ 0.0307 in]</b> Single Sided Panel Size, l ≤ 200 mm [7.874 in] Single Sided Panel Size, 200 mm < l ≤ 300 mm [7.874 in < l ≤ 11.81 in] Double Sided Panel Size, l ≤ 200 mm [7.874 in] Double Sided Panel Size, 200 mm < l ≤ 300 mm [7.874 in < l ≤ 11.81 in]	2.0% 2.0% 1.0% 1.5%
<b>For Laminate with Thickness, 0.78 mm &lt; t ≤ 1.67 mm [0.0307 in &lt; t ≤ 0.0657 in]</b> Single Sided Panel Size, l ≤ 200 mm [7.874 in] Single Sided Panel Size, 200 mm < l ≤ 300 mm [7.874 in < l ≤ 11.81 in] Double Sided Panel Size, l ≤ 200 mm [7.874 in] Double Sided Panel Size, 200 mm < l ≤ 300 mm [7.874 in < l ≤ 11.81 in]	1.5% 1.5% 0.5% 1.0%
<b>For Laminate with Thickness, t &gt; 1.67 mm [t &gt; 0.0657 in]</b> Single Sided Panel Size, l ≤ 200 mm [7.874 in] Single Sided Panel Size, 200 mm < l ≤ 300 mm [7.874 in < l ≤ 11.81 in] Double Sided Panel Size, l ≤ 200 mm [7.874 in] Double Sided Panel Size, 200 mm < l ≤ 300 mm [7.874 in < l ≤ 11.81 in]	1.5% 1.5% 0.5% 1.0%



methods and values **shall** be as agreed upon between user and supplier.

All foil weights may be plated up to 35  $\mu\text{m}$  [0.001 in] and the peel strength tested to the original specified value.

**3.9.1.1.1 Peel Strength after Thermal Stress** When specimens are tested in accordance with Table 3-1, the minimum average peel strength following thermal stress **shall** be as indicated in the applicable specification sheet.

**3.9.1.1.2 Peel Strength at Elevated Temperature** When specimens are tested in accordance with Table 3-1, the specimens **shall** meet the requirements of the applicable specification sheet.

**3.9.1.1.3 Peel Strength after Process Chemicals (Optional)** When specimens are tested in accordance with Table 3-1, the minimum average peel strength after process solutions **shall** be as indicated in the applicable specification sheet.

**3.9.1.2 Dimensional Stability** When specimens are tested in accordance with Table 3-1, the nominal dimensional stability **shall** be as agreed upon between user and supplier. The tolerance **shall** be Range A unless otherwise specified on the purchase order or by other agreement between user and supplier:

Range A	$\pm 300$ ppm (0.0003 cm/cm [0.0003 in/in])
Range B	$\pm 200$ ppm (0.0002 cm/cm [0.0002 in/in])
Range C	$\pm 100$ ppm (0.0001 cm/cm [0.0001 in/in])
Range X	Unspecified, not applicable or as agreed upon between user and supplier.

**3.9.1.3 Flexural Strength** The metal cladding of specimens **shall** be completely removed by etching in accordance with 3.8.2.4. When specimens are tested in accordance with Table 3-1, the average minimum flexural strength **shall** be as indicated in the applicable specification sheet.

**3.9.1.4 Flexural Strength at Elevated Temperature** The metal cladding of the specimens **shall** be completely removed by etching in accordance with 3.8.2.4. When specimens are tested in accordance with Table 3-1, the average minimum flexural strength at elevated temperature **shall** be as indicated in the applicable specification sheet.

### 3.9.2 Physical Requirements of Prepreg Materials

**3.9.2.1 Resin Content** The quantity of resin on a particular reinforcement **shall** be specified by resin content or total treated weight.

**3.9.2.1.1 Resin Content Percent (RC) (by Treated Weight)** When specimens are tested in accordance with Table 3-2, the percentage of resin content **shall** be as indicated on the applicable specification sheet or as agreed upon between user and supplier. In the case of any dispute, the referee test method will be in accordance with IPC-TM-650, Method 2.3.16.1 (see 3.9.2.1.2).

**3.9.2.1.2 Resin Content Percent (RC) (by Burn-Off)** When specimens are tested in accordance with Table 3-2, the percentage of resin content **shall** be as indicated on the applicable specification sheet or as agreed upon between user and supplier.

**3.9.2.1.3 Treated Weight Total (TW)** When specimens are tested in accordance with Table 3-2, the total treated weight of the resin and reinforcement combined **shall** be as indicated on the applicable specification sheet or as agreed upon between user and supplier.

**3.9.2.1.4 Variation Within a Panel** Resin content variation **shall** be no greater than that specified in the applicable specification sheet or as agreed upon between user and supplier.

**3.9.2.2 Flow Parameter** The amount the resin will flow under certain controlled conditions **shall** be specified by resin flow percent (MF), scaled flow thickness (SC), no flow (NF), rheological flow (RE), delta H (DH), or percent cure (PC) as indicated on the procurement document or as agreed upon between user and supplier.

**3.9.2.2.1 Resin Flow Percent (MF)** When specimens are tested in accordance with Table 3-2, the nominal resin flow percent **shall** be as indicated on the procurement document, and the tolerance of the resin flow percent measurement **shall** meet the requirements of the applicable specification sheet or as agreed upon between user and supplier.

**3.9.2.2.2 Scaled Flow Thickness (SC)** When specimens are tested in accordance with Table 3-2, the nominal per ply thickness **shall** be as indicated on the procurement document. The per ply thickness **shall** not vary from the nominal thickness more than specified on the applicable specification sheet or as agreed upon between user and supplier.

**3.9.2.2.3 No Flow (NF)** When specimens are tested in accordance with Table 3-2, the nominal resin flow range for no flow **shall** be as indicated on the procurement document. The resin flow percent for no flow **shall** not vary from the nominal value more than specified on the applicable specification sheet or as agreed upon between user and supplier.

**3.9.2.2.4 Rheological Flow (RE)** When specimens are tested in accordance with Table 3-2, the nominal rheological flow and tolerance **shall** be as indicated in the procurement document or as agreed upon between user and supplier.

**3.9.2.2.5 Delta H (DH)** When specimens are tested in accordance with Table 3-2, the nominal delta H and tolerance **shall** be as indicated in the procurement document or as agreed upon between user and supplier.

**3.9.2.2.6 Percent Cure (PC)** When specimens are tested in accordance with Table 3-2, the nominal cure percent and tolerance **shall** be as indicated in the procurement document or as agreed upon between user and supplier.

**3.9.2.2.7 Gel Time (GT) (Optional Test)** When specimens are tested in accordance with Table 3-2, the nominal gel time **shall** be as indicated on the procurement document. The gel time **shall** not vary from the nominal gel time more than specified on the applicable specification sheet or as agreed upon between user and supplier.

**3.9.2.2.8 Volatile Content (VC) (Optional Test)** When specimens are tested in accordance with Table 3-2, the volatile content **shall** not exceed the maximum as indicated on the applicable specification sheet or as agreed upon between user and supplier.

**3.10 Chemical Requirements**

**3.10.1 Chemical Requirements of Laminate Materials**

**3.10.1.1 Flammability** When specimens are tested in accordance with Table 3-1 and UL94 flammability requirements, the rating **shall** be as indicated in the applicable specification sheet and Table 3-9. The optional conditioning of 24 hours at 125°C is acceptable for materials described in this document.

If applicable specification sheet indicates not applicable (N/A), no requirement, or as agreed upon between user and supplier (AABUS), the materials must be tested for flammability and results recorded during the qualification process.

**3.10.1.2 Thermal Stress** When specimens are tested in accordance with Table 3-1, the specimens **shall** exhibit no evidence of blistering, delamination, wrinkling, or cracking.

**3.10.1.3 Solderability** When laminates are tested as specified in Table 3-1, the metal-clad surfaces **shall** not exhibit non-wetting or more than 5% dewetting. Prior to testing, specimens **shall** be cleaned as follows:

**Table 3-9 Flammability Requirements**

Property	Requirement	
	Designation	
	V-0	V-1
Flaming combustion time after each application of the flame for each test specimen	≤10 seconds	≤30 seconds
Total flaming combustion time for the 10 flame applications for each set of five specimens	<50 seconds	<250 seconds
Glowing combustion time after the second removal of the test flame	≤30 seconds	≤60 seconds
Flaming or glowing combustion up to the holding clamp	None	None
Dripping flaming particles that ignite the tissue paper	None	None

Specimens 75 mm x 75 mm [2.95 in x 2.95 in] **shall** be cut, wiped with isopropyl alcohol, and immersed in a 20% by volume solution of hydrochloric acid, technical grade, 5.6°C Baume, maintained at 21°C ± 5°C [69.8°F ± 9°F] for 15 seconds. The specimens **shall** be rinsed with a cold water spray rinse for five seconds and blown dry with filtered, oil free, compressed air.

**3.10.1.4 Chemical Resistance (Optional)** When specimens are tested in accordance with Table 3-1, the weight change following chemical exposure **shall** be as agreed upon between user and supplier.

**3.10.1.5 Metal Surfaces Cleanability** When specimens are tested in accordance with Table 3-1, the material **shall** meet the metal surface cleanability requirements as agreed upon between user and supplier.

**3.10.1.6 Glass Transition Temperature (T<sub>g</sub>) (Optional)** When specimens are tested in accordance with Table 3-1, the T<sub>g</sub> **shall** meet the values as agreed upon between user and supplier.

**3.10.1.7 Delta T<sub>g</sub> (Optional)** When specimens are tested in accordance with Table 3-1, the delta T<sub>g</sub> **shall** meet the values as agreed upon between user and supplier.

**3.10.1.8 Coefficient of Thermal Expansion (CTE) (Optional)** When specimens are tested in accordance with Table 3-1, the X/Y CTE **shall** meet the values as agreed upon between user and supplier.

**3.10.1.9 Total Halogen Content (Optional)** When specimens are tested in accordance with Table 3-1, the total halogen content **shall** meet the values specified in the applicable specification sheet.

### 3.10.2 Chemical Requirements of Prepreg Materials

**3.10.2.1 Flammability** When laminated specimens are tested in accordance with Table 3-2 and UL94 flammability requirements, the rating **shall** be as indicated in the applicable specification sheet and Table 3-7. Prepreg must be laminated to produce a minimum thickness of 0.50 mm [0.020 in].

If the applicable specification sheet indicates not applicable (N/A), no requirement, or as agreed upon between user and supplier (AABUS), the materials must be tested for flammability and results recorded during the qualification process.

**3.10.2.2 Chemical Resistance (Optional)** When specimens are tested in accordance with Table 3-2, the weight change following chemical exposure **shall** be as agreed upon between user and supplier.

**3.10.2.3 Presence of Dicyandiamide (Dicy) (Optional)** When specimens are tested in accordance with Table 3-2, the amount of acceptable dicy crystals **shall** be as agreed upon between user and supplier.

### 3.11 Electrical Requirements

#### 3.11.1 Electrical Requirements of Laminate Materials

**3.11.1.1 Permittivity** When specimens are tested in accordance with Table 3-1, the average maximum permittivity **shall** be as indicated in the applicable specification sheet. Different test methods can be specified depending upon the frequency (i.e., 1MHz, 1GHz, etc.) of the test. See IPC-4121 for specific permittivity information by construction and resin content.

**3.11.1.2 Loss Tangent** When specimens are tested in accordance with Table 3-1, the average maximum loss tangent **shall** be as indicated in the applicable specification sheet. Different test methods can be specified depending upon the frequency (i.e., 1MHz, 1GHz, etc.) of test. See IPC-4121 for specific loss tangent information by construction and resin content.

**3.11.1.3 Volume Resistivity** When specimens are tested in accordance with Table 3-1, the minimum volume resistivity **shall** be as indicated in the applicable specification sheet.

**3.11.1.4 Surface Resistivity** When specimens are tested in accordance with Table 3-1, the minimum surface resistivity **shall** be as indicated in the applicable specification sheet.

**3.11.1.5 Arc Resistance** The metal cladding of specimens **shall** be completely removed by etching as specified

in 3.8.2.4. End point or failure occurs when a conducting path is formed across the surface and the arc disappears into the material. When specimens are tested in accordance with Table 3-1, the average minimum arc resistance **shall** be as indicated in the applicable specification sheet.

**3.11.1.6 Dielectric Breakdown** When specimens are tested in accordance with Table 3-1, the dielectric breakdown **shall** be as indicated in the applicable specification sheet.

**3.11.1.7 Electric Strength** When specimens are tested in accordance with Table 3-1, the electric strength **shall** be as indicated in the specification sheet.

**3.11.2 Electrical Requirements of Prepreg Materials** Electrical properties **shall** be tested on specimens cut from fully cured two-ply samples of a minimum size of 150 mm x 150 mm [5.91 in x 5.91 in] that have been prepared in accordance with the manufacturer's recommendations.

**3.11.2.1 Permittivity** When specimens are tested at 1 MHz in accordance with Table 3-2, the average maximum permittivity **shall** be as indicated in the applicable specification sheet.

**3.11.2.2 Loss Tangent** When specimens are tested at 1 MHz in accordance with Table 3-2, the average maximum loss tangent **shall** be as indicated in the applicable specification sheet.

**3.11.2.3 Electric Strength** When specimens are tested in accordance with Table 3-2, the minimum electric strength **shall** be as indicated in the specification sheet.

### 3.12 Environmental Requirements

#### 3.12.1 Environmental Requirements of Laminate Materials

**3.12.1.1 Moisture Absorption** When specimens meeting the thickness requirements are tested in accordance with Table 3-1, the average maximum moisture absorption **shall** be as indicated in the applicable specification sheet.

**3.12.1.2 Fungus Resistance** When tested in accordance with Table 3-1, the specimen **shall** resist fungus growth.

**3.12.1.3 Pressure Vessel (Optional)** When tested in accordance with Table 3-1, the specimens **shall** be evaluated using the criteria as agreed upon between user and supplier.

**3.12.1.4 Conductive Anodic Filament (CAF) Growth (Optional)** Conductive anodic filament (CAF) growth resistance is recognized as a significant material attribute. Requirements for CAF will be considered as a specification



sheet element at such time that a standardized test method and performance level requirements are developed. Until then, the test method and performance level requirements **shall** be as agreed upon between user and supplier.

### 3.12.2 Environmental Requirements of Prepreg Materials

**3.12.2.1 Fungus Resistance** When tested for qualification in accordance with Table 3-2, the specimen **shall** resist fungus growth.

### 3.13 Substitutability

**3.13.1 Substitutability of Classes of Pits and Dents** Laminates inspected, certified, or marked to a tighter class of pits and dents **shall** be substitutable for laminates ordered to a lower class of pits and dents.

**3.13.2 Substitutability of Classes of Thickness Tolerance** Laminates inspected, certified, or marked to a tighter class of thickness tolerance **shall** be substitutable for laminates ordered to a lower class of thickness tolerance.

**3.13.3 Remarking of Substituted Laminates** Substituted laminates provided under the provisions of the foregoing requirements need not be remarked to lesser grades or classes unless specified by the purchase order. Lot or date codes **shall** not be changed

### 3.14 Marking

**3.14.1 Marking Laminate Materials** Laminate sheets or cut-to-size panels **shall** be marked as specified in the ordering data. When applicable, the need for marking, location of the marking, information presented in the marking, and the type of marking **shall** be specified. Types of acceptable markings are:

- A. Ink of non-corrosive types that **shall** remain legible during normal handling but readily removable prior to fabrication, which will not affect the physical or electrical properties of the base material
- B. Ink of non-corrosive types that **shall** remain legible during normal handling but act as an etch resist to permanently mark panels.
- C. Labels that remain securely affixed and legible during normal handling
- D. A metal embossing stamp or engraver.

