

Revision Date: March 2006

SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/01				Keywords: (For Search Only)	
REINFORCEMENT:	1: Cellulose paper	2: N/A	NOT Grade Requirement		
RESIN SYSTEM:	Primary: Phenolic		See Section 7		
	Secondary 1: N/A	Secondary 2: N/A	Single-Sided		
FLAME RETARDANT MECHANISM:	N/A	Minimum UL94 Requirement: HB	XXXPC		
FILLERS:	N/A		Phenolic / Paper		
ID REFERENCE:	UL/ANSI: XXXPC	MIL-S-13949: N/A	Consumer Electronics		
	ANSI: XXXPC/01		Punchable		
GLASS TRANSITION (T_g):	N/A				
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very lowprofile copper foil – all copper foil >17 µm [0.669 mil].	–	–		2.4.8	
B. Standard profile copper foil	–	1.05 [6.00]	N/mm [lb/in]	2.4.8.2	3.9.1.1.1
1. After thermal stress	–	–		2.4.8.3	3.9.1.1.2
2. At 105°C [221°F]	–	–			3.9.1.1.3
3. After process solutions	–	–			
C. All other foil – composite	–	–			
2. Volume Resistivity, minimum					
A. C-96/35/90	–	10 ⁴	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	–			
3. Surface Resistivity, minimum					
A. C-96/35/90	–	10 ³	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	–			
4. Moisture Absorption, maximum	–	1.3	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	15	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	–	4.8	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	–	0.04	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	83 [12,040]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	72 [10,440]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	–	–	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 260°C [500°F], minimum Note: Use peel specimen.	–	Pass Visual	rating	2.4.13.1	3.10.1.2
12. Electric Strength, minimum (Laminate & prepreg as laminated)	–	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	–	HB minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			

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SPECIFICATION SHEET		
SPECIFICATION SHEET #: IPC-4101/02		
REINFORCEMENT:	1: Cellulose paper	2: N/A
RESIN SYSTEM:	Primary: Phenolic	
	Secondary 1: N/A	Secondary 2: N/A
FLAME RETARDANT MECHANISM:	Bromine/Chlorine	Minimum UL94 Requirement: V-1
FILLERS:	N/A	
ID REFERENCE:	UL/ANSI: FR-1	MIL-S-13949: N/A
	ANSI: FR-1/02	
GLASS TRANSITION (T _g):	N/A	
		Keywords: (For Search Only) NOT Grade Requirement See Section 7 Single-Sided Phenolic / Paper FR-1 Consumer Electronics Punchable

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 μm [0.669 mil].	–	–		2.4.8	
B. Standard profile copper foil	–	1.05 [6.00]	N/mm [lb/in]	2.4.8.2	3.9.1.1.1
1. After thermal stress	–	–		2.4.8.3	3.9.1.1.2
2. At 105°C [221°F]	–	–			3.9.1.1.3
3. After process solutions	–	–			
C. All other foil – composite	–	–			
2. Volume Resistivity, minimum					
A. C-96/35/90	–	10 ³	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	–			
3. Surface Resistivity, minimum					
A. C-96/35/90	–	10 ²	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	–			
4. Moisture Absorption, maximum	–	5.6	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	5.0	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	–	6.0	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	–	0.06	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	82 [11,890]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	69 [10,010]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	–	20	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s 260°C [500°F], minimum Note: Use peel specimen.	–	Pass Visual	rating	2.4.13.1	3.10.1.2
12. Electric Strength, minimum (Laminate & prepreg as laminated)	–	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	–	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			

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SPECIFICATION SHEET

SPECIFICATION SHEET #: IPC-4101/03

REINFORCEMENT: 1: Cellulose paper

2: N/A

RESIN SYSTEM: Primary: Phenolic

Secondary 1: N/A

Secondary 2: N/A

Minimum UL94 Requirement: V-1

FLAME RETARDANT MECHANISM: Bromine/Chlorine

FILLERS: N/A

ID REFERENCE: UL/ANSI: FR-2

MIL-S-13949: N/A

GLASS TRANSITION (T_g): ANSI: FR-2/03

N/A

Keywords: (For Search Only)
NOT Grade Requirement
See Section 7

Single-Sided

FR-2

Phenolic / Paper

Consumer Electronics

Punchable

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 μm [0.669 mil].	–	–			
B. Standard profile copper foil	–	1.05 [5.996]	N/mm [lb/in]	2.4.8	3.9.1.1.1
1. After thermal stress	–	–			3.9.1.1.2
2. At 105°C [221°F]	–	–			3.9.1.1.3
3. After process solutions	–	–			
C. All other foil – composite	–	–			
2. Volume Resistivity, minimum					
A. C-96/35/90	–	10 ³	MΩ-cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	–			
3. Surface Resistivity, minimum					
A. C-96/35/90	–	10 ³	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	–			
4. Moisture Absorption, maximum	–	1.3	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	15	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	–	5.0	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	–	0.045	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	83 [12,040]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	72 [10,440]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	–	20	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s 260°C [500°F], minimum Note: Use peel specimen.	–	Pass Visual	rating	2.4.13.1	3.10.1.2
12. Electric Strength, minimum (Laminate & prepreg as laminated)	–	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	–	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/04					
REINFORCEMENT: 1: Cellulose paper		2: N/A		Keywords: (For Search Only) NOT Grade Requirement See Section 7	
RESIN SYSTEM: <i>Primary:</i> Epoxy		<i>Secondary 1:</i> N/A		<i>Secondary 2:</i> N/A	
FLAME RETARDANT MECHANISM: Bromine/Chlorine/Antimony oxide		<i>Minimum UL94 Requirement:</i> V-1		Single-Sided	
FILLERS: N/A				FR-3	
ID REFERENCE: <i>UL/ANSI:</i> FR-3		<i>MIL-S-13949:</i> N/A		Epoxy / Paper	
GLASS TRANSITION (T_g): N/A				Consumer Electronics	
				Punchable	
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 μm [0.669 mil].	–	–		2.4.8	
B. Standard profile copper foil	–	1.25 [7.14]	N/mm [lb/in]	2.4.8.2	3.9.1.1.1
1. After thermal stress	–	0.80 [4.57]		2.4.8.3	3.9.1.1.2
2. At 125°C [257°F]	–	–			3.9.1.1.3
3. After process solutions	–	–			
C. All other foil – composite	–	–			
2. Volume Resistivity, minimum					
A. C-96/35/90	–	10 ⁴	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	–			
3. Surface Resistivity, minimum					
A. C-96/35/90	–	10 ³	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	–			
4. Moisture Absorption, maximum	–	1.0	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	30	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	–	4.8	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	–	0.04	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	138 [20,020]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	110 [16,950]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	–	20	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s 260°C [500°F], minimum					
A. Unetched	–	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	–	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	–	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	–	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/05					
REINFORCEMENT: 1: Cellulose paper		2: N/A		Keywords: (For Search Only)	
RESIN SYSTEM: Primary: Phenolic		Secondary 1: N/A		NOT Grade Requirement	
Secondary 2: N/A		Minimum UL94 Requirement: V-1		See Section 7	
FLAME RETARDANT MECHANISM: Phosphorus†				Single-Sided	
FILLERS: N/A				FR-2	
ID REFERENCE: UL/ANSI: FR-2		MIL-S-13949: N/A		Phenolic / Paper	
ANSI: FR-2/05		†900 ppm max. Br or Cl and		Low Halogen Content	
GLASS TRANSITION (T_g): N/A		1500 ppm max. Br + Cl		Consumer Electronics	
Punchable					
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil].	–	–		2.4.8	
B. Standard profile copper foil			N/mm [lb/in]	2.4.8.2	3.9.1.1.1
1. After thermal stress	–	–		2.4.8.3	3.9.1.1.2
2. At 125°C [257°F]	–	–			3.9.1.1.3
3. After process solutions	–	–			
C. All other foil – composite	–	–			
2. Volume Resistivity, minimum					
A. 96/35/90	–	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	–			
3. Surface Resistivity, minimum					
A. 96/35/90	–	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	–			
4. Moisture Absorption, maximum	–	–	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	–	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	–	–	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	–	–	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	–	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	–			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	–	–	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 260°C [500°F], minimum Note: Use peel specimen.	–	–	rating	2.4.13.1	3.10.1.2
12. Electric Strength, minimum (Laminate & prepreg as laminated)	–	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	–	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Halogen Content, maximum					
–Chlorine	900	900	ppm	2.3.41	3.10.1.9
–Bromine	900	900			
–Chlorine+Bromine	1500	1500			
15. Other	–	–			

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/10					
REINFORCEMENT:	1: Woven E-glass, surface	2: Cellulose paper, core	Keywords: (For Search Only) NOT Grade Requirement See Section 7		
RESIN SYSTEM:	Primary: Epoxy	Secondary 2: N/A	Epoxy / Woven Glass / Paper		
	Secondary 1: Phenolic	Minimum UL94 Requirement: V-0	Composite		
FLAME RETARDANT MECHANISM:	Bromine/Antimony oxide	MIL-S-13949: N/A	Single-Sided		
FILLERS:	N/A		Consumer Electronics		
ID REFERENCE:	UL/ANSI: CEM-1		Punchable		
	ANSI: CEM-1/10		CEM-1		
GLASS TRANSITION (T _g):	100°C minimum				
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil].	–	–		2.4.8	
B. Standard profile copper foil	–	1.05 [6.00]	N/mm [lb/in]	2.4.8.2	3.9.1.1.1
1. After thermal stress	–	–		2.4.8.3	3.9.1.1.2
2. At 125°C [257°F]	–	–			3.9.1.1.3
3. After process solutions	–	–			
C. All other foil – composite	–	–			
2. Volume Resistivity, minimum					
A. C-96/35/90	–	10 ⁶	MΩ-cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	10 ³			
3. Surface Resistivity, minimum					
A. C-96/35/90	–	10 ⁴	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	10 ³			
4. Moisture Absorption, maximum	–	0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	–	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	–	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	242 [35,100]*	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	172 [24,950]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	–	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s 260°C [500°F], minimum					
A. Unetched	–	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	–	–			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	–	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	–	V-0 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			

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

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/11					
REINFORCEMENT: 1: Woven E-glass, surface		2: Nonwoven E-glass core		Keywords: (For Search Only) NOT Grade Requirement See Section 7	
RESIN SYSTEM: <i>Primary:</i> Polyester		<i>Secondary 2:</i> N/A			
<i>Secondary 1:</i> Vinyl ester		Minimum UL94 Requirement: V-1		Composite	
FLAME RETARDANT MECHANISM: Bromine		<i>MIL-S-13949:</i> N/A		Single-Sided	
FILLERS: Inorganic fillers				Consumer Electronics	
ID REFERENCE: <i>UL/ANSI:</i> N/A				Punchable	
<i>ANSI:</i> CRM-5/11				Polyester / Woven Glass / Nonwoven Glass	
GLASS TRANSITION (T_g): N/A				CRM-5	
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil].	–	–		2.4.8	
B. Standard profile copper foil	–	0.90 [5.14]	N/mm [lb/in]	2.4.8.2	3.9.1.1.1
1. After thermal stress	–	AABUS		2.4.8.3	3.9.1.1.2
2. At 125°C [257°F]	–	0.70 [4.00]			3.9.1.1.3
3. After process solutions	–	–			
C. All other foil – composite	–	–			
2. Volume Resistivity, minimum					
A. C-96/35/90	–	10 ⁷	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	–			
3. Surface Resistivity, minimum					
A. C-96/35/90	–	10 ⁶	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	–			
4. Moisture Absorption, maximum	–	0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	–	4.1	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	–	0.022	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	241 [34,950]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	138 [20,020]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	–	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s 260°C [500°F], minimum					
A. Unetched	–	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	–	–			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	–	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	–	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/12					
REINFORCEMENT: 1: Woven E-glass, surface		2: Nonwoven E-glass core		Keywords: (For Search Only)	
RESIN SYSTEM: Primary: Epoxy		Secondary 1: N/A		NOT Grade Requirement	
Secondary 2: N/A		Minimum UL94 Requirement: V-0		See Section 7	
FLAME RETARDANT MECHANISM: Bromine		FILLERS: With or without inorganic fillers		Epoxy / Woven Glass / Nonwoven Glass	
ID REFERENCE: UL/ANSI: CEM-3		MIL-S-13949: N/A		Composite	
ANSI: CEM-3/12		GLASS TRANSITION (T _g): N/A		Consumer Electronics	
				Punchable	
				Double-Sided	
				CEM-3	
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil].	–	–		2.4.8	
B. Standard profile copper foil	–	1.05 [5.996]	N/mm [lb/in]	2.4.8.2	3.9.1.1.1
1. After thermal stress	–	0.90 [5.14]		2.4.8.3	3.9.1.1.2
2. At 105°C [221°F]	–	0.90 [5.14]			3.9.1.1.3
3. After process solutions	–	–			
C. All other foil – composite	–	–			
2. Volume Resistivity, minimum					
A. C-96/35/90	–	10 ⁶	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	10 ³			
3. Surface Resistivity, minimum					
A. C-96/35/90	–	10 ⁴	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	10 ³			
4. Moisture Absorption, maximum	–	0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	–	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	–	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	276 [40,030]*	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	186 [26,980]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	–	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s 260°C [500°F], minimum					
A. Unetched	–	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	–	–			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	–	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	–	V-0 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			

