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Specification for Base Materials for Rigid and Multilayer Printed Boards

Supersedes IPC-4101E

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An international standard developed by IPC



BUILD ELECTRONICS BETTER



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

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

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Table of Contents

1 SCOPE	1	3.5	Verification of Manufacturer's Quality System	11
1.1 Classification	1	3.6	Conflict	11
1.1.1 Specification Sheet Description	1	3.7	Materials	11
1.1.2 Nominal Laminate Thickness	1	3.7.1	Metal Cladding	11
1.1.3 Metal Cladding Type and Nominal Weight/Thickness	2	3.7.2	Reinforcement Fabric	11
1.1.4 Thickness Tolerance (Laminate)	2	3.7.3	Resin Systems	11
1.1.5 Surface Quality Class	2	3.8	General Requirements	11
1.1.6 Reinforcement Style	2	3.8.1	Fabricated Sheets and Panels	11
1.1.7 Prepreg Parameters	2	3.8.2	Inspection Lot	12
1.1.8 Color	4	3.8.3	Visual Properties	12
1.2 Dimensions and Tolerances	4	3.8.4	Dimensional	14
1.2.1 Metric and Imperial Measurements	4	3.9	Physical Requirements	15
2 APPLICABLE DOCUMENTS	4	3.9.1	Physical Requirements of Laminate Materials	15
2.1 IPC	4	3.9.2	Physical Requirements of Prepreg Materials	17
2.2 National Conference of Standards Laboratories (NCSL)	6	3.10	Chemical Requirements	18
2.3 International Standards	6	3.10.1	Chemical Requirements of Laminate Materials	18
2.4 Underwriters Laboratories (UL)	6	3.10.2	Chemical Requirements of Prepreg Materials	20
2.5 European Union	6	3.11	Electrical Requirements	20
2.6 ASTM International	6	3.11.1	Electrical Requirements of Laminate Materials	20
3 REQUIREMENTS	6	3.11.2	Electrical Requirements of Prepreg Materials	20
3.1 Terms and Definitions	6	3.12	Environmental Requirements	20
3.1.1 Qualification Assessment	6	3.12.1	Environmental Requirements of Laminate Materials	20
3.1.2 Quality Conformance Testing	6	3.12.2	Environmental Requirements of Prepreg Materials	21
3.1.3 Supplier's Quality System	6	3.13	Substitutability	21
3.1.4 Process Control Testing	6	3.13.1	Permissible Substitutions of Specification Sheet Materials	21
3.1.5 Self Declaration	6	3.13.2	Substitutability of Classes of Pits and Dents	21
3.1.6 Quality Assessment Data	7	3.13.3	Substitutability of Classes of Thickness Tolerance	21
3.1.7 Sample Qualification	7	3.13.4	Remarking of Substituted Laminates	21
3.1.8 Production Data	7	3.14	Marking	21
3.1.9 Customer Test Data	7	3.14.1	Marking Laminate Materials	21
3.1.10 Internal Assessment	7	3.14.2	Marking Prepreg Materials	22
3.1.11 Individual Customer Audit	7	3.14.3	Marking of Shipping Containers	22
3.1.12 Independent Third Party Assessment	7	3.15	Workmanship	22
3.1.13 Epoxy, Multifunctional	7	3.16	Material Safety	22
3.1.14 Epoxy, Difunctional	7	3.17	Prepreg Shelf Life	22
3.1.15 AABUS	7			
3.2 Specification Sheets	7			
3.3 Manufacturer Quality Profile	7			
3.4 Qualification Testing	7			
3.4.1 Qualification Testing of Laminate	11			
3.4.2 Qualification Testing of Prepreg	11			

4	QUALITY ASSURANCE PROVISIONS	22	7.2	Segmented Keyword Search Terms and All Specification Sheets that Use the Specific Key Words for Searching	26
4.1	Quality System	22			
4.2	Responsibility for Inspection	22	7.3	Keyword Search Terms for All Specification Sheets	26
4.2.1	Test Equipment and Inspection Facilities	23			
4.3	Qualification Testing	23			
4.3.1	Samples	23			
4.3.2	Frequency	23			
4.3.3	Laminator Qualification Profile	23			
4.3.4	Changes in Composition	23			
4.3.5	Qualification Data Retention	23			
4.4	Quality Conformance Inspection	23			
4.4.1	Frequency	23			
4.4.2	Acceptance Criteria	24			
4.4.3	Rejected Lots	24			
4.4.4	Conformance Data Retention	24			
4.4.5	Certificate of Conformance	24			
4.5	Statistical Process Control (SPC)	24			
5	PREPARATION FOR DELIVERY	24			
5.1	Packaging Materials	24			
5.2	Authorized Distributors	24			
6	NOTES	25			
6.1	Ordering Information	25			
6.1.1	Ordering Data for Laminate Materials	25			
6.1.2	Ordering Data for Prepreg Materials	25			
6.2	New Materials	25			
7	KEYWORDS	26			
7.1	Keyword Search Terms (Electronic/Soft Copy Searches)	26			
				APPENDIX A (IPC-4101 supplemental inspection requirements if required in purchase order or master drawing)	162
				Figures	
			Figure 3-1	Thickness Measurements for Laminates	15
				Tables	
			Table 1-1	Metal Cladding Types	2
			Table 1-2	Copper Foil Weight and Thickness	3
			Table 3-1	Reference Information and Test Frequency of Laminate	8
			Table 3-2	Reference Information and Test Frequency of Prepreg	10
			Table 3-3	Point Value for Longest Dimensions of Indentation	12
			Table 3-4	Surface Quality Classification	13
			Table 3-5	Permissible Variation in Length and Width of Laminates	14
			Table 3-6	Permissible Variation in Length and Width of Prepregs	14
			Table 3-7	Thickness and Tolerances for Laminates	16
			Table 3-8	Permissible Bow and Twist for Laminates, % ..	16
			Table 3-9	Flammability Requirements	19
			Table 3-10	Permissible Material Substitutions	21
			Table 4-1	Quality Conformance Plan for Monthly, Quarterly and Annual Tests – Laminate	23
			Table 4-2	Quality Conformance Plan for Monthly, Quarterly and Annual Tests – Prepreg	23

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.

Specification sheets have no cancellation date. When no revision of IPC-4101 is called out, the latest revision of IPC-4101 **shall** apply. If previous revisions are used, then the specification sheet and revision **shall** be called out.

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. In the example shown in 1.1, 1500 designates a laminate with thickness of 1.5 mm [0.0591 in], which would be specified as 0591 when using Imperial units.

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-4562, IPC-4563, or IPC-CF-152 as appropriate. Cladding types C and R, and cladding types H and S, may be used interchangeably. The acceptability for the interchangeability **shall** be as agreed between user and supplier (AABUS). 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.

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)
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
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

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-4562, IPC-4563, 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 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 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:

- E7628 represents E-glass reinforcement style 7628 per IPC-4412.
- S0313 represents S-glass reinforcement style 313 per IPC-SG-141.
- A3080 represents aramid reinforcement style 3080 per IPC-A-142.
- 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

Table 1-2 Copper Foil Weight and Thickness

Foil Designation	Common Industry Terminology	Metric		English		
		Area Weight (g/m ²)	Nominal Thickness (μm)	Area Weight (oz/ft ²)	Area Weight (g/254 in ²)	Nominal Thickness (10 ⁻³ in)
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 (10⁻³ in) = 1.35 x Area Wt. (oz/ft²)

Where 1.35 is a factor determined from the density of copper foil assumed to be 8.93 g/cm³ [5.16 oz/in³]. This factor is within 1% for all densities from 8.81 g/cm³ to 8.99 g/cm³.

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

For double-sided bond treated foils, the nominal area weight **shall** be increased by 4.58 g/m² [0.75 g/254 in² or 0.0150 oz/ft²] to the values in Table 1-2 to determine the upper tolerance limits.

Caution: 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.

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 AABUS 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 AABUS. Additional test(s) **shall** be specified by AABUS 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



Documents

Document Sharing Hub

1.1.8 Color 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 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 IPC¹

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-152 Composite Metallic Material Specification for Printed Wiring Boards

IPC-TM-650 Test Methods²

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

2.2.18 Determination of Thickness of Laminates by Mechanical Measurement

2.2.18.1 Determination of Thickness of Metallic Clad Laminates, Cross-Sectional

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

2.3.16 Resin Content of Prepreg, by Burn-Off

2.3.16.1 Resin Content of Prepreg, by Treated Weight

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

2.3.41 Test Method for Total Halogen Content in Base Materials

1. www.ipc.org

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

- 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
- 2.4.24.1 Time to Delamination (TMA method)
- 2.4.24.4 Glass Transition and Modulus of Materials Used in High Density Interconnection (HDI) and Microvias – DMA Method
- 2.4.24.6 Decomposition Temperature (T_d) of Laminate Material Using TGA
- 2.4.25 Glass Transition Temperature and Cure Factor by DSC³
- 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
- 2.4.52 Fracture Toughness of Resin Systems for Base Materials
- 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)
- 2.5.5.5 Stripline Test for Permittivity and Loss Tangent (Dielectric Constant and Dissipation Factor) at X-Band
- 2.5.5.9 Permittivity and Loss Tangent, Parallel Plate, 1 MHz to 1.5 GHz
- 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
- 2.6.25 Conductive Anodic Filament (CAF) Resistance Test: X-Y Axis

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-4563 Resin Coated Copper Foil for Printed Boards Guideline

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

3. Test Method 2.4.25 also describes the delta glass transition temperature test (Delta T_g)

IPC-9691 User Guide for the IPC-TM-650, Method 2.6.25, Conductive Anodic Filament (CAF) Resistance Test (Electrochemical Migration Testing)

J-STD-003 Solderability Tests for Printed Boards

2.2 National Conference of Standards Laboratories (NCSL)⁴

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

2.3 International Standards⁵

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

2.4 Underwriters Laboratories (UL)⁶

UL 94 Flammability

2.5 European Union⁷

Restriction of Hazardous Substances (RoHS) for Electrical and Electronic Equipment Directive

2.6 ASTM International⁸

ASTM D5470 Standard Test Method for Thermal Transmission Properties of Thin Thermally Conductive Solid Electrical Insulation Materials

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 user and a supplier for laminates and prepregs. The supplier **shall** produce an assessment of capabilities and sources of verification for the user to evaluate. The user must then review this assessment and determine whether the information and 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 supplier. There is no minimum level of qualification assessment verification required by this specification, and it is between the user and supplier 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 demonstrates 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 supplier'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 Supplier's Quality System The supplier'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 or ISO 10012-1.

3.1.4 Process Control Testing Process control testing is performed for the purpose of setting the critical steps of the manufacturers' initial process to a nominal value.

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 (see 3.3).

4. www.ncsli.org

5. www.ansi.org

6. www.ul.com

7. www.ec.europa.eu/environment

8. www.astm.org

3.1.6 Quality Assessment Data The data contained in the self assessment is compiled and analyzed for 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.

3.1.15 AABUS Stands for: As Agreed Between User and Supplier. It indicates that additional or alternate requirements are to be decided between the user and the supplier in the procurement documentation, including contractual requirements, modifications to purchase documentation and information on the drawing. Agreements can be used to define test methods, conditions, frequencies, categories or acceptance criteria within a test, if not already established.

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 prepreps **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 prepreps. The supplier **shall** retain on file, supporting data that the materials meet the requirements of this specification 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. All notations of MIL-S-13949 in this document are strictly for reference only.