**3.14.2 Marking Prepreg Materials** Prepreg sheets or panels **shall** have a label attached to the unit package. Prepreg rolls **shall** have a label securely attached to the compatible protective bag enveloping the roll and a label attached to the inside mandrel at both ends.

**3.14.3 Marking of Shipping Containers** Laminate and prepreg sheets or cut-to-size panels **shall** have a shipping label attached to the packing container. All labels **shall** remain securely affixed and legible during normal handling. Location of the label and the type of marking **shall** be as specified in the drawing or ordering data or, if not specified, **shall** be the supplier's standard labeling and marking. The following information is to be included:

- a. Specification number and type of material
- b. Manufacturer's material designation and lot number
- c. Quantity unit of issue and dimensions
- d. Gross weight
- e. Date packed (date of packing for shipment to customer or warehouse)
- f. Contract number and manufacturer's source code number, when applicable
- g. Manufacturer's name and address
- h. Date of manufacture (date when the material was impregnated)
- i. Prepreg parameters (to include as a minimum, the resin content percent or treated weight total, resin flow percent or scaled flow thickness, as applicable)

**3.15 Workmanship** Laminate and prepreg base materials **shall** be manufactured and processed in such a manner as to be uniform in quality and **shall** be free from defects (except as specified elsewhere in this specification) that will affect processability, product life, and serviceability.

**3.16 Material Safety** Laminate and prepreg base materials supplied to this specification **shall** have available a Material Safety Data Sheet (MSDS) and other additional safety information as appropriate upon request.

**3.17 Prepreg Shelf Life** Unless otherwise specified, prepreg supplied **shall** be capable and certified to meet all the requirements specified when stored per Condition 1 or Condition 2 for the applicable specification sheet requirements.

*Condition 1:* Six months when stored at <5°C [41°F]

*Condition 2:* Three months when stored at <20°C [68°F] and <50 % RH

Prepreg exceeding the shelf life requirements prior to shipment to the user must be retested and recertified by the supplier or authorized distributor before the prepreg can be sold as material in compliance with and certified to this specification. For the purposes of retesting and recertification by the supplier or authorized distributor for sale as certified material, shelf life begins at the date of manufacture of the prepreg. Prepreg should be stored in the absence of a catalytic environment such as UV light or excessive

radiation. Prepreg should be allowed to equilibrate at processing conditions before use.

#### 4 QUALITY ASSURANCE PROVISIONS

**4.1 Quality System** A quality system **shall** be documented to support the conformance testing frequency selected by the laminate and prepreg manufacturer.

**4.2 Responsibility for Inspection** Unless otherwise specified in the purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the purchase order, the supplier may use his own or any other facility suitable for the performance of the inspection requirements herein.

**4.2.1 Test Equipment and Inspection Facilities** Testing and measuring equipment and inspection facilities of sufficient accuracy, quality, and quantity to permit performance of the required inspection **shall** be established and maintained by the supplier in accordance with IPC-QL-653. The establishment and maintenance of a calibration system to control the accuracy of the measuring and test equipment **shall** be in accordance with ANSI/NCSL Z540-1-1994 or ISO 10012-1.

#### 4.3 Qualification Testing

**4.3.1 Samples** When required under the provisions of Table 3-1 for laminates and Table 3-2 for prepregs, sample sheets **shall** be selected from normal production for each manufacturer's brand type for which qualification is sought. The number of samples required per lot sampled **shall** also be as specified in Table 3-1 or Table 3-2. The number of specimens required for the individual test methods **shall** be cut from the sheets and inspected as specified.

**4.3.2 Frequency** Each material (as outlined in the specification sheets) **shall** undergo qualification once. The supplier, upon demand, **shall** provide sufficient data, as determined by the Manufacturer's Quality System, that the supplied material is qualified to this specification. A record of those materials qualified to this specification **shall** be listed in the self declaration form provided by the supplier in IPC-1730.

**4.3.3 Laminator Qualification Profile** The manufacturer **shall** verify on a periodic basis (every two years, minimum) that the information contained in IPC-1730 accurately reflects overall capability.

**4.3.4 Changes in Composition** Any changes to the chemical composition must be evaluated by the supplier as to the effect on performance properties or processing char-

acteristics. It is the responsibility of the supplier to communicate product changes that have the potential to change performance properties or processing characteristics with the user. The product shall be requalified if deemed necessary.

**4.3.5 Qualification Data Retention** The qualification data **shall** be maintained by the supplier for the commercial life of the product plus three years.

**4.4 Quality Conformance Inspection** Quality conformance inspection **shall** be as documented in the laminate and prepreg supplier's manufacturing quality system. If a documented quality system does not exist, conformance testing **shall** be conducted in accordance with Table 3-1 for laminates and Table 3-2 for prepregs. Additional testing required by the user must be included in the purchase order.

**4.4.1 Frequency** The frequency of conformance testing **shall** be as specified in the Manufacturer's Quality System or as specified in Table 3-1 for laminates, Table 3-2 for prepregs, or by the purchase order. Where lot is indicated in Table 3-1, only one sheet is to be randomly selected from each lot for testing. Where "lot" is indicated for Table 3-2 for prepreg, the sample **shall** be selected as specified in 3.8.2.2. Additional samples may be taken to satisfy the terms of the purchase order.

When a period of one month or greater is indicated in Table 3-1, the sampling plan **shall** be as described in Table 4-1 for laminate and Table 4-2 for prepreg materials.

**Table 4-1 Quality Conformance Plan for Monthly, Quarterly and Annual Tests – Laminate**

Total Number of Laminated Sheets Produced During Each Sampling Period	Sample Size	Acceptance Number
≤200	1	0
201 to 1000 inclusive	2	0
1,001 to 10,000 inclusive	3	0
≥10,001	4	0

**Table 4-2 Quality Conformance Plan for Monthly, Quarterly and Annual Tests – Prepreg**

Total Linear Dimension of Prepreg Produced During Each Sampling Period (m) [yd]	Sample Size	Acceptance Number
≤730 [798.3]	1	0
731 [799.4] to 10,000 [10936.1]	2	0
≥10,001 [10937.2]	3	0

**4.4.2 Acceptance Criteria** The acceptance number for all tests conducted on a lot, monthly, quarterly and annual basis will be zero (0). No failure **shall** be allowed for any specimen tested.

**4.4.3 Rejected Lots** If an inspection lot is rejected, the supplier may rework it to correct the defects or screen out the defective units and resubmit for reinspection. Resubmitted lots **shall** be inspected using tightened inspection. Such lots **shall** be separate from new lots and **shall** be clearly identified as reinspected lots while the material is within the manufacturer's facility. If the defect cannot be screened out, the supplier **shall** sample additional lots and make processing corrections as necessary. If the additional lots inspected show the same defect, it **shall** be the supplier's responsibility to contact the user(s) regarding the problem.

**4.4.4 Conformance Data Retention** Quality conformance data **shall** be maintained for a minimum of three years from the date of test.

**4.4.5 Certificate of Conformance** The certificate of conformance **shall** contain the following items as a minimum:

- The name and address of the supplier.
- The designation code from the classification (see 1.1).
- The supplier's grade designation.
- The lot(s) code for the material to be certified.
- The statement, "This material has been manufactured, tested, and certified in accordance with the provisions of this document and the applicable slash sheet. For example, IPC-4101/21."
- The original signature or line of authority of a designated company representative.

**4.5 Statistical Process Control (SPC)** SPC utilizes systematic statistical techniques to analyze a process or its outputs. The purposes of these analyses are to take appropriate actions to achieve and improve process capability. The primary goal of SPC is to continually reduce variations in processes, products, or services in order to provide product meeting or exceeding real or important customer requirements.

Implementation of SPC **shall** be in accordance with IPC-9191. Depending on the progress made in implementing SPC on a particular product, an individual supplier may demonstrate compliance to specification with any of the following:

Quality conformance evaluations

End-product control

In-process product control

Process parameter control

An individual supplier may choose to use a combination of the four assurance techniques listed above to prove compliance.

**Example:**

A product with 15 characteristics may meet specifications by quality conformance evaluations on two characteristics, in-process product evaluations on five characteristics, and process parameter control for five characteristics. The remaining three characteristics may meet specification by a combination of in-process control and quality conformance evaluations. Evidence of compliance to the specification at the level of SPC implementation claimed is auditable by the customer or an appointed third party.

Requirements are dynamic in nature and are based on what is accepted in the worldwide market. Requirements may be stated as a reduction of variation around a target value, as opposed to just meeting the specification, drawing, etc.

## 5 PREPARATION FOR DELIVERY

**5.1 Packaging Materials** Laminate and prepreg base materials **shall** be packed in a manner that will afford adequate protection against corrosion, deterioration, and physical damage during shipment and storage.

**5.2 Authorized Distributors** The laminate and prepreg base material manufacturer may authorize distributors to act as sales and/or fabrication and inspection agents. The manufacturer **shall** be responsible for assuring materials processed by authorized agents meet the applicable requirements of this specification. Authorized distributors **shall** be responsible for the requirements of 3.8.3, 4.2, 4.2.1, 5.1, and 6.1 as applicable and as determined by the manufacturer's level of authorization. The type and frequency of audits **shall** be as determined by the manufacturer's quality system.

## 6 NOTES

### 6.1 Ordering Information

**6.1.1 Ordering Data for Laminate Materials** Purchase orders should specify the following:

- A. Title, number, and revision letter of this specification
- B. Specification sheet number and revision level
- C. Specific exemptions to the specifications, if any
- D. Title, number, and date of any applicable drawing
- E. Information for preparation of delivery, if applicable (see Section 5)
- F. Part classification (see 1.1), identification, and marking instructions
- G. Production inspection, if applicable (see 4.4)
- H. Nominal thickness, width, and length of material (see 3.8.4)
- I. The range of tolerance around the nominal dimensional stability (see 3.9.1.2)

- J. All exceptions as agreed upon between user and supplier
- K. Description of any test method not found in IPC-TM-650 or deviations from specified test methods
- L. Request for certification, if applicable
- M. Request for a test data report and desired test methods, if applicable

**6.1.2 Ordering Data for Prepreg Materials** Purchase orders should specify the following:

- A. Title, number, and revision letter of the specification
- B. Specification sheet number and revision level
- C. All exceptions as agreed upon between user and supplier
- D. Title, number, and date of any applicable drawing
- E. Information for preparation of delivery, if applicable (see Section 5)
- F. Part Classification (see 1.1), identification, and marking instructions
- G. Production inspection, if applicable (see 4.4)

- H. Nominal thickness, width, and length of material (see 3.8.4)
- I. Class, grade or range of property requirements, if applicable
- J. Resin content parameter and nominal value (see 1.1.7)
- K. Resin flow parameter and nominal value (see 1.1.7)
- L. Other prepreg parameters if applicable (see 1.1.7)
- M. Description of any test method not found in IPC-TM-650 or deviations from specified test methods
- N. Request for certification, if applicable
- O. Request for a test data report and desired test methods, if applicable

**6.2 New Materials** Users and material developers are encouraged to supply information on new materials for review by the IPC Laminate/Prepreg Materials Subcommittee (3-11). Users who wish to invoke this specification for metal-clad materials not listed **shall** list a L+zero (L0) for the specification sheet number for laminate materials and a P+zero (P0) for the specification sheet number for prepreg materials.

## Specification Sheets for Laminates and Prepregs

<b>SPECIFICATION SHEET #:</b>	IPC-4101/00	
<b>REINFORCEMENT:</b>	1: Cellulose paper	2: None
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Phenolic <b>Secondary 1:</b> None	<b>Secondary 2:</b> None
<b>FLAME RETARDANT MECHANISM:</b>	N/A	<b>UL94 Requirement:</b> HB
<b>FILLERS:</b>	None	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> XPC <b>ANSI:</b> XPC/00	<b>MIL-S-13949:</b> N/A
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	N/A	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/01	
<b>REINFORCEMENT:</b>	1: Cellulose paper	2: None
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Phenolic <b>Secondary 1:</b> None	<b>Secondary 2:</b> None
<b>FLAME RETARDANT MECHANISM:</b>	N/A	<b>UL94 Requirement:</b> HB
<b>FILLERS:</b>	None	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> XXXPC <b>ANSI:</b> XXXPC/01	<b>MIL-S-13949:</b> N/A
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	N/A	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/02	
<b>REINFORCEMENT:</b>	1: Cellulose paper	2: None
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Phenolic <b>Secondary 1:</b> None	<b>Secondary 2:</b> None
<b>FLAME RETARDANT MECHANISM:</b>	Bromine/Chlorine	<b>Minimum UL94 Requirement:</b> V-1
<b>FILLERS:</b>	None	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> FR-1 <b>ANSI:</b> FR-1/02	<b>MIL-S-13949:</b> N/A
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	N/A	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/03	
<b>REINFORCEMENT:</b>	1: Cellulose paper	2: None
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Phenolic <b>Secondary 1:</b> None	<b>Secondary 2:</b> None
<b>FLAME RETARDANT MECHANISM:</b>	Bromine/Chlorine	<b>Minimum UL94 Requirement:</b> V-1
<b>FILLERS:</b>	None	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> FR-2 <b>ANSI:</b> FR-2/03	<b>MIL-S-13949:</b> N/A
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	N/A	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/04	
<b>REINFORCEMENT:</b>	1: Cellulose paper	2: None
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy <b>Secondary 1:</b> None	<b>Secondary 2:</b> None
<b>FLAME RETARDANT MECHANISM:</b>	Bromine/Chlorine/Antimony oxide	<b>Minimum UL94 Requirement:</b> V-1
<b>FILLERS:</b>	None	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> FR-3 <b>ANSI:</b> FR-3/04	<b>MIL-S-13949:</b> N/A
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	N/A	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/10	
<b>REINFORCEMENT:</b>	1: Woven E-glass, surface	2: Cellulose paper, core
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy <b>Secondary 1:</b> Phenolic	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	Bromine/Antimony oxide	<b>UL94 Requirement:</b> V-0
<b>FILLERS:</b>	N/A	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> CEM-1 <b>ANSI:</b> CEM-1/10	<b>MIL-S-13949:</b> N/A
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	100°C minimum	

<b>SPECIFICATION SHEET #:</b>	IPC-4101/11	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass, surface	<b>2:</b> Nonwoven E-glass core
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Polyester <b>Secondary 1:</b> Vinyl ester	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	Bromine	
<b>FILLERS:</b>	Inorganic fillers	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> N/A <b>ANSI:</b> CRM-5/11	<b>MIL-S-13949:</b> N/A
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	N/A	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/12	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass, surface	<b>2:</b> Nonwoven E-glass core
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy <b>Secondary 1:</b> N/A	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	Bromine	<b>UL94 Requirement:</b> V-0
<b>FILLERS:</b>	With or without inorganic fillers	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> CEM-3 <b>ANSI:</b> CEM-3/12	<b>MIL-S-13949:</b> N/A
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	N/A	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/13	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Polyester <b>Secondary 1:</b> Vinyl ester	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	Bromine	
<b>FILLERS:</b>	Inorganic fillers	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> N/A <b>ANSI:</b> 4101/13	<b>MIL-S-13949:</b> N/A
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	N/A	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/20	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy <b>Secondary 1:</b> N/A	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	N/A	<b>UL94 Requirement:</b> HB
<b>FILLERS:</b>	N/A	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> G-10 <b>ANSI:</b> G-10/20	<b>MIL-S-13949:</b> /03 - GE, GEN
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	N/A	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/21	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Difunctional epoxy <b>Secondary 1:</b> Multifunctional epoxy	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	Bromine	<b>Minimum UL94 Requirement:</b> V-1
<b>FILLERS:</b>	N/A	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> FR-4 <b>ANSI:</b> FR-4/21	<b>MIL-S-13949:</b> /04 - GF, GFN, GFK, GFP, GFM
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	110°C to 150°C	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/22	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy, hot strength retention <b>Secondary 1:</b> N/A	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	N/A	<b>UL94 Requirement:</b> HB
<b>FILLERS:</b>	N/A	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> G-11 <b>ANSI:</b> G-11/22	<b>MIL-S-13949:</b> /02 - GB, GBN, GBP
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	135°C - 175°C	