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

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/13					
REINFORCEMENT:	1: Woven E-glass	2: N/A	Keywords: (For Search Only) NOT Grade Requirement See Section 7		
RESIN SYSTEM:	Primary: Polyester Secondary 1: Vinyl ester	Secondary 2: N/A Minimum UL94 Requirement: V-1	Polyester / Glass Low Dk / Df		
FLAME RETARDANT MECHANISM:	Bromine	MIL-S-13949: N/A			
FILLERS:	Inorganic fillers				
ID REFERENCE:	UL/ANSI: N/A ANSI: 4101/13				
GLASS TRANSITION (T_g):	N/A				
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum A. Low profile copper foil and very low profile copper foil – all copper foil >17 μm [0.669 mil]. B. Standard profile copper foil 1. After thermal stress 2. At 125°C [257°F] 3. After process solutions C. All other foil – composite	AABUS 0.70 [4.00] 0.60 [3.43] 0.70 [4.00] AABUS	– – – – –	N/mm [lb/in]	2.4.8 2.4.8.2 2.4.8.3	3.9.1.1 3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
2. Volume Resistivity, minimum A. C-96/35/90 B. After moisture resistance C. At elevated temperature E-24/125	10 ⁶ – 10 ³	– – –	MΩ–cm	2.5.17.1	3.11.1.3
3. Surface Resistivity, minimum A. C-96/35/90 B. After moisture resistance C. At elevated temperature E-24/125	10 ⁶ – 10 ³	– – –	MΩ	2.5.17.1	3.11.1.4
4. Moisture Absorption, maximum	0.30	–	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	–	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	AABUS	–	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	AABUS	–	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum A. Length direction B. Cross direction	– –	– –	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	–	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum A. Unetched B. Etched	Pass Visual Pass Visual	– –	rating	2.4.13.1	3.10.1.2
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	–	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/14					
REINFORCEMENT: 1: Woven E-glass, surface		2: Nonwoven E-glass Core		Keywords: (For Search Only) NOT Grade Requirement See Section 7	
RESIN SYSTEM: Primary: Epoxy		Secondary 1: N/A		Composite	
Secondary 2: N/A		Minimum UL94 Requirement: V-0		Double-Sided	
FLAME RETARDANT MECHANISM: Phosphorus†		MIL-S-13949: N/A		Low Halogen Content	
FILLERS: With or without inorganic fillers		†900 ppm max. Br or Cl		Consumer Electronics	
ID REFERENCE: UL/ANSI: CEM-3		and 1500 ppm max. Br + Cl		Punchable	
ANSI: CEM-3/14				CEM-3	
GLASS TRANSITION (T _g): N/A					
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil].	–	–	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	–	–		2.4.8.2	
1. After thermal stress	–	–		2.4.8.3	
2. At 125°C [257°F]	–	–			
3. After process solutions	–	–			
C. All other foil – composite	–	–			
2. Volume Resistivity, minimum					
A. 96/35/90	–	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	–			
3. Surface Resistivity, minimum					
A. 96/35/90	–	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	–			
4. Moisture Absorption, maximum	–	–	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	–	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	–	–	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	–	–	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	–	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	–			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	–	–	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 260°C [500°F], minimum					
A. Unetched	–	–	rating	2.4.13.1	3.10.1.2
B. Etched	–	–			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	–	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	–	V-0 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Halogen Content, maximum					
–Chlorine	900	900	ppm	2.3.41	3.10.1.9
–Bromine	900	900			
–Chlorine+Bromine	1500	1500			
15. Other	–	–			

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/20			Keywords: (For Search Only)		
REINFORCEMENT:	1: Woven E-glass	2: N/A	NOT Grade Requirement		
RESIN SYSTEM:	Primary: Epoxy		See Section 7		
	Secondary 1: N/A	Secondary 2: N/A	Epoxy / Woven Glass		
FLAME RETARDANT MECHANISM:	N/A	Minimum UL94 Requirement: HB	G-10		
FILLERS:	N/A		Non-Flame Retardant		
ID REFERENCE:	UL/ANSI: G-10	MIL-S-13949: /03 - GE, GEN			
	ANSI: G-10/20				
GLASS TRANSITION (T _g):	N/A				
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil].	AABUS	AABUS	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	0.80 [4.57]	1.05 [6.00]		2.4.8.2	
1. After thermal stress	AABUS	0.70 [4.00]		2.4.8.3	
2. At 125°C [257°F]	AABUS	0.80 [4.57]			
3. After process solutions	AABUS	AABUS			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 ⁶	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 ⁶			
C. At elevated temperature E-24/125	10 ³	10 ³			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 ⁴	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 ⁴			
C. At elevated temperature E-24/125	10 ³	10 ³			
4. Moisture Absorption, maximum	–	0.35	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	414 [60,050]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	HB minimum	HB minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
PREPREG REQUIREMENTS					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	–	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	HB	rating	UL94	3.10.2.1	
6. Other	–				

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SPECIFICATION SHEET		
SPECIFICATION SHEET #: IPC-4101/21		
REINFORCEMENT: 1: Woven E-glass	2: N/A	Keywords: (For Search Only) NOT Grade Requirement See Section 7 <hr/> FR-4 GFN Epoxy / Woven Glass
RESIN SYSTEM: Primary: Difunctional epoxy	Secondary 2: N/A	
Secondary 1: Multifunctional epoxy	Minimum UL94 Requirement: V-0	
FLAME RETARDANT MECHANISM: Bromine, RoHS Compliant		
FILLERS: N/A		
ID REFERENCE: UL/ANSI: FR-4/21	MIL-S-13949: /04	
GLASS TRANSITION (T _g): 110°C minimum	- GF, GFN, GFK, GFP, GFM	
UL MAX. OPERATING TEMP: N/A		

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil]. B. Standard profile copper foil 1. After thermal stress 2. At 125°C [257°F] 3. After process solutions C. All other foil – composite	0.70 [4.00] 0.80 [4.57] 0.70 [4.00] 0.55 [3.14] AABUS	0.70 [4.00] 1.05 [6.00] 0.70 [4.00] 0.80 [4.57] AABUS	N/mm [lb/in]	2.4.8 2.4.8.2 2.4.8.3	3.9.1.1 3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
2. Volume Resistivity, minimum A. 96/35/90 B. After moisture resistance C. At elevated temperature E-24/125	10 ⁶ – 10 ³	– 10 ⁶ 10 ³	MΩ–cm	2.5.17.1	3.11.1.3
3. Surface Resistivity, minimum A. 96/35/90 B. After moisture resistance C. At elevated temperature E-24/125	10 ⁴ – 10 ³	– 10 ⁴ 10 ³	MΩ	2.5.17.1	3.11.1.4
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)*	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)*	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum A. Length direction B. Cross direction	– –	415 [60,190] 345 [50,040]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum A. Unetched B. Etched	Pass Visual Pass Visual	Pass Visual Pass Visual	rating	2.4.13.1	3.10.1.2
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-0 minimum	V-0 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17
2. Reinforcement	As per IPC-4412 or AABUS.			
3. Volatile content maximum	0.75	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7
5. Flammability (as laminated)	V-0 minimum	rating	UL94	3.10.2.1
6. Other	–			

*See Slash Sheet 1 in IPC-4121.

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/22					
REINFORCEMENT:	1: Woven E-glass	2: N/A	Keywords: (For Search Only) NOT Grade Requirement See Section 7		
RESIN SYSTEM:	Primary: Epoxy, hot strength retention Secondary 1: N/A	Secondary 2: N/A Minimum UL94 Requirement: HB	Epoxy / Woven Glass Hot Flex Strength G-11 Non-Flame Retardant		
FLAME RETARDANT MECHANISM:	N/A				
FILLERS:	N/A				
ID REFERENCE:	UL/ANSI: G-11 ANSI: G-11/22	MIL-S-13949: /02 - GB, GBN, GBP			
GLASS TRANSITION (T_g):	135°C - 175°C				
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil]. B. Standard profile copper foil 1. After thermal stress 2. At 150°C [302°F] 3. After process solutions C. All other foil – composite	AABUS 1.05 [6.00] 0.80 [4.57] 0.80 [4.57] AABUS	AABUS 1.45 [8.28] 0.90 [5.14] 0.90 [5.14] AABUS	N/mm [lb/in]	2.4.8 2.4.8.2 2.4.8.3	3.9.1.1 3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
2. Volume Resistivity, minimum A. After humidity conditioning B. At elevated temperature (150°C [302°F])	10 ⁶ 10 ³	10 ⁴ 10 ³	MΩ-cm	2.5.17.1	3.11.1.3
3. Surface Resistivity, minimum A. After humidity conditioning B. At elevated temperature (150°C [302°F])	10 ⁴ – 10 ³	– 10 ⁴ 10 ³	MΩ	2.5.17.1	3.11.1.4
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum A. Length direction B. Cross direction	415 [60,190] 345 [50,040]	415 [60,190] 345 [50,040]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
9. Flexural Strength at Elevated Temperature 150°C, length direction, minimum	207 [30,020]	207 [30,020]	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum A. Unetched B. Etched	Pass Visual Pass Visual	Pass Visual Pass Visual	rating	2.4.13.1	3.10.1.2
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	HB minimum	HB minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
PREPREG REQUIREMENTS					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	–	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	HB minimum	rating	UL94	3.10.2.1	
6. Other	–				

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/23					
REINFORCEMENT: 1: Woven E-glass		2: N/A		Keywords: (For Search Only)	
RESIN SYSTEM: Primary: Epoxy, hot strength retention		Secondary 1: N/A		NOT Grade Requirement	
FLAME RETARDANT MECHANISM: Bromine		Secondary 2: N/A		See Section 7	
FILLERS: N/A		Minimum UL94 Requirement: V-1		Epoxy / Woven Glass	
ID REFERENCE: UL/ANSI: FR-5		MIL-S-13949: /05		Hot Flex Strength	
GLASS TRANSITION (T _g): 135°C - 185°C		- GH, GHN, GHP		FR-5	
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 μm [0.669 mil].	AABUS	AABUS	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	1.05 [6.00]	1.45 [8.28]		2.4.8.2	
1. After thermal stress	0.80 [4.57]	0.90 [5.14]		2.4.8.3	
2. At 150°C [302°F]	0.80 [4.57]	0.90 [5.14]			
3. After process solutions	AABUS	AABUS			
C. All other foil – composite					
2. Volume Resistivity, minimum					
A. After humidity conditioning	10 ⁶	10 ⁴	MΩ-cm	2.5.17.1	3.11.1.3
B. At elevated temperature (150°C [302°F])	10 ³	10 ³			
3. Surface Resistivity, minimum					
A. After humidity conditioning	10 ⁴	10 ⁴	MΩ	2.5.17.1	3.11.1.4
B. At elevated temperature (150°C [302°F])	10 ³	10 ³			
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)*	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)*	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature 150°C, length direction, minimum	–	207 [30,020]	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
PREPREG REQUIREMENTS					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	0.75	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1	
6. Other	–				

*See Slash Sheet 2 in IPC-4121.

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/24					
REINFORCEMENT:	1: Woven E-glass	2: N/A	Keywords: (For Search Only) NOT Grade Requirement See Section 7		
RESIN SYSTEM:	Primary: Epoxy Secondary 1: Multifunctional epoxy	Secondary 2: N/A Minimum UL94 Requirement: V-0	Epoxy / Woven Glass FR-4 Multifunctional Epoxy GFN		
FLAME RETARDANT MECHANISM:	Bromine, RoHS Compliant				
FILLERS:	N/A				
ID REFERENCE:	UL/ANSI: FR-4/24	MIL-S-13949: /04			
GLASS TRANSITION (T_g):	150°C minimum	- GF, GFG, GFN			
UL Max. Operating Temp:	N/A				
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil]. B. Standard profile copper foil 1. After thermal stress 2. At 125°C [257°F] 3. After process solutions C. All other foil – composite	0.70 [4.00]	0.70 [4.00] 1.05 [6.00] 0.70 [4.00] 0.80 [4.57] AABUS	N/mm [lb/in]	2.4.8 2.4.8.2 2.4.8.3	3.9.1.1 3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
2. Volume Resistivity, minimum A. C-96/35/90 B. After moisture resistance C. At elevated temperature E-24/125	10 ⁶ – 10 ³	– 10 ⁴ 10 ³	MΩ–cm	2.5.17.1	3.11.1.3
3. Surface Resistivity, minimum A. C-96/35/90 B. After moisture resistance C. At elevated temperature E-24/125	10 ⁴ – 10 ³	– 10 ⁴ 10 ³	MΩ	2.5.17.1	3.11.1.4
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)*	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)*	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum A. Length direction B. Cross direction	– –	415 [60,190] 345 [50,040]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum A. Unetched B. Etched	Pass Visual Pass Visual	Pass Visual Pass Visual	rating	2.4.13.1	3.10.1.2
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-0 minimum	V-0 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
PREPREG REQUIREMENTS					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	1.5	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-0 minimum	rating	UL94	3.10.2.1	
6. Other	–				

*See Slash Sheet 2 in IPC-4121.