Table 3-1 Reference Information and Test Frequency of Laminate

Tests	Requirement Paragraph	Test ¹ Method	Qualification Testing	Conformance Testing	Conformance Testing Frequency	Specimens per Sheet Sampled
General						
Visual Properties	3.8.3.1	2.1.5	✓	✓	Audit ²	-
Surface Finishes	3.8.3.1.1 - 3.8.3.1.5	2.1.5 2.1.9	✓		Audit ²	
Surface/Sub-Surface Imperfections	3.8.3.1.6		✓	✓	Lot	3
Dimensional						
Length/Width	3.8.4.1	2.2.19.1	✓	✓	Audit ⁹	-
Squareness	3.8.4.1.1	2.2.19.1	✓	✓	Audit ⁹	-
Thickness	3.8.4.2	2.2.18 2.2.18.1	✓	✓	Audit ⁹	-
Bow/Twist	3.8.4.3	2.4.22.1	✓	✓	Lot	1
Physical						
Peel Strength After Thermal Stress	3.9.1.1.1	2.4.8	✓	✓	Lot	4 ⁵
Peel Strength at Elevated Temperature ⁴	3.9.1.1.2	2.4.8 2.4.8.2 2.4.8.3	✓	✓	3 Months	4 ⁵
Peel Strength After Exposure to Process Solutions ^{3,4}	3.9.1.1.3	2.4.8	✓	✓	3 Months	4 ⁵
Dimensional Stability ¹¹	3.9.1.2	2.4.39	✓	✓	1 Month	3
Flexural Strength ¹³	3.9.1.3	2.4.4	✓	✓	12 Months	6 ⁷
Flexural Strength at Elevated Temperatures ⁴	3.9.1.4	2.4.4.1	✓	✓	3 Months	3 ⁸
Thermal Conductivity ⁴	3.9.1.5	ASTM D5470 AABUS	✓	✓	3 Months	1
X/Y CTE ^{3,4}	3.9.1.6	2.4.41 2.4.41.1	✓	✓	Lot	1
Z-Axis CTE ^{3,4}	3.9.1.7	2.4.24	✓	✓	3 Months	1
Polymer Fracture Toughness ^{3,4}	3.9.1.8	2.4.52	✓			
Chemical						
Flammability ^{10,12}	3.10.1.1	UL94	✓	✓	1 Month	10
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 ³	3.10.1.4	2.3.4.2	✓	✓	Lot	1
Metal Surface Cleanability ³	3.10.1.5	2.3.1.1	✓	✓	Lot	1
T _g ³	3.10.1.6	2.4.24 2.4.24.4 2.4.25	✓	✓	Lot	1
Delta T _g ³	3.10.1.7	2.4.25	✓	✓	Lot ⁴	1
Decomposition Temperature ^{3,4}	3.10.1.8	2.4.24.6	✓	✓	3 Months	1
Time to Delaminate (TMA) ^{3,4}	3.10.1.9	2.4.24.1 ¹⁵	✓	✓	3 Months	1
Electrical						
Permittivity ⁴ (1 MHz)	3.11.1.1	2.5.5.2 2.5.5.3 2.5.5.5 2.5.5.9	✓	✓	1 Month	3

Table 3-1 Reference Information and Test Frequency of Laminate (cont.)

Tests	Requirement Paragraph	Test ¹ Method	Qualification Testing	Conformance Testing	Conformance Testing Frequency	Specimens per Sheet Sampled
Electrical (continued)						
Loss Tangent ⁴ (1 MHz)	3.11.1.2	2.5.5.2 2.5.5.3 2.5.5.5 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 ¹⁴	3.11.1.5	2.5.1	✓	✓	12 Months	3
Dielectric Breakdown	3.11.1.6	2.5.6	✓	✓	3 Months	3 ⁶
Electric Strength	3.11.1.7	2.5.6.2	✓	✓	3 Months	3
Environmental						
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 ^{3,4}	3.12.1.3	2.6.16	✓	✓	Lot ⁴	3
Total Halogen Content ^{3,4}	3.12.1.4	2.3.41	✓		Audit ⁴	1
CAF Growth Resistance ^{3,4}	3.12.1.5	2.6.25	✓			

¹ All methods are from IPC-TM-650 unless otherwise noted.

² 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

³ Optional tests **shall** be AABUS.

⁴ Applicability to specific materials only and not all materials **shall** be AABUS.

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

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

⁷ Three lengthwise and three crosswise specimens.

⁸ All lengthwise specimens.

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

¹⁰ 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].

¹¹ Nominal value **shall** be AABUS.

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

¹³ 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 specification sheets for the flexural strength measurements.

¹⁴ All arc resistance testing **shall** be performed on laminate thickness >0.1 mm [0.004 in] as per Method 2.5.1.

¹⁵ Note that Method 2.4.24.1 is to be used for T260, T288 and T300 as described in 3.10.1.9.

Table 3-2 Reference Information and Test Frequency of Prepreg

Tests	Requirement Paragraph	Test ¹ Method	Qualification Testing	Conformance Testing	Conformance Testing Frequency	Specimens per Unit sampled
General						
Visual Properties	3.8.3.2	2.1.5	✓	✓	Lot	1
Dimensional						
Length/Width	3.8.4.1.2	2.2.19.1	✓	✓	Audit ⁶	
Squareness	3.8.4.1.2	2.2.19.1	✓	✓	Audit ⁶	
Physical						
Resin Content Percent by Treated Weight ²	3.9.2.1.1	2.3.16.1		✓	Lot	1
Resin Content Percent by Burn-Off ²	3.9.2.1.2	2.3.16	✓	✓	Lot	1
Treated Weight Total ²	3.9.2.1.3	2.3.16.2		✓	Lot	1
Resin Flow Percent ³	3.9.2.2.1	2.3.17	✓	✓	Lot	1
Scaled Flow Thickness ³	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 ⁴	3.9.2.2.4	AABUS		✓	Lot	1
Delta H ⁴	3.9.2.2.5	AABUS		✓	Lot	1
Percent Cure	3.9.2.2.6	AABUS		✓	Lot	1
Gel Time ⁴	3.9.2.2.7	2.3.18	✓	✓	Lot	1
Volatile Content ⁴	3.9.2.2.8	2.3.19	✓	✓	Lot	1
Thermal Conductivity ⁵	3.9.2.2.9	ASTM D5470 AABUS	✓	✓	3 Months	1
Chemical						
Flammability ^{7,8,9}	3.10.2.1	UL94	✓	✓	1 Month	10
Chemical Resistance ^{4,8}	3.10.2.2	2.3.4.2		✓	Lot	
Presence of Dicy ⁴	3.10.2.3	2.1.10	✓	✓	Lot	1
Electrical						
Permittivity ^{5,8}	3.11.2.1	2.5.5.2 2.5.5.3 2.5.5.5 2.5.5.9	✓	✓	1 Month ⁵	3
Loss Tangent ^{5,8}	3.11.2.2	2.5.5.2 2.5.5.3 2.5.5.5 2.5.5.9	✓	✓	1 Month ⁵	3
Electric Strength ⁸	3.11.2.3	2.5.6.2	✓	✓	3 Months	3
Environmental						
Fungus Resistance ⁸	3.12.2.1	2.6.1	✓			
CAF Growth Resistance ^{4,8}	3.12.2.2	2.6.25	✓			

¹ All methods are from IPC-TM-650 unless otherwise noted.² 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 2.3.16.2.³ For prepreg types other than no flow prepreg, either resin flow percent or scaled flow thickness may be specified for qualification and conformance testing.⁴ Optional tests **shall** be AABUS.⁵ Applicability to specific materials only and not all materials - **shall** be AABUS.⁶ Supplier **shall** use a statistical sampling plan to assure conformance to dimensional specifications.⁷ For flammability see Footnote 10 of Table 3-1. Prepreg conformance is satisfied by testing laminate samples from the same specification sheet.⁸ Tests to be conducted after pressing the prepreg into a laminate.⁹ 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.

3.4.1 Qualification Testing of Laminate Qualification of laminates **shall** require test data for both thin (<0.50 mm [<0.0197 in]) and thick (≥ 0.50 mm [≥ 0.0197 in]) materials. One set of test information for laminate 0.10 mm [0.00394 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 [0.00394 in], but <0.50 mm [0.0197 in], all laminates from that thickness up to and including 0.50 mm [0.0197 in] **shall** qualify laminates included in that range. One set of test information for a laminate of ≥ 0.8 mm [≥ 0.0315 in] thickness **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.

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-4563, IPC-CF-152 or AABUS. For alternate metal claddings not covered by industry standards, requirements **shall** be AABUS.

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 AABUS.

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 AABUS.

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 AABUS. 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 ≥ 0.55 m² [5.92 ft²]. 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 m² [5.92 ft²]. 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 m² [5.92 ft²]. The working border **shall** be the area excluding a 15 mm ± 3 mm [0.591 in ± 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 mm $\pm$ 5 mm [0.984 in $\pm$ 0.197 in] from all edges.

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 AABUS.

3.8.2 Inspection Lot

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

- Material covered by a single specification sheet and the same metal cladding type.
- One press load or 200 sheets, whichever is greater. The 200 sheets **shall** 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 **shall** require an additional prepreg inspection point. Allowance of this **shall** be AABUS.

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 AABUS.

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 (also termed 6/6 or 1.0) 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 (also termed 6/6 or 1.0) 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.

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 (also termed 6/6 or 1.0) vision of the sheet or panel.

Table 3-4 Surface Quality Classification

Surface Quality Class	Maximum Point Count	Other Requirements
Class A ¹	29	
Class B	17	
Class C	5	Longest Dimensions $\leq 380 \mu\text{m}$ [0.01496 in]
Class D ²	0	Longest Dimensions $< 125 \mu\text{m}$ [0.00492 in] Resin spots = 0
Class X	AABUS	

¹ Class A requirements **shall** apply, unless otherwise specified.

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

3.8.3.1.3 Scratches Scratches are not permitted where any part of the defect is $\geq 20\%$ of the nominal foil thickness (i.e., $3.4 \mu\text{m}$ [0.000134 in] for $17 \mu\text{m}$ [0.000669 in] 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 $\geq 5\%$ 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 that no subsurface imperfections are present in excess of those shown below. 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 AABUS.

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^2 [5.92 ft^2] 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.
- The foreign inclusions are translucent.
- Opaque foreign fibers are $\leq 13 \text{ mm}$ [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.
- Opaque foreign matter other than fibers **shall not** exceed 0.50 mm [0.019 in]. Opaque foreign inclusions $< 0.13 \text{ mm}$ [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.
- Voids are $< 0.075 \text{ mm}$ [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 (also termed 6/6 or 1.0) vision.

3.8.3.2.1 Inclusions Metallic inclusions are not acceptable. Nonmetallic inclusions or foreign material **shall** be acceptable, provided they are $< 0.50 \text{ mm}$ [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.

- Overall prepreg thickness increases from reinforcement imperfections is 99% maximum.
- 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 ± 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 AABUS. Adjacent edges **shall** be perpendicular within 0.075 mm [0.0029 in] per 25 mm [0.984 in] for laminate.

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

Panels	Variations
<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 $\leq$ Width $\leq$ 1.5 m [1.48 ft $\leq$ Width $\leq$ 4.92 ft] 0.45 m $\leq$ Length $\leq$ 3.6 m [1.48 ft $\leq$ Length $\leq$ 11.8 ft]	+25.0/-0.0 mm [+0.984/-0.000 in]

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 AABUS. Adjacent edges **shall** be perpendicular, within 0.13 mm [0.00512 in] per 25 mm [0.984 in].