<b>SPECIFICATION SHEET #:</b>	IPC-4101/23	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy, hot strength retention <b>Secondary 1:</b> N/A	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	Bromine	<b>Minimum UL94 Requirement:</b> V-1
<b>FILLERS:</b>	N/A	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> FR-5 <b>ANSI:</b> FR-5/23	<b>MIL-S-13949:</b> /05 - GH, GHN, GHP
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	135°C - 185°C	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/24	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy <b>Secondary 1:</b> Multifunctional epoxy	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	Bromine	<b>Minimum UL94 Requirement:</b> V-1
<b>FILLERS:</b>	N/A	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> FR-4 <b>ANSI:</b> FR-4/24	<b>MIL-S-13949:</b> /04 - GF, GFG, GFN
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	150°C - 200°C	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/25	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy <b>Secondary 1:</b> Polyphenylene oxide	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	Bromine	
<b>FILLERS:</b>	N/A	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> N/A <b>ANSI:</b> 4101/25	<b>MIL-S-13949:</b> /04 - GF, GFG, GFN
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	150°C - 200°C	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/26	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy <b>Secondary 1:</b> Multifunctional epoxy	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	Bromine	<b>Minimum UL94 Requirement:</b> V-1
<b>FILLERS:</b>	N/A	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> FR-4 <b>ANSI:</b> FR-4/26	<b>MIL-S-13949:</b> /04 - GF, GFT
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	170°C - 220°C	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/27	
<b>REINFORCEMENT:</b>	<b>1:</b> Unidirectional E-glass, cross plied	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy <b>Secondary 1:</b> Multifunctional epoxy	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	Bromine	
<b>FILLERS:</b>	N/A	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> N/A <b>ANSI:</b> 4101/27	<b>MIL-S-13949:</b> N/A
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	110°C minimum	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/28	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy <b>Secondary 1:</b> (Non-epoxy)	<b>Secondary 2:</b> (Non-epoxy)
<b>FLAME RETARDANT MECHANISM:</b>	Bromine	
<b>FILLERS:</b>	N/A	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> N/A <b>ANSI:</b> 4101/28	<b>MIL-S-13949:</b> /04 - GFN, GFT
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	170°C - 220°C	

<b>SPECIFICATION SHEET #:</b>	IPC-4101/29	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy <b>Secondary 1:</b> Triazine	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	Bromine	
<b>FILLERS:</b>	N/A	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> N/A <b>ANSI:</b> 4101/29	<b>MIL-S-13949:</b> /04 - GFN, GFT
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	170°C - 220°C	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/30	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Bismaleimide/Triazine (BT) <b>Secondary 1:</b> Epoxy	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	Bromine	<b>Minimum UL94 Requirement:</b> HB
<b>FILLERS:</b>	N/A	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> GPY <b>ANSI:</b> GPY/30	<b>MIL-S-13949:</b> /26 - GIT
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	170°C - 220°C	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/40	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Polyimide <b>Secondary 1:</b> N/A	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	N/A	<b>Minimum UL94 Requirement:</b> HB
<b>FILLERS:</b>	With or without inorganic fillers	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> GPY <b>ANSI:</b> GPY/40	<b>MIL-S-13949:</b> /10 - GI, GIN, GIJ, GIP, GIL
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	200°C minimum	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/41	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Polyimide <b>Secondary 1:</b> N/A	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	N/A	<b>Minimum UL94 Requirement:</b> HB
<b>FILLERS:</b>	With or without inorganic fillers	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> GPY <b>ANSI:</b> GPY/41	<b>MIL-S-13949:</b> /10 - GIL, GIP
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	250°C minimum	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/42	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass	<b>2:</b> None
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Polyimide <b>Secondary 1:</b> Epoxy	<b>Secondary 2:</b> None
<b>FLAME RETARDANT MECHANISM:</b>	N/A	<b>Minimum UL94 Requirement:</b> HB
<b>FILLERS:</b>	With or without inorganic fillers	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> GPY <b>ANSI:</b> GPY/42	<b>MIL-S-13949:</b> /10 - GIJ
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	200°C - 250°C	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/50	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven aramid	<b>2:</b> None
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy <b>Secondary 1:</b> Multifunctional epoxy	<b>Secondary 2:</b> None
<b>FLAME RETARDANT MECHANISM:</b>	Bromine	
<b>FILLERS:</b>	None	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> N/A <b>ANSI:</b> 4101/50	<b>MIL-S-13949:</b> /15 - AF, AFN, AFG
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	150°C - 200°C	



<b>SPECIFICATION SHEET #:</b>	IPC-4101/53	
<b>REINFORCEMENT:</b>	<b>1:</b> Nonwoven aramid paper	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Polyimide <b>Secondary 1:</b> Epoxy	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	N/A	
<b>FILLERS:</b>	N/A	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> N/A <b>ANSI:</b> 4101/53	<b>MIL-S-13949:</b> /31 - BIN, BIL, BIJ
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	220°C minimum	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/54	
<b>REINFORCEMENT:</b>	<b>1:</b> Unidirectional aramid fiber, cross-plyed	<b>2:</b> None
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Cyanate ester <b>Secondary 1:</b> None	<b>Secondary 2:</b> None
<b>FLAME RETARDANT MECHANISM:</b>	Bromine	
<b>FILLERS:</b>	None	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> N/A <b>ANSI:</b> 4101/54	<b>MIL-S-13949:</b> N/A
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	230°C	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/55	
<b>REINFORCEMENT:</b>	<b>1:</b> Nonwoven aramid paper	<b>2:</b> None
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy <b>Secondary 1:</b> Multifunctional epoxy	<b>Secondary 2:</b> None
<b>FLAME RETARDANT MECHANISM:</b>	Bromine	
<b>FILLERS:</b>	None	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> N/A <b>ANSI:</b> 4101/55	<b>MIL-S-13949:</b> /22 - BF, BFN, BFG
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	150°C to 200°C	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/56	
<b>REINFORCEMENT:</b>	<b>1:</b> Nonwoven aramid paper	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Polyimide <b>Secondary 1:</b> N/A	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	N/A	
<b>FILLERS:</b>	N/A	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> N/A <b>ANSI:</b> 4101/56	<b>MIL-S-13949:</b> /31 - BIL
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	250°C minimum	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/60	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven quartz fiber	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Polyimide <b>Secondary 1:</b> N/A	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	Bromine (if applicable)	
<b>FILLERS:</b>	N/A	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> N/A <b>ANSI:</b> 4101/60	<b>MIL-S-13949:</b> /19 - QIL
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	250°C minimum	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/70	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven S-2 glass	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Cyanate ester <b>Secondary 1:</b> N/A	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	Bromine	
<b>FILLERS:</b>	N/A	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> N/A <b>ANSI:</b> 4101/70	<b>MIL-S-13949:</b> N/A
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	230°C minimum	

<b>SPECIFICATION SHEET #:</b>	IPC-4101/71	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Cyanate ester <b>Secondary 1:</b> N/A	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	Bromine	
<b>FILLERS:</b>	N/A	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> N/A <b>ANSI:</b> 4101/71	<b>MIL-S-13949:</b> /29 - GCN
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	230°C minimum	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/80	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass, surface	<b>2:</b> Cellulose paper, core
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy <b>Secondary 1:</b> Phenolic Bromine/Antimony oxide	<b>Secondary 2:</b> N/A <b>UL94 Requirement:</b> V-0
<b>FLAME RETARDANT MECHANISM:</b>	Kaolin and/or inorganic catalyst	
<b>FILLERS:</b>		
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> CEM-1 <b>ANSI:</b> CEM-1/80	<b>MIL-S-13949:</b> N/A
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	100°C minimum	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/81	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass, surface	<b>2:</b> Nonwoven E-glass (chopped felt), core
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy <b>Secondary 1:</b> Multifunctional epoxy	<b>Secondary 2:</b> N/A <b>UL94 Requirement:</b> V-0
<b>FLAME RETARDANT MECHANISM:</b>	Bromine	
<b>FILLERS:</b>	Kaolin and/or inorganic catalyst	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> CEM-3 <b>ANSI:</b> CEM-3/81	<b>MIL-S-13949:</b> N/A
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	N/A	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/82	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy <b>Secondary 1:</b> Multifunctional epoxy	<b>Secondary 2:</b> N/A <b>Minimum UL94 Requirement:</b> V-1
<b>FLAME RETARDANT MECHANISM:</b>	Bromine	
<b>FILLERS:</b>	Kaolin and/or inorganic catalyst	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> FR-4 <b>ANSI:</b> FR-4/82	<b>MIL-S-13949:</b> N/A
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	110°C minimum	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/83	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy <b>Secondary 1:</b> Multifunctional epoxy	<b>Secondary 2:</b> N/A <b>Minimum UL94 Requirement:</b> V-1
<b>FLAME RETARDANT MECHANISM:</b>	Bromine	
<b>FILLERS:</b>	Kaolin and/or inorganic catalyst	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> FR-4 <b>ANSI:</b> FR-4/83	<b>MIL-S-13949:</b> N/A
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	150°C - 200°C	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/90	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass, surface	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Polyphenylene ether <b>Secondary 1:</b> N/A	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	Bromine/Antimony oxide	
<b>FILLERS:</b>	N/A	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> N/A <b>ANSI:</b> 4101/90	<b>MIL-S-13949:</b> N/A
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	175°C minimum	

<b>SPECIFICATION SHEET #:</b>	IPC-4101/91	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Polyphenylene ether <b>Secondary 1:</b> N/A	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	Bromine	
<b>FILLERS:</b>	N/A	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> N/A <b>ANSI:</b> 4101/91	<b>MIL-S-13949:</b> N/A
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	175°C minimum	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/92	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy <b>Secondary 1:</b> Multifunctional epoxy	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	Phosphorous	<b>Minimum UL94 Requirement:</b> V-1
<b>FILLERS:</b>	N/A	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> FR-4 <b>ANSI:</b> FR-4/92	<b>MIL-S-13949:</b> N/A
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	110°C - 150°C	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/93	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy <b>Secondary 1:</b> Multifunctional epoxy	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	Aluminum hydroxide	<b>Minimum UL94 Requirement:</b> V-1
<b>FILLERS:</b>	N/A	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> FR-4 <b>ANSI:</b> FR-4/93	<b>MIL-S-13949:</b> N/A
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	110°C - 150°C	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/94	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy <b>Secondary 1:</b> Multifunctional epoxy	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	Phosphorous	<b>Minimum UL94 Requirement:</b> V-1
<b>FILLERS:</b>	N/A	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> FR-4 <b>ANSI:</b> FR-4/94	<b>MIL-S-13949:</b> N/A
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	150°C - 200°C	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/95	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy <b>Secondary 1:</b> Multifunctional epoxy	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	Aluminum hydroxide	<b>Minimum UL94 Requirement:</b> V-1
<b>FILLERS:</b>	N/A	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> FR-4 <b>ANSI:</b> FR-4/95	<b>MIL-S-13949:</b> N/A
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	150°C - 200°C	
<b>SPECIFICATION SHEET #:</b>	IPC-4101/96	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Polyphenylene ether <b>Secondary 1:</b> N/A	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	Non-Bromine/Non-Antimony	
<b>FILLERS:</b>	N/A	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> N/A <b>ANSI:</b> 4101/96	<b>MIL-S-13949:</b> N/A
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	175°C minimum	

---

<b>SPECIFICATION SHEET #:</b>	IPC-4101/97	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Difunctional epoxy <b>Secondary 1:</b> Multifunctional epoxy	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	Bromine	<b>Minimum UL94 Requirement:</b> V-1
<b>FILLERS:</b>	Inorganic fillers	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> FR-4 <b>ANSI:</b> FR-4/97	<b>MIL-S-13949:</b> /4 - GF, GFN, GFK, GFP, GFM
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	110°C to 150°C	

---

<b>SPECIFICATION SHEET #:</b>	IPC-4101/98	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy <b>Secondary 1:</b> Multifunctional epoxy	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	Bromine	<b>Minimum UL94 Requirement:</b> V-1
<b>FILLERS:</b>	Inorganic fillers	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> FR-4 <b>ANSI:</b> FR-4/98	<b>MIL-S-13949:</b> /04 - GF, GFG, GFN
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	150°C - 200°C	

---

**Revision Date: December 2001**

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/00				
<b>REINFORCEMENT:</b>	1: Cellulose paper		2: None		
<b>RESIN SYSTEM:</b>	Primary: Phenolic		Secondary 2: None		
	Secondary 1: None		UL94 Requirement: HB		
<b>FLAME RETARDANT MECHANISM:</b>	N/A				
<b>FILLERS:</b>	None				
<b>ID REFERENCE:</b>	UL/ANSI: XPC		MIL-S-13949: N/A		
	ANSI: XPC/00				
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	N/A				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	–	AABUS	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	–	1.05 [6.00]		2.4.8.2	
1. After thermal stress	–	–		2.4.8.3	
2. At 105°C [221°F]	–	–			
3. After process solutions	–	–			
C. All other foil – composite	–	AABUS			
2. Volume Resistivity, minimum					
A. After humidity conditioning	–	10 <sup>4</sup>	MΩ–cm	2.5.17.1	3.11.1.3
B. At elevated temperature	–	–			
3. Surface Resistivity, minimum					
A. After humidity conditioning	–	10 <sup>3</sup>	MΩ	2.5.17.1	3.11.1.4
B. At elevated temperature	–	–			
4. Moisture Absorption, maximum	–	1.3	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	15	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	–	5.6	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	–	0.07	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	82 [11,890]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	72 [10,440]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	–	–	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 260°C [500°F], minimum Note: Use peel specimen.	–	Pass Visual	rating	2.4.13.1	3.10.1.2
12. Electric Strength, minimum (Laminate & prepreg as laminated)	–	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	–	HB	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	–	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4110 or AABUS.				
3. Volatile content maximum	–	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Other	–				
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