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/25			Keywords: (For Search Only) NOT Grade Requirement See Section 7		
REINFORCEMENT:	1: Woven E-glass	2: N/A			
RESIN SYSTEM:	Primary: Epoxy	Secondary 1: Polyphenylene oxide	Secondary 2: N/A		
FLAME RETARDANT MECHANISM:	Bromine	Minimum UL94 Requirement: V-1	Epoxy / PPO / Woven Glass Low Dk / Df		
FILLERS:	N/A	MIL-S-13949: /04			
ID REFERENCE:	UL/ANSI: N/A	- GF, GFG, GFN			
GLASS TRANSITION (T_g):	150°C - 200°C				
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil].	0.70 [4.00]	0.70 [4.00]	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	0.80 [4.57]	1.05 [6.00]		2.4.8.2	
1. After thermal stress	0.70 [4.00]	0.70 [4.00]		2.4.8.3	
2. At 125°C [257°F]	0.55 [3.14]	0.80 [4.57]			
3. After process solutions		AABUS			
C. All other foil – composite		AABUS			
2. Volume Resistivity, minimum			MΩ-cm	2.5.17.1	3.11.1.3
A. C-96/35/90	10 ⁶	–			
B. After moisture resistance	–	10 ⁶			
C. At elevated temperature E-24/125	10 ³	10 ³			
3. Surface Resistivity, minimum			MΩ	2.5.17.1	3.11.1.4
A. C-96/35/90	10 ⁴	–			
B. After moisture resistance	–	10 ⁴			
C. At elevated temperature E-24/125	10 ³	10 ³			
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	4.4	4.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum			N/mm ² [lb/in ²]	2.4.4	3.9.1.3
A. Length direction	–	415 [60,190]			
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum			rating	2.4.13.1	3.10.1.2
A. Unetched	Pass Visual	Pass Visual			
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
PREPREG REQUIREMENTS					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	0.5	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1	
6. Other	–				

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/26			Keywords: (For Search Only)		
REINFORCEMENT:	1: Woven E-glass	2: N/A	NOT Grade Requirement		
RESIN SYSTEM:	Primary: Epoxy		See Section 7		
	Secondary 1: Multifunctional epoxy	Secondary 2: N/A	Epoxy / Woven Glass		
FLAME RETARDANT MECHANISM:	Bromine, RoHS Compliant	Minimum UL94 Requirement: V-0	FR-4		
FILLERS:	N/A		GFT		
ID REFERENCE:	UL/ANSI: FR-4/26	MIL-S-13949: /04 - GF, GFT	CAF Resistant		
GLASS TRANSITION (T_g):	170°C minimum				
UL MAX. OPERATING TEMP:	N/A				
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil].	0.70 [4.00]	0.70 [4.00]	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	0.80 [4.57]	1.05 [6.00]		2.4.8.2	
1. After thermal stress	0.70 [4.00]	0.70 [4.00]		2.4.8.3	
2. At 125°C [257°F]	0.55 [3.14]	0.80 [4.57]			
3. After process solutions	AABUS	AABUS			
C. All other foil – composite					
2. Volume Resistivity, minimum					
A. C-96/35/90	10 ⁶	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 ⁶			
C. At elevated temperature E-24/125	10 ³	10 ³			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 ⁴	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 ⁴			
C. At elevated temperature E-24/125	10 ³	10 ³			
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)*	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)*	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-0 minimum	V-0 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. CAF Resistance	–	AABUS	Pass/Fail †	2.6.25	3.12.1.4
15. Other	–	–			

*See Slash Sheet 2 in IPC-4121.

†Pass or Fail are determined by Fail being ≥1 decade drop in the sample's initial insulation resistance value.

PREPREG REQUIREMENTS				
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17
2. Reinforcement	As per IPC-4412 or AABUS.			
3. Volatile content maximum	0.5	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7
5. Flammability (as laminated)	V-0 minimum	rating	UL94	3.10.2.1
6. Other	–			

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SPECIFICATION SHEET

SPECIFICATION SHEET #: IPC-4101/27

REINFORCEMENT: 1: Unidirectional E-glass, cross plied

2: N/A

RESIN SYSTEM: Primary: Epoxy

Secondary 1: Multifunctional epoxy

Secondary 2: N/A

Minimum UL94 Requirement: V-1

FLAME RETARDANT MECHANISM: Bromine

FILLERS: N/A

ID REFERENCE: UL/ANSI: N/A

ANSI: 4101/27

MIL-S-13949: N/A

GLASS TRANSITION (T_g): 110°C minimumKeywords: (For Search Only)
NOT Grade Requirement
See Section 7

Crossplied Unidirectional

FR-4

Epoxy / Woven Glass

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil]. B. Standard profile copper foil 1. After thermal stress 2. At 125°C [257°F] 3. After process solutions C. All other foil – composite	0.70 [4.00]	0.70 [4.00]	N/mm [lb/in]	2.4.8	3.9.1.1
	0.80 [4.57]	1.05 [6.00]		2.4.8.2	3.9.1.1.1
	0.70 [4.00]	0.70 [4.00]		2.4.8.3	3.9.1.1.2
	0.55 [3.14] AABUS	0.80 [4.57] AABUS			3.9.1.1.3
2. Volume Resistivity, minimum A. C-96/35/90 B. After moisture resistance C. At elevated temperature E-24/125	10 ⁶ – 10 ³	– 10 ⁶ 10 ³	MΩ–cm	2.5.17.1	3.11.1.3
3. Surface Resistivity, minimum A. C-96/35/90 B. After moisture resistance C. At elevated temperature E-24/125	10 ⁴ – 10 ³	– 10 ⁴ 10 ³	MΩ	2.5.17.1	3.11.1.4
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.030	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum A. Length direction B. Cross direction	– –	294 [42,640] 294 [42,640]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum A. Unetched B. Etched	Pass Visual Pass Visual	Pass Visual Pass Visual	rating	2.4.13.1	3.10.1.2
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			

PREPREG REQUIREMENTS

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

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/28					
REINFORCEMENT: 1: Woven E-glass		2: N/A		Keywords: (For Search Only)	
RESIN SYSTEM: <i>Primary:</i> Epoxy		<i>Secondary 1:</i> (Non-epoxy)		NOT Grade Requirement	
FLAME RETARDANT MECHANISM: Bromine		<i>Secondary 2:</i> (Non-epoxy)		See Section 7	
FILLERS: N/A		Minimum UL94 Requirement: V-1		Epoxy / Non-Epoxy / Woven Glass	
ID REFERENCE: <i>UL/ANSI:</i> N/A		<i>MIL-S-13949:</i> /04 - GFN, GFT		GFT	
GLASS TRANSITION (T_g): 170°C - 220°C					
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil].	0.70 [4.00]	0.70 [4.00]	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	0.80 [4.57]	1.05 [6.00]		2.4.8.2	
1. After thermal stress	0.70 [4.00]	0.70 [4.00]		2.4.8.3	
2. At 125°C [257°F]	0.55 [3.14]	0.80 [4.57]			
3. After process solutions	AABUS	AABUS			
C. All other foil – composite					
2. Volume Resistivity, minimum					
A. After humidity conditioning	10 ⁶	10 ⁶	MΩ-cm	2.5.17.1	3.11.1.3
B. At elevated temperature	10 ³	10 ³			
3. Surface Resistivity, minimum					
A. After humidity conditioning	10 ⁴	10 ⁴	MΩ	2.5.17.1	3.11.1.4
B. At elevated temperature	10 ³	10 ³			
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.030	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
PREPREG REQUIREMENTS					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	0.5	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1	
6. Other	–				

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/29					
REINFORCEMENT: 1: Woven E-glass		2: N/A		Keywords: (For Search Only)	
RESIN SYSTEM: Primary: Epoxy				NOT Grade Requirement	
Secondary 1: Cyanate ester		Secondary 2: N/A		See Section 7	
FLAME RETARDANT MECHANISM: Bromine		Minimum UL94 Requirement: V-1		Epoxy / Cyanate Ester / Woven Glass	
FILLERS: N/A				CAF Resistant	
ID REFERENCE: UL/ANSI: N/A		MIL-S-13949: /04			
ANSI: 4101/29		- GFN, GFT			
GLASS TRANSITION (T_g): 170°C - 220°C					
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper weights >17 μm [0.669 mil].	0.70 [4.00]	0.70 [4.00]	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	0.80 [4.57]	1.05 [6.00]		2.4.8.2	
1. After Thermal Stress	0.70 [4.00]	0.70 [4.00]		2.4.8.3	
2. At 125°C	0.55 [3.14]	0.80 [4.57]			
3. After Process Solutions	AABUS	AABUS			
C. All other foil – composite					
2. Volume Resistivity, minimum					
A. C-96/35/90	10 ⁶	–	MΩ-cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 ⁶			
C. At elevated temperature E-24/125	10 ³	10 ³			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 ⁴	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 ⁴			
C. At elevated temperature E-24/125	10 ³	10 ³			
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminated & Prepreg as laminated)	4.4	4.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminated & Prepreg as laminated)	0.015	0.015	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 Sec at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminated & Prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminated & Prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. CAF Resistance	–	AABUS	Pass/Fail †	2.6.25	3.12.1.4
15. Other	–	–			

† Pass or Fail are determined by Fail being ≥1 decade drop in the sample's initial insulation resistance value.

PREPREG REQUIREMENTS				
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, maximum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17
2. Reinforcement	As per IPC-EG-140			
3. Volatile content maximum	2.2	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1
6. Other	–			

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/30					
REINFORCEMENT:	1: Woven E-glass	2: N/A	Keywords: (For Search Only) NOT Grade Requirement See Section 7		
RESIN SYSTEM:	Primary: Bismaleimide/Triazine (BT) Secondary 1: Epoxy	Secondary 2: N/A	BT / Epoxy / Woven Glass		
FLAME RETARDANT MECHANISM:	Bromine	Minimum UL94 Requirement: HB	GPY		
FILLERS:	N/A		CAF Resistant		
ID REFERENCE:	UL/ANSI: GPY ANSI: GPY/30	MIL-S-13949: /26 - GIT, GMT			
GLASS TRANSITION (T _g):	170°C - 220°C				
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 μm [0.669 mil].	0.55 [3.14]	0.55 [3.14]	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	0.90 [5.14]	0.90 [5.14]		2.4.8.2	
1. After thermal stress	0.35 [2.00]	0.35 [2.00]		2.4.8.3	
2. At 150°C [302°F]	0.70 [4.00]	0.70 [4.00]			
3. After process solutions					
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 ⁶	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 ⁶			
C. At elevated temperature E-24/125	10 ³	10 ³			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 ⁶	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 ⁶			
C. At elevated temperature E-24/125	10 ⁵	10 ⁵			
4. Moisture Absorption, maximum	–	0.35	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)**	4.8	4.8	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)**	0.020	0.020	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	369 [53,520]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	325 [47,140]			
9. Flexural Strength at Elevated Temperature, E1/150, length direction, minimum	–	207 [30,020]	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability* (Laminate & prepreg as laminated)	HB minimum	HB minimum	rating	UL94	3.10.2.1 3.10.1.1
14. CAF Resistance	–	AABUS	Pass/Fail †	2.6.25	3.12.1.4
15. Other	–	–			

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

**See Slash Sheet 3 in IPC-4121.

† Pass or Fail are determined by Fail being ≥1 decade drop in the sample's initial insulation resistance value.