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

Panels	Grade A ¹	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]
Rolls		
Width	+6.4/-0.0 mm [+0.252/-0.000 in]	
Length	$\pm 1\%$ of specified value	

¹ Grade A requirements **shall** apply, unless otherwise specified.

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 [+0.252/-0.000 in] of the specified value.

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).

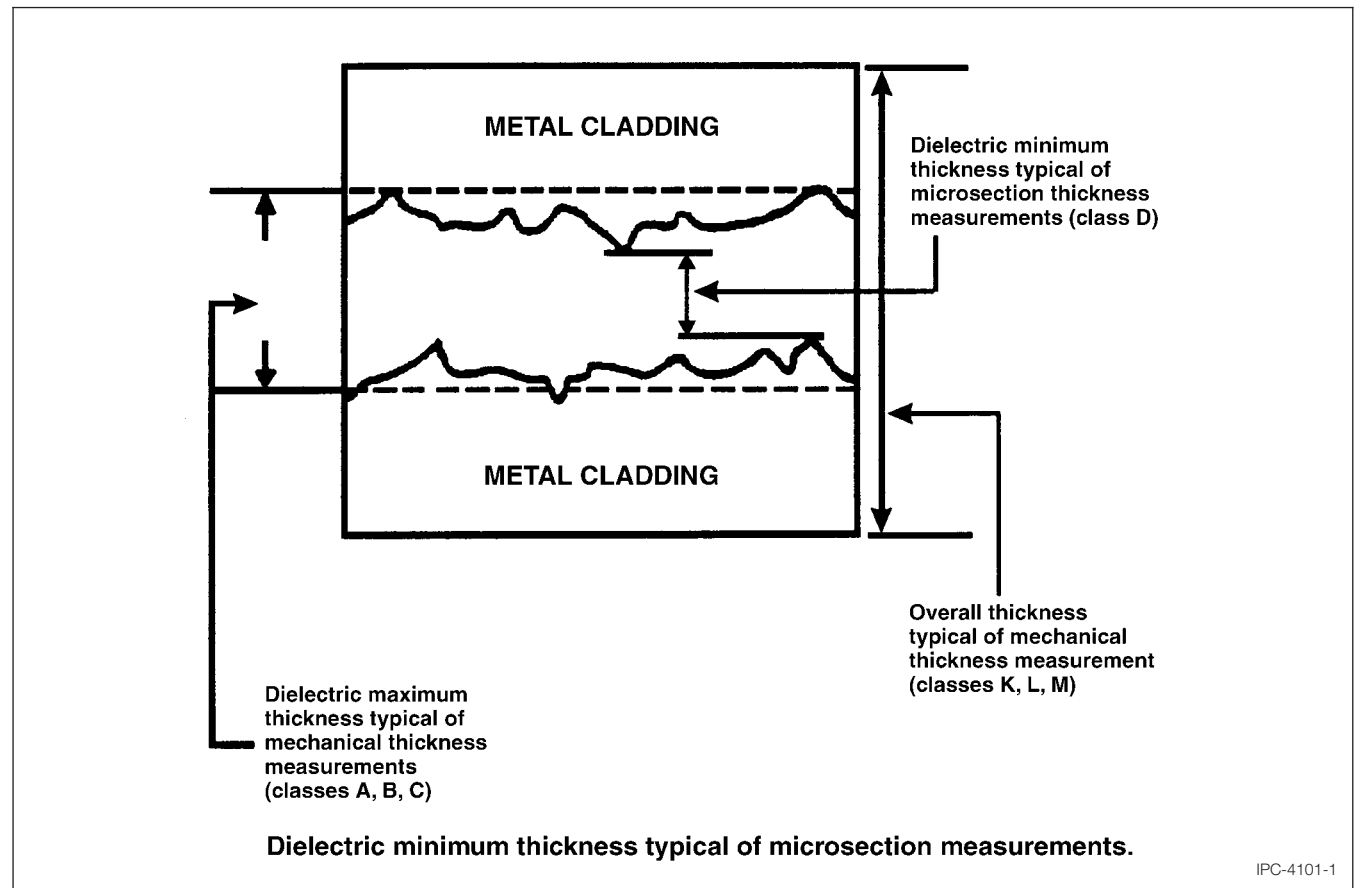


Figure 3-1 Thickness Measurements for Laminates

3.8.4.2.3 Class K, L and 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** 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 AABUS. 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 methods and values **shall** be AABUS.

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]	± 0.025 [± 0.000984]	± 0.018 [± 0.000709]	± 0.013 [± 0.000512]	-0.013 [-0.000512] + 0.025 [+ 0.000984]
0.120 to 0.164 [0.0047 to 0.0065]	± 0.038 [± 0.00150]	± 0.025 [± 0.000984]	± 0.018 [± 0.000709]	-0.018 [-0.000709] + 0.030 [+ 0.00118]
0.165 to 0.299 [0.0065 to 0.0118]	± 0.050 [± 0.00197]	± 0.038 [± 0.00150]	± 0.025 [± 0.000984]	-0.025 [-0.000984] + 0.038 [+ 0.00150]
0.300 to 0.499 [0.0118 to 0.0196]	± 0.064 [± 0.00252]	± 0.050 [± 0.00197]	± 0.038 [± 0.00150]	-0.038 [-0.00150] + 0.050 [+ 0.0197]
0.500 to 0.785 [0.0197 to 0.0309]	± 0.075 [± 0.00295]	± 0.064 [± 0.00252]	± 0.050 [± 0.00197]	-0.050 [-0.0197] + 0.064 [+ 0.00252]
0.786 to 1.039 [0.0309 to 0.04091]	± 0.165 [± 0.006496]	± 0.10 [± 0.00394]	± 0.075 [± 0.00295]	—
1.040 to 1.674 [0.04091 to 0.06594]	± 0.190 [± 0.007480]	± 0.13 [± 0.00512]	± 0.075 [± 0.00295]	—
1.675 to 2.564 [0.06594 to 0.10094]	± 0.23 [± 0.00906]	± 0.18 [± 0.00709]	± 0.10 [± 0.00394]	—
2.565 to 3.579 [0.10094 to 0.14091]	± 0.30 [± 0.0118]	± 0.23 [± 0.00906]	± 0.13 [± 0.00512]	—
3.580 to 6.35 [0.14094 to 0.250]	± 0.56 [± 0.0220]	± 0.30 [± 0.0118]	± 0.15 [± 0.00591]	—

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

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

All foil weights may be plated up to 35 µm [0.00138 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 Test) 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 AABUS. The tolerance **shall** be Range A unless otherwise specified on the purchase order or AABUS:

Range A ± 300 ppm (0.0003 cm/cm [0.0003 in/in])

Range B ± 200 ppm (0.0002 cm/cm [0.0002 in/in])

Range C ± 100 ppm (0.0001 cm/cm [0.0001 in/in])

Range X Unspecified, not applicable or AABUS.

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.

3.9.1.5 Thermal Conductivity [$\pm$] w/(m²K) According to the manufacturer's instructions, laminated specimens are prepared from the thermally conductive material that are approximately 0.25 mm [0.010 in], 0.50 mm [0.020 in] and 0.75 mm [0.030 in] thicknesses. When specimens are tested in accordance with Table 3-1, the thermal conductivity **shall** meet one of the following levels as specified on the purchase order or in the applicable specification sheet.

Level A	≤ 1.0
Level B	$> 1.0 \leq 2.0$
Level C	$> 2.0 \leq 3.0$
Level D	$> 3.0 \leq 5.0$
Level X	AABUS

3.9.1.6 Coefficient of Thermal Expansion (CTE) (Optional Test) When specimens are tested in accordance with Table 3-1, the X/Y CTE **shall** meet the values AABUS.

3.9.1.7 Z-Axis CTE / Total Expansion (Optional Test) When specimens are tested in accordance with Table 3-1, the Z-Axis CTE **shall** meet the values as specified on the purchase order or in the applicable specification sheet. The terms: "Alpha 1" and "Alpha 2" are defined as: Alpha 1 is the Z-axis CTE as measured at a temperature below the quoted T_g of the material in question and Alpha 2 is the Z-axis CTE as measured at a temperature above the quoted T_g of the material in question. The value required from -50 °C to 260 °C is Total Expansion and not CTE.

Note: Test specimens **shall** be constructed such that their thickness will be 1.5-2.36 mm [0.0591-0.0929 in] thick and have a retained resin content of 40-45%.

3.9.1.8 Fracture Toughness (Optional Test) The fracture toughness of the base resin system is recognized as a significant material attribute. A test method, identified as TM 2.4.52 is in IPC-TM-650. Performance level requirements will be developed in the future and fracture toughness may then be considered as a specification sheet element. Until that takes place, when specimens are tested in accordance with this test method, the fracture toughness **shall** be AABUS.

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 AABUS. 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 AABUS.

Note: Any fillers added to the resin in the manufacture of the prepreg **shall** be considered to be part of the resin weight percentage and not part of the reinforcement weight percentage of the total weight of prepreg.

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 AABUS.

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 AABUS.

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 AABUS.

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 AABUS.

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 AABUS.

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 AABUS.

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 AABUS.

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 AABUS.

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 AABUS.

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 AABUS.

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 AABUS.

3.9.2.2.9 Thermal Conductivity (Prepreg Reference) [=] W/(m²K) According to the manufacturer's instructions, laminated specimens are prepared from the thermally conductive prepreg material that are approximately 0.25 mm [0.010 in], 0.50 mm [0.020 in] and 0.75 mm [0.030 in] thicknesses. When specimens are tested in accordance with Table 3-1, the thermal conductivity **shall** meet one of the following levels as specified on the purchase order or in the applicable specification sheet.

Level A ≤1.0

Level B >1.0 ≤2.0

Level C >2.0 ≤3.0

Level D >3.0 ≤5.0

Level X AABUS

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 the applicable specification sheet indicates no requirement (None) or AABUS, the materials must be tested for flammability and results recorded during the qualification process. If the specification sheet denotes the Flame Retardant Mechanism as: "RoHS Compliant Bromine," this **shall** be taken to mean that the bromine flame retardant is compliant with the EU RoHS requirements.

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 ° Baume that is 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 Test) When specimens are tested in accordance with Table 3-1, the weight change following chemical exposure **shall** be AABUS.

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 AABUS.

3.10.1.6 Glass Transition Temperature (T_g) (Optional Test) When specimens are tested in accordance with Table 3-1, the T_g **shall** meet the values as required in the specification sheet or AABUS. It is recognized that different test methods yield different T_g results. In stating the test results, the test method used **shall** be stipulated.

The thermal analysis test methods to be considered in conjunction with this document are:

- Differential Scanning Calorimetry (DSC)
- Thermal Mechanical Analysis (TMA)
- Dynamic Mechanical Analysis (DMA)

The T_g is an inherent transition property of each polymer that occurs over a broad range in temperature. It arises when the polymer's molecular mobility increases as a result of an externally applied heat source.

No single T_g test method is inherently superior to another; they all simply measure different physical changes that occur in a polymer specimen near and around the T_g . The DSC measures the change in heat capacity of a polymer as it transitions in a controlled manner from one temperature to another. The TMA measures the rate of physical expansion of a polymer over a similar externally applied temperature transition. Finally, the DMA measures the polymer's relative change in stiffness as it again, transitions between two temperatures.