## Revision Date: December 2001

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/01				
<b>REINFORCEMENT:</b>	1: Cellulose paper	2: None			
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Phenolic				
	<b>Secondary 1:</b> None	<b>Secondary 2:</b> None			
<b>FLAME RETARDANT MECHANISM:</b>	N/A	<b>UL94 Requirement:</b> HB			
<b>FILLERS:</b>	None				
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> XXXPC	<b>MIL-S-13949:</b> N/A			
	<b>ANSI:</b> XXXPC/01				
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	N/A				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very lowprofile copper foil – all copper foil >17µm [0.669 mil].	–	–	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	–	1.05 [6.00]		2.4.8.2	
1. After thermal stress	–	–		2.4.8.3	
2. At 105°C [221°F]	–	–			
3. After process solutions	–	–			
C. All other foil – composite	–	–			
2. Volume Resistivity, minimum					
A. C-96/35/90	–	10 <sup>4</sup>	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	–			
3. Surface Resistivity, minimum					
A. C-96/35/90	–	10 <sup>3</sup>	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	–			
4. Moisture Absorption, maximum	–	1.3	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	15	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	–	4.8	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	–	0.04	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	83 [12,040]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	72 [10,440]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	–	–	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 260°C [500°F], minimum Note: Use peel specimen.	–	Pass Visual	rating	2.4.13.1	3.10.1.2
12. Electric Strength, minimum (Laminate & prepreg as laminated)	–	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	–	HB	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	–	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4110 or AABUS.				
3. Volatile content maximum	–	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Other	–				
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

## Revision Date: December 2001

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/02				
<b>REINFORCEMENT:</b>	1: Cellulose paper	2: None			
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Phenolic				
	<b>Secondary 1:</b> None	<b>Secondary 2:</b> None			
<b>FLAME RETARDANT MECHANISM:</b>	Bromine/Chlorine	<b>Minimum UL94 Requirement:</b> V-1			
<b>FILLERS:</b>	None				
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> FR-1	<b>MIL-S-13949:</b> N/A			
	<b>ANSI:</b> FR-1/02				
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	N/A				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	–	–	N/mm [lb/in]	2.4.8 2.4.8.2 2.4.8.3	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	–	1.05 [6.00]			
1. After thermal stress	–	–			
2. At 105°C [221°F]	–	–			
3. After process solutions	–	–			
C. All other foil – composite	–	–			
2. Volume Resistivity, minimum					
A. C-96/35/90	–	10 <sup>3</sup>	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	–			
3. Surface Resistivity, minimum					
A. C-96/35/90	–	10 <sup>2</sup>	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	–			
4. Moisture Absorption, maximum	–	5.6	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	5.0	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	–	6.0	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	–	0.06	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	82 [11,890]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	69 [10,010]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	–	20	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s 260°C [500°F], minimum Note: Use peel specimen.	–	Pass Visual	rating	2.4.13.1	3.10.1.2
12. Electric Strength, minimum (Laminate & prepreg as laminated)	–	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	–	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	–	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4110 or AABUS.				
3. Volatile content maximum	–	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Other	–				
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

## Revision Date: December 2001

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/03				
<b>REINFORCEMENT:</b>	1: Cellulose paper	2: None			
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Phenolic				
	<b>Secondary 1:</b> None	<b>Secondary 2:</b> None			
<b>FLAME RETARDANT MECHANISM:</b>	Bromine/Chlorine	<b>Minimum UL94 Requirement:</b> V-1			
<b>FILLERS:</b>	None				
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> FR-2	<b>MIL-S-13949:</b> N/A			
	<b>ANSI:</b> FR-2/03				
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	N/A				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	–	–			
B. Standard profile copper foil					
1. After thermal stress	–	1.05 [6.00]	N/mm [lb/in]	2.4.8	3.9.1.1.1
2. At 105°C [221°F]	–	–			3.9.1.1.2
3. After process solutions	–	–			3.9.1.1.3
C. All other foil – composite	–	–			
2. Volume Resistivity, minimum					
A. C-96/35/90	–	10 <sup>3</sup>	MΩ-cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	–			
3. Surface Resistivity, minimum					
A. C-96/35/90	–	10 <sup>3</sup>	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	–			
4. Moisture Absorption, maximum	–	1.3	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	15	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	–	5.0	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	–	0.045	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	83 [12,040]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	72 [10,440]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	–	20	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s 260°C [500°F], minimum Note: Use peel specimen.	–	Pass Visual	rating	2.4.13.1	3.10.1.2
12. Electric Strength, minimum (Laminate & prepreg as laminated)	–	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	–	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	–	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4110 or AABUS.				
3. Volatile content maximum	–	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Other	–				
6. Other	–				

\*AABUS = As agreed upon between user and supplier.



## Revision Date: December 2001

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/04				
<b>REINFORCEMENT:</b>	1: Cellulose paper	2: None			
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy	<b>Secondary 1:</b> None			
	<b>Secondary 1:</b> None	<b>Secondary 2:</b> None			
<b>FLAME RETARDANT MECHANISM:</b>	Bromine/Chlorine/Antimony oxide	<b>Minimum UL94 Requirement:</b> V-1			
<b>FILLERS:</b>	None				
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> FR-3	<b>MIL-S-13949:</b> N/A			
	<b>ANSI:</b> FR-3/04				
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	N/A				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	–	–	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	–	1.25 [7.14]		2.4.8.2	
1. After thermal stress	–	0.80 [4.57]		2.4.8.3	
2. At 125°C [257°F]	–	–			
3. After process solutions	–	–			
C. All other foil – composite	–	–			
2. Volume Resistivity, minimum					
A. C-96/35/90	–	10 <sup>4</sup>	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	–			
3. Surface Resistivity, minimum					
A. C-96/35/90	–	10 <sup>3</sup>	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	–			
4. Moisture Absorption, maximum	–	1.0	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	30	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	–	4.8	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	–	0.04	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	138 [20,020]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	110 [16,950]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	–	20	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s 260°C [500°F], minimum					
A. Unetched	–	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	–	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	–	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	–	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	–	Days	AABUS	3.17	
2. Reinforcement	As per IPC-EG-140 or AABUS				
3. Volatile content maximum	–	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Other	–				
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

## Revision Date: December 2001

**SPECIFICATION SHEET**

<b>SPECIFICATION SHEET #:</b>	IPC-4101/10	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass, surface	<b>2:</b> Cellulose paper, core
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	<b>Secondary 1:</b> Phenolic	<b>UL94 Requirement:</b> V-0
<b>FILLERS:</b>	Bromine/Antimony oxide	
<b>ID REFERENCE:</b>	N/A	<b>MIL-S-13949:</b> N/A
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	<b>UL/ANSI:</b> CEM-1	
	<b>ANSI:</b> CEM-1/10	
	100°C minimum	

**LAMINATE REQUIREMENTS**

Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	–	–	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	–	1.05 [6.00]		2.4.8.2	
1. After thermal stress	–	–		2.4.8.3	
2. At 125°C [257°F]	–	–			
3. After process solutions	–	–			
C. All other foil – composite	–	–			
2. Volume Resistivity, minimum					
A. C-96/35/90	–	10 <sup>6</sup>	MΩ-cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	10 <sup>3</sup>			
3. Surface Resistivity, minimum					
A. C-96/35/90	–	10 <sup>4</sup>	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	10 <sup>3</sup>			
4. Moisture Absorption, maximum	–	0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	–	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	–	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	242 [35,100]**	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	172 [24,950]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	–	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s 260°C [500°F], minimum					
A. Unetched	–	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	–	–			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	–	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	–	V-0	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			

**PREPREG REQUIREMENTS**

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	–	Days	AABUS	3.17
2. Reinforcement	As per IPC-4110 and IPC-4412 or AABUS.			
3. Volatile content maximum	–	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7
5. Other	–			
6. Other	–			

\*AABUS = As agreed upon between user and supplier.

\*\*As measured on a 1.57 mm [0.06181 in] thick sample.

**Revision Date: December 2001**

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/11				
<b>REINFORCEMENT:</b>	1: Woven E-glass, surface		2: Nonwoven E-glass core		
<b>RESIN SYSTEM:</b>	Primary: Polyester		Secondary 2: N/A		
	Secondary 1: Vinyl ester				
<b>FLAME RETARDANT MECHANISM:</b>	Bromine				
<b>FILLERS:</b>	Inorganic fillers				
<b>ID REFERENCE:</b>	UL/ANSI: N/A		MIL-S-13949: N/A		
	ANSI: CRM-5/11				
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	N/A				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	–	–	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	–	0.90 [5.14]		2.4.8.2	
1. After thermal stress	–	AABUS		2.4.8.3	
2. At 125°C [257°F]	–	0.70 [4.00]			
3. After process solutions	–	–			
C. All other foil – composite	–	–			
2. Volume Resistivity, minimum					
A. C-96/35/90	–	10 <sup>7</sup>	MΩ-cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	–			
3. Surface Resistivity, minimum					
A. C-96/35/90	–	10 <sup>6</sup>	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	–			
4. Moisture Absorption, maximum	–	0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	–	4.1	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	–	0.022	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	241 [34,950]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	138 [20,020]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	–	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s 260°C [500°F], minimum					
A. Unetched	–	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	–	–			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	–	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	–	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	–	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 and IPC-4130 or AABUS.				
3. Volatile content maximum	–	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Other	–				
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

## Revision Date: December 2001

**SPECIFICATION SHEET**

<b>SPECIFICATION SHEET #:</b>	IPC-4101/12	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass, surface	<b>2:</b> Nonwoven E-glass core
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy	
	<b>Secondary 1:</b> N/A	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	Bromine	<b>UL94 Requirement:</b> V-0
<b>FILLERS:</b>	With or without inorganic fillers	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> CEM-3	<b>MIL-S-13949:</b> N/A
	<b>ANSI:</b> CEM-3/12	
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	N/A	

**LAMINATE REQUIREMENTS**

Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	–	–			
B. Standard profile copper foil				2.4.8	
1. After thermal stress	–	1.05 [6.00]	N/mm [lb/in]	2.4.8.2	3.9.1.1.1
2. At 105°C [221°F]	–	0.90 [5.14]		2.4.8.3	3.9.1.1.2
3. After process solutions	–	0.90 [5.14]			3.9.1.1.3
C. All other foil – composite	–	–			
2. Volume Resistivity, minimum					
A. C-96/35/90	–	10 <sup>6</sup>	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	10 <sup>3</sup>			
3. Surface Resistivity, minimum					
A. C-96/35/90	–	10 <sup>4</sup>	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	10 <sup>3</sup>			
4. Moisture Absorption, maximum	–	0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	–	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	–	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	276 [40,030]**	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	186 [26,980]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	–	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s 260°C [500°F], minimum					
A. Unetched	–	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	–	–			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	–	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	–	V-0	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			

**PREPREG REQUIREMENTS**

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	–	Days	AABUS	3.17
2. Reinforcement	As per IPC-4412 and IPC-4130 or AABUS.			
3. Volatile content maximum	–	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7
5. Other	–			
6. Other	–			

\*AABUS = As agreed upon between user and supplier.

\*\*As measured on a 1.57 mm [0.06181 in] thick sample.

**Revision Date: December 2001**

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/13				
<b>REINFORCEMENT:</b>	1: Woven E-glass		2: N/A		
<b>RESIN SYSTEM:</b>	Primary: Polyester		Secondary 2: N/A		
<b>FLAME RETARDANT MECHANISM:</b>	Bromine		Secondary 1: Vinyl ester		
<b>FILLERS:</b>	Inorganic fillers				
<b>ID REFERENCE:</b>	UL/ANSI: N/A		MIL-S-13949: N/A		
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	ANSI: 4101/13				
	N/A				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	AABUS	–	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil		–		2.4.8.2	
1. After thermal stress	0.70 [4.00]	–		2.4.8.3	
2. At 125°C [257°F]	0.60 [3.43]	–			
3. After process solutions	0.70 [4.00]	–			
C. All other foil – composite	AABUS	–			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 <sup>6</sup>	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	10 <sup>3</sup>	–			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 <sup>6</sup>	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	10 <sup>3</sup>	–			
4. Moisture Absorption, maximum	0.30	–	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	–	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	AABUS	–	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	AABUS	–	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	–			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	–	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	–	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	–			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	–	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	N/A	N/A	N/A	N/A	N/A
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	N/A	N/A	N/A	N/A	N/A
4. Prepreg Parameters	N/A	N/A	N/A	N/A	N/A
5. Other	N/A				
6. Other	N/A				

\*AABUS = As agreed upon between user and supplier.

## Revision Date: December 2001

**SPECIFICATION SHEET**

<b>SPECIFICATION SHEET #:</b>	IPC-4101/20	
<b>REINFORCEMENT:</b>	1: Woven E-glass	2: N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy	<b>Secondary 1:</b> N/A
	<b>Secondary 2:</b> N/A	<b>UL94 Requirement:</b> HB
<b>FLAME RETARDANT MECHANISM:</b>	N/A	
<b>FILLERS:</b>	N/A	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> G-10	<b>MIL-S-13949:</b> /03 - GE, GEN
	<b>ANSI:</b> G-10/20	
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	N/A	

**LAMINATE REQUIREMENTS**

Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	AABUS	AABUS	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	0.80 [4.57]	1.05 [6.00]		2.4.8.2	
1. After thermal stress	AABUS	0.70 [4.00]		2.4.8.3	
2. At 125°C [257°F]	AABUS	0.80 [4.57]			
3. After process solutions	AABUS	AABUS			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 <sup>6</sup>	–	MΩ-cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 <sup>6</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 <sup>4</sup>	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 <sup>4</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
4. Moisture Absorption, maximum	–	0.35	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	414 [60,050]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	HB	HB	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			

**PREPREG REQUIREMENTS**

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17
2. Reinforcement	As per IPC-4412 or AABUS.			
3. Volatile content maximum	–	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7
5. Flammability (as laminated)	HB	rating	UL94	3.10.2.1
6. Other	–			

\*AABUS = As agreed upon between user and supplier.