PREPREG REQUIREMENTS				
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17
2. Reinforcement	As per IPC-4412 or AABUS.			
3. Volatile content maximum	2.0	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7
5. Flammability* (as laminated)	HB minimum	rating	UL94	3.10.2.1
6. Other	–			

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

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/31				Keywords: (For Search Only)	
REINFORCEMENT: 1: N/A		2: N/A		NOT Grade Requirement	
RESIN SYSTEM: Primary: Epoxy				See Section 7	
FLAME RETARDANT MECHANISM: N/A		Secondary 1: Multifunctional epoxy		Non-Reinforced Film	
FILLERS (≥5%): Inorganic fillers		Secondary 2: N/A		Thermally Conductive	
ID REFERENCE: UL/ANSI: N/A		Minimum UL94 Requirement: N/A		Heatsink Application	
GLASS TRANSITION (T_g): 90°C minimum					
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					
A. Low profile copper foil and very low profile copper foil – all copper weights >17 μm [0.669 mil].	AABUS		N/mm [lb/in]	2.4.8	3.9.1.1
B. Standard profile copper foil	0.70 [4.00]			2.4.8.2	3.9.1.1.1
1. After thermal stress	0.70 [4.00]			2.4.8.3	3.9.1.1.2
2. At 125°C [257°F]	0.70 [4.00]				3.9.1.1.3
3. After process solutions	AABUS				
C. All other foil – composite					
2. Volume Resistivity, minimum					
A. C-96/35/90	10 ⁴		MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–				
C. At elevated temperature E-24/125	10 ⁴				
3. Surface Resistivity, minimum					
A. C-96/35/90	10 ⁴		MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–				
C. At elevated temperature E-24/125	–				
4. Moisture Absorption, maximum	–		%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–		kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum			–	2.5.5.2	3.11.1.1 3.11.2.1
	7			2.5.5.3	
				2.5.5.9	
7. Loss Tangent at 1 MHz, maximum			–	2.5.5.2	3.11.1.2 3.11.2.2
	0.001			2.5.5.3	
				2.5.5.9	
8. Flexural Strength, minimum					
A. Length direction	–		N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–				
9. Flexural Strength at Elevated Temperature, length direction, minimum	–		N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	–		s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual		rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual				
12. Electric Strength, minimum	–		kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability	–		rating	UL94	3.10.2.1 3.10.1.1
14. Thermal Conductivity Class	B		W/m ² K	ASTM 5470	3.9.1.5
15. Other	–	–			

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/32					
REINFORCEMENT:	1. Woven E-Glass	2: N/A	Keywords: (For Search Only) NOT Grade Requirement See Section 7		
RESIN SYSTEM:	Primary: Epoxy Secondary 1: Multifunctional epoxy	Secondary 2: N/A Minimum UL94 Requirement: N/A	Thermally Conductive Heatsink Application		
FLAME RETARDANT MECHANISM:	N/A				
FILLERS (≥5%):	Inorganic fillers				
ID REFERENCE:	UL/ANSI: N/A ANSI: N/A				
GLASS TRANSITION (T _g):	90°C minimum				
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum A. Low profile copper foil and very low profile copper foil – all copper weights >17 μm [0.669 mil]. B. Standard profile copper foil 1. After thermal stress 2. At 125°C [257°F] 3. After process solutions C. All other foil – composite	AABUS 0.70 [4.00] 0.70 [4.00] 0.70 [4.00] AABUS		N/mm [lb/in]	2.4.8 2.4.8.2 2.4.8.3	3.9.1.1 3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
2. Volume Resistivity, minimum A. C-96/35/90 B. After moisture resistance C. At elevated temperature E-24/125	10 ⁴ – 10 ⁴		MΩ–cm	2.5.17.1	3.11.1.3
3. Surface Resistivity, minimum A. C-96/35/90 B. After moisture resistance C. At elevated temperature E-24/125	10 ⁴ – –		MΩ	2.5.17.1	3.11.1.4
4. Moisture Absorption, maximum	0.8		%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–		kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum	7		–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum	0.001		–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum A. Length direction B. Cross direction	– –		N/mm ² [lb/in ²]	2.4.4	3.9.1.3
9. Flexural Strength at Elevated Temperature, length direction, minimum	–		N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	–		s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum A. Unetched B. Etched	Pass Visual Pass Visual		rating	2.4.13.1	3.10.1.2
12. Electric Strength, minimum	–		kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability	–		rating	UL94	3.10.2.1 3.10.1.1
14. Thermal Conductivity Class	A		W/m ² K	ASTM 5470	3.9.1.5
15. Other	–	–			

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/33					
REINFORCEMENT: 1: N/A		2: N/A		Keywords: (For Search Only)	
RESIN SYSTEM: <i>Primary:</i> Epoxy				NOT Grade Requirement	
<i>Secondary 1:</i> Multifunctional epoxy		<i>Secondary 2:</i> N/A		See Section 7	
FLAME RETARDANT MECHANISM: N/A		Minimum UL94 Requirement: N/A		Non-Reinforced Film	
FILLERS (≥5%): Inorganic fillers				Thermally Conductive	
ID REFERENCE: <i>UL/ANSI:</i> N/A				Heatsink Application	
<i>ANSI:</i> N/A					
GLASS TRANSITION (T_g): 150°C minimum					
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					
A. Low profile copper foil and very low profile copper foil – all copper weights >17 μm [0.669 mil].	AABUS		N/mm	2.4.8	3.9.1.1
B. Standard profile copper foil	0.70 [4.00]		[lb/in]	2.4.8.2	3.9.1.1.1
1. After thermal stress	0.70 [4.00]			2.4.8.3	3.9.1.1.2
2. At 125°C [257°F]	0.70 [4.00]				3.9.1.1.3
3. After process solutions	AABUS				
C. All other foil – composite					
2. Volume Resistivity, minimum					
A. C-96/35/90	10 ⁴		MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–				
C. At elevated temperature E-24/125	10 ⁴				
3. Surface Resistivity, minimum					
A. C-96/35/90	10 ⁴		MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–				
C. At elevated temperature E-24/125	–				
4. Moisture Absorption, maximum	0.8		%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–		kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum			–	2.5.5.2	3.11.1.1
	7			2.5.5.3	3.11.2.1
				2.5.5.9	
7. Loss Tangent at 1 MHz, maximum			–	2.5.5.2	3.11.1.2
	0.001			2.5.5.3	3.11.2.2
				2.5.5.9	
8. Flexural Strength, minimum					
A. Length direction	–		N/mm ²	2.4.4	3.9.1.3
B. Cross direction	–		[lb/in ²]		
9. Flexural Strength at Elevated Temperature, length direction, minimum	–		N/mm ²	2.4.4.1	3.9.1.4
			[lb/in ²]		
10. Arc Resistance, minimum	–		s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual		rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual				
12. Electric Strength, minimum	–		kV/mm	2.5.6.2	3.11.1.7
					3.11.2.3
13. Flammability	–		rating	UL94	3.10.2.1
					3.10.1.1
14. Thermal Conductivity Class	X		W/m ² K	ASTM 5470	3.9.1.5
15. Other	–	–			

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SPECIFICATION SHEET		
SPECIFICATION SHEET #: IPC-4101/40		
REINFORCEMENT:	1: Woven E-glass	2: N/A
RESIN SYSTEM:	Primary: Polyimide	
	Secondary 1: N/A	Secondary 2: N/A
FLAME RETARDANT MECHANISM:	N/A	Minimum UL94 Requirement: HB
FILLERS:	With or without inorganic fillers	
ID REFERENCE:	UL/ANSI: GPY	MIL-S-13949: /10
	ANSI: GPY/40	- GI, GIN, GIJ, GIP, GIL
GLASS TRANSITION (T _g):	200°C minimum	
		Keywords: (For Search Only) NOT Grade Requirement See Section 7 Polyimide / Woven Glass High Reliability GPY

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil]. B. Standard profile copper foil 1. After thermal stress 2. At 125°C [257°F] 3. After process solutions C. All other foil – composite	AABUS 0.90 [5.14] 0.70 [4.00] 0.80 [4.57] –	AABUS 0.90 [5.14] 0.70 [4.00] 0.95 [5.42] –	N/mm [lb/in]	2.4.8 2.4.8.2 2.4.8.3	3.9.1.1 3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
2. Volume Resistivity, minimum A. After humidity conditioning B. At elevated temperature (204°C [399.2°F])	6 x 10 ⁴ 6 x 10 ⁴	10 ⁶ 10 ⁶	MΩ-cm	2.5.17.1	3.11.1.3
3. Surface Resistivity, minimum A. After humidity conditioning B. At elevated temperature (204°C [399.2°F])	10 ⁴ 10 ⁴	10 ⁶ 10 ⁶	MΩ	2.5.17.1	3.11.1.4
4. Moisture Absorption, maximum	–	0.50 ≤ t <1.55 mm 1.0 1.55 ≤ t ≤ 6.35 mm 0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)**	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)**	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum A. Length direction B. Cross direction	– –	415 [60,190] 325 [47,140]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
9. Flexural Strength at Elevated Temperature, E1/204, length direction, minimum	–	311 [45,110]	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	120	120	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum A. Unetched B. Etched	Pass Visual Pass Visual	Pass Visual Pass Visual	rating	2.4.13.1	3.10.1.2
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability* (Laminate & prepreg as laminated)	HB minimum	HB minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17
2. Reinforcement	As per IPC-4412 or AABUS.			
3. Volatile content maximum	4.0	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7
5. Flammability* (as laminated)	HB minimum	rating	UL94	3.10.2.1
6. Other	–			

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

**See Slash Sheet 5 in IPC-4121.

Revision Date: March 2006

SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/41					
REINFORCEMENT: 1: Woven E-glass		2: N/A		Keywords: (For Search Only) NOT Grade Requirement See Section 7	
RESIN SYSTEM: <i>Primary:</i> Polyimide		<i>Secondary 2:</i> N/A		Polyimide / Woven Glass	
<i>Secondary 1:</i> N/A		Minimum UL94 Requirement: HB		High Reliability	
FLAME RETARDANT MECHANISM: N/A		<i>MIL-S-13949:</i> /10 - GIL, GIP		GPY	
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					
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil]. B. Standard profile copper foil 1. After thermal stress 2. At 125°C [257°F] 3. After process solutions C. All other foil – composite	AABUS 0.70 [4.00] 0.60 [3.43] 0.60 [3.43] –	AABUS 0.80 [4.57] 0.70 [4.00] 0.70 [4.00] –	N/mm [lb/in]	2.4.8 2.4.8.2 2.4.8.3	3.9.1.1 3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
2. Volume Resistivity, minimum A. After humidity conditioning B. At elevated temperature (204°C [399.2°F])	6 x 10 ⁴ 6 x 10 ⁴	10 ⁶ 10 ⁶	MΩ-cm	2.5.17.1	3.11.1.3
3. Surface Resistivity, minimum A. After humidity conditioning B. At elevated temperature (204°C [399.2°F])	10 ⁴ 10 ⁴	10 ⁶ 10 ⁶	MΩ	2.5.17.1	3.11.1.4
4. Moisture Absorption, maximum	–	0.50 ≤ t < 1.55 mm 1.0 1.55 ≤ t ≤ 6.35 mm 0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)**	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)**	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum A. Length direction B. Cross direction	– –	415 [60,190] 325 [47,140]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
9. Flexural Strength at Elevated Temperature, E1/204, length direction, minimum	–	311 [45,110]	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	120	120	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum A. Unetched B. Etched	Pass Visual Pass Visual	Pass Visual Pass Visual	rating	2.4.13.1	3.10.1.2
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability* (Laminate & prepreg as laminated)	HB minimum	HB minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
PREPREG REQUIREMENTS					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	4.0	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability* (as laminated)	HB minimum	rating	UL94	3.10.2.1	
6. Other	–				

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

**See Slash Sheet 5 in IPC-4121.

Revision Date: March 2006

SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/42					
REINFORCEMENT: 1: Woven E-glass		2: N/A		Keywords: (For Search Only) NOT Grade Requirement See Section 7	
RESIN SYSTEM: Primary: Polyimide		Secondary 2: N/A		Polyimide / Epoxy / Woven Glass	
Secondary 1: Epoxy		Minimum UL94 Requirement: HB		High Reliability	
FLAME RETARDANT MECHANISM: N/A		MIL-S-13949: /10 - GIJ		GPY	
FILLERS: With or without inorganic fillers					
ID REFERENCE: UL/ANSI: GPY					
ANSI: GPY/42					
GLASS TRANSITION (T _g): 200°C - 250°C					
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil].	AABUS	AABUS	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	0.90 [5.14]	0.90 [5.14]		2.4.8.2	
1. After thermal stress	0.70 [4.00]	0.70 [4.00]		2.4.8.3	
2. At 170°C [338°F]	0.80 [4.57]	0.95 [5.42]			
3. After process solutions	AABUS	AABUS			
C. All other foil – composite					
2. Volume Resistivity, minimum					
A. After humidity conditioning	6 x 10 ⁴	10 ⁶	MΩ-cm	2.5.17.1	3.11.1.3
B. At elevated temperature (204°C [399.2°F])	6 x 10 ⁴	10 ⁶			
3. Surface Resistivity, minimum					
A. After humidity conditioning	10 ⁴	10 ⁶	MΩ	2.5.17.1	3.11.1.4
B. At elevated temperature (204°C [399.2°F])	10 ⁴	10 ⁶			
4. Moisture Absorption, maximum					
	–	0.50 ≤ t < 1.55 mm 1.0 1.55 ≤ t ≤ 6.35 mm 0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum					
	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)**					
	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)**					
	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	325 [47,140]			
9. Flexural Strength at Elevated Temperature, E1/204, length direction, minimum					
	–	311 [45,110]	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum					
	120	120	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)					
	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability* (Laminate & prepreg as laminated)					
	HB minimum	HB minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other					
	–	–			
PREPREG REQUIREMENTS					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	4.0	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability* (as laminated)	HB minimum	rating	UL94	3.10.2.1	
6. Other	–				

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

**See Slash Sheet 5 in IPC-4121.

Revision Date: March 2006

SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/50				Keywords: (For Search Only)	
REINFORCEMENT:	1: Woven aramid	2: N/A		NOT Grade Requirement	
RESIN SYSTEM:	Primary: Epoxy			See Section 7	
	Secondary 1: Multifunctional epoxy	Secondary 2: N/A		Epoxy / Woven Aramid	
FLAME RETARDANT MECHANISM:	Bromine	Minimum UL94 Requirement: V-1		Low X/Y CTE	
FILLERS:	N/A			Low Dk / Df	
ID REFERENCE:	UL/ANSI: N/A	MIL-S-13949: /15			
	ANSI: 4101/50	- AF, AFN, AFG			
GLASS TRANSITION (T_g):	150°C - 200°C				
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 μm [0.669 mil].	AABUS	AABUS	N/mm [lb/in]	2.4.8	
B. Standard profile copper foil	0.70 [4.00]	0.80 [4.57]		2.4.8.2	3.9.1.1.1
1. After thermal stress	0.60 [3.43]	0.70 [4.00]		2.4.8.3	3.9.1.1.2
2. At 125°C [257°F]	0.55 [3.14]	0.70 [4.00]			3.9.1.1.3
3. After process solutions	AABUS	AABUS			
C. All other foil – composite					
2. Volume Resistivity, minimum					
A. C-96/35/90	10 ⁶	10 ⁶	MΩ-cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	10 ³	10 ³			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 ⁴	10 ⁴	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	10 ³	10 ³			
4. Moisture Absorption, maximum	–	2.0	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	4.5	4.5	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	345 [50,040]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	277 [40,180]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Opaque Foreign Inclusions					
≤508 microns as per area, max	16	16	Counts	–	3.8.3.1.7
≤508 microns as per area, max	4	4			
≤508 microns ≤1016 as per area, max	2	2			
>1016 microns as per area, max	0	0			
15. Other	–	–			
PREPREG REQUIREMENTS					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	0.75	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1	
6. Other	–				