Please note that the T_g value of a polymer as tested by each of the thermal analysis techniques can result in significantly different results; sometimes as much as 20 °C between test methods. Accordingly, the test equipment used **shall** be noted along with the reported value of the T_g ; e.g., 132 °C (DSC) or 143 °C (DMA).

3.10.1.7 Delta T_g (Optional Test) When specimens are tested in accordance with Table 3-1, the delta T_g **shall** meet the values AABUS.

3.10.1.8 Decomposition Temperature (Optional Test) When specimens are tested in accordance with Table 3-1, the decomposition temperature **shall** meet the values as specified on the purchase order or in the applicable specification sheet.

3.10.1.9 Time to Delaminate (TMA) (Optional Test) When specimens are tested in accordance with Table 3-1, the T260, T288 and T300 results **shall** meet the values specified on the purchase order or in the applicable specification sheet. The test specimens **shall** be constructed such that their thickness **shall** be 1.5-2.36 mm [0.0591-0.0929 in] thick and have a retained resin content of 40-45%. The test method procedure in Test Method 2.4.24.1 **shall** be followed for the testing at both 288 °C (T288) and 300 °C (T300) except for: a) The different ultimate temperature and b) The sample cladding requirement **shall** be per the 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 3-9. Prepreg must be laminated to produce a minimum thickness of 0.50 mm [0.020 in]. If the applicable specification sheet indicates no requirement (None) or AABUS, the materials must be tested for flammability and results recorded during the qualification process.

3.10.2.2 Chemical Resistance (Optional Test) When specimens are tested in accordance with Table 3-2, the weight change following chemical exposure **shall** be AABUS.

3.10.2.3 Presence of Dicyandiamide (Dicy) (Optional Test) When specimens are tested in accordance with Table 3-2, the amount of acceptable dicy crystals **shall** be AABUS.

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 the 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 Test) When tested in accordance with Table 3-1. The criteria used to evaluate the specimens **shall** be AABUS.

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

Note 1: The Test Method 2.3.41 is titled: “Total Halogen Content.”

Note 2: Test specimens **shall** be constructed such that their thickness will be 1.5-2.36 mm [0.0591-0.0929 in] thick and have a retained resin content of 40-45%.

3.12.1.5 Conductive Anodic Filament (CAF) Growth (Optional Test) Conductive anodic filament (CAF) growth resistance is recognized as a significant material attribute. IPC-9691, a CAF user’s guideline, provides information about CAF and how the test method should be utilized. Requirements for CAF will be considered as a specification sheet element at such time that by using TM 2.6.25, the performance level requirements are developed. Until then, the performance level requirements **shall** be AABUS.

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.

3.12.2.2 Conductive Anodic Filament (CAF) Growth (Optional Test) Conductive anodic filament (CAF) growth resistance is recognized as a significant material attribute. IPC-9691, a CAF user’s guideline, provides information about CAF and how the test method should be utilized. Requirements for CAF will be considered as a specification sheet element at such time that by using TM 2.6.25, the performance level requirements are developed. Until then, the performance level requirements **shall** be AABUS.

3.13 Substitutability

3.13.1 Permissible Substitutions of Specification Sheet Materials For purposes of use, the following base material substitutions in Table 3-10 **shall** be allowed:

Table 3-10 Permissible Material Substitutions

Original Drawings Released Before December 31, 2016	Permissible Substitutions from Other IPC-4101 Current Revision Specification Sheets
/21	/24, /26, /97, /98, /99, /101, /121, /124, /126, /129
/24	/26, /98, /99, /124, /126, /129
/26	/126, /129
/30	/135
/129	/98, /99, /101, /126

3.13.2 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.

3.13.3 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.

3.13.4 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 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. Deviations to these requirements **shall** be AABUS.

Condition 1: 180 days when stored at <5 °C [41 °F]

Condition 2: 90 days when stored at <23 °C [73 °F] and <50% RH

Prepreg exceeding the shelf life requirements prior to shipment to the user **shall** 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/NCSS Z540-1 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 characteristics. 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 **shall** 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

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 an L+zero (L0) for the specification sheet number for laminate materials and a P+zero (P0) for the specification sheet number for prepreg materials.

7 KEYWORDS

Keywords, as part of the header section for each specification sheet, are intended to be used as search terms to provide information as to the typical property, application, design and performance characteristics of that base material. The Keywords will assist the reader by providing detail not found in the composition or performance requirements sections. The Keywords are **not specification requirements** nor are they intended to be restrictive as to the use of the material described. Similarly, having a particular Keyword in the header section, does not guarantee the acceptability of this material for a specific application. Examples to clarify the use of Keywords are shown below:

Example 1: One Keyword for IPC-4101/10 reads “Single-Sided.” This Keyword indicates that the typical application for this base material grade is for single-sided PCBs. This Keyword does not suggest that this base material cannot be used for double-sided PCBs, as well.

Example 2: A Keyword for IPC-4101/99 is “Lead-Free FR-4.” The Keyword “Lead-Free FR-4” indicates that the base material is intended to be compatible for lead-free assembly. Other FR-4 base materials not having a Keyword “Lead-Free FR-4” may never-the-less, be suitable for use in lead-free soldering.

Example 3: A Keyword for IPC-4101/03 reads “Consumer Electronics.” The Keyword indicates that the base material is typically or often used in consumer electronics. The Keyword does not indicate that IPC-4101/03 material is only useable for consumer electronics, but it can be used for other applications, as well.

7.1 Keyword Search Terms (Electronic/Soft Copy Searches) There are five categories of search terms that will be listed. These categories are intended to allow the document user to more easily find the best search term to see those particular Specification Sheets of most interest. The electronic search capability allows for only one search term (Keyword) to be used at any one time. The user is strongly advised to high-light and click on a specific Keyword search term and use that with which to run the search of interest in lieu of keying in, and potentially making an error with the search. There are a total of 62 Keyword search terms. Please note: To assist those searches performed with the hard copy of this specification, following each keyword search term are all specification sheets that use this keyword as a search term.

7.2 Segmented Keyword Search Terms and All Specification Sheets that Use the Specific Keywords for Searching

Material Composition Keywords	All Appropriate Specification Sheets
BT / Epoxy / Woven Glass	/30, /135
Cyanate Ester / Woven Glass	/71
Cyanate Ester / Woven S-2 Glass	/70
Cyanate Ester / Woven Quartz	/61
Epoxy / Cyanate Ester / Woven Glass	/29, /72, /73
Epoxy / Non-Epoxy / Nonwoven Aramid	/58
Epoxy / Nonwoven Aramid	/55
Epoxy / Paper	/04
Epoxy / PPO / Woven Glass	/25, /103, /134
Epoxy / Woven Aramid	/50
Epoxy / Woven Glass	/20, /21, /22, /23, /24, /26, /27, /97, /98, /99, /101, /121, /122, /124, /125, /126, /127, /128, /129, /130, /131
Epoxy / Woven Glass / 150 RTI	/151, /152, /153, /154
Epoxy / Woven Glass / Nonwoven Glass	/12, /16, /35, /81
Epoxy / Woven Glass / Paper	/10, /15, /80
Phenolic / Paper	/00, /01, /02, /03, /05
Polyester / Glass	/13
Polyester / Woven Glass / Nonwoven Glass	/11
Polyimide / Epoxy / Woven Glass	/42
Polyimide / Nonwoven Aramid	/53
Polyimide / Woven Glass	/40, /41, /43, /44
Polyimide / Woven Quartz	/60
PPE / Woven Glass	/90, /91, /96, /102, /134

Description or Application Keywords	All Appropriate Specification Sheets
Additive / Semi-Additive	/80, /81
Composite	/10, /11, /12, /14, /15, /16, /35
Consumer Electronics	/00, /01, /02, /03, /04, /05, /10, /11, /12, /14, /15, /16, /80, /81
Crossplied Unidirectional	/27
Double-Sided	/12, /14, /16, /81
Heatsink Application	/31, /32, /33, /34, /35
Lead-Free FR-4	/99, /101, /121, /122, /124, /125, /126, /127, /128, /129, /130, /131
Lead-Free Non-FR-4	/16, /102, /103
Microvia	/53, /55, /58
Non-Reinforced Film	/31, /33, /34
Punchable	/00, /01, /02, /03, /04, /05, /10, /11, /12, /14, /15, /16, /80, /81
Single-Sided	/00, /01, /02, /03, /04, /05, /10, /11, /15, /80

ANSI or Military Keywords	All Appropriate Specification Sheets
CEM-1	/10, /15, /80
CEM-3	/12, /14, /16, /35, /81
CRM-5	/11
FR-1	/02
FR-2	/03, /05
FR-3	/04
FR-4.0	/21, /24, /26, /27, /72, /73, /97, /98, /99, /101, /121, /124, /126, /129
FR-4.1	/122, /125, /127, /128, /130, /131
FR-15.0	/151, /152
FR-15.1	/153, /154
FR-5	/23
G-10	/20
G-11	/22
XPC	/00
XXXPC	/01
GFN	/21, /24, /97, /98
GFT	/26
GPY	/30, /40, /41, /42, /135

Material Property Keywords	All Appropriate Specification Sheets
CAF Resistance	/29, /30, /61, /70, /71, /72, /73, /102, /126, /129, /130, /131, /134, /135
High Decomposition Temperature	/99, /124, /125, /126, /128, /129, /130, /131, /134
High Reliability	/40, /41, /42, /43, /44
Hot Flex Strength	/22, /23
Low Dk / Df	/13, /25, /43, /44, /50, /53, /55, /58, /61, /70, /71, /72, /73, /90, /91, /96, /102, /103, /134
Low Halogen Content	/05, /14, /15, /35, /44, /58, /96, /122, /125, /127, /128, /130, /131, /134
Low X / Y CTE	/50, /53, /55, /58, /60, /61, /70
Low Z-axis CTE	/43, /44, /99, /101, /102, /121, /122, /124, /125, /126, /127, /128, /129, /130, /131
Non-Flame Retardant	/20, /22
Thermally Conductive	/31, /32, /33, /34, /35

Material Modifier Keywords	All Appropriate Specification Sheets
Fillers	/10, /11, /12, /13, /14, /15, /16, /31, /32, /33, /34, /35, /40, /41, /42, /43, /44, /80, /81, /97, /98, /99, /101, /102, /103, /126, /127, /128, /130, /134, /135
Multifunctional Epoxy	/24, /55, /98

7.3 Keyword Search Terms for All Specification Sheets

IPC-4101 Specification Sheet Number	KEYWORDS - For Search Only - NOT GRADE REQUIREMENTS
/00	Single-Sided XPC Phenolic / Paper Consumer Electronics Punchable
/01	Single-Sided XXXPC Phenolic / Paper Consumer Electronics Punchable
/02	Single-Sided Phenolic / Paper FR-1 Consumer Electronics Punchable
/03	Single-Sided FR-2 Phenolic / Paper Consumer Electronics Punchable
/04	Single-Sided FR-3 Epoxy / Paper Consumer Electronics Punchable
/05	Single-Sided FR-2 Phenolic / Paper Low Halogen Content Consumer Electronics Punchable
/10	Epoxy / Woven Glass / Paper Composite Single-Sided Consumer Electronics Punchable CEM-1 Fillers
/11	Composite Single-Sided Consumer Electronics Punchable Polyester / Woven Glass / Nonwoven Glass CRM-5 Fillers
/12	Epoxy / Woven Glass / Nonwoven Glass Composite Consumer Electronics Punchable Double-Sided CEM-3 Fillers
/13	Polyester / Glass Low Dk / Df Fillers
/14	Composite Double-Sided Low Halogen Content Consumer Electronics Punchable CEM-3 Fillers