## Revision Date: December 2001

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/21				
<b>REINFORCEMENT:</b>	1: Woven E-glass		2: N/A		
<b>RESIN SYSTEM:</b>	Primary: Difunctional epoxy		Secondary 2: N/A		
	Secondary 1: Multifunctional epoxy		Minimum UL94 Requirement: V-1		
<b>FLAME RETARDANT MECHANISM:</b>	Bromine				
<b>FILLERS:</b>	N/A				
<b>ID REFERENCE:</b>	UL/ANSI: FR-4		MIL-S-13949: /04 - GF, GFN, GFK, GFP, GFM		
	ANSI: FR-4/21				
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	110°C to 150°C				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	0.70 [4.00]	0.70 [4.00]	N/mm [lb/in]	2.4.8 2.4.8.2 2.4.8.3	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil					
1. After thermal stress	0.80 [4.57]	1.05 [6.00]			
2. At 125°C [257°F]	0.70 [4.00]	0.70 [4.00]			
3. After process solutions	0.55 [3.14]	0.80 [4.57]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. 96/35/90	10 <sup>6</sup>	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 <sup>6</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
3. Surface Resistivity, minimum					
A. 96/35/90	10 <sup>4</sup>	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 <sup>4</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	0.75	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1	
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

## Revision Date: December 2001

**SPECIFICATION SHEET**

<b>SPECIFICATION SHEET #:</b>	IPC-4101/22	
<b>REINFORCEMENT:</b>	1: Woven E-glass	2: N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy, hot strength retention	<b>Secondary 2:</b> N/A
	<b>Secondary 1:</b> N/A	<b>UL94 Requirement:</b> HB
<b>FLAME RETARDANT MECHANISM:</b>	N/A	
<b>FILLERS:</b>	N/A	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> G-11	<b>MIL-S-13949:</b> /02 - GB, GBN, GBP
	<b>ANSI:</b> G-11/22	
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	135°C - 175°C	

**LAMINATE REQUIREMENTS**

Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	AABUS	AABUS	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil				2.4.8.2	
1. After thermal stress	1.05 [6.00]	1.45 [8.28]		2.4.8.3	
2. At 150°C [302°F]	0.80 [4.57]	0.90 [5.14]			
3. After process solutions	0.80 [4.57]	0.90 [5.14]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. After humidity conditioning	10 <sup>6</sup>	10 <sup>4</sup>	MΩ-cm	2.5.17.1	3.11.1.3
B. At elevated temperature (150°C [302°F])	10 <sup>3</sup>	10 <sup>3</sup>			
3. Surface Resistivity, minimum					
A. After humidity conditioning	10 <sup>4</sup>	–	MΩ	2.5.17.1	3.11.1.4
B. At elevated temperature (150°C [302°F])	– 10 <sup>3</sup>	10 <sup>4</sup> 10 <sup>3</sup>			
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	415 [60,190]	415 [60,190]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	345 [50,040]	345 [50,040]			
9. Flexural Strength at Elevated Temperature 150°C, length direction, minimum	207 [30,020]	207 [30,020]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	HB	HB	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			

**PREPREG REQUIREMENTS**

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17
2. Reinforcement	As per IPC-4412 or AABUS.			
3. Volatile content maximum	–	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7
5. Flammability (as laminated)	HB	rating	UL94	3.10.2.1
6. Other	–			

## Revision Date: December 2001

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/23				
<b>REINFORCEMENT:</b>	1: Woven E-glass		2: N/A		
<b>RESIN SYSTEM:</b>	Primary: Epoxy, hot strength retention		Secondary 2: N/A		
	Secondary 1: N/A		Minimum UL94 Requirement: V-1		
<b>FLAME RETARDANT MECHANISM:</b>	Bromine				
<b>FILLERS:</b>	N/A				
<b>ID REFERENCE:</b>	UL/ANSI: FR-5		MIL-S-13949: /05 - GH, GHN, GHP		
	ANSI: FR-5/23				
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	135°C - 185°C				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	AABUS	AABUS	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil				2.4.8.2	
1. After thermal stress	1.05 [6.00]	1.45 [8.28]		2.4.8.3	
2. At 150°C [302°F]	0.80 [4.57]	0.90 [5.14]			
3. After process solutions	0.80 [4.57]	0.90 [5.14]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. After humidity conditioning	10 <sup>6</sup>	10 <sup>4</sup>	MΩ-cm	2.5.17.1	3.11.1.3
B. At elevated temperature (150°C [302°F])	10 <sup>3</sup>	10 <sup>3</sup>			
3. Surface Resistivity, minimum					
A. After humidity conditioning	10 <sup>4</sup>	10 <sup>4</sup>	MΩ	2.5.17.1	3.11.1.4
B. At elevated temperature (150°C [302°F])	10 <sup>3</sup>	10 <sup>3</sup>			
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature 150°C, length direction, minimum	–	207 [30,020]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	0.75	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1	
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

## Revision Date: December 2001

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/24				
<b>REINFORCEMENT:</b>	1: Woven E-glass	2: N/A			
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy	<b>Secondary 1:</b> Multifunctional epoxy		<b>Secondary 2:</b> N/A	
<b>FLAME RETARDANT MECHANISM:</b>	Bromine			<b>Minimum UL94 Requirement:</b> V-1	
<b>FILLERS:</b>	N/A				
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> FR-4	<b>ANSI:</b> FR-4/24		<b>MIL-S-13949:</b> /04 - GF, GFG, GFN	
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	150°C - 200°C				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	0.70 [4.00]	0.70 [4.00]	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil				2.4.8.2	
1. After thermal stress	0.80 [4.57]	1.05 [6.00]		2.4.8.3	
2. At 125°C [257°F]	0.70 [4.00]	0.70 [4.00]			
3. After process solutions	0.55 [3.14]	0.80 [4.57]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 <sup>6</sup>	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 <sup>4</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 <sup>4</sup>	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 <sup>4</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	1.5	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1	
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

## Revision Date: December 2001

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/25				
<b>REINFORCEMENT:</b>	1: Woven E-glass		2: N/A		
<b>RESIN SYSTEM:</b>	Primary: Epoxy		Secondary 2: N/A		
<b>FLAME RETARDANT MECHANISM:</b>	Bromine		Secondary 1: Polyphenylene oxide		
<b>FILLERS:</b>	N/A				
<b>ID REFERENCE:</b>	UL/ANSI: N/A		MIL-S-13949: /04 - GF, GFG, GFN		
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	150°C - 200°C		ANSI: 4101/25		
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	0.70 [4.00]	0.70 [4.00]	N/mm [lb/in]	2.4.8 2.4.8.2 2.4.8.3	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil					
1. After thermal stress	0.80 [4.57]	1.05 [6.00]			
2. At 125°C [257°F]	0.70 [4.00]	0.70 [4.00]			
3. After process solutions	0.55 [3.14]	0.80 [4.57]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 <sup>6</sup>	–	MΩ-cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 <sup>6</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 <sup>4</sup>	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 <sup>4</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	4.4	4.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	0.5	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1	
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

## Revision Date: December 2001

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/26				
<b>REINFORCEMENT:</b>	1: Woven E-glass		2: N/A		
<b>RESIN SYSTEM:</b>	Primary: Epoxy		Secondary 2: N/A		
<b>FLAME RETARDANT MECHANISM:</b>	Bromine		Minimum UL94 Requirement: V-1		
<b>FILLERS:</b>	N/A				
<b>ID REFERENCE:</b>	UL/ANSI: FR-4		MIL-S-13949: /04 - GF, GFT		
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	170°C - 220°C		ANSI: FR-4/26		
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	0.70 [4.00]	0.70 [4.00]	N/mm [lb/in]	2.4.8 2.4.8.2 2.4.8.3	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil					
1. After thermal stress	0.80 [4.57]	1.05 [6.00]			
2. At 125°C [257°F]	0.70 [4.00]	0.70 [4.00]			
3. After process solutions	0.55 [3.14]	0.80 [4.57]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 <sup>6</sup>	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 <sup>6</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 <sup>4</sup>	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 <sup>4</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	4.3	4.5	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.025	0.025	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	0.5	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1	
6. Other	–				

\*AABUS = As agreed upon between user and supplier.



**Revision Date: December 2001**

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/27				
<b>REINFORCEMENT:</b>	1: Unidirectional E-glass, cross plied		2: N/A		
<b>RESIN SYSTEM:</b>	Primary: Epoxy		Secondary 2: N/A		
	Secondary 1: Multifunctional epoxy		Secondary 2: N/A		
<b>FLAME RETARDANT MECHANISM:</b>	Bromine				
<b>FILLERS:</b>	N/A				
<b>ID REFERENCE:</b>	UL/ANSI: N/A		MIL-S-13949: N/A		
	ANSI: 4101/27				
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	110°C minimum				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	0.70 [4.00]	0.70 [4.00]	N/mm [lb/in]	2.4.8 2.4.8.2 2.4.8.3	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil					
1. After thermal stress	0.80 [4.57]	1.05 [6.00]			
2. At 125°C [257°F]	0.70 [4.00]	0.70 [4.00]			
3. After process solutions	0.55 [3.14]	0.80 [4.57]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 <sup>6</sup>	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 <sup>6</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 <sup>4</sup>	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 <sup>4</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.030	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	294 [42,640]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	294 [42,640]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	–	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	–	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1	
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

## Revision Date: December 2001

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/28				
<b>REINFORCEMENT:</b>	1: Woven E-glass		2: N/A		
<b>RESIN SYSTEM:</b>	Primary: Epoxy		Secondary 2: (Non-epoxy)		
<b>FLAME RETARDANT MECHANISM:</b>	Bromine		Secondary 1: (Non-epoxy)		
<b>FILLERS:</b>	N/A				
<b>ID REFERENCE:</b>	UL/ANSI: N/A		MIL-S-13949: /04 - GFN, GFT		
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	170°C - 220°C		ANSI: 4101/28		
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	0.70 [4.00]	0.70 [4.00]	N/mm [lb/in]	2.4.8 2.4.8.2 2.4.8.3	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil					
1. After thermal stress	0.80 [4.57]	1.05 [6.00]			
2. At 125°C [257°F]	0.70 [4.00]	0.70 [4.00]			
3. After process solutions	0.55 [3.14]	0.80 [4.57]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. After humidity conditioning	10 <sup>6</sup>	10 <sup>6</sup>	MΩ-cm	2.5.17.1	3.11.1.3
B. At elevated temperature	10 <sup>3</sup>	10 <sup>3</sup>			
3. Surface Resistivity, minimum					
A. After humidity conditioning	10 <sup>4</sup>	10 <sup>4</sup>	MΩ	2.5.17.1	3.11.1.4
B. At elevated temperature	10 <sup>3</sup>	10 <sup>3</sup>			
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.030	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	0.5	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1	
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

**Revision Date: December 2001**

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/29				
<b>REINFORCEMENT:</b>	1: Woven E-glass		2: N/A		
<b>RESIN SYSTEM:</b>	Primary: Epoxy		Secondary 2: N/A		
	Secondary 1: Triazine				
<b>FLAME RETARDANT MECHANISM:</b>	Bromine				
<b>FILLERS:</b>	N/A				
<b>ID REFERENCE:</b>	UL/ANSI: N/A		MIL-S-13949: /04 - GFN, GFT		
	ANSI: 4101/29				
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	170°C - 220°C				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper weights >17 microns.	0.70 [4.00]	0.70 [4.00]	N/mm [lb/in]	2.4.8 2.4.8.2 2.4.8.3	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil					
1. After Thermal Stress	0.80 [4.57]	1.05 [6.00]			
2. At 125°C	0.70 [4.00]	0.70 [4.00]			
3. After Process Solutions	0.55 [3.14]	0.80 [4.57]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 <sup>6</sup>	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 <sup>6</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 <sup>4</sup>	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 <sup>4</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & Prepreg as laminated)	4.4	4.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & Prepreg as laminated)	0.015	0.015	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 Sec at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & Prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & Prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, maximum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-EG-140				
3. Volatile content maximum	2.2	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1	
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

## Revision Date: December 2001

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/30				
<b>REINFORCEMENT:</b>	1: Woven E-glass		2: N/A		
<b>RESIN SYSTEM:</b>	Primary: Bismaleimide/Triazine (BT)		Secondary 2: N/A		
<b>FLAME RETARDANT MECHANISM:</b>	Bromine		Minimum UL94 Requirement: HB		
<b>FILLERS:</b>	N/A				
<b>ID REFERENCE:</b>	UL/ANSI: GPY		MIL-S-13949: /26 - GIT		
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	170°C - 220°C		ANSI: GPY/30		
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	0.55 [3.14]	0.55 [3.14]	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil				2.4.8.2	
1. After thermal stress	0.90 [5.14]	0.90 [5.14]		2.4.8.3	
2. At 150°C [302°F]	0.35 [2.00]	0.35 [2.00]			
3. After process solutions	0.70 [4.00]	0.70 [4.00]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 <sup>6</sup>	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 <sup>6</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 <sup>6</sup>	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 <sup>6</sup>			
C. At elevated temperature E-24/125	10 <sup>5</sup>	10 <sup>5</sup>			
4. Moisture Absorption, maximum	–	0.35	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	4.8	4.8	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.020	0.020	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	369 [53,520]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	325 [47,140]			
9. Flexural Strength at Elevated Temperature, E1/150, length direction, minimum	–	207 [30,020]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability** (Laminate & prepreg as laminated)	HB	HB	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	2.0	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability** (as laminated)	HB	rating	UL94	3.10.2.1	
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

\*\*Tested for qualification as a minimum requirement. Conformance testing AABUS.

**Revision Date: December 2001**

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/40				
<b>REINFORCEMENT:</b>	1: Woven E-glass		2: N/A		
<b>RESIN SYSTEM:</b>	UL/ANSI: GPY Primary: Polyimide		Secondary 2: N/A		
<b>FLAME RETARDANT MECHANISM:</b>	N/A		Secondary 1: N/A Minimum UL94 Requirement: HB		
<b>FILLERS:</b>	With or without inorganic fillers				
<b>ID REFERENCE:</b>	ANSI: GPY/40		MIL-S-13949: /10 - GI, GIN, GIJ, GIP, GIL		
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	200°C minimum				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	AABUS	AABUS	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil				2.4.8.2	
1. After thermal stress	0.90 [5.14]	0.90 [5.14]		2.4.8.3	
2. At 125°C [257°F]	0.70 [4.00]	0.70 [4.00]			
3. After process solutions	0.80 [4.57]	0.95 [5.42]			
C. All other foil – composite	–	–			
2. Volume Resistivity, minimum					
A. After humidity conditioning	6 x 10 <sup>4</sup>	10 <sup>6</sup>	MΩ–cm	2.5.17.1	3.11.1.3
B. At elevated temperature (204°C [399.2°F])	6 x 10 <sup>4</sup>	10 <sup>6</sup>			
3. Surface Resistivity, minimum					
A. After humidity conditioning	10 <sup>4</sup>	10 <sup>6</sup>	MΩ	2.5.17.1	3.11.1.4
B. At elevated temperature (204°C [399.2°F])	10 <sup>4</sup>	10 <sup>6</sup>			
4. Moisture Absorption, maximum	–	0.50 ≤ t < 1.55 mm 1.0 1.55 ≤ t ≤ 6.35 mm 0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	325 [47,140]			
9. Flexural Strength at Elevated Temperature, E1/204, length direction, minimum	–	311 [45,110]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	120	120	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability** (Laminate & prepreg as laminated)	HB	HB	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	4.0	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability** (as laminated)	HB	rating	UL94	3.10.2.1	
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

\*\*Tested for qualification as a minimum requirement. Conformance testing AABUS.

## Revision Date: December 2001

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/41				
<b>REINFORCEMENT:</b>	1: Woven E-glass		2: N/A		
<b>RESIN SYSTEM:</b>	Primary: Polyimide		Secondary 2: N/A		
	Secondary 1: N/A		Minimum UL94 Requirement: HB		
<b>FLAME RETARDANT MECHANISM:</b>	N/A				
<b>FILLERS:</b>	With or without inorganic fillers				
<b>ID REFERENCE:</b>	UL/ANSI: GPY		MIL-S-13949: /10 - GIL, GIP		
	ANSI: GPY/41				
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	250°C minimum				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	AABUS	AABUS	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil				2.4.8.2	
1. After thermal stress	0.70 [4.00]	0.80 [4.57]		2.4.8.3	
2. At 125°C [257°F]	0.60 [3.43]	0.70 [4.00]			
3. After process solutions	0.60 [3.43]	0.70 [4.00]			
C. All other foil – composite	–	–			
2. Volume Resistivity, minimum					
A. After humidity conditioning	6 x 10 <sup>4</sup>	10 <sup>6</sup>	MΩ–cm	2.5.17.1	3.11.1.3
B. At elevated temperature (204°C [399.2°F])	6 x 10 <sup>4</sup>	10 <sup>6</sup>			
3. Surface Resistivity, minimum					
A. After humidity conditioning	10 <sup>4</sup>	10 <sup>6</sup>	MΩ	2.5.17.1	3.11.1.4
B. At elevated temperature (204°C [399.2°F])	10 <sup>4</sup>	10 <sup>6</sup>			
4. Moisture Absorption, maximum	–	0.50 ≤ t < 1.55 mm 1.0 1.55 ≤ t ≤ 6.35 mm 0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	325 [47,140]			
9. Flexural Strength at Elevated Temperature, E1/204, length direction, minimum	–	311 [45,110]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	120	120	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability** (Laminate & prepreg as laminated)	HB	HB	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	4.0	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability** (as laminated)	HB	rating	UL94	3.10.2.1	
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

\*\*Tested for qualification as a minimum requirement. Conformance testing AABUS.