Revision Date: March 2006

SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/53					
REINFORCEMENT:	1: Nonwoven aramid paper	2: N/A	Keywords: (For Search Only) NOT Grade Requirement See Section 7		
RESIN SYSTEM:	Primary: Polyimide	Secondary 2: N/A	Polyimide / Epoxy / Nonwoven Aramid		
	Secondary 1: N/A	Minimum UL94 Requirement: HB	Low X/Y CTE		
FLAME RETARDANT MECHANISM:	N/A		Microvia		
FILLERS:	N/A		Low Dk / Df		
ID REFERENCE:	UL/ANSI: N/A	MIL-S-13949: /31			
	ANSI: 4101/53	- BIN, BIJ			
GLASS TRANSITION (T _g):	220°C minimum				
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil].	AABUS	AABUS	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	0.54 [3.08]	0.54 [3.08]		2.4.8.2	
1. After thermal stress	0.49 [2.80]	0.49 [2.80]		2.4.8.3	
2. At 125°C [257°F]	0.49 [2.80]	0.49 [2.80]			
3. After process solutions	0.49 [2.80]	0.49 [2.80]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. After moisture resistance	10 ⁶	10 ⁶	MΩ-cm	2.5.17.1	3.11.1.3
B. At elevated temperature E-24/125	10 ³	10 ³			
3. Surface Resistivity, minimum					
A. After moisture resistance	10 ⁴	10 ⁴	MΩ	2.5.17.1	3.11.1.4
B. At elevated temperature E-24/125	10 ³	10 ³			
4. Moisture Absorption, maximum	3.5	3.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	4.5	4.5	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	207 [30,020]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	207 [30,020]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability* (Laminate & prepreg as laminated)	HB minimum	HB minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
PREPREG REQUIREMENTS					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	DAYS	AABUS	3.17	
2. Reinforcement	As per IPC-4411 or AABUS.				
3. Volatile content maximum	2.5	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability* (as laminated)	HB minimum	rating	UL94	3.10.2.1	
6. Other	–				

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

Revision Date: March 2006

SPECIFICATION SHEET

SPECIFICATION SHEET #: IPC-4101/54

REINFORCEMENT: 1: Unidirectional aramid fiber, cross-plyed 2: N/A

RESIN SYSTEM: Primary: Cyanate ester

Secondary 1: N/A

Secondary 2: N/A

Minimum UL94 Requirement: V-1

FLAME RETARDANT MECHANISM: Bromine

FILLERS: N/A

ID REFERENCE: UL/ANSI: N/A

ANSI: 4101/54

MIL-S-13949: N/A

GLASS TRANSITION (T_g): 230°C minimumKeywords: (For Search Only)
NOT Grade Requirement
See Section 7

Cyanate Ester / Woven Aramid

Low Dk / Df

Low X/Y CTE

Crossplied Unidirectional

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil]. B. Standard profile copper foil 1. After thermal stress 2. At 170°C [338°F] 3. After process solutions C. All other foil – composite	AABUS 0.70 [4.00] AABUS 0.60 [3.43] AABUS	AABUS 0.70 [4.00] AABUS 0.60 [3.43] AABUS	N/mm [lb/in]	2.4.8 2.4.8.2 2.4.8.3	3.9.1.1 3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
2. Volume Resistivity, minimum A. C-96/35/90 B. After moisture resistance C. At elevated temperature E-24/125	6 x 10 ⁴ – 10 ³	6 x 10 ⁴ – 10 ³	MΩ–cm	2.5.17.1	3.11.1.3
3. Surface Resistivity, minimum A. C-96/35/90 B. After moisture resistance C. At elevated temperature E-24/125	10 ⁴ – 10 ³	10 ⁴ – 10 ³	MΩ	2.5.17.1	3.11.1.4
4. Moisture Absorption, maximum	–	2.0	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	4.2	4.2	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.025	0.025	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum A. Length direction B. Cross direction	– –	345 [50,040] 277 [40,180]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum A. Unetched B. Etched	Pass Visual Pass Visual	Pass Visual Pass Visual	rating	2.4.13.1	3.10.1.2
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17
2. Reinforcement	As per IPC-4411 or AABUS.			
3. Volatile content maximum	1.5	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1
6. Other	–			

Revision Date: March 2006

SPECIFICATION SHEET		
SPECIFICATION SHEET #: IPC-4101/55		
REINFORCEMENT:	1: Nonwoven aramid paper	2: N/A
RESIN SYSTEM:	Primary: Epoxy	
	Secondary 1: Multifunctional epoxy	Secondary 2: N/A
FLAME RETARDANT MECHANISM:	Bromine	Minimum UL94 Requirement: V-1
FILLERS:	N/A	
ID REFERENCE:	UL/ANSI: N/A	MIL-S-13949: /22
	ANSI: 4101/55	- BF, BFN, BFG
GLASS TRANSITION (T _g):	150°C to 200°C	
		Keywords: (For Search Only) NOT Grade Requirement See Section 7
		Epoxy / Nonwoven Aramid Microvia Multifunctional Epoxy Low Dk / Df Low X/Y CTE

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil].	AABUS	AABUS	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	0.55 [3.14]	0.55 [3.14]		2.4.8.2	
1. After thermal stress	0.50 [2.86]	0.50 [2.86]		2.4.8.3	
2. At 125°C [257°F]	0.50 [2.86]	0.50 [2.86]			
3. After process solutions	0.50 [2.86]	0.50 [2.86]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 ⁶	10 ⁶	MΩ-cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	10 ³	10 ³			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 ⁴	10 ⁴	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	10 ³	10 ³			
4. Moisture Absorption, maximum	–	2.0	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	4.5	4.5	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	277 [40,180]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	277 [40,180]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	DAYS	AABUS	3.17
2. Reinforcement	As per IPC-4411 or AABUS.			
3. Volatile content maximum	1.5	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1
6. Other	–			

Revision Date: March 2006

SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/57					
REINFORCEMENT: 1: Nonwoven aramid paper		2: N/A		Keywords: (For Search Only)	
RESIN SYSTEM: Primary: Epoxy		Secondary 1: Multifunctional epoxy		NOT Grade Requirement	
FLAME RETARDANT MECHANISM: Phosphorus†		Secondary 2: N/A		See Section 7	
FILLERS: N/A		Minimum UL94 Requirement: V-1		Epoxy / Nonwoven Aramid	
ID REFERENCE: UL/ANSI: N/A		MIL-S-13949: /22 - BF, BFN, BFG		Multifunctional Epoxy	
GLASS TRANSITION (T_g): 150°C to 200°C		†900 ppm max. Br or Cl		Low Halogen Content	
		and 1500 ppm max. Br + Cl		Microvia	
				Low X/Y CTE	
				Low Dk / Df	
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil].	–	–		2.4.8	
B. Standard profile copper foil			N/mm [lb/in]	2.4.8.2	3.9.1.1.1
1. After thermal stress	–	–		2.4.8.3	3.9.1.1.2
2. At 125°C [257°F]	–	–			3.9.1.1.3
3. After process solutions	–	–			
C. All other foil – composite	–	–			
2. Volume Resistivity, minimum					
A. 96/35/90	–	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	–			
3. Surface Resistivity, minimum					
A. 96/35/90	–	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	–			
4. Moisture Absorption, maximum	–	–	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	–	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	–	–	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	–	–	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	–	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	–			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	–	–	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 260°C [500°F], minimum Note: Use peel specimen.	–	–	rating	2.4.13.1	3.10.1.2
12. Electric Strength, minimum (Laminate & prepreg as laminated)	–	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Halogen Content, maximum					
–Chlorine	900	900	ppm	2.3.41	3.10.1.9
–Bromine	900	900			
–Chlorine+Bromine	1500	1500			
15. Other	–	–			

PREPREG REQUIREMENTS				
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17
2. Reinforcement	IPC-4412, -EG-140, -SG-141, -A-142, -QF-143, -4110, -4130, -4411 or AABUS			
3. Volatile content maximum	1.5	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1
6. Other	–			

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/58			Keywords: (For Search Only)		
REINFORCEMENT: 1: Nonwoven aramid paper			NOT Grade Requirement		
RESIN SYSTEM: <i>Primary:</i> Multifunctional epoxy			See Section 7		
<i>Secondary 1:</i> Non-epoxy			<i>Secondary 2:</i> N/A		
FLAME RETARDANT MECHANISM: Phosphorus†			Minimum UL94 Requirement: V-0		
FILLERS: N/A			Epoxy / Non-Epoxy / Nonwoven Aramid		
ID REFERENCE: <i>UL/ANSI:</i> N/A			Low Halogen Content		
<i>ANSI:</i> 4101/58			Microvia		
GLASS TRANSITION (T_g): 135°C to 185°C			Low X/Y CTE		
			Low Dk / Df		
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil].	AABUS	AABUS	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil				2.4.8.2	
1. After thermal stress	0.55 [3.14]	0.55 [3.14]		2.4.8.3	
2. At 125°C [257°F]	0.50 [2.86]	0.50 [2.86]			
3. After process solutions	0.50 [2.86]	0.50 [2.86]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 ⁶	10 ⁶	MΩ-cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	10 ³	10 ³			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 ⁴	10 ⁴	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	10 ³	10 ³			
4. Moisture Absorption, maximum	–	2.0	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	4.5	4.5	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	277 [40,180]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	277 [40,180]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-0 minimum	V-0 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Halogen Content, maximum					
–Chlorine	900	900	ppm	2.3.41	3.10.1.9
–Bromine	900	900			
–Chlorine+Bromine	1500	1500			
15. Other	–	–			

PREPREG REQUIREMENTS				
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	DAYS	AABUS	3.17
2. Reinforcement	As per IPC-4411 or AABUS.			
3. Volatile content maximum	1.5	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7
5. Flammability (as laminated)	V-0 minimum	rating	UL94	3.10.2.1
6. Other	–			

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/60					
REINFORCEMENT:	1: Woven quartz fiber	2: N/A	Keywords: (For Search Only) NOT Grade Requirement See Section 7		
RESIN SYSTEM:	Primary: Polyimide	Secondary 1: N/A	Polyimide / Woven Quartz		
FLAME RETARDANT MECHANISM:	Bromine (if applicable)	Secondary 2: N/A	Low X/Y CTE		
FILLERS:	N/A	Minimum UL94 Requirement: HB			
ID REFERENCE:	UL/ANSI: N/A	MIL-S-13949: /19 - QIL			
GLASS TRANSITION (T _g):	250°C minimum				
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil].	AABUS	AABUS	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	0.90 [5.14]	1.05 [6.00]		2.4.8.2	
1. After thermal stress	0.70 [4.00]	0.70 [4.00]		2.4.8.3	
2. At 125°C [257°F]	0.80 [4.57]	0.95 [5.42]			
3. After process solutions	AABUS	AABUS			
C. All other foil – composite					
2. Volume Resistivity, minimum					
A. C-96/35/90	6 x 10 ⁴	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 ⁶			
C. At elevated temperature E-24/125	6 x 10 ⁴	10 ⁶			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 ⁴	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 ⁶			
C. At elevated temperature E-24/125	6 x 10 ⁴	10 ⁶			
4. Moisture Absorption, maximum	–	1.0	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	3.4	3.8	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.010	0.010	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	311 [45,110]			
9. Flexural Strength at Elevated Temperature 204°C, length direction, minimum	–	311 [45,110]	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	120	120	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability* (Laminate & prepreg as laminated)	HB minimum	HB minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
PREPREG REQUIREMENTS					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-QF-143 or AABUS.				
3. Volatile content maximum	1.5	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability* (as laminated)	HB	rating	UL94	3.10.2.1	
6. Other	–				

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

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/70					
REINFORCEMENT:	1: Woven S-2 glass	2: N/A	Keywords: (For Search Only) NOT Grade Requirement See Section 7		
RESIN SYSTEM:	Primary: Cyanate ester Secondary 1: N/A	Secondary 2: N/A Minimum UL94 Requirement: V-1	Cyanate Ester / Woven S-2 Glass Low X/Y CTE Low Dk / Df CAF Resistant		
FLAME RETARDANT MECHANISM:	Bromine				
FILLERS:	N/A				
ID REFERENCE:	UL/ANSI: N/A ANSI: 4101/70	MIL-S-13949: N/A			
GLASS TRANSITION (T_g):	230°C minimum				
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil]. B. Standard profile copper foil 1. After thermal stress 2. At 170°C [338°F] 3. After process solutions C. All other foil – composite	AABUS 0.70 [4.00] 0.70 [4.00] 0.70 [4.00] AABUS	AABUS 0.70 [4.00] 0.70 [4.00] 0.70 [4.00] AABUS	N/mm [lb/in]	2.4.8 2.4.8.2 2.4.8.3	3.9.1.1 3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
2. Volume Resistivity, minimum A. C-96/35/90 B. After moisture resistance C. At elevated temperature E-24/204	10 ⁶ – 10 ⁴	– 10 ⁶ 10 ³	MΩ–cm	2.5.17.1	3.11.1.3
3. Surface Resistivity, minimum A. C-96/35/90 B. After moisture resistance C. At elevated temperature E-24/204	10 ⁶ – 6 x 10 ⁴	– 10 ⁶ 10 ⁵	MΩ	2.5.17.1	3.11.1.4
4. Moisture Absorption, maximum	–	3.0	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	4.3	4.3	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.015	0.015	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum A. Length direction B. Cross direction	– –	345 [50,040] 345 [50,040]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
9. Flexural Strength at Elevated Temperature 204°C, length direction, minimum	–	277 [40,180]	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	120	120	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum A. Unetched B. Etched	Pass Visual Pass Visual	Pass Visual Pass Visual	rating	2.4.13.1	3.10.1.2
12. Electric Strength, minimum (Laminate & prepreg as laminated)	–	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. CAF Resistance	–	AABUS	Pass/Fail †	2.6.25	3.12.1.4
15. Other	–	–			

† Pass or Fail are determined by Fail being ≥1 decade drop in the sample's initial insulation resistance value.