IPC-4101 Specification Sheet Number	KEYWORDS - For Search Only - NOT GRADE REQUIREMENTS
/15	Epoxy / Woven Glass / Paper Composite Single-Sided Consumer Electronics Punchable CEM-1 Low Halogen Content Fillers
/16	Epoxy / Woven Glass / Nonwoven Glass Composite Consumer Electronics Punchable Double-Sided CEM-3 Lead-Free Non-FR-4 Fillers
/20	Epoxy / Woven Glass G-10 Non-Flame Retardant
/21	FR-4.0 GFN Epoxy / Woven Glass
/22	Epoxy / Woven Glass Hot Flex Strength G-11 Non-Flame Retardant
/23	Epoxy / Woven Glass Hot Flex Strength FR-5
/24	Epoxy / Woven Glass FR-4.0 Multifunctional Epoxy GFN
/25	Epoxy / PPO / Woven Glass Low Dk / Df
/26	Epoxy / Woven Glass FR-4.0 GFT
/27	Crossplied Unidirectional FR-4.0 Epoxy / Woven Glass
/29	Epoxy / Cyanate Ester / Woven Glass CAF Resistance
/30	BT / Epoxy / Woven Glass GPY CAF Resistance
/31	Non-Reinforced Film Thermally Conductive Heatsink Application Fillers
/32	Thermally Conductive Heatsink Application Fillers
/33	Non-Reinforced Film Thermally Conductive Heatsink Application Fillers
/34	Non-Reinforced Film Thermally Conductive Heatsink Application Fillers

IPC-4101 Specification Sheet Number	KEYWORDS - For Search Only - NOT GRADE REQUIREMENTS
/35	CEM-3 Low Halogen Content Thermally Conductive Heatsink Application Fillers
/40	Polyimide / Woven Glass High Reliability GPY Fillers
/41	Polyimide / Woven Glass High Reliability GPY Fillers
/42	Polyimide / Epoxy / Woven Glass High Reliability GPY Fillers
/43	Polyimide / Woven Glass Non-GPY High Reliability Low Moisture Absorption Low Loss Tangent Low Z-axis CTE Greater Time to Delaminate Fillers
/44	Polyimide / Woven Glass Non-GPY High Reliability Low Moisture Absorption Low Permittivity Low Loss Tangent Low Z-axis CTE Greater Time to Delaminate V-0 Flammability Fillers
/50	Epoxy / Woven Aramid Low X / Y CTE Low Dk / Df
/53	Polyimide / Nonwoven Aramid Low X / Y CTE Microvia Low Dk / Df
/55	Epoxy / Nonwoven Aramid Microvia Multifunctional Epoxy Low Dk / Df Low X / Y CTE
/58	Epoxy / Non-Epoxy / Nonwoven Aramid Low Halogen Content Microvia Low X / Y CTE Low Dk / Df
/60	Polyimide / Woven Quartz Low X / Y CTE
/61	Cyanate Ester / Woven Quartz Low X / Y CTE Low Dk / Df CAF Resistance
/70	Cyanate Ester / Woven S-2 Glass Low X / Y CTE Low Dk / Df CAF Resistance

IPC-4101 Specification Sheet Number	KEYWORDS - For Search Only - NOT GRADE REQUIREMENTS
/71	Cyanate Ester / Woven Glass Low Dk / Df CAF Resistance
/72	Epoxy / Cyanate Ester / Woven Glass Low Dk / Df CAF Resistance FR-4.0
/73	Epoxy / Cyanate Ester / Woven Glass Low Dk / Df CAF Resistance FR-4.0
/80	Epoxy / Woven Glass / Paper Punchable Additive / Semi-Additive Consumer Electronics CEM-1 Single-Sided Fillers
/81	Epoxy / Woven Glass / Nonwoven Glass Punchable Additive / Semi-Additive Consumer Electronics CEM-3 Double-Sided Fillers
/90	PPE / Woven Glass Low Dk / Df
/91	PPE / Woven Glass Low Dk / Df
/96	PPE / Woven Glass Low Halogen Content Low Dk / Df
/97	Epoxy / Woven Glass FR-4.0 GFN Fillers
/98	Epoxy / Woven Glass FR-4.0 GFN Multifunctional Epoxy Fillers
/99	Epoxy / Woven Glass Lead-Free FR-4.0 High Decomposition Temperature Low Z-axis CTE Fillers
/101	Epoxy / Woven Glass Lead-Free FR-4.0 Low Z-axis CTE Fillers
/102	PPE / Woven Glass Low Dk / Df Low Z-axis CTE CAF Resistance Lead-Free Non-FR-4 Fillers
/103	Epoxy / PPO / Woven Glass Low Dk / Df Lead-Free Non-FR-4 Fillers

IPC-4101 Specification Sheet Number	KEYWORDS - For Search Only - NOT GRADE REQUIREMENTS
/121	Epoxy / Woven Glass Lead-Free FR-4.0 Low Z-axis CTE
/122	Epoxy / Woven Glass Lead-Free FR-4.1 Low Z-axis CTE Low Halogen Content
/124	Epoxy / Woven Glass Lead-Free FR-4.0 Low Z-axis CTE High Decomposition Temperature
/125	Epoxy / Woven Glass Lead-Free FR-4.1 Low Z-axis CTE High Decomposition Temperature Low Halogen Content
/126	Epoxy / Woven Glass Lead-Free FR-4.0 Low Z-axis CTE High Decomposition Temperature CAF Resistance Fillers
/127	Epoxy / Woven Glass Lead-Free FR-4.1 Low Z-axis CTE Low Halogen Content Fillers
/128	Epoxy / Woven Glass Lead-Free FR-4.1 High Decomposition Temperature Low Z-axis CTE Low Halogen Content Fillers
/129	Epoxy / Woven Glass Lead-Free FR-4.0 Low Z-axis CTE High Decomposition Temperature CAF Resistance
/130	Epoxy / Woven Glass Lead-Free FR-4.1 Low Z-axis CTE High Decomposition Temperature CAF Resistance Low Halogen Content Fillers
/131	Epoxy / Woven Glass Lead-Free FR-4.1 Low Z-axis CTE High Decomposition Temperature CAF Resistance Low Halogen Content
/134	PPO / Woven Glass Low Dk / Df Low Halogen Content High Tg / Td
/135	BT / Epoxy / Woven Glass GPY CAF Resistance Fillers

IPC-4101 Specification Sheet Number	KEYWORDS - For Search Only - NOT GRADE REQUIREMENTS
/151	Epoxy / Woven Glass Lead-Free FR-15.0 150 RTI High Decomposition Temperature Low Z-axis CTE Fillers
/152	Epoxy / Woven Glass Lead-Free FR-15.0 150 RTI High Decomposition Temperature Low Z-axis CTE Fillers
/153	Epoxy / Woven Glass Lead-Free FR-15.1 150 RTI High Decomposition Temperature Low Z-axis CTE Fillers Low Halogen Content
/154	Epoxy / Woven Glass Lead-Free FR-15.1 150 RTI High Decomposition Temperature Low Z-axis CTE Fillers Low Halogen Content

Summary Information for Specification Sheets for Laminates and Prepregs

SPECIFICATION SHEET #: IPC-4101/00 REINFORCEMENT: 1: Cellulose paper RESIN SYSTEM: <i>Primary:</i> Phenolic <i>Secondary 1:</i> NONE FLAME RETARDANT MECHANISM: NONE FILLERS: NONE ID REFERENCE: <i>UL/ANSI:</i> XPC <i>ANSI:</i> XPC/00 GLASS TRANSITION (T_g): Not Specified	2: NONE <i>Secondary 2:</i> NONE Minimum UL94 Requirement: HB MIL-S-13949: NONE	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Single-Sided XPC Phenolic / Paper Consumer Electronics Punchable
SPECIFICATION SHEET #: IPC-4101/01 REINFORCEMENT: 1: Cellulose paper RESIN SYSTEM: <i>Primary:</i> Phenolic <i>Secondary 1:</i> NONE FLAME RETARDANT MECHANISM: NONE FILLERS: NONE ID REFERENCE: <i>UL/ANSI:</i> XXXPC <i>ANSI:</i> XXXPC/01 GLASS TRANSITION (T_g): Not Specified	2: NONE <i>Secondary 2:</i> NONE Minimum UL94 Requirement: HB MIL-S-13949: NONE	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Single-Sided XXXPC Phenolic / Paper Consumer Electronics Punchable
SPECIFICATION SHEET #: IPC-4101/02 REINFORCEMENT: 1: Cellulose paper RESIN SYSTEM: <i>Primary:</i> Phenolic <i>Secondary 1:</i> NONE FLAME RETARDANT MECHANISM: Bromine/Chlorine FILLERS: NONE ID REFERENCE: <i>UL/ANSI:</i> FR-1 <i>ANSI:</i> FR-1/02 GLASS TRANSITION (T_g): Not Specified	2: NONE <i>Secondary 2:</i> NONE Minimum UL94 Requirement: V-1 MIL-S-13949: NONE	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Single-Sided Phenolic / Paper FR-1 Consumer Electronics Punchable
SPECIFICATION SHEET #: IPC-4101/03 REINFORCEMENT: 1: Cellulose paper RESIN SYSTEM: <i>Primary:</i> Phenolic <i>Secondary 1:</i> NONE FLAME RETARDANT MECHANISM: Bromine/Chlorine FILLERS: NONE ID REFERENCE: <i>UL/ANSI:</i> FR-2 <i>ANSI:</i> FR-2/03 GLASS TRANSITION (T_g): Not Specified	2: NONE <i>Secondary 2:</i> NONE Minimum UL94 Requirement: V-1 MIL-S-13949: NONE	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Single-Sided FR-2 Phenolic / Paper Consumer Electronics Punchable
SPECIFICATION SHEET #: IPC-4101/04 REINFORCEMENT: 1: Cellulose paper RESIN SYSTEM: <i>Primary:</i> Epoxy <i>Secondary 1:</i> NONE FLAME RETARDANT MECHANISM: Bromine/Chlorine/Antimony oxide FILLERS: NONE ID REFERENCE: <i>UL/ANSI:</i> FR-3 <i>ANSI:</i> FR-3/04 GLASS TRANSITION (T_g): Not Specified	2: NONE <i>Secondary 2:</i> NONE Minimum UL94 Requirement: V-1 MIL-S-13949: NONE	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Single-Sided FR-3 Epoxy / Paper Consumer Electronics Punchable
SPECIFICATION SHEET #: IPC-4101/05 REINFORCEMENT: 1: Cellulose paper RESIN SYSTEM: <i>Primary:</i> Phenolic <i>Secondary 1:</i> NONE FLAME RETARDANT MECHANISM: Phosphorus† FILLERS: NONE ID REFERENCE: <i>UL/ANSI:</i> FR-2 <i>ANSI:</i> FR-2/05 GLASS TRANSITION (T_g): Not Specified	2: NONE <i>Secondary 2:</i> NONE Minimum UL94 Requirement: V-1 MIL-S-13949: NONE †900 ppm max. Br or Cl and 1500 ppm max. Br + Cl	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Single-Sided FR-2 Phenolic / Paper Low Halogen Content Consumer Electronics Punchable