**Revision Date: December 2001**

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/42				
<b>REINFORCEMENT:</b>	1: Woven E-glass		2: None		
<b>RESIN SYSTEM:</b>	Primary: Polyimide		Secondary 2: None		
<b>FLAME RETARDANT MECHANISM:</b>	N/A		Minimum UL94 Requirement: HB		
<b>FILLERS:</b>	With or without inorganic fillers				
<b>ID REFERENCE:</b>	UL/ANSI: GPY		MIL-S-13949: /10 - GIJ		
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	200°C - 250°C		ANSI: GPY/42		
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	AABUS	AABUS	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil				2.4.8.2	
1. After thermal stress	0.90 [5.14]	0.90 [5.14]		2.4.8.3	
2. At 170°C [338°F]	0.70 [4.00]	0.70 [4.00]			
3. After process solutions	0.80 [4.57]	0.95 [5.42]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. After humidity conditioning	6 x 10 <sup>4</sup>	10 <sup>6</sup>	MΩ–cm	2.5.17.1	3.11.1.3
B. At elevated temperature (204°C [399.2°F])	6 x 10 <sup>4</sup>	10 <sup>6</sup>			
3. Surface Resistivity, minimum					
A. After humidity conditioning	10 <sup>4</sup>	10 <sup>6</sup>	MΩ	2.5.17.1	3.11.1.4
B. At elevated temperature (204°C [399.2°F])	10 <sup>4</sup>	10 <sup>6</sup>			
4. Moisture Absorption, maximum	–	0.50 ≤ t < 1.55 mm 1.0 1.55 ≤ t ≤ 6.35 mm 0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	325 [47,140]			
9. Flexural Strength at Elevated Temperature, E1/204, length direction, minimum	–	311 [45,110]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	120	120	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability** (Laminate & prepreg as laminated)	HB	HB	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	4.0	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability** (as laminated)	HB	rating	UL94	3.10.2.1	
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

\*\*Tested for qualification as a minimum requirement. Conformance testing AABUS.

**Revision Date: December 2001**

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/50				
<b>REINFORCEMENT:</b>	1: Woven aramid	2: None			
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy <b>Secondary 1:</b> Multifunctional epoxy		<b>Secondary 2:</b> None		
<b>FLAME RETARDANT MECHANISM:</b>	Bromine				
<b>FILLERS:</b>	None				
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> N/A <b>ANSI:</b> 4101/50		<b>MIL-S-13949:</b> /15 - AF, AFN, AFG		
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	150°C - 200°C				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil]. B. Standard profile copper foil 1. After thermal stress 2. At 125°C [257°F] 3. After process solutions C. All other foil – composite	AABUS  0.70 [4.00] 0.60 [3.43] 0.55 [3.14] AABUS	AABUS  0.80 [4.57] 0.70 [4.00] 0.70 [4.00] AABUS	N/mm [lb/in]	2.4.8 2.4.8.2 2.4.8.3	3.9.1.1  3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
2. Volume Resistivity, minimum A. C-96/35/90 B. After moisture resistance C. At elevated temperature E-24/125	10 <sup>6</sup> – 10 <sup>3</sup>	10 <sup>6</sup> – 10 <sup>3</sup>	MΩ-cm	2.5.17.1	3.11.1.3
3. Surface Resistivity, minimum A. C-96/35/90 B. After moisture resistance C. At elevated temperature E-24/125	10 <sup>4</sup> – 10 <sup>3</sup>	10 <sup>4</sup> – 10 <sup>3</sup>	MΩ	2.5.17.1	3.11.1.4
4. Moisture Absorption, maximum	–	2.0	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	4.5	4.5	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum A. Length direction B. Cross direction	– –	345 [50,040] 277 [40,180]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum A. Unetched B. Etched	Pass Visual Pass Visual	Pass Visual Pass Visual	rating	2.4.13.1	3.10.1.2
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Opaque Foreign Inclusions ≤508 microns as per area, max ≤508 microns as per area, max ≤508 microns ≤1016 as per area, max >1016 microns as per area, max	16 4 2 0	16 4 2 0	Counts Counts Counts Counts	–	3.8.3.1.7
15. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	0.75	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1	
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

## Revision Date: December 2001

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/53				
<b>REINFORCEMENT:</b>	1: Nonwoven aramid paper		2: N/A		
<b>RESIN SYSTEM:</b>	Primary: Polyimide		Secondary 2: N/A		
	Secondary 1: Epoxy				
<b>FLAME RETARDANT MECHANISM:</b>	N/A				
<b>FILLERS:</b>	N/A				
<b>ID REFERENCE:</b>	UL/ANSI: N/A		MIL-S-13949: /31 - BIN, BIL, BIJ		
	ANSI: 4101/53				
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	220°C minimum				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	AABUS	AABUS	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil				2.4.8.2	
1. After thermal stress	0.55 [3.14]	0.55 [3.14]		2.4.8.3	
2. At 125°C [257°F]	0.50 [2.86]	0.50 [2.86]			
3. After process solutions	0.50 [2.86]	0.50 [2.86]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. After moisture resistance	10 <sup>6</sup>	10 <sup>6</sup>	MΩ–cm	2.5.17.1	3.11.1.3
B. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
3. Surface Resistivity, minimum					
A. After moisture resistance	10 <sup>4</sup>	10 <sup>4</sup>	MΩ	2.5.17.1	3.11.1.4
B. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
4. Moisture Absorption, maximum	–	3.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	4.5	4.5	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	207 [30,020]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	207 [30,020]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability** (Laminate & prepreg as laminated)	HB minimum	HB minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	DAYS	AABUS	3.17	
2. Reinforcement	As per IPC-4411 or AABUS.				
3. Volatile content maximum	2.5%	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability** (as laminated)	HB	rating	UL94	3.10.2.1	
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

\*\*Tested for qualification as a minimum requirement. Conformance testing AABUS.

## Revision Date: December 2001

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/54				
<b>REINFORCEMENT:</b>	1: Unidirectional aramid fiber, cross-plyed 2: None				
<b>RESIN SYSTEM:</b>	Primary: Cyanate ester Secondary 1: None Secondary 2: None				
<b>FLAME RETARDANT MECHANISM:</b>	Bromine				
<b>FILLERS:</b>	None				
<b>ID REFERENCE:</b>	UL/ANSI: N/A MIL-S-13949: N/A ANSI: 4101/54				
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	230°C				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil]. B. Standard profile copper foil 1. After thermal stress 2. At 170°C [338°F] 3. After process solutions C. All other foil – composite	AABUS  0.70 [4.00] AABUS 0.60 [3.43] AABUS	AABUS  0.70 [4.00] AABUS 0.60 [3.43] AABUS	N/mm [lb/in]	2.4.8 2.4.8.2 2.4.8.3	3.9.1.1  3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
2. Volume Resistivity, minimum A. C-96/35/90 B. After moisture resistance C. At elevated temperature E-24/125	6 x 10 <sup>4</sup> – 10 <sup>3</sup>	6 x 10 <sup>4</sup> – 10 <sup>3</sup>	MΩ-cm	2.5.17.1	3.11.1.3
3. Surface Resistivity, minimum A. C-96/35/90 B. After moisture resistance C. At elevated temperature E-24/125	10 <sup>4</sup> – 10 <sup>3</sup>	10 <sup>4</sup> – 10 <sup>3</sup>	MΩ	2.5.17.1	3.11.1.4
4. Moisture Absorption, maximum	–	2.0	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	4.2	4.2	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.025	0.025	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum A. Length direction B. Cross direction	– –	345 [50,040] 277 [40,180]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum A. Unetched B. Etched	Pass Visual Pass Visual	Pass Visual Pass Visual	rating	2.4.13.1	3.10.1.2
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4411 or AABUS.				
3. Volatile content maximum	1.5	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1	
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

## Revision Date: December 2001

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/55				
<b>REINFORCEMENT:</b>	1: Nonwoven aramid paper		2: None		
<b>RESIN SYSTEM:</b>	Primary: Epoxy		Secondary 1: Multifunctional epoxy		
<b>FLAME RETARDANT MECHANISM:</b>	Bromine		Secondary 2: None		
<b>FILLERS:</b>	None				
<b>ID REFERENCE:</b>	UL/ANSI: N/A		MIL-S-13949: /22 - BF, BFN, BFG		
<b>ANSI:</b>	4101/55				
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	150°C to 200°C				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	AABUS	AABUS	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil				2.4.8.2	
1. After thermal stress	0.55 [3.14]	0.55 [3.14]		2.4.8.3	
2. At 125°C [257°F]	0.50 [2.86]	0.50 [2.86]			
3. After process solutions	0.50 [2.86]	0.50 [2.86]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 <sup>6</sup>	10 <sup>6</sup>	MΩ-cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 <sup>4</sup>	10 <sup>4</sup>	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
4. Moisture Absorption, maximum	–	2.0	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	4.5	4.5	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	277 [40,180]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	277 [40,180]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	DAYS	AABUS	3.17	
2. Reinforcement	As per IPC-4411 or AABUS.				
3. Volatile content maximum	1.5	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1	
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

## Revision Date: December 2001

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/56				
<b>REINFORCEMENT:</b>	1: Nonwoven aramid paper		2: N/A		
<b>RESIN SYSTEM:</b>	Primary: Polyimide		Secondary 2: N/A		
	Secondary 1: N/A				
<b>FLAME RETARDANT MECHANISM:</b>	N/A				
<b>FILLERS:</b>	N/A				
<b>ID REFERENCE:</b>	UL/ANSI: N/A		MIL-S-13949: /31 - BIL		
	ANSI: 4101/56				
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	250°C minimum				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	AABUS	AABUS	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil				2.4.8.2	
1. After thermal stress	0.55 [3.14]	0.55 [3.14]		2.4.8.3	
2. At 125°C [257°F]	0.50 [2.86]	0.50 [2.86]			
3. After process solutions	0.50 [2.86]	0.50 [2.86]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. After moisture resistance	10 <sup>6</sup>	10 <sup>6</sup>	MΩ–cm	2.5.17.1	3.11.1.3
B. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
3. Surface Resistivity, minimum					
A. After moisture resistance	10 <sup>4</sup>	10 <sup>4</sup>	MΩ	2.5.17.1	3.11.1.4
B. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
4. Moisture Absorption, maximum	–	3.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	4.5	4.5	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	207 [30,020]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	207 [30,020]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability** (Laminate & prepreg as laminated)	HB minimum	HB minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4411 or AABUS.				
3. Volatile content maximum	2.5%	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability** (as laminated)	HB	rating	UL94	3.10.2.1	
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

\*\*Tested for qualification as a minimum requirement. Conformance testing AABUS.



## Revision Date: December 2001

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/60				
<b>REINFORCEMENT:</b>	1: Woven quartz fiber		2: N/A		
<b>RESIN SYSTEM:</b>	Primary: Polyimide		Secondary 2: N/A		
	Secondary 1: N/A				
<b>FLAME RETARDANT MECHANISM:</b>	Bromine (if applicable)				
<b>FILLERS:</b>	N/A				
<b>ID REFERENCE:</b>	UL/ANSI: N/A		MIL-S-13949: /19 - QIL		
	ANSI: 4101/60				
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	250°C minimum				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	AABUS	AABUS	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil				2.4.8.2	
1. After thermal stress	0.90 [5.14]	1.05 [6.00]		2.4.8.3	
2. At 125°C [257°F]	0.70 [4.00]	0.70 [4.00]			
3. After process solutions	0.80 [4.57]	0.95 [5.42]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	6 x 10 <sup>4</sup>	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 <sup>6</sup>			
C. At elevated temperature E-24/125	6 x 10 <sup>4</sup>	10 <sup>6</sup>			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 <sup>4</sup>	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 <sup>6</sup>			
C. At elevated temperature E-24/125	6 x 10 <sup>4</sup>	10 <sup>6</sup>			
4. Moisture Absorption, maximum	–	1.0	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	3.4	3.8	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.010	0.010	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	311 [45,110]			
9. Flexural Strength at Elevated Temperature 204°C, length direction, minimum	–	311 [45,110]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	120	120	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability** (Laminate & prepreg as laminated)	HB minimum	HB minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-QF-143 or AABUS.				
3. Volatile content maximum	1.5	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability** (as laminated)	HB	rating	UL94	3.10.2.1	
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

\*\*Tested for qualification as a minimum requirement. Conformance testing AABUS.

## Revision Date: December 2001

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/70				
<b>REINFORCEMENT:</b>	1: Woven S-2 glass		2: N/A		
<b>RESIN SYSTEM:</b>	Primary: Cyanate ester		Secondary 2: N/A		
<b>FLAME RETARDANT MECHANISM:</b>	Bromine		Secondary 1: N/A		
<b>FILLERS:</b>	N/A		Secondary 2: N/A		
<b>ID REFERENCE:</b>	UL/ANSI: N/A		MIL-S-13949: N/A		
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	ANSI: 4101/70				
	230°C minimum				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	AABUS	AABUS	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil				2.4.8.2	
1. After thermal stress	0.70 [4.00]	0.70 [4.00]		2.4.8.3	
2. At 170°C [338°F]	0.70 [4.00]	0.70 [4.00]			
3. After process solutions	0.70 [4.00]	0.70 [4.00]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 <sup>6</sup>	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 <sup>6</sup>			
C. At elevated temperature E-24/204	10 <sup>4</sup>	10 <sup>3</sup>			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 <sup>6</sup>	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 <sup>6</sup>			
C. At elevated temperature E-24/204	6 x 10 <sup>4</sup>	10 <sup>5</sup>			
4. Moisture Absorption, maximum	–	3.0	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	4.3	4.3	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.015	0.015	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	345 [50,040]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature 204°C, length direction, minimum	–	277 [40,180]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	120	120	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	–	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-SG-141 or AABUS.				
3. Volatile content maximum	1.5	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1	
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

## Revision Date: December 2001

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/71				
<b>REINFORCEMENT:</b>	1: Woven E-glass		2: N/A		
<b>RESIN SYSTEM:</b>	Primary: Cyanate ester		Secondary 2: N/A		
	Secondary 1: N/A				
<b>FLAME RETARDANT MECHANISM:</b>	Bromine				
<b>FILLERS:</b>	N/A				
<b>ID REFERENCE:</b>	UL/ANSI: N/A		MIL-S-13949: /29 - GCN		
	ANSI: 4101/71				
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	230°C minimum				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	AABUS	AABUS	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil				2.4.8.2	
1. After thermal stress	0.70 [4.00]	0.70 [4.00]		2.4.8.3	
2. At 125°C [257°F]	0.70 [4.00]	0.70 [4.00]			
3. After process solutions	0.70 [4.00]	0.70 [4.00]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 <sup>6</sup>	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 <sup>6</sup>			
C. At elevated temperature E-24/204	10 <sup>4</sup>	10 <sup>3</sup>			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 <sup>6</sup>	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 <sup>6</sup>			
C. At elevated temperature E-24/204	10 <sup>4</sup>	10 <sup>6</sup>			
4. Moisture Absorption, maximum	–	1.0	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	40	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	4.5	4.5	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.015	0.015	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	345 [50,040]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature 204°C, length direction, minimum	–	277 [40,180]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	120	120	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-EG-140 or AABUS.				
3. Volatile content maximum	1.5	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1	
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

## Revision Date: December 2001

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/80				
<b>REINFORCEMENT:</b>	1: Woven E-glass, surface		2: Cellulose paper, core		
<b>RESIN SYSTEM:</b>	Primary: Epoxy		Secondary 2: N/A		
<b>FLAME RETARDANT MECHANISM:</b>	Bromine/Antimony oxide		Secondary 1: Phenolic		
<b>FILLERS:</b>	Kaolin and/or inorganic catalyst		UL94 Requirement: V-0		
<b>ID REFERENCE:</b>	UL/ANSI: CEM-1		MIL-S-13949: N/A		
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	ANSI: CEM-1/80		100°C minimum		
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	–	–	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	–	–		2.4.8.2	
1. After thermal stress	–	–		2.4.8.3	
2. At 125°C [257°F]	–	–			
3. After process solutions	–	–			
C. All other foil – composite	-	-			
2. Volume Resistivity, minimum					
A. C-96/35/90	–	10 <sup>6</sup>	MΩ-cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	-	10 <sup>3</sup>			
3. Surface Resistivity, minimum					
A. C-96/35/90	–	10 <sup>4</sup>	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	-	10 <sup>3</sup>			
4. Moisture Absorption, maximum	–	0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	–	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	–	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	242 [35,100]**	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	172 [24,950]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	–	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	–	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	–	–			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	–	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-0	V-0	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-EG-140 or AABUS.				
3. Volatile content maximum	–	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Other	–				
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

\*\*As measured on a 1.57 mm [0.06181 in] thick sample.