PREPREG REQUIREMENTS				
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17
2. Reinforcement	As per IPC-SG-141 or AABUS.			
3. Volatile content maximum	1.5	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1
6. Other	–			

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/71					
REINFORCEMENT:	1: Woven E-glass	2: N/A	Keywords: (For Search Only) NOT Grade Requirement See Section 7		
RESIN SYSTEM:	Primary: Cyanate ester	Secondary 2: N/A	Cyanate Ester / Woven Glass		
	Secondary 1: N/A	Minimum UL94 Requirement: V-1	Low Dk / Df		
FLAME RETARDANT MECHANISM:	Bromine		CAF Resistant		
FILLERS:	N/A				
ID REFERENCE:	UL/ANSI: N/A	MIL-S-13949: /29 - GCN			
	ANSI: 4101/71				
GLASS TRANSITION (T _g):	230°C minimum				
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil].	AABUS	AABUS	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	0.70 [4.00]	0.70 [4.00]		2.4.8.2	
1. After thermal stress	0.70 [4.00]	0.70 [4.00]		2.4.8.3	
2. At 125°C [257°F]	0.70 [4.00]	0.70 [4.00]			
3. After process solutions	0.70 [4.00]	0.70 [4.00]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 ⁶	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 ⁶			
C. At elevated temperature E-24/204	10 ⁴	10 ³			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 ⁶	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 ⁶			
C. At elevated temperature E-24/204	10 ⁴	10 ⁶			
4. Moisture Absorption, maximum	–	1.0	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	40	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)*	4.5	4.5	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)*	0.015	0.015	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	345 [50,040]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature 204°C, length direction, minimum	–	277 [40,180]	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	120	120	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. CAF Resistance	–	AABUS	Pass/Fail †	2.6.25	3.12.1.4
15. Other	–	–			

*See Slash Sheet 4 in IPC-4121.

†Pass or Fail are determined by Fail being ≥1 decade drop in the sample's initial insulation resistance value.

PREPREG REQUIREMENTS				
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17
2. Reinforcement	As per IPC-EG-140 or AABUS.			
3. Volatile content maximum	1.5	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1
6. Other	–			

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/80					
REINFORCEMENT:	1: Woven E-glass, surface	2: Cellulose paper, core	Keywords: (For Search Only) NOT Grade Requirement See Section 7		
RESIN SYSTEM:	Primary: Epoxy Secondary 1: Phenolic	Secondary 2: N/A Minimum UL94 Requirement: V-0	Epoxy / Woven Glass / Paper Punchable Additive / Semi-Additive Consumer Electronics CEM-1 Single-Sided		
FLAME RETARDANT MECHANISM:	Bromine/Antimony oxide				
FILLERS:	Kaolin and/or inorganic catalyst				
ID REFERENCE:	UL/ANSI: CEM-1 ANSI: CEM-1/80	MIL-S-13949: N/A			
GLASS TRANSITION (T _g):	100°C minimum				
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil].	–	–		2.4.8	
B. Standard profile copper foil	–	–	N/mm [lb/in]	2.4.8.2	3.9.1.1.1
1. After thermal stress	–	–		2.4.8.3	3.9.1.1.2
2. At 125°C [257°F]	–	–			3.9.1.1.3
3. After process solutions	–	–			
C. All other foil – composite	–	–			
2. Volume Resistivity, minimum					
A. C-96/35/90	–	10 ⁶	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	10 ³			
3. Surface Resistivity, minimum					
A. C-96/35/90	–	10 ⁴	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	10 ³			
4. Moisture Absorption, maximum	–	0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	–	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	–	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	242 [35,100]*	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	172 [24,950]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	–	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	–	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	–	–			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	–	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-0 minimum	V-0 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			

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

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/81					
REINFORCEMENT: 1: Woven E-glass, surface		2: Nonwoven E-glass (chopped felt), core		Keywords: (For Search Only)	
RESIN SYSTEM: Primary: Epoxy		Secondary 1: Multifunctional epoxy		NOT Grade Requirement	
FLAME RETARDANT MECHANISM: Bromine		Secondary 2: N/A		See Section 7	
FILLERS: Kaolin and/or inorganic catalyst		Minimum UL94 Requirement: V-0		Epoxy / Woven Glass / Nonwoven Glass	
ID REFERENCE: UL/ANSI: CEM-3		MIL-S-13949: N/A		Punchable	
GLASS TRANSITION (T_g): N/A				Additive / Semi-Additive	
				Consumer Electronics	
				CEM-3	
				Double-Sided	
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil].	–	–		2.4.8	
B. Standard profile copper foil	–	–	N/mm [lb/in]	2.4.8.2	3.9.1.1.1
1. After thermal stress	–	–		2.4.8.3	3.9.1.1.2
2. At 125°C [257°F]	–	–			3.9.1.1.3
3. After process solutions	–	–			
C. All other foil – composite	–	–			
2. Volume Resistivity, minimum					
A. C-96/35/90	–	10 ⁶	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	10 ³			
3. Surface Resistivity, minimum					
A. C-96/35/90	–	10 ⁴	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	–			
C. At elevated temperature E-24/125	–	10 ³			
4. Moisture Absorption, maximum	–	0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	–	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	–	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	276 [40,030]*	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	186 [26,980]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	–	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	–	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	–	–			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	–	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-0 minimum	V-0 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			

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

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SPECIFICATION SHEET		Keywords: (For Search Only)	
SPECIFICATION SHEET #: IPC-4101/82		NOT Grade Requirement	
REINFORCEMENT:	1: Woven E-glass	2: N/A	See Section 7
RESIN SYSTEM:	Primary: Epoxy	Secondary 1: Multifunctional epoxy	Epoxy / Woven Glass
FLAME RETARDANT MECHANISM:	Bromine, RoHS Compliant	Secondary 2: N/A	Additive / Semi-Additive
FILLERS:	Kaolin and/or inorganic catalyst	Minimum UL94 Requirement: V-1	Consumer Electronics
ID REFERENCE:	UL/ANSI: FR-4	MIL-S-13949: N/A	FR-4
GLASS TRANSITION (T _g):	110°C minimum		

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil].	–	–	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	–	–		2.4.8.2	
1. After thermal stress	–	–		2.4.8.3	
2. At 125°C [257°F]	–	–			
3. After process solutions	–	–			
C. All other foil – composite	–	–			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 ⁶	–	MΩ-cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 ⁶			
C. At elevated temperature E-24/125	10 ³	10 ³			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 ⁴	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 ⁴			
C. At elevated temperature E-24/125	10 ³	10 ³			
4. Moisture Absorption, maximum	–	0.35	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.030	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	–	–			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17
2. Reinforcement	As per IPC-EG-140 or AABUS.			
3. Volatile content maximum	–	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1
6. Other	–			

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/83					
REINFORCEMENT: 1: Woven E-glass		2: N/A		Keywords: (For Search Only)	
RESIN SYSTEM: Primary: Epoxy		Secondary 1: Multifunctional epoxy		NOT Grade Requirement	
FLAME RETARDANT MECHANISM: Bromine, RoHS Compliant		Secondary 2: N/A		See Section 7	
FILLERS: Kaolin and/or inorganic catalyst		Minimum UL94 Requirement: V-1		Epoxy / Woven Glass	
ID REFERENCE: UL/ANSI: FR-4		MIL-S-13949: N/A		Multifunctional Epoxy	
GLASS TRANSITION (T_g): 150°C - 200°C				Additive / Semi-Additive	
				Consumer Electronics	
				FR-4	
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil].	–	–		2.4.8	
B. Standard profile copper foil			N/mm [lb/in]	2.4.8.2	3.9.1.1.1
1. After thermal stress	–	–		2.4.8.3	3.9.1.1.2
2. At 125°C [257°F]	–	–			3.9.1.1.3
3. After process solutions	–	–			
C. All other foil – composite	–	–			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 ⁶	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 ⁴			
C. At elevated temperature E-24/125	10 ³	10 ³			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 ⁴	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 ⁴			
C. At elevated temperature E-24/125	10 ³	10 ³			
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	90	90	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
PREPREG REQUIREMENTS					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	1.5	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1	
6. Other	–				

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/90					
REINFORCEMENT: 1: Woven E-glass, surface		2: N/A		Keywords: (For Search Only) NOT Grade Requirement See Section 7	
RESIN SYSTEM: <i>Primary:</i> Polyphenylene ether		<i>Secondary 1:</i> N/A		<i>Secondary 2:</i> N/A	
FLAME RETARDANT MECHANISM: Bromine/Antimony oxide		Minimum UL94 Requirement: V-1		PPE / Woven Glass	
FILLERS: N/A		MIL-S-13949: N/A		Low Dk / Df	
ID REFERENCE: <i>UL/ANSI:</i> N/A					
GLASS TRANSITION (T_g): 175°C minimum					
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil].	0.70 [4.00]	0.70 [4.00]	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	0.70 [4.00]	0.70 [4.00]		2.4.8.2	
1. After thermal stress	0.70 [4.00]	0.70 [4.00]		2.4.8.3	
2. At 125°C [257°F]	0.70 [4.00]	0.70 [4.00]			
3. After process solutions	0.55 [3.14]	0.55 [3.14]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum			MΩ-cm	2.5.17.1	3.11.1.3
A. C-96/35/90	10 ⁶	–			
B. After moisture resistance	–	10 ⁶			
C. At elevated temperature E-24/125	10 ⁶	10 ⁶			
3. Surface Resistivity, minimum			MΩ	2.5.17.1	3.11.1.4
A. C-96/35/90	10 ⁵	–			
B. After moisture resistance	–	10 ⁵			
C. At elevated temperature E-24/125	10 ⁵	10 ⁵			
4. Moisture Absorption, maximum	–	0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	4.2	4.2	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.015	0.015	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum			N/mm ² [lb/in ²]	2.4.4	3.9.1.3
A. Length direction	–	415 [60,190]			
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum			rating	2.4.13.1	3.10.1.2
A. Unetched	Pass Visual	Pass Visual			
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
PREPREG REQUIREMENTS					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-EG-140				
3. Volatile content maximum	–	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1	
6. Other	–				

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/91			Keywords: (For Search Only) NOT Grade Requirement See Section 7		
REINFORCEMENT:	1: Woven E-glass	2: N/A			
RESIN SYSTEM:	Primary: Polyphenylene ether	Secondary 1: N/A			
FLAME RETARDANT MECHANISM:	Bromine	Secondary 2: N/A			
FILLERS:	N/A	Minimum UL94 Requirement: V-1	PPE / Woven Glass Low Dk / Df		
ID REFERENCE:	UL/ANSI: N/A	MIL-S-13949: N/A			
GLASS TRANSITION (T_g):	175°C minimum				
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil].	0.52 [2.97]	0.52 [2.97]	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	0.52 [2.97]	0.52 [2.97]		2.4.8.2	
1. After thermal stress	0.52 [2.97]	0.52 [2.97]		2.4.8.3	
2. At 125°C [257°F]	0.52 [2.97]	0.52 [2.97]			
3. After process solutions	0.41 [2.34]	0.41 [2.34]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 ⁶	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 ⁶			
C. At elevated temperature E-24/125	10 ⁶	10 ⁶			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 ⁵	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 ⁵			
C. At elevated temperature E-24/125	10 ⁵	10 ⁵			
4. Moisture Absorption, maximum	–	0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	4.2	4.2	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.015	0.015	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
PREPREG REQUIREMENTS					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-EG-140				
3. Volatile content maximum	–	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1	
6. Other	–				