SPECIFICATION SHEET #: IPC-4101/10 REINFORCEMENT: 1: Woven E-glass, surface RESIN SYSTEM: <i>Primary:</i> Epoxy <i>Secondary 1:</i> Phenolic FLAME RETARDANT MECHANISM: Bromine/Antimony oxide FILLERS: With or without inorganic fillers ID REFERENCE: <i>UL/ANSI:</i> CEM-1 <i>ANSI:</i> CEM-1/10 GLASS TRANSITION (T_g): 100 °C minimum	2: Cellulose paper, core Secondary 2: NONE Minimum UL94 Requirement: V-0 MIL-S-13949: NONE	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Epoxy / Woven Glass / Paper Composite Single-Sided Consumer Electronics Punchable CEM-1 Fillers
SPECIFICATION SHEET #: IPC-4101/11 REINFORCEMENT: 1: Woven E-glass, surface RESIN SYSTEM: <i>Primary:</i> Polyester <i>Secondary 1:</i> Vinyl ester FLAME RETARDANT MECHANISM: Bromine FILLERS: Inorganic fillers ID REFERENCE: <i>UL/ANSI:</i> NONE <i>ANSI:</i> CRM-5/11 GLASS TRANSITION (T_g): Not Specified	2: Nonwoven E-glass core Secondary 2: NONE Minimum UL94 Requirement: V-1 MIL-S-13949: NONE	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Composite Single-Sided Consumer Electronics Punchable Polyester / Woven Glass / Nonwoven Glass CRM-5 Fillers
SPECIFICATION SHEET #: IPC-4101/12 REINFORCEMENT: 1: Woven E-glass, surface RESIN SYSTEM: <i>Primary:</i> Epoxy <i>Secondary 1:</i> NONE FLAME RETARDANT MECHANISM: Bromine FILLERS: With or without inorganic fillers ID REFERENCE: <i>UL/ANSI:</i> CEM-3 <i>ANSI:</i> CEM-3/12 GLASS TRANSITION (T_g): Not Specified	2: Nonwoven E-glass core Secondary 2: NONE Minimum UL94 Requirement: V-0 MIL-S-13949: NONE	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Epoxy / Woven Glass / Nonwoven Glass Composite Consumer Electronics Punchable Double-Sided CEM-3 Fillers
SPECIFICATION SHEET #: IPC-4101/13 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Polyester <i>Secondary 1:</i> Vinyl ester FLAME RETARDANT MECHANISM: Bromine FILLERS: Inorganic fillers ID REFERENCE: <i>UL/ANSI:</i> NONE <i>ANSI:</i> 4101/13 GLASS TRANSITION (T_g): Not Specified	2: NONE Secondary 2: NONE Minimum UL94 Requirement: V-1 MIL-S-13949: NONE	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Polyester / Glass Low Dk / Df Fillers
SPECIFICATION SHEET #: IPC-4101/14 REINFORCEMENT: 1: Woven E-glass, surface RESIN SYSTEM: <i>Primary:</i> Epoxy <i>Secondary 1:</i> NONE FLAME RETARDANT MECHANISM: Phosphorus† FILLERS: With or without inorganic fillers ID REFERENCE: <i>UL/ANSI:</i> CEM-3 <i>ANSI:</i> CEM-3/14 GLASS TRANSITION (T_g): Not Specified	2: Nonwoven E-glass Core Secondary 2: NONE Minimum UL94 Requirement: V-0 MIL-S-13949: NONE †900 ppm max. Br or Cl and 1500 ppm max. Br + Cl	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Composite Double-Sided Low Halogen Content Consumer Electronics Punchable CEM-3 Fillers
SPECIFICATION SHEET #: IPC-4101/15 REINFORCEMENT: 1: Woven E-glass, surface RESIN SYSTEM: <i>Primary:</i> Epoxy <i>Secondary 1:</i> Phenolic FLAME RETARDANT MECHANISM: Phosphorus† FILLERS: With or without inorganic fillers ID REFERENCE: <i>UL/ANSI:</i> NONE <i>ANSI:</i> CEM-1 GLASS TRANSITION (T_g): 100 °C minimum	2: Cellulose paper, Core Secondary 2: NONE Minimum UL94 Requirement: V-0 MIL-S-13949: NONE †900 ppm max. Br or Cl and 1500 ppm max. Br + Cl	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Epoxy / Woven Glass / Paper Composite Single-Sided Consumer Electronics Punchable CEM-1 Low Halogen Content Fillers

SPECIFICATION SHEET #: IPC-4101/16 REINFORCEMENT: 1: Woven E-glass, surface RESIN SYSTEM: <i>Primary:</i> Epoxy <i>Secondary 1:</i> Phenolic FLAME RETARDANT MECHANISM: Bromine FILLERS: Contains inorganic fillers ID REFERENCE: <i>UL/ANSI:</i> NONE <i>ANSI:</i> CEM-3/16 GLASS TRANSITION (T_g): 110 °C minimum	2: Nonwoven E-glass core <i>Secondary 2:</i> NONE Minimum UL94 Requirement: V-0 MIL-S-13949: NONE	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Epoxy / Woven Glass / Nonwoven Glass Composite Consumer Electronics Punchable Double-Sided CEM-3 Lead-Free Non-FR-4 Fillers
SPECIFICATION SHEET #: IPC-4101/20 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Epoxy <i>Secondary 1:</i> NONE FLAME RETARDANT MECHANISM: NONE FILLERS: NONE ID REFERENCE: <i>UL/ANSI:</i> G-10 <i>ANSI:</i> G-10/20 GLASS TRANSITION (T_g): NONE	2: NONE <i>Secondary 2:</i> NONE Minimum UL94 Requirement: HB MIL-S-13949: /03 - GE, GEN	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Epoxy / Woven Glass G-10 Non-Flame Retardant
SPECIFICATION SHEET #: IPC-4101/21 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Difunctional epoxy <i>Secondary 1:</i> Multifunctional epoxy FLAME RETARDANT MECHANISM: RoHS Compliant Bromine FILLERS: <5% ID REFERENCE: <i>UL/ANSI:</i> FR-4.0/21 GLASS TRANSITION (T_g): 110 °C minimum	2: NONE <i>Secondary 2:</i> NONE Minimum UL94 Requirement: V-0 MIL-S-13949: /04 - GF, GFN, GFK, GFP, GFM	Keywords: (For Search Only) NOT Grade Requirement See Section 7 FR-4.0 GFN Epoxy / Woven Glass
SPECIFICATION SHEET #: IPC-4101/22 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Epoxy, hot strength retention <i>Secondary 1:</i> NONE FLAME RETARDANT MECHANISM: NONE FILLERS: NONE ID REFERENCE: <i>UL/ANSI:</i> G-11 <i>ANSI:</i> G-11/22 GLASS TRANSITION (T_g): 135 °C - 175 °C	2: NONE <i>Secondary 2:</i> NONE Minimum UL94 Requirement: HB MIL-S-13949: /02 - GB, GBN, GBP	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Epoxy / Woven Glass Hot Flex Strength G-11 Non-Flame Retardant
SPECIFICATION SHEET #: IPC-4101/23 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Epoxy, hot strength retention <i>Secondary 1:</i> NONE FLAME RETARDANT MECHANISM: Bromine FILLERS: NONE ID REFERENCE: <i>UL/ANSI:</i> FR-5 <i>ANSI:</i> FR-5/23 GLASS TRANSITION (T_g): 135 °C - 185 °C	2: NONE <i>Secondary 2:</i> NONE Minimum UL94 Requirement: V-1 MIL-S-13949: /05 - GH, GHN, GHP	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Epoxy / Woven Glass Hot Flex Strength FR-5
SPECIFICATION SHEET #: IPC-4101/24 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Epoxy <i>Secondary 1:</i> Multifunctional epoxy FLAME RETARDANT MECHANISM: RoHS Compliant Bromine FILLERS: <5% ID REFERENCE: <i>UL/ANSI:</i> FR-4.0/24 GLASS TRANSITION (T_g): 150 °C minimum	2: NONE <i>Secondary 2:</i> NONE Minimum UL94 Requirement: V-0 MIL-S-13949: /04 - GF, GFG, GFN	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Epoxy / Woven Glass FR-4.0 Multifunctional Epoxy GFN
SPECIFICATION SHEET #: IPC-4101/25 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Epoxy <i>Secondary 1:</i> Polyphenylene oxide FLAME RETARDANT MECHANISM: Bromine FILLERS: NONE ID REFERENCE: <i>UL/ANSI:</i> NONE <i>ANSI:</i> 4101/25 GLASS TRANSITION (T_g): 150 °C - 200 °C	2: NONE <i>Secondary 2:</i> NONE Minimum UL94 Requirement: V-1 MIL-S-13949: /04 - GF, GFG, GFN	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Epoxy / PPO / Woven Glass Low Dk / Df

SPECIFICATION SHEET #: IPC-4101/26 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Epoxy <i>Secondary 1:</i> Multifunctional epoxy FLAME RETARDANT MECHANISM: RoHS Compliant Bromine <5% FILLERS: <i>Secondary 2:</i> NONE ID REFERENCE: <i>Minimum UL94 Requirement:</i> V-0 GLASS TRANSITION (T_g): <i>MIL-S-13949:</i> /04 - GF, GFT 170 °C minimum	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Epoxy / Woven Glass FR-4.0 GFT
SPECIFICATION SHEET #: IPC-4101/27 REINFORCEMENT: 1: Unidirectional E-glass, cross plied RESIN SYSTEM: <i>Primary:</i> Epoxy <i>Secondary 1:</i> Multifunctional epoxy FLAME RETARDANT MECHANISM: Bromine FILLERS: NONE ID REFERENCE: <i>Secondary 2:</i> NONE <i>Minimum UL94 Requirement:</i> V-1 GLASS TRANSITION (T_g): <i>MIL-S-13949:</i> NONE 110 °C minimum	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Crossplied Unidirectional FR-4.0 Epoxy / Woven Glass
SPECIFICATION SHEET #: IPC-4101/29 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Epoxy <i>Secondary 1:</i> Cyanate ester FLAME RETARDANT MECHANISM: Bromine FILLERS: NONE ID REFERENCE: <i>Secondary 2:</i> NONE <i>Minimum UL94 Requirement:</i> V-1 GLASS TRANSITION (T_g): <i>MIL-S-13949:</i> /04 170 °C - 220 °C	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Epoxy / Cyanate Ester / Woven Glass CAF Resistance
SPECIFICATION SHEET #: IPC-4101/30 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Bismaleimide/Triazine (BT) <i>Secondary 1:</i> Epoxy FLAME RETARDANT MECHANISM: Bromine FILLERS: NONE ID REFERENCE: <i>Secondary 2:</i> NONE <i>Minimum UL94 Requirement:</i> HB GLASS TRANSITION (T_g): <i>MIL-S-13949:</i> /26 - GIT, GMT 170 °C - 220 °C	Keywords: (For Search Only) NOT Grade Requirement See Section 7 BT / Epoxy / Woven Glass GPY CAF Resistance
SPECIFICATION SHEET #: IPC-4101/31 REINFORCEMENT: 1: NONE RESIN SYSTEM: <i>Primary:</i> Epoxy <i>Secondary 1:</i> Multifunctional epoxy FLAME RETARDANT MECHANISM: NONE FILLERS (≥5%): Inorganic fillers ID REFERENCE: <i>Secondary 2:</i> NONE <i>Minimum UL94 Requirement:</i> NONE GLASS TRANSITION (T_g): <i>ANSI:</i> NONE 90 °C minimum	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Non-Reinforced Film Thermally Conductive Heatsink Application Fillers
SPECIFICATION SHEET #: IPC-4101/32 REINFORCEMENT: 1: Woven E-Glass RESIN SYSTEM: <i>Primary:</i> Epoxy <i>Secondary 1:</i> Multifunctional epoxy FLAME RETARDANT MECHANISM: NONE FILLERS (≥5%): Inorganic fillers ID REFERENCE: <i>Secondary 2:</i> NONE <i>Minimum UL94 Requirement:</i> NONE GLASS TRANSITION (T_g): <i>ANSI:</i> NONE 90 °C minimum	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Thermally Conductive Heatsink Application Fillers
SPECIFICATION SHEET #: IPC-4101/33 REINFORCEMENT: 1: NONE RESIN SYSTEM: <i>Primary:</i> Epoxy <i>Secondary 1:</i> Multifunctional epoxy FLAME RETARDANT MECHANISM: NONE FILLERS (≥5%): Inorganic fillers ID REFERENCE: <i>Secondary 2:</i> NONE <i>Minimum UL94 Requirement:</i> NONE GLASS TRANSITION (T_g): <i>ANSI:</i> NONE 150 °C minimum	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Non-Reinforced Film Thermally Conductive Heatsink Application Fillers