**Revision Date: December 2001**

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/81				
<b>REINFORCEMENT:</b>	1: Woven E-glass, surface		2: Nonwoven E-glass (chopped felt), core		
<b>RESIN SYSTEM:</b>	Primary: Epoxy		Secondary 2: N/A		
<b>FLAME RETARDANT MECHANISM:</b>	Bromine		Secondary 1: Multifunctional epoxy		
<b>FILLERS:</b>	Kaolin and/or inorganic catalyst		Secondary 2: N/A		
<b>ID REFERENCE:</b>	UL/ANSI: CEM-3		UL94 Requirement: V-0		
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	ANSI: CEM-3/81		MIL-S-13949: N/A		
N/A					
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	–	–	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	–	–		2.4.8.2	
1. After thermal stress	–	–		2.4.8.3	
2. At 125°C [257°F]	–	–			
3. After process solutions	–	–			
C. All other foil – composite	–	–			
2. Volume Resistivity, minimum					
A. C-96/35/90	–	10 <sup>6</sup>	MΩ-cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	10 <sup>3</sup>			
3. Surface Resistivity, minimum					
A. C-96/35/90	–	10 <sup>4</sup>	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	10 <sup>3</sup>			
4. Moisture Absorption, maximum	–	0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	–	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	–	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	276 [40,030]**	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	186 [26,980]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	–	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	–	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	–	–			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	–	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-0	V-0	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-EG-140 or AABUS.				
3. Volatile content maximum	–	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Other	–				
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

\*\*As measured on a 1.57 mm [0.06181 in] thick sample.

## Revision Date: December 2001

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/82				
<b>REINFORCEMENT:</b>	1: Woven E-glass	2: N/A			
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy				
	<b>Secondary 1:</b> Multifunctional epoxy	<b>Secondary 2:</b> N/A			
<b>FLAME RETARDANT MECHANISM:</b>	Bromine	<b>Minimum UL94 Requirement:</b> V-1			
<b>FILLERS:</b>	Kaolin and/or inorganic catalyst				
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> FR-4	<b>MIL-S-13949:</b> N/A			
	<b>ANSI:</b> FR-4/82				
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	110°C minimum				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	–	–	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	–	–		2.4.8.2	
1. After thermal stress	–	–		2.4.8.3	
2. At 125°C [257°F]	–	–			
3. After process solutions	–	–			
C. All other foil – composite	–	–			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 <sup>6</sup>	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 <sup>6</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 <sup>4</sup>	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 <sup>4</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
4. Moisture Absorption, maximum	–	0.35	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.030	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	–	–			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-EG-140 or AABUS.				
3. Volatile content maximum	–	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1	
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

## Revision Date: December 2001

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/83				
<b>REINFORCEMENT:</b>	1: Woven E-glass	2: N/A			
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy	<b>Secondary 1:</b> Multifunctional epoxy		<b>Secondary 2:</b> N/A	
<b>FLAME RETARDANT MECHANISM:</b>	Bromine			<b>Minimum UL94 Requirement:</b> V-1	
<b>FILLERS:</b>	Kaolin and/or inorganic catalyst				
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> FR-4	<b>ANSI:</b> FR-4/83		<b>MIL-S-13949:</b> N/A	
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	150°C - 200°C				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	–	–	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	–	–		2.4.8.2	
1. After thermal stress	–	–		2.4.8.3	
2. At 125°C [257°F]	–	–			
3. After process solutions	–	–			
C. All other foil – composite	–	–			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 <sup>6</sup>	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 <sup>4</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 <sup>4</sup>	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 <sup>4</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	90	90	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other					
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	1.5	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1	
6. Other	–				

\*AABUS = As agreed upon between user and supplier.



## Revision Date: December 2001

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/90				
<b>REINFORCEMENT:</b>	1: Woven E-glass, surface		2: N/A		
<b>RESIN SYSTEM:</b>	Primary: Polyphenylene ether		Secondary 2: N/A		
<b>FLAME RETARDANT MECHANISM:</b>	Bromine/Antimony oxide		Secondary 1: N/A		
<b>FILLERS:</b>	N/A		Secondary 2: N/A		
<b>ID REFERENCE:</b>	UL/ANSI: N/A		MIL-S-13949: N/A		
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	ANSI: 4101/90				
	175°C minimum				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	0.70 [4.00]	0.70 [4.00]	N/mm [lb/in]	2.4.8 2.4.8.2 2.4.8.3	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil					
1. After thermal stress	0.70 [4.00]	0.70 [4.00]			
2. At 125°C [257°F]	0.70 [4.00]	0.70 [4.00]			
3. After process solutions	0.55 [3.14]	0.55 [3.14]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 <sup>6</sup>	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 <sup>6</sup>			
C. At elevated temperature E-24/125	10 <sup>6</sup>	10 <sup>6</sup>			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 <sup>5</sup>	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 <sup>5</sup>			
C. At elevated temperature E-24/125	10 <sup>5</sup>	10 <sup>5</sup>			
4. Moisture Absorption, maximum	–	0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	4.2	4.2	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.015	0.015	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-EG-140				
3. Volatile content maximum	–	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1	
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

## Revision Date: December 2001

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/91				
<b>REINFORCEMENT:</b>	1: Woven E-glass		2: N/A		
<b>RESIN SYSTEM:</b>	Primary: Polyphenylene ether		Secondary 2: N/A		
	Secondary 1: N/A				
<b>FLAME RETARDANT MECHANISM:</b>	Bromine				
<b>FILLERS:</b>	N/A				
<b>ID REFERENCE:</b>	UL/ANSI: N/A		MIL-S-13949: N/A		
	ANSI: 4101/91				
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	175°C minimum				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	0.70 [4.00]	0.70 [4.00]	N/mm [lb/in]	2.4.8 2.4.8.2 2.4.8.3	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil					
1. After thermal stress	0.70 [4.00]	0.70 [4.00]			
2. At 125°C [257°F]	0.70 [4.00]	0.70 [4.00]			
3. After process solutions	0.55 [3.14]	0.55 [3.14]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 <sup>6</sup>	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 <sup>6</sup>			
C. At elevated temperature E-24/125	10 <sup>6</sup>	10 <sup>6</sup>			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 <sup>5</sup>	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 <sup>5</sup>			
C. At elevated temperature E-24/125	10 <sup>5</sup>	10 <sup>5</sup>			
4. Moisture Absorption, maximum	–	0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	4.2	4.2	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.015	0.015	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-EG-140				
3. Volatile content maximum	–	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1	
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

## Revision Date: December 2001

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/92				
<b>REINFORCEMENT:</b>	1: Woven E-glass	2: N/A			
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy	<b>Secondary 1:</b> Multifunctional epoxy		<b>Secondary 2:</b> N/A	
<b>FLAME RETARDANT MECHANISM:</b>	Phosphorous			<b>Minimum UL94 Requirement:</b> V-1	
<b>FILLERS:</b>	N/A				
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> FR-4	<b>ANSI:</b> FR-4/92		<b>MIL-S-13949:</b> N/A	
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	110°C - 150°C				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	0.70 [4.00]	0.70 [4.00]	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil				2.4.8.2	
1. After thermal stress	0.80 [4.57]	1.05 [6.00]		2.4.8.3	
2. At 125°C [257°F]	0.70 [4.00]	0.70 [4.00]			
3. After process solutions	0.55 [3.14]	0.80 [4.57]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 <sup>6</sup>	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 <sup>6</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 <sup>4</sup>	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 <sup>4</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Halogen Content, maximum	TBD	TBD	ppm	TBD	3.10.1.9
15. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	0.75	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1	
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

## Revision Date: December 2001

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/93				
<b>REINFORCEMENT:</b>	1: Woven E-glass		2: N/A		
<b>RESIN SYSTEM:</b>	Primary: Epoxy		Secondary 2: N/A		
<b>FLAME RETARDANT MECHANISM:</b>	Aluminum hydroxide		Minimum UL94 Requirement: V-1		
<b>FILLERS:</b>	N/A				
<b>ID REFERENCE:</b>	UL/ANSI: FR-4		MIL-S-13949: N/A		
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	110°C - 150°C		ANSI: FR-4/93		
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	0.70 [4.00]	0.70 [4.00]	N/mm [lb/in]	2.4.8 2.4.8.2 2.4.8.3	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil					
1. After thermal stress	0.80 [4.57]	1.05 [6.00]			
2. At 125°C [257°F]	0.70 [4.00]	0.70 [4.00]			
3. After process solutions	0.55 [3.14]	0.80 [4.57]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 <sup>6</sup>	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 <sup>6</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 <sup>4</sup>	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 <sup>4</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Halogen Content, maximum	TBD	TBD	ppm	TBD	3.10.1.9
15. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	0.75	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1	
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

## Revision Date: December 2001

**SPECIFICATION SHEET**

<b>SPECIFICATION SHEET #:</b>	IPC-4101/94	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy	
	<b>Secondary 1:</b> Multifunctional epoxy	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	Phosphorous	<b>Minimum UL94 Requirement:</b> V-1
<b>FILLERS:</b>	N/A	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> FR-4	<b>MIL-S-13949:</b> N/A
	<b>ANSI:</b> FR-4/94	
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	150°C - 200°C	

**LAMINATE REQUIREMENTS**

Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	0.70 [4.00]	0.70 [4.00]	N/mm [lb/in]	2.4.8 2.4.8.2 2.4.8.3	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil					
1. After thermal stress	0.80 [4.57]	1.05 [6.00]			
2. At 125°C [257°F]	0.70 [4.00]	0.70 [4.00]			
3. After process solutions	0.55 [3.14]	0.80 [4.57]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 <sup>6</sup>	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 <sup>4</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 <sup>4</sup>	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 <sup>4</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	90	90	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Halogen Content, maximum	TBD	TBD	ppm	TBD	3.10.1.9
15. Other	–	–			

**PREPREG REQUIREMENTS**

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17
2. Reinforcement	As per IPC-4412 or AABUS.			
3. Volatile content maximum	1.5	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1
6. Other	–			

\*AABUS = As agreed upon between user and supplier.

**Revision Date: December 2001**

<b>SPECIFICATION SHEET</b>		
<b>SPECIFICATION SHEET #:</b>	IPC-4101/95	
<b>REINFORCEMENT:</b>	<b>1:</b> Woven E-glass	<b>2:</b> N/A
<b>RESIN SYSTEM:</b>	<b>Primary:</b> Epoxy	
	<b>Secondary 1:</b> Multifunctional epoxy	<b>Secondary 2:</b> N/A
<b>FLAME RETARDANT MECHANISM:</b>	Aluminum hydroxide	<b>Minimum UL94 Requirement:</b> V-1
<b>FILLERS:</b>	N/A	
<b>ID REFERENCE:</b>	<b>UL/ANSI:</b> FR-4	<b>MIL-S-13949:</b> N/A
	<b>ANSI:</b> FR-4/95	
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	150°C - 200°C	

**LAMINATE REQUIREMENTS**

Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	0.70 [4.00]	0.70 [4.00]	N/mm [lb/in]	2.4.8 2.4.8.2 2.4.8.3	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil					
1. After thermal stress	0.80 [4.57]	1.05 [6.00]			
2. At 125°C [257°F]	0.70 [4.00]	0.70 [4.00]			
3. After process solutions	0.55 [3.14]	0.80 [4.57]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 <sup>6</sup>	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 <sup>4</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 <sup>4</sup>	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 <sup>4</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	90	90	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Halogen Content, maximum	TBD	TBD	ppm	TBD	3.10.1.9
15. Other	–	–			

**PREPREG REQUIREMENTS**

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17
2. Reinforcement	As per IPC-4412 or AABUS.			
3. Volatile content maximum	1.5	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1
6. Other	–			

\*AABUS = As agreed upon between user and supplier.

## Revision Date: December 2001

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/96				
<b>REINFORCEMENT:</b>	1: Woven E-glass		2: N/A		
<b>RESIN SYSTEM:</b>	Primary: Polyphenylene ether		Secondary 2: N/A		
<b>FLAME RETARDANT MECHANISM:</b>	Non-Bromine/Non-Antimony		Secondary 1: N/A		
<b>FILLERS:</b>	N/A		Secondary 2: N/A		
<b>ID REFERENCE:</b>	UL/ANSI: N/A		MIL-S-13949: N/A		
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	ANSI: 4101/96				
	175°C minimum				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	0.70 [4.00]	0.70 [4.00]	N/mm [lb/in]	2.4.8 2.4.8.2 2.4.8.3	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil					
1. After thermal stress	0.70 [4.00]	0.70 [4.00]			
2. At 125°C [257°F]	0.70 [4.00]	0.70 [4.00]			
3. After process solutions	0.55 [3.14]	0.55 [3.14]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 <sup>6</sup>	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 <sup>6</sup>			
C. At elevated temperature E-24/125	10 <sup>6</sup>	10 <sup>6</sup>			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 <sup>5</sup>	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 <sup>5</sup>			
C. At elevated temperature E-24/125	10 <sup>5</sup>	10 <sup>5</sup>			
4. Moisture Absorption, maximum	–	0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	4.2	4.2	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.015	0.015	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	s	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-EG-140				
3. Volatile content maximum	–	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1	
6. Other	–				

\*AABUS = As agreed upon between user and supplier.



## Revision Date: December 2001

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/97				
<b>REINFORCEMENT:</b>	1: Woven E-glass		2: N/A		
<b>RESIN SYSTEM:</b>	Primary: Difunctional epoxy		Secondary 2: N/A		
	Secondary 1: Multifunctional epoxy		Minimum UL94 Requirement: V-1		
<b>FLAME RETARDANT MECHANISM:</b>	Bromine				
<b>FILLERS:</b>	Inorganic fillers				
<b>ID REFERENCE:</b>	UL/ANSI: FR-4		MIL-S-13949: /04 - GF, GFN, GFK, GFP, GFM		
	ANSI: FR-4/97				
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	110°C to 150°C				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	0.70 [4.00]	0.70 [4.00]	N/mm [lb/in]	2.4.8 2.4.8.2 2.4.8.3	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil					
1. After thermal stress	0.80 [4.57]	1.05 [6.00]			
2. At 125°C [257°F]	0.70 [4.00]	0.70 [4.00]			
3. After process solutions	0.55 [3.14]	0.80 [4.57]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. °C [°F] - 96/35/90 [204.8/95/194]	10 <sup>6</sup>	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 <sup>6</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
3. Surface Resistivity, minimum					
A. °C [°F] - 96/35/90 [204.8/95/194]	10 <sup>4</sup>	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 <sup>4</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	0.75	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1	
6. Other	–				

\*AABUS = As agreed upon between user and supplier.