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/92					
REINFORCEMENT:	1: Woven E-glass	2: N/A	Keywords: (For Search Only) NOT Grade Requirement See Section 7		
RESIN SYSTEM:	Primary: Epoxy	Secondary 1: Multifunctional epoxy	Secondary 2: N/A	Epoxy / Woven Glass	
FLAME RETARDANT MECHANISM:	Phosphorus†	Minimum UL94 Requirement: V-1	Low Halogen Content		
FILLERS:	N/A	MIL-S-13949: N/A	FR-4		
ID REFERENCE:	UL/ANSI: FR-4	†900 ppm max. Br or Cl			
GLASS TRANSITION (T _g):	ANSI: FR-4/92 110°C - 150°C	and 1500 ppm max. Br + Cl			
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil].	0.70 [4.00]	0.70 [4.00]	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	0.80 [4.57]	1.05 [6.00]		2.4.8.2	
1. After thermal stress	0.70 [4.00]	0.70 [4.00]		2.4.8.3	
2. At 125°C [257°F]	0.55 [3.14]	0.80 [4.57]			
3. After process solutions	AABUS	AABUS			
C. All other foil – composite					
2. Volume Resistivity, minimum					
A. C-96/35/90	10 ⁶	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 ⁶			
C. At elevated temperature E-24/125	10 ³	10 ³			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 ⁴	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 ⁴			
C. At elevated temperature E-24/125	10 ³	10 ³			
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Halogen Content, maximum					
–Chlorine	900	900	ppm	2.3.41	3.10.1.9
–Bromine	900	900			
–Chlorine+Bromine	1500	1500			
15. Other	–	–			

PREPREG REQUIREMENTS				
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17
2. Reinforcement	As per IPC-4412 or AABUS.			
3. Volatile content maximum	0.75	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1
6. Other	–			

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/93					
REINFORCEMENT:	1: Woven E-glass	2: N/A	Keywords: (For Search Only) NOT Grade Requirement See Section 7		
RESIN SYSTEM:	Primary: Epoxy Secondary 1: Multifunctional epoxy	Secondary 2: N/A	Epoxy / Woven Glass		
FLAME RETARDANT MECHANISM:	Aluminum hydroxide†	Minimum UL94 Requirement: V-1	Low Halogen Content		
FILLERS:	N/A	MIL-S-13949: N/A	FR-4		
ID REFERENCE:	UL/ANSI: FR-4 ANSI: FR-4/93	†900 ppm max. Br or Cl and 1500 ppm max. Br + Cl			
GLASS TRANSITION (T _g):	110°C - 150°C				
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil].	0.70 [4.00]	0.70 [4.00]	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	0.80 [4.57]	1.05 [6.00]		2.4.8.2	
1. After thermal stress	0.70 [4.00]	0.70 [4.00]		2.4.8.3	
2. At 125°C [257°F]	0.55 [3.14]	0.80 [4.57]			
3. After process solutions		AABUS			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 ⁶	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 ⁶			
C. At elevated temperature E-24/125	10 ³	10 ³			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 ⁴	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 ⁴			
C. At elevated temperature E-24/125	10 ³	10 ³			
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Halogen Content, maximum					
–Chlorine	900	900	ppm	2.3.41	3.10.1.9
–Bromine	900	900			
–Chlorine+Bromine	1500	1500			
15. Other	–	–			

PREPREG REQUIREMENTS				
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17
2. Reinforcement	As per IPC-4412 or AABUS.			
3. Volatile content maximum	0.75	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1
6. Other	–			

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/94					
REINFORCEMENT:	1: Woven E-glass	2: N/A	Keywords: (For Search Only) NOT Grade Requirement See Section 7		
RESIN SYSTEM:	Primary: Epoxy Secondary 1: Multifunctional epoxy	Secondary 2: N/A Minimum UL94 Requirement: V-1	Epoxy / Woven Glass Low Halogen Content FR-4 Multifunctional Epoxy		
FLAME RETARDANT MECHANISM:	Phosphorous†	MIL-S-13949: N/A			
FILLERS:	N/A	†900 ppm max. Br or Cl and 1500 ppm max. Br + Cl			
ID REFERENCE:	UL/ANSI: FR-4 ANSI: FR-4/94				
GLASS TRANSITION (T _g):	150°C - 200°C				
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil]. B. Standard profile copper foil 1. After thermal stress 2. At 125°C [257°F] 3. After process solutions C. All other foil – composite	0.70 [4.00] 0.80 [4.57] 0.70 [4.00] 0.55 [3.14] AABUS	0.70 [4.00] 1.05 [6.00] 0.70 [4.00] 0.80 [4.57] AABUS	N/mm [lb/in]	2.4.8 2.4.8.2 2.4.8.3	3.9.1.1 3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
2. Volume Resistivity, minimum A. C-96/35/90 B. After moisture resistance C. At elevated temperature E-24/125	10 ⁶ – 10 ³	– 10 ⁴ 10 ³	MΩ–cm	2.5.17.1	3.11.1.3
3. Surface Resistivity, minimum A. C-96/35/90 B. After moisture resistance C. At elevated temperature E-24/125	10 ⁴ – 10 ³	– 10 ⁴ 10 ³	MΩ	2.5.17.1	3.11.1.4
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum A. Length direction B. Cross direction	– –	415 [60,190] 345 [50,040]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	90	90	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum A. Unetched B. Etched	Pass Visual Pass Visual	Pass Visual Pass Visual	rating	2.4.13.1	3.10.1.2
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Halogen Content, maximum –Chlorine –Bromine –Chlorine+Bromine	900 900 1500	900 900 1500	ppm	2.3.41	3.10.1.9
15. Other	–	–			

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

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/95					
REINFORCEMENT:	1: Woven E-glass	2: N/A	Keywords: (For Search Only) NOT Grade Requirement See Section 7		
RESIN SYSTEM:	Primary: Epoxy	Secondary 1: Multifunctional epoxy	Secondary 2: N/A	Epoxy / Woven Glass	
FLAME RETARDANT MECHANISM:	Aluminum hydroxide†	Minimum UL94 Requirement: V-1	Low Halogen Content		
FILLERS:	N/A	MIL-S-13949: N/A	FR-4		
ID REFERENCE:	UL/ANSI: FR-4	†900 ppm max. Br or Cl	Multifunctional Epoxy		
GLASS TRANSITION (T _g):	150°C - 200°C	and 1500 ppm max. Br + Cl			
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil].	0.70 [4.00]	0.70 [4.00]	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	0.80 [4.57]	1.05 [6.00]		2.4.8.2	
1. After thermal stress	0.70 [4.00]	0.70 [4.00]		2.4.8.3	
2. At 125°C [257°F]	0.55 [3.14]	0.80 [4.57]			
3. After process solutions	AABUS	AABUS			
C. All other foil – composite					
2. Volume Resistivity, minimum			MΩ-cm	2.5.17.1	3.11.1.3
A. C-96/35/90	10 ⁶	–			
B. After moisture resistance	–	10 ⁴			
C. At elevated temperature E-24/125	10 ³	10 ³			
3. Surface Resistivity, minimum			MΩ	2.5.17.1	3.11.1.4
A. C-96/35/90	10 ⁴	–			
B. After moisture resistance	–	10 ⁴			
C. At elevated temperature E-24/125	10 ³	10 ³			
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum			N/mm ² [lb/in ²]	2.4.4	3.9.1.3
A. Length direction	–	415 [60,190]			
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	90	90	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum			rating	2.4.13.1	3.10.1.2
A. Unetched	Pass Visual	Pass Visual			
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Halogen Content, maximum			ppm	2.3.41	3.10.1.9
–Chlorine	900	900			
–Bromine	900	900			
–Chlorine+Bromine	1500	1500			
15. Other	–	–			

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

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/96					
REINFORCEMENT:	1: Woven E-glass	2: N/A	Keywords: (For Search Only) NOT Grade Requirement See Section 7		
RESIN SYSTEM:	Primary: Polyphenylene ether	Secondary 1: N/A	PPE / Woven Glass		
FLAME RETARDANT MECHANISM:	Non-Bromine/Non-Antimony†	Secondary 2: N/A	Low Halogen Content		
FILLERS:	N/A	Minimum UL94 Requirement: V-1	Low Dk / Df		
ID REFERENCE:	UL/ANSI: N/A	MIL-S-13949: N/A			
GLASS TRANSITION (T _g):	ANSI: 4101/96 175°C minimum	†900 ppm max. Br or Cl and 1500 ppm max. Br + Cl			
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil].	0.70 [4.00]	0.70 [4.00]	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil	0.70 [4.00]	0.70 [4.00]		2.4.8.2	
1. After thermal stress	0.70 [4.00]	0.70 [4.00]		2.4.8.3	
2. At 125°C [257°F]	0.70 [4.00]	0.70 [4.00]			
3. After process solutions	0.55 [3.14]	0.55 [3.14]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 ⁶	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 ⁶			
C. At elevated temperature E-24/125	10 ⁶	10 ⁶			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 ⁵	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 ⁵			
C. At elevated temperature E-24/125	10 ⁵	10 ⁵			
4. Moisture Absorption, maximum	–	0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	4.2	4.2	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.015	0.015	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	s	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-1 minimum	V-1 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Halogen Content, maximum					
–Chlorine	900	900	ppm	2.3.41	3.10.1.9
–Bromine	900	900			
–Chlorine+Bromine	1500	1500			
15. Other	–	–			

PREPREG REQUIREMENTS				
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17
2. Reinforcement	As per IPC-EG-140			
3. Volatile content maximum	–	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7
5. Flammability (as laminated)	V-1 minimum	rating	UL94	3.10.2.1
6. Other	–			

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/97					
REINFORCEMENT:	1: Woven E-glass	2: N/A	Keywords: (For Search Only) NOT Grade Requirement See Section 7		
RESIN SYSTEM:	Primary: Difunctional epoxy	Secondary 1: Multifunctional epoxy	Secondary 2: N/A	FR-4	
FLAME RETARDANT MECHANISM:	Bromine, RoHS Compliant	Minimum UL94 Requirement: V-0	GFN		
FILLERS:	Inorganic fillers	MIL-S-13949: /04	Epoxy / Woven Glass		
ID REFERENCE:	UL/ANSI: FR-4	- GF, GFN, GFK, GFP, GFM	Fillers		
GLASS TRANSITION (T _g):	110°C minimum				
UL MAX. OPERATING TEMP:	N/A				
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil].	0.70 [4.00]	0.70 [4.00]	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil				2.4.8.2	
1. After thermal stress	0.80 [4.57]	1.05 [6.00]		2.4.8.3	
2. At 125°C [257°F]	0.70 [4.00]	0.70 [4.00]			
3. After process solutions	0.55 [3.14]	0.80 [4.57]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. °C [°F] - 96/35/90 [204.8/95/194]	10 ⁶	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 ⁶			
C. At elevated temperature E-24/125	10 ³	10 ³			
3. Surface Resistivity, minimum					
A. °C [°F] - 96/35/90 [204.8/95/194]	10 ⁴	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 ⁴			
C. At elevated temperature E-24/125	10 ³	10 ³			
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-0 minimum	V-0 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
PREPREG REQUIREMENTS					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	0.75	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-0 minimum	rating	UL94	3.10.2.1	
6. Other	–				

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/98					
REINFORCEMENT: 1: Woven E-glass		2: N/A		Keywords: (For Search Only) NOT Grade Requirement See Section 7	
RESIN SYSTEM: Primary: Epoxy		Secondary 1: Multifunctional epoxy		Epoxy / Woven Glass	
FLAME RETARDANT MECHANISM: Bromine, RoHS Compliant		Secondary 2: N/A		FR-4	
FILLERS: Inorganic fillers		Minimum UL94 Requirement: V-0		Multifunctional Epoxy	
ID REFERENCE: UL/ANSI: FR-4		MIL-S-13949: /04 - GF, GFG, GFN		GFN	
GLASS TRANSITION (T_g): 150°C minimum				Fillers	
UL MAX. OPERATING TEMP: N/A					
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					3.9.1.1
A. Low profile copper foil and very low profile copper foil – all copper foil >17 µm [0.669 mil].	0.70 [4.00]	0.70 [4.00]	N/mm [lb/in]	2.4.8	3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil				2.4.8.2	
1. After thermal stress	0.80 [4.57]	1.05 [6.00]		2.4.8.3	
2. At 125°C [257°F]	0.70 [4.00]	0.70 [4.00]			
3. After process solutions	0.55 [3.14]	0.80 [4.57]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 ⁶	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 ⁴			
C. At elevated temperature E-24/125	10 ³	10 ³			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 ⁴	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 ⁴			
C. At elevated temperature E-24/125	10 ³	10 ³			
4. Moisture Absorption, maximum	–	0.80	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-0 minimum	V-0 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Other	–	–			
PREPREG REQUIREMENTS					
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.	
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17	
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	1.5	%	2.3.19	3.9.2.2.8	
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7	
5. Flammability (as laminated)	V-0 minimum	rating	UL94	3.10.2.1	
6. Other	–				

Revision Date: March 2006

SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/99					
REINFORCEMENT: 1: Woven E-glass		2: N/A		Keywords: (For Search Only)	
RESIN SYSTEM: Primary: Epoxy		Secondary 1: Multifunctional epoxy		NOT Grade Requirement	
Secondary 2: Modified Epoxy or Non-epoxy (max. wt. 5%)		Minimum UL94 Requirement: V-0		See Section 7	
FLAME RETARDANT MECHANISM: Bromine, RoHS Compliant		Contains inorganic fillers		Lead-Free FR-4	
FILLERS (≥5%):				High Decomposition Temperature	
ID REFERENCE: UL/ANSI: FR-4/99				Low Z-axis CTE	
GLASS TRANSITION (T _g): 150°C minimum					
UL MAX. OPERATING TEMP: AABUS					
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					
A. Low profile copper foil and very low profile copper foil – all copper weights >17 μm [0.669 mil].	AABUS	AABUS	N/mm [lb/in]	2.4.8	3.9.1.1
B. Standard profile copper foil				2.4.8.2	3.9.1.1.1
1. After thermal stress	0.80 [4.57]	1.05 [6.00]		2.4.8.3	3.9.1.1.2
2. At 125°C [257°F]	0.70 [4.00]	0.70 [4.00]			3.9.1.1.3
3. After process solutions	0.55 [3.14]	0.80 [4.57]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 ⁶	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 ⁴			
C. At elevated temperature E-24/125	10 ³	10 ³			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 ⁴	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 ⁴			
C. At elevated temperature E-24/125	10 ³	10 ³			
4. Moisture Absorption, maximum	–	0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)*	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)*	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-0 minimum	V-0 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Glass Transition Temperature	–	150 minimum	°C	2.4.24 2.4.25	3.10.1.6
15. Decomposition Temperature	–	325 minimum	°C	TBD (5% wt loss)	3.10.1.10
16. Z-Axis CTE					
A. Alpha 1	–	60 maximum	PPM/°C PPM/°C %	2.4.24	3.10.1.11
B. Alpha 2	–	300 maximum			
C. 50 to 260°C	–	3.5 maximum			
17. Thermal Resistance (Copper removed)					
A. T260	–	30 minimum	Minutes	2.4.24.1	3.10.1.12
B. T288	–	10 minimum			
C. T300	–	AABUS			
18. Other	–	–			

*See Slash Sheet 2 in IPC-4121.