SPECIFICATION SHEET #: IPC-4101/34 REINFORCEMENT: 1: NONE RESIN SYSTEM: <i>Primary:</i> Epoxy <i>Secondary 1:</i> Multifunctional epoxy FLAME RETARDANT MECHANISM: NONE FILLERS (≥5%): Inorganic fillers ID REFERENCE: <i>UL/ANSI:</i> NONE <i>ANSI:</i> NONE GLASS TRANSITION (T_g): 185 °C minimum	2: NONE Secondary 2: NONE Minimum UL94 Requirement: NONE	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Non-Reinforced Film Thermally Conductive Heatsink Application Fillers
SPECIFICATION SHEET #: IPC-4101/35 REINFORCEMENT: 1: Woven E-glass, surface RESIN SYSTEM: <i>Primary:</i> Epoxy <i>Secondary 1:</i> Phenolic FLAME RETARDANT MECHANISM: Phosphorus FILLERS (≥5%): Inorganic fillers ID REFERENCE: <i>UL/ANSI:</i> CEM-3 <i>ANSI:</i> CEM-3 GLASS TRANSITION (T_g): 110 °C minimum	2: NONE Secondary 2: NONE Minimum UL94 Requirement: V-0	Keywords: (For Search Only) NOT Grade Requirement See Section 7 CEM-3 Low Halogen Content Thermally Conductive Heatsink Application Fillers
SPECIFICATION SHEET #: IPC-4101/40 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Polyimide <i>Secondary 1:</i> NONE FLAME RETARDANT MECHANISM: AABUS FILLERS: With or without inorganic fillers ID REFERENCE: <i>UL/ANSI:</i> GPY <i>ANSI:</i> GPY/40 GLASS TRANSITION (T_g): 200 °C minimum	2: NONE Secondary 2: NONE Minimum UL94 Requirement: HB MIL-S-13949: /10 - GI, GIN, GIJ, GIP, GIL	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Polyimide / Woven Glass High Reliability GPY Fillers
SPECIFICATION SHEET #: IPC-4101/41 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Polyimide <i>Secondary 1:</i> NONE FLAME RETARDANT MECHANISM: AABUS FILLERS: With or without inorganic fillers ID REFERENCE: <i>UL/ANSI:</i> GPY <i>ANSI:</i> GPY/41 GLASS TRANSITION (T_g): 250 °C minimum	2: NONE Secondary 2: NONE Minimum UL94 Requirement: HB MIL-S-13949: /10 - GIL, GIP	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Polyimide / Woven Glass High Reliability GPY Fillers
SPECIFICATION SHEET #: IPC-4101/42 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Polyimide <i>Secondary 1:</i> Epoxy FLAME RETARDANT MECHANISM: AABUS FILLERS: With or without inorganic fillers ID REFERENCE: <i>UL/ANSI:</i> GPY <i>ANSI:</i> GPY/42 GLASS TRANSITION (T_g): 200 °C minimum	2: NONE Secondary 2: NONE Minimum UL94 Requirement: HB MIL-S-13949: /10 - GIJ	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Polyimide / Epoxy / Woven Glass High Reliability GPY Fillers
SPECIFICATION SHEET #: IPC-4101/43 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Polyimide <i>Secondary 1:</i> NONE FLAME RETARDANT MECHANISM: AABUS FILLERS: Contains inorganic fillers ID REFERENCE: <i>UL/ANSI:</i> NONE <i>ANSI:</i> NONE GLASS TRANSITION (T_g): 250 °C minimum	2: NONE Secondary 2: NONE Minimum UL94 Requirement: HB MIL-S-13949: /10 - GI, GIN, GIL, GIP	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Polyimide / Woven Glass Non-GPY High Reliability Low Moisture Absorption Low Loss Tangent Low Z-axis CTE Greater Time to Delaminate Fillers

SPECIFICATION SHEET #: IPC-4101/44 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Polyimide <i>Secondary 1:</i> Modified Polyimide FLAME RETARDANT MECHANISM: Nitrogen / inorganic compound† INORGANIC FILLERS (≥5%): Contains inorganic fillers ID REFERENCE: <i>UL/ANSI:</i> NONE GLASS TRANSITION (T_g): 250 °C minimum	2: NONE Secondary 2: NONE Minimum UL94 Requirement: V-0 MIL-S-13949: NONE †900 ppm max. Br or Cl and max. Br + Cl 1500 ppm max. (if appropriate)	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Polyimide / Woven Glass Non-GPY High Reliability Low Moisture Absorption Low Permittivity Low Loss Tangent Low Z-axis CTE Greater Time to Delaminate V-0 Flammability Fillers
SPECIFICATION SHEET #: IPC-4101/50 REINFORCEMENT: 1: Woven aramid RESIN SYSTEM: <i>Primary:</i> Epoxy <i>Secondary 1:</i> Multifunctional epoxy FLAME RETARDANT MECHANISM: Bromine FILLERS: NONE ID REFERENCE: <i>UL/ANSI:</i> NONE <i>ANSI:</i> 4101/50 GLASS TRANSITION (T_g): 150 °C - 200 °C	2: NONE Secondary 2: NONE Minimum UL94 Requirement: V-1 MIL-S-13949: /15 - AF, AFN, AFG	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Epoxy / Woven Aramid Low X / Y CTE Low Dk / Df
SPECIFICATION SHEET #: IPC-4101/53 REINFORCEMENT: 1: Nonwoven aramid paper RESIN SYSTEM: <i>Primary:</i> Polyimide <i>Secondary 1:</i> NONE FLAME RETARDANT MECHANISM: NONE FILLERS: NONE ID REFERENCE: <i>UL/ANSI:</i> NONE <i>ANSI:</i> 4101/53 GLASS TRANSITION (T_g): 220 °C minimum	2: NONE Secondary 2: NONE Minimum UL94 Requirement: HB MIL-S-13949: /31 - BIN, BIJ	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Polyimide / Nonwoven Aramid Low X / Y CTE Microvia Low Dk / Df
SPECIFICATION SHEET #: IPC-4101/55 REINFORCEMENT: 1: Nonwoven aramid paper RESIN SYSTEM: <i>Primary:</i> Epoxy <i>Secondary 1:</i> Multifunctional epoxy FLAME RETARDANT MECHANISM: Bromine FILLERS: NONE ID REFERENCE: <i>UL/ANSI:</i> NONE <i>ANSI:</i> 4101/55 GLASS TRANSITION (T_g): 150 °C to 200 °C	2: NONE Secondary 2: NONE Minimum UL94 Requirement: V-1 MIL-S-13949: /22 - BF, BFN, BFG	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Epoxy / Nonwoven Aramid Microvia Multifunctional Epoxy Low Dk / Df Low X / Y CTE
SPECIFICATION SHEET #: IPC-4101/58 REINFORCEMENT: 1: Nonwoven aramid paper RESIN SYSTEM: <i>Primary:</i> Multifunctional epoxy <i>Secondary 1:</i> Non-Epoxy FLAME RETARDANT MECHANISM: Phosphorus† FILLERS: NONE ID REFERENCE: <i>UL/ANSI:</i> NONE <i>ANSI:</i> 4101/58 GLASS TRANSITION (T_g): 135 °C to 185 °C	2: NONE Secondary 2: NONE Minimum UL94 Requirement: V-0 MIL-S-13949: NONE †900 ppm max. Br or Cl and 1500 ppm max. Br + Cl	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Epoxy / Non-Epoxy / Nonwoven Aramid Low Halogen Content Microvia Low X / Y CTE Low Dk / Df
SPECIFICATION SHEET #: IPC-4101/60 REINFORCEMENT: 1: Woven quartz fiber RESIN SYSTEM: <i>Primary:</i> Polyimide <i>Secondary 1:</i> NONE FLAME RETARDANT MECHANISM: Bromine (if applicable) FILLERS: NONE ID REFERENCE: <i>UL/ANSI:</i> NONE <i>ANSI:</i> 4101/60 GLASS TRANSITION (T_g): 250 °C minimum	2: NONE Secondary 2: NONE Minimum UL94 Requirement: HB MIL-S-13949: /19 - QIL	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Polyimide / Woven Quartz Low X / Y CTE

SPECIFICATION SHEET #: IPC-4101/61 REINFORCEMENT: 1: Woven Quartz RESIN SYSTEM: <i>Primary:</i> Cyanate Ester <i>Secondary 1:</i> NONE FLAME RETARDANT MECHANISM: RoHS Compliant Bromine FILLERS: NONE ID REFERENCE: <i>UL/ANSI:</i> NONE <i>ANSI:</i> 4101/61 GLASS TRANSITION (T_g): 220 °C minimum	2: NONE <i>Secondary 2:</i> NONE Minimum UL94 Requirement: V-0 MIL-S-13949: /19 - QIL	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Cyanate Ester / Woven Quartz Low X / Y CTE Low Dk / Df CAF Resistance
SPECIFICATION SHEET #: IPC-4101/70 REINFORCEMENT: 1: Woven S-2 glass RESIN SYSTEM: <i>Primary:</i> Cyanate ester <i>Secondary 1:</i> NONE FLAME RETARDANT MECHANISM: Bromine FILLERS: NONE ID REFERENCE: <i>UL/ANSI:</i> NONE <i>ANSI:</i> 4101/70 GLASS TRANSITION (T_g): 230 °C minimum	2: NONE <i>Secondary 2:</i> NONE Minimum UL94 Requirement: V-1 MIL-S-13949: NONE	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Cyanate Ester / Woven S-2 Glass Low X / Y CTE Low Dk / Df CAF Resistance
SPECIFICATION SHEET #: IPC-4101/71 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Cyanate ester <i>Secondary 1:</i> NONE FLAME RETARDANT MECHANISM: Bromine FILLERS: NONE ID REFERENCE: <i>UL/ANSI:</i> NONE <i>ANSI:</i> 4101/71 GLASS TRANSITION (T_g): 230 °C minimum	2: NONE <i>Secondary 2:</i> NONE Minimum UL94 Requirement: V-1 MIL-S-13949: /29 - GCN	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Cyanate Ester / Woven Glass Low Dk / Df CAF Resistance
SPECIFICATION SHEET #: IPC-4101/72 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Epoxy <i>Secondary 1:</i> Cyanate Ester FLAME RETARDANT MECHANISM: RoHS Compliant Bromine FILLERS (≥5%): Contains inorganic fillers ID REFERENCE: <i>UL/ANSI:</i> FR-4.0 <i>ANSI:</i> 4101/72 GLASS TRANSITION (T_g): 170 °C minimum	2: NONE <i>Secondary 2:</i> Non-epoxy Minimum UL94 Requirement: V-0	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Cyanate Ester / Woven Glass Low Dk / Df CAF Resistance FR-4.0
SPECIFICATION SHEET #: IPC-4101/73 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Epoxy <i>Secondary 1:</i> Cyanate Ester FLAME RETARDANT MECHANISM: RoHS Compliant Bromine FILLERS (≥5%): Contains inorganic fillers ID REFERENCE: <i>UL/ANSI:</i> FR-4.0/73 <i>ANSI:</i> 4101/73 GLASS TRANSITION (T_g): 170 °C minimum	2: NONE <i>Secondary 2:</i> Modified Epoxy or Non-epoxy Minimum UL94 Requirement: V-0	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Cyanate Ester / Woven Glass Low Dk / Df CAF Resistance FR-4.0
SPECIFICATION SHEET #: IPC-4101/80 REINFORCEMENT: 1: Woven E-glass, surface RESIN SYSTEM: <i>Primary:</i> Epoxy <i>Secondary 1:</i> Phenolic FLAME RETARDANT MECHANISM: Bromine/Antimony oxide FILLERS: Kaolin and/or inorganic catalyst ID REFERENCE: <i>UL/ANSI:</i> CEM-1 <i>ANSI:</i> CEM-1/80 GLASS TRANSITION (T_g): 100 °C minimum	2: Cellulose paper, core <i>Secondary 2:</i> NONE Minimum UL94 Requirement: V-0 MIL-S-13949: NONE	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Epoxy / Woven Glass / Paper Punchable Additive / Semi-Additive Consumer Electronics CEM-1 Single-Sided Fillers