## Revision Date: December 2001

<b>SPECIFICATION SHEET</b>					
<b>SPECIFICATION SHEET #:</b>	IPC-4101/98				
<b>REINFORCEMENT:</b>	1: Woven E-glass		2: N/A		
<b>RESIN SYSTEM:</b>	Primary: Epoxy		Secondary 2: N/A		
<b>FLAME RETARDANT MECHANISM:</b>	Bromine		Minimum UL94 Requirement: V-1		
<b>FILLERS:</b>	Inorganic fillers		MIL-S-13949: /04 - GF, GFG, GFN		
<b>ID REFERENCE:</b>	UL/ANSI: FR-4				
<b>GLASS TRANSITION (T<sub>g</sub>):</b>	150°C - 200°C				
<b>LAMINATE REQUIREMENTS</b>					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17µm [0.669 mil].	0.70 [4.00]	0.70 [4.00]	N/mm [lb/in]	2.4.8 2.4.8.2 2.4.8.3	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil					
1. After thermal stress	0.80 [4.57]	1.05 [6.00]			
2. At 125°C [257°F]	0.70 [4.00]	0.70 [4.00]			
3. After process solutions	0.55 [3.14]	0.80 [4.57]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 <sup>6</sup>	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 <sup>4</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 <sup>4</sup>	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 <sup>4</sup>			
C. At elevated temperature E-24/125	10 <sup>3</sup>	10 <sup>3</sup>			
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm <sup>2</sup> [lb/in <sup>2</sup> ]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
<b>PREPREG REQUIREMENTS</b>					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	1.5	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1	
6. Other	–				

\*AABUS = As agreed upon between user and supplier.



ASSOCIATION CONNECTING  
ELECTRONICS INDUSTRIES

# ANSI/IPC-T-50 Terms and Definitions for Interconnecting and Packaging Electronic Circuits Definition Submission/Approval Sheet

The purpose of this form is to keep current with terms routinely used in the industry and their definitions. Individuals or companies are invited to comment. Please complete this form and return to:

IPC  
2215 Sanders Road  
Northbrook, IL 60062-6135  
Fax: 847 509.9798

### SUBMITTOR INFORMATION:

Name: \_\_\_\_\_  
Company: \_\_\_\_\_  
City: \_\_\_\_\_  
State/Zip: \_\_\_\_\_  
Telephone: \_\_\_\_\_  
Date: \_\_\_\_\_

- This is a **NEW** term and definition being submitted.
- This is an **ADDITION** to an existing term and definition(s).
- This is a **CHANGE** to an existing definition.

Term	Definition

If space not adequate, use reverse side or attach additional sheet(s).

Artwork:  Not Applicable  Required  To be supplied

Included: Electronic File Name: \_\_\_\_\_

Document(s) to which this term applies: \_\_\_\_\_

Committees affected by this term: \_\_\_\_\_

Office Use	
IPC Office	Committee 2-30
Date Received: _____	Date of Initial Review: _____
Comments Collated: _____	Comment Resolution: _____
Returned for Action: _____	Committee Action: <input type="checkbox"/> Accepted <input type="checkbox"/> Rejected
Revision Inclusion: _____	<input type="checkbox"/> Accept Modify
IEC Classification	
Classification Code • Serial Number	
Terms and Definition Committee Final Approval Authorization: Committee 2-30 has approved the above term for release in the next revision.	
Name: _____ Committee: <u>IPC 2-30</u> Date: _____	

This Page Intentionally Left Blank

## Technical Questions

The IPC staff will research your technical question and attempt to find an appropriate specification interpretation or technical response. Please send your technical query to the technical department via:

tel 847/509-9700

fax 847/509-9798

www.ipc.org

e-mail: answers@ipc.org

## IPC World Wide Web Page [www.ipc.org](http://www.ipc.org)

Our home page provides access to information about upcoming events, publications and videos, membership, and industry activities and services. Visit soon and often.

## IPC Technical Forums

IPC technical forums are opportunities to network on the Internet. It's the best way to get the help you need today! Over 2,500 people are already taking advantage of the excellent peer networking available through e-mail forums provided by IPC. Members use them to get timely, relevant answers to their technical questions. Contact KeachSasamori@ipc.org for details. Here are a few of the forums offered.

### TechNet@ipc.org

TechNet forum is for discussion of issues related to printed circuit board design, assembly, manufacturing, comments or questions on IPC specifications, or other technical inquiries. IPC also uses TechNet to announce meetings, important technical issues, surveys, etc.

### ComplianceNet@ipc.org

ComplianceNet forum covers environmental, safety and related regulations or issues.

### DesignerCouncil@ipc.org

Designers Council forum covers information on upcoming IPC Designers Council activities as well as information, comments, and feedback on current designer issues, local chapter meetings, new chapters forming, and job opportunities. In addition, IPC can set up a mailing list for your individual Chapter so that your chapter can share information about upcoming meetings, events and issues related specifically to your chapter.

### Gencam@ipc.org

Gencam deals with issues regarding the Gencam™ standards and specifications for Printed Circuit Board Layout and Design.

### LeadFree@ipc.org

This forum acts as a peer interaction resource for staying on top of lead elimination activities worldwide and within IPC.

### IPC\_New\_Releases@ipc.org

This is an announcement forum which subscribers can receive notice of new IPC publications, updates and standards.

## ADMINISTERING YOUR SUBSCRIPTION STATUS:

All commands (such as subscribe and signoff) must be sent to listserv@ipc.org. Please DO NOT send any command to the mail list address, (i.e. <mail list>@ipc.org), as it would be distributed to all the subscribers.

Example for subscribing:

To: LISTSERV@IPC.ORG

Subject:

Message: subscribe TechNet Joseph H. Smith

Example for signing off:

To: LISTSERV@IPC.ORG

Subject:

Message: signoff DesignerCouncil

Please note you must send messages to the mail list address ONLY from the e-mail address to which you want to apply changes. In other words, if you want to sign off the mail list, you must send the signoff command from the address that you want removed from the mail list. Many participants find it helpful to signoff a list when travelling or on vacation and to resubscribe when back in the office.

## How to post to a forum:

To send a message to all the people currently subscribed to the list, just send to <mail list>@ipc.org. Please note, use the mail list address that you want to reach in place of the <mail list> string in the above instructions.

Example:

To: TechNet@IPC.ORG

Subject: <your subject>

Message: <your message>

The associated e-mail message text will be distributed to everyone on the list, including the sender. Further information on how to access previous messages sent to the forums will be provided upon subscribing.

For more information, contact Keach Sasamori

tel 847/790-5315

fax 847/504-2315

e-mail: sasako@ipc.org

[www.ipc.org/html/forum.htm](http://www.ipc.org/html/forum.htm)

## Education and Training

IPC conducts local educational workshops and national conferences to help you better understand conventional and emerging technologies. Members receive discounts on registration fees. Visit [www.ipc.org](http://www.ipc.org) to see what programs are coming to your area.

### IPC Certification Programs

IPC provides world-class training and certification programs based on several widely-used IPC standards, including the IPC-A-610, the J-STD-001, and the IPC-A-600. IPC-sponsored certification gives your company a competitive advantage and your workforce valuable recognition.

For more information on programs, contact Alexandra Curtis  
 tel 847/790-5377 fax 847/509-9798  
 e-mail: [curtal@ipc.org](mailto:curtal@ipc.org) www.[ipc.org](http://ipc.org)

### IPC Video Tapes and CD-ROMs

IPC video tapes and CD-ROMs can increase your industry know-how and on the job effectiveness. Members receive discounts on purchases.

For more information on IPC Video/CD Training, contact Mark Pritchard  
 tel 505/758-7937 ext. 202 fax 505/758-7938  
 e-mail: [markp@ipcvideo.org](mailto:markp@ipcvideo.org) www.[ipc.org](http://ipc.org)

### IPC Printed Circuits Expo<sup>®</sup>



IPC Printed Circuits Expo is the largest trade exhibition in North America devoted to the PWB manufacturing industry. Over 90 technical presentations make up this superior technical conference. Visit [www.ipcprintedcircuitexpo.org](http://www.ipcprintedcircuitexpo.org) for upcoming dates and information.

#### Exhibitor information:

Contact: Mary MacKinnon  
 Sales Manager  
 tel 847/790-5386  
 e-mail: [MaryMacKinnon@ipc.org](mailto:MaryMacKinnon@ipc.org)

#### Registration information:

Alicia Balonek  
 Exhibits Manager  
 tel 847/790-5398  
 e-mail: [AliciaBalonek@ipc.org](mailto:AliciaBalonek@ipc.org)

tel 847/790-5361  
 fax 847/509-9798  
 e-mail: [registration@ipc.org](mailto:registration@ipc.org)

### APEX<sup>®</sup> / IPC SMEMA Council Electronics Assembly Process Exhibition & Conference



APEX is the premier technical conference and exhibition dedicated entirely to the electronics assembly industry. Visit [www.GoAPEX.org](http://www.GoAPEX.org) for upcoming dates and more information.

#### Exhibitor information:

Contact: Mary MacKinnon  
 tel 847/790-5386  
 e-mail: [MaryMacKinnon@ipc.org](mailto:MaryMacKinnon@ipc.org)

#### Registration information:

tel 847/790-5360  
 fax 847/509-9798  
 e-mail: [goapex@ipc.org](mailto:goapex@ipc.org)

### How to Get Involved

The first step is to join IPC. An application for membership can be found in the back of this publication. Once you become a member, the opportunities to enhance your competitiveness are vast. Join a technical committee and learn from our industry's best while you help develop the standards for our industry. Participate in market research programs which forecast the future of our industry. Participate in Capitol Hill Day and lobby your Congressmen and Senators for better industry support. Pick from a wide variety of educational opportunities: workshops, tutorials, and conferences. More up-to-date details on IPC opportunities can be found on our web page: [www.ipc.org](http://www.ipc.org).

For information on how to get involved, contact:

Jeanette Ferdman, Membership Director  
 tel 847/790-5309 fax 847/509-9798  
 e-mail: [JeanetteFerdman@ipc.org](mailto:JeanetteFerdman@ipc.org) www.[ipc.org](http://ipc.org)



# Application for Site Membership

Thank you for your decision to join IPC members on the “Intelligent Path to Competitiveness”! IPC Membership is **site specific**, which means that IPC member benefits are available to all individuals employed at the site designated on the other side of this application.

To help IPC serve your member site in the most efficient manner possible, please tell us what your facility does by choosing the most appropriate member category. *(Check one box only.)*

Independent Printed Board Manufacturers

This facility manufactures and sells to other companies, printed wiring boards (PWBs) or other electronic interconnection products on the merchant market. What products do you make for sale?

- One-sided and two-sided rigid printed boards       Multilayer printed boards       Other interconnections  
 Flexible printed boards

Name of Chief Executive Officer/President \_\_\_\_\_

---

Independent Electronic Assembly EMSI Companies

This facility assembles printed wiring boards, on a contract basis, and may offer other electronic interconnection products for sale.

Name of Chief Executive Officer/President \_\_\_\_\_

---

OEM–Manufacturers of any end product using PCB/PCAs or Captive Manufacturers of PCBs/PCAs

This facility purchases, uses and/or manufactures printed wiring boards or other interconnection products for use in a final product, which we manufacture and sell.

What is your company's primary product line? \_\_\_\_\_

---

Industry Suppliers

This facility supplies raw materials, machinery, equipment or services used in the manufacture or assembly of electronic interconnection products.

What products do you supply? \_\_\_\_\_

---

Government Agencies/Academic Technical Liaisons

We are representatives of a government agency, university, college, technical institute who are directly concerned with design, research, and utilization of electronic interconnection devices. (Must be a non-profit or not-for-profit organization.)





ASSOCIATION CONNECTING  
ELECTRONICS INDUSTRIES®

# Application for Site Membership

## Site Information:

Company Name \_\_\_\_\_

Street Address \_\_\_\_\_

City \_\_\_\_\_ State \_\_\_\_\_ Zip/Postal Code \_\_\_\_\_ Country \_\_\_\_\_

Main Switchboard Phone No. \_\_\_\_\_ Main Fax \_\_\_\_\_

Name of Primary Contact \_\_\_\_\_

Title \_\_\_\_\_ Mail Stop \_\_\_\_\_

Phone \_\_\_\_\_ Fax \_\_\_\_\_ e-mail \_\_\_\_\_

Company e-mail address \_\_\_\_\_ Website URL \_\_\_\_\_

### Please Check One:

- \$1,000.00 Annual dues for Primary Site Membership (Twelve months of IPC membership begins from the time the application and payment are received)
- \$800.00 Annual dues for Additional Facility Membership: Additional membership for a site within an organization where another site is considered to be the primary IPC member.
- \$600.00\*\* Annual dues for an independent PCB/PWA fabricator or independent EMSI provider with annual sales of less than \$1,000,000.00. \*\*Please provide proof of annual sales.
- \$250.00 Annual dues for Government Agency/not-for-profit organization

**TMRC Membership**  Please send me information about membership in the Technology Market Research Council (TMRC)

## Payment Information:

Enclosed is our check for \$ \_\_\_\_\_

Please bill my credit card: (circle one) MC AMEX VISA DINERS

Card No. \_\_\_\_\_ Exp date \_\_\_\_\_

Authorized Signature \_\_\_\_\_

### Mail application with check or money order to:

IPC  
Dept. 77-3491  
Chicago, IL 60678-3491

### Fax/Mail application with credit card payment to:

IPC  
2215 Sanders Road  
Northbrook, IL 60062-6135  
Tel: 847 509.9700  
Fax: 847 509.9798  
<http://www.ipc.org>

Please attach business card  
of primary contact here



ASSOCIATION CONNECTING  
ELECTRONICS INDUSTRIES®

# Standard Improvement Form

IPC-4101A

The purpose of this form is to provide the Technical Committee of IPC with input from the industry regarding usage of the subject standard.

Individuals or companies are invited to submit comments to IPC. All comments will be collected and dispersed to the appropriate committee(s).

If you can provide input, please complete this form and return to:

IPC  
2215 Sanders Road  
Northbrook, IL 60062-6135  
Fax 847 509.9798  
E-mail: answers@ipc.org

---

1. I recommend changes to the following:

Requirement, paragraph number \_\_\_\_\_  
 Test Method number \_\_\_\_\_, paragraph number \_\_\_\_\_

The referenced paragraph number has proven to be:

Unclear  Too Rigid  In Error  
 Other \_\_\_\_\_

---

2. Recommendations for correction:

---

---

---

---

---

---

3. Other suggestions for document improvement:

---

---

---

---

---

---

Submitted by:

Name \_\_\_\_\_ Telephone \_\_\_\_\_

Company \_\_\_\_\_ E-mail \_\_\_\_\_

Address \_\_\_\_\_

City/State/Zip \_\_\_\_\_ Date \_\_\_\_\_

---



ASSOCIATION CONNECTING  
ELECTRONICS INDUSTRIES®

ISBN #1-580982-78-6

2215 Sanders Road, Northbrook, IL 60062-6135  
Tel. 847.509.9700 Fax 847.509.9798  
[www.ipc.org](http://www.ipc.org)