SPECIFICATION SHEET #: IPC-4101/81 REINFORCEMENT: 1: Woven E-glass, surface RESIN SYSTEM: <i>Primary:</i> Epoxy <i>Secondary 1:</i> Multifunctional epoxy FLAME RETARDANT MECHANISM: Bromine FILLERS: Kaolin and/or inorganic catalyst ID REFERENCE: <i>UL/ANSI:</i> CEM-3 <i>ANSI:</i> CEM-3/81 GLASS TRANSITION (T_g): Not Specified	2: Nonwoven E-glass (chopped felt), core <i>Secondary 2:</i> NONE Minimum UL94 Requirement: V-0 MIL-S-13949: NONE	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Epoxy / Woven Glass / Nonwoven Glass Punchable Additive / Semi-Additive Consumer Electronics CEM-3 Double-Sided Fillers
SPECIFICATION SHEET #: IPC-4101/90 REINFORCEMENT: 1: Woven E-glass, surface RESIN SYSTEM: <i>Primary:</i> Polyphenylene ether <i>Secondary 1:</i> NONE FLAME RETARDANT MECHANISM: Bromine/Antimony oxide FILLERS: NONE ID REFERENCE: <i>UL/ANSI:</i> NONE <i>ANSI:</i> 4101/90 GLASS TRANSITION (T_g): 175 °C minimum	2: NONE <i>Secondary 2:</i> NONE Minimum UL94 Requirement: V-1 MIL-S-13949: NONE	Keywords: (For Search Only) NOT Grade Requirement See Section 7 PPE / Woven Glass Low Dk / Df
SPECIFICATION SHEET #: IPC-4101/91 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Polyphenylene ether <i>Secondary 1:</i> NONE FLAME RETARDANT MECHANISM: Bromine FILLERS: NONE ID REFERENCE: <i>UL/ANSI:</i> NONE <i>ANSI:</i> 4101/91 GLASS TRANSITION (T_g): 175 °C minimum	2: NONE <i>Secondary 2:</i> NONE Minimum UL94 Requirement: V-1 MIL-S-13949: NONE	Keywords: (For Search Only) NOT Grade Requirement See Section 7 PPE / Woven Glass Low Dk / Df
SPECIFICATION SHEET #: IPC-4101/96 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Polyphenylene ether <i>Secondary 1:</i> NONE FLAME RETARDANT MECHANISM: Phosphorus† FILLERS: NONE ID REFERENCE: <i>UL/ANSI:</i> NONE <i>ANSI:</i> 4101/96 GLASS TRANSITION (T_g): 175 °C minimum	2: NONE <i>Secondary 2:</i> NONE Minimum UL94 Requirement: V-1 MIL-S-13949: NONE †900 ppm max. Br or Cl and 1500 ppm max. Br + Cl	Keywords: (For Search Only) NOT Grade Requirement See Section 7 PPE / Woven Glass Low Halogen Content Low Dk / Df
SPECIFICATION SHEET #: IPC-4101/97 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Difunctional epoxy <i>Secondary 1:</i> Multifunctional epoxy FLAME RETARDANT MECHANISM: RoHS Compliant Bromine FILLERS: Contains inorganic fillers ID REFERENCE: <i>UL/ANSI:</i> FR-4.0 <i>ANSI:</i> FR-4.0/97 GLASS TRANSITION (T_g): 110 °C minimum	2: NONE <i>Secondary 2:</i> NONE Minimum UL94 Requirement: V-0 MIL-S-13949: /04 - GF, GFN, GFK, GFP, GFM	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Epoxy / Woven Glass FR-4.0 GFN Fillers
SPECIFICATION SHEET #: IPC-4101/98 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Epoxy <i>Secondary 1:</i> Multifunctional epoxy FLAME RETARDANT MECHANISM: RoHS Compliant Bromine FILLERS: Contains inorganic fillers ID REFERENCE: <i>UL/ANSI:</i> FR-4.0 <i>ANSI:</i> FR-4.0/98 GLASS TRANSITION (T_g): 150 °C minimum	2: NONE <i>Secondary 2:</i> NONE Minimum UL94 Requirement: V-0 MIL-S-13949: /04 - GF, GFG, GFN	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Epoxy / Woven Glass FR-4.0 GFN Multifunctional Epoxy Fillers
SPECIFICATION SHEET #: IPC-4101/99 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Epoxy <i>Secondary 1:</i> Multifunctional epoxy FLAME RETARDANT MECHANISM: RoHS Compliant Bromine FILLERS: Contains inorganic fillers ID REFERENCE: <i>UL/ANSI:</i> FR-4.0/99 GLASS TRANSITION (T_g): 150 °C minimum	2: NONE <i>Secondary 2:</i> Modified Epoxy or Non-Epoxy (max. wt. 5%) Minimum UL94 Requirement: V-0	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Epoxy / Woven Glass Lead-Free FR-4.0 High Decomposition Temperature Low Z-axis CTE Fillers

SPECIFICATION SHEET #: IPC-4101/101 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Difunctional Epoxy <i>Secondary 1:</i> Multifunctional epoxy FLAME RETARDANT MECHANISM: RoHS Compliant Bromine FILLERS: Contains inorganic fillers ID REFERENCE: <i>UL/ANSI:</i> FR-4.0/101 GLASS TRANSITION (T_g): 110 °C minimum	2: NONE Secondary 2: Modified Epoxy or Non-Epoxy (max. wt. 5%) Minimum UL94 Requirement: V-0	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Epoxy / Woven Glass Lead-Free FR-4.0 Low Z-axis CTE Fillers
SPECIFICATION SHEET #: IPC-4101/102 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Modified Polyphenylene Ether <i>Secondary 1:</i> NONE FLAME RETARDANT MECHANISM: RoHS Compliant Bromine FILLERS (≥5%): Contains inorganic fillers ID REFERENCE: <i>UL/ANSI:</i> NONE <i>ANSI:</i> 4101/102 GLASS TRANSITION (T_g): 185 °C minimum	2: NONE Secondary 2: NONE Minimum UL94 Requirement: V-0 MIL-S-13949: NONE	Keywords: (For Search Only) NOT Grade Requirement See Section 7 PPE / Woven Glass Low Dk / Df Low Z-axis CTE CAF Resistance Lead-Free Non-FR-4.0 Fillers
SPECIFICATION SHEET #: IPC-4101/103 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Epoxy <i>Secondary 1:</i> Polyphenylene oxide FLAME RETARDANT MECHANISM: RoHS Compliant Bromine FILLERS: Contains inorganic fillers ID REFERENCE: <i>UL/ANSI:</i> NONE <i>ANSI:</i> 4101/103 GLASS TRANSITION (T_g): 150 °C minimum	2: NONE Secondary 2: NONE Minimum UL94 Requirement: V-1 MIL-S-13949: NONE	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Epoxy / PPO / Woven Glass Low Dk / Df Lead-Free Non-FR-4.0 Fillers
SPECIFICATION SHEET #: IPC-4101/121 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Difunctional Epoxy <i>Secondary 1:</i> Multifunctional epoxy FLAME RETARDANT MECHANISM: RoHS Compliant Bromine FILLERS: <5% ID REFERENCE: <i>UL/ANSI:</i> FR-4.0/121 GLASS TRANSITION (T_g): 110 °C minimum	2: NONE Secondary 2: Modified Epoxy or Non-Epoxy (max. wt. 5%) Minimum UL94 Requirement: V-0	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Epoxy / Woven Glass Lead-Free FR-4.0 Low Z-axis CTE
SPECIFICATION SHEET #: IPC-4101/122 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Difunctional Epoxy <i>Secondary 1:</i> Multifunctional Epoxy FLAME RETARDANT MECHANISM: Phosphorus, Nitrogen and/or inorganic compound† FILLERS: <5% ID REFERENCE: <i>UL/ANSI:</i> FR-4.1/122 GLASS TRANSITION (T_g): 110 °C minimum	2: NONE Secondary 2: Modified Epoxy or Non-Epoxy (max. wt. 5%) Minimum UL94 Requirement: V-0 MIL-S-13949: NONE †900 ppm max. Br or Cl and 1500 ppm max. Br + Cl	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Epoxy / Woven Glass Lead-Free FR-4.1 Low Z-axis CTE Low Halogen Content
SPECIFICATION SHEET #: IPC-4101/124 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Epoxy <i>Secondary 1:</i> Multifunctional epoxy FLAME RETARDANT MECHANISM: RoHS Compliant Bromine FILLERS: <5% ID REFERENCE: <i>UL/ANSI:</i> FR-4.0/124 GLASS TRANSITION (T_g): 150 °C minimum	2: NONE Secondary 2: Modified Epoxy or Non-Epoxy (max. wt. 5%) Minimum UL94 Requirement: V-0	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Epoxy / Woven Glass Lead-Free FR-4.0 Low Z-axis CTE High Decomposition Temperature
SPECIFICATION SHEET #: IPC-4101/125 REINFORCEMENT: 1: Woven E-glass RESIN SYSTEM: <i>Primary:</i> Epoxy <i>Secondary 1:</i> Multifunctional Epoxy FLAME RETARDANT MECHANISM: Phosphorus, Nitrogen and/or inorganic compound† FILLERS: <5% ID REFERENCE: <i>UL/ANSI:</i> FR-4.1/125 GLASS TRANSITION (T_g): 150 °C minimum	2: NONE Secondary 2: Modified Epoxy or Non-Epoxy (max. wt. 5%) Minimum UL94 Requirement: V-0 MIL-S-13949: NONE †900 ppm max. Br or Cl and 1500 ppm max. Br + Cl	Keywords: (For Search Only) NOT Grade Requirement See Section 7 Epoxy / Woven Glass Lead-Free FR-4.1 Low Z-axis CTE High Decomposition Temperature Low Halogen Content