PREPREG REQUIREMENTS				
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17
2. Reinforcement	As per IPC-4412 or AABUS.			
3. Volatile content maximum	1.5	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7
5. Flammability (as laminated)	V-0 minimum	rating	UL94	3.10.2.1
6. Other	–			

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/101					
REINFORCEMENT:	1: Woven E-glass	2: N/A	Keywords: (For Search Only)		
RESIN SYSTEM:	Primary: Difunctional Epoxy		NOT Grade Requirement		
	Secondary 1: Multifunctional epoxy	Secondary 2: Modified Epoxy or Non-epoxy (max. wt. 5%)	See Section 7		
FLAME RETARDANT MECHANISM:	Bromine, RoHS Compliant	Minimum UL94 Requirement: V-0	Lead-Free FR-4		
FILLERS (≥5%):	Contains inorganic fillers		Low Z-axis CTE		
ID REFERENCE:	UL/ANSI: FR-4/101				
GLASS TRANSITION (T _g):	110°C minimum				
UL MAX. OPERATING TEMP:	AABUS				
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					
A. Low profile copper foil and very low profile copper foil – all copper weights >17 µm [0.669 mil].	AABUS	AABUS	N/mm [lb/in]	2.4.8	3.9.1.1
B. Standard profile copper foil				2.4.8.2	3.9.1.1.1
1. After thermal stress	0.80 [4.57]	1.05 [6.00]		2.4.8.3	3.9.1.1.2
2. At 125°C [257°F]	0.70 [4.00]	0.70 [4.00]			3.9.1.1.3
3. After process solutions	0.55 [3.14]	0.80 [4.57]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 ⁶	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 ⁴			
C. At elevated temperature E-24/125	10 ³	10 ³			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 ⁴	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 ⁴			
C. At elevated temperature E-24/125	10 ³	10 ³			
4. Moisture Absorption, maximum	–	0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)*	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)*	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-0 minimum	V-0 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Glass Transition Temperature	–	110 minimum	°C	2.4.24 2.4.25	3.10.1.6
15. Decomposition Temperature	–	310 minimum	°C	TBD (5% wt loss)	3.10.1.10
16. Z-Axis CTE					
A. Alpha 1	–	60 maximum	PPM/°C PPM/°C %	2.4.24	3.10.1.11
B. Alpha 2	–	300 maximum			
C. 50 to 260°C	–	4.0 maximum			
17. Thermal Resistance (Copper removed)					
A. T260	–	30 minimum	Minutes	2.4.24.1	3.10.1.12
B. T288	–	5 minimum			
C. T300	–	AABUS			
18. Other	–	–			

*See Slash Sheet 2 in IPC-4121.

PREPREG REQUIREMENTS				
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17
2. Reinforcement	As per IPC-4412 or AABUS.			
3. Volatile content maximum	1.5	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7
5. Flammability (as laminated)	V-0 minimum	rating	UL94	3.10.2.1
6. Other	–			

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/121					
REINFORCEMENT:	1: Woven E-glass	2: N/A	Keywords: (For Search Only)		
RESIN SYSTEM:	Primary: Difunctional Epoxy		NOT Grade Requirement		
	Secondary 1: Multifunctional epoxy		See Section 7		
FLAME RETARDANT MECHANISM:	Bromine, RoHS Compliant	Secondary 2: Modified Epoxy or Non-epoxy (max. wt. 5%)	Lead-Free FR-4		
FILLERS (≥5%):	N/A	Minimum UL94 Requirement: V-0	Low Z-axis CTE		
ID REFERENCE:	UL/ANSI: FR-4/121				
GLASS TRANSITION (T _g):	110°C minimum				
UL MAX. OPERATING TEMP:	AABUS				
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					
A. Low profile copper foil and very low profile copper foil – all copper weights >17 μm [0.669 mil].	AABUS	AABUS	N/mm [lb/in]	2.4.8	3.9.1.1
B. Standard profile copper foil				2.4.8.2	3.9.1.1.1
1. After thermal stress	0.80 [4.57]	1.05 [6.00]		2.4.8.3	3.9.1.1.2
2. At 125°C [257°F]	0.70 [4.00]	0.70 [4.00]			3.9.1.1.3
3. After process solutions	0.55 [3.14]	0.80 [4.57]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 ⁶	–	MΩ-cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 ⁴			
C. At elevated temperature E-24/125	10 ³	10 ³			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 ⁴	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 ⁴			
C. At elevated temperature E-24/125	10 ³	10 ³			
4. Moisture Absorption, maximum	–	0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)*	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)*	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-0 minimum	V-0 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Glass Transition Temperature	–	110 minimum	°C	2.4.24 2.4.25	3.10.1.6
15. Decomposition Temperature	–	310 minimum	°C	TBD (5% wt loss)	3.10.1.10
16. Z-Axis CTE					
A. Alpha 1	–	60 maximum	PPM/°C PPM/°C %	2.4.24	3.10.1.11
B. Alpha 2	–	300 maximum			
C. 50 to 260°C	–	4.0 maximum			
17. Thermal Resistance (Copper removed)					
A. T260	–	30 minimum	Minutes	2.4.24.1	3.10.1.12
B. T288	–	5 minimum			
C. T300	–	AABUS			
18. Other	–	–			

*See Slash Sheet 2 in IPC-4121.

PREPREG REQUIREMENTS				
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17
2. Reinforcement	As per IPC-4412 or AABUS.			
3. Volatile content maximum	1.5	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7
5. Flammability (as laminated)	V-0 minimum	rating	UL94	3.10.2.1
6. Other	–			

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/124					
REINFORCEMENT:	1: Woven E-glass	2: N/A	Keywords: (For Search Only)		
RESIN SYSTEM:	Primary: Epoxy		NOT Grade Requirement		
	Secondary 1: Multifunctional epoxy	Secondary 2: Modified Epoxy or Non-epoxy (max. wt. 5%)	See Section 7		
FLAME RETARDANT MECHANISM:	Bromine, RoHS Compliant	Minimum UL94 Requirement: V-0	Lead-Free FR-4		
FILLERS (≥5%):	N/A		Low Z-axis CTE		
ID REFERENCE:	UL/ANSI: FR-4/124		High Decomposition Temperature		
GLASS TRANSITION (T _g):	150°C minimum				
UL MAX. OPERATING TEMP:	AABUS				
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					
A. Low profile copper foil and very low profile copper foil – all copper weights >17 μm [0.669 mil].	AABUS	AABUS	N/mm [lb/in]	2.4.8	3.9.1.1
B. Standard profile copper foil				2.4.8.2	3.9.1.1.1
1. After thermal stress	0.80 [4.57]	1.05 [6.00]		2.4.8.3	3.9.1.1.2
2. At 125°C [257°F]	0.70 [4.00]	0.70 [4.00]			3.9.1.1.3
3. After process solutions	0.55 [3.14]	0.80 [4.57]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 ⁶	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 ⁴			
C. At elevated temperature E-24/125	10 ³	10 ³			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 ⁴	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 ⁴			
C. At elevated temperature E-24/125	10 ³	10 ³			
4. Moisture Absorption, maximum	–	0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)*	5.4	5.4	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.1 3.11.2.1
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)*	0.035	0.035	–	2.5.5.2 2.5.5.3 2.5.5.9	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-0 minimum	V-0 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Glass Transition Temperature	–	150 minimum	°C	2.4.24 2.4.25	3.10.1.6
15. Decomposition Temperature	–	325 minimum	°C	TBD (5% wt loss)	3.10.1.10
16. Z-Axis CTE					
A. Alpha 1	–	60 maximum	PPM/°C PPM/°C %	2.4.24	3.10.1.11
B. Alpha 2	–	300 maximum			
C. 50 to 260°C	–	3.5 maximum			
17. Thermal Resistance (Copper removed)					
A. T260	–	30 minimum	Minutes	2.4.24.1	3.10.1.12
B. T288	–	10 minimum			
C. T300	–	AABUS			
18. Other	–	–			

*See Slash Sheet 2 in IPC-4121.

PREPREG REQUIREMENTS				
Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	Days	AABUS	3.17
2. Reinforcement	As per IPC-4412 or AABUS.			
3. Volatile content maximum	1.5	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	–	AABUS	AABUS	1.1.7
5. Flammability (as laminated)	V-0 minimum	rating	UL94	3.10.2.1
6. Other	–			

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SPECIFICATION SHEET					
SPECIFICATION SHEET #: IPC-4101/126					
REINFORCEMENT: 1: Woven E-glass		2: N/A		Keywords: (For Search Only)	
RESIN SYSTEM: Primary: Epoxy		Secondary 1: Multifunctional epoxy		NOT Grade Requirement	
		Secondary 2: Modified Epoxy or Non-epoxy (max. wt. 5%)		See Section 7	
FLAME RETARDANT MECHANISM: Bromine, RoHS Compliant		Minimum UL94 Requirement: V-0		Lead-Free FR-4	
FILLERS (≥5%): Contains inorganic fillers				Low Z-axis CTE	
ID REFERENCE: UL/ANSI: FR-4/126				High Decomposition Temperature	
GLASS TRANSITION (T_g): 170°C minimum				CAF Resistant	
UL MAX. OPERATING TEMP: 130°C					
LAMINATE REQUIREMENTS					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					
A. Low profile copper foil and very low profile copper foil – all copper weights >17 μm [0.669 mil].	AABUS	AABUS	N/mm [lb/in]	2.4.8	3.9.1.1
B. Standard profile copper foil				2.4.8.2	3.9.1.1.1
1. After thermal stress	0.80 [4.57]	1.05 [6.00]		2.4.8.3	3.9.1.1.2
2. At 125°C [257°F]	0.70 [4.00]	0.70 [4.00]			3.9.1.1.3
3. After process solutions	0.55 [3.14]	0.80 [4.57]			
C. All other foil – composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10 ⁶	–	MΩ–cm	2.5.17.1	3.11.1.3
B. After moisture resistance	–	10 ⁴			
C. At elevated temperature E-24/125	10 ³	10 ³			
3. Surface Resistivity, minimum					
A. C-96/35/90	10 ⁴	–	MΩ	2.5.17.1	3.11.1.4
B. After moisture resistance	–	10 ⁴			
C. At elevated temperature E-24/125	10 ³	10 ³			
4. Moisture Absorption, maximum	–	0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)*					
100 MHz	5.4	5.4	–	2.5.5.2	3.11.1.1
1 GHz	5.3	5.3		2.5.5.3	3.11.2.1
	5.2	5.2		2.5.5.9	
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)*	0.035	0.035	–	2.5.5.2	3.11.1.2
				2.5.5.3	3.11.2.2
				2.5.5.9	
8. Flexural Strength, minimum					
A. Length direction	–	415 [60,190]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3
B. Cross direction	–	345 [50,040]			
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5
11. Thermal Stress 10 s at 288°C [550.4°F], minimum					
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability (Laminate & prepreg as laminated)	V-0 minimum	V-0 minimum	rating	UL94	3.10.2.1 3.10.1.1
14. Glass Transition Temperature	–	170 minimum	°C	2.4.24 2.4.25	3.10.1.6
15. Decomposition Temperature	–	340 minimum	°C	ASTM D3850 (5% wt loss)	3.10.1.10

LAMINATE REQUIREMENTS (continued)					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
16. Z-Axis CTE A. Alpha 1 B. Alpha 2 C. 50 to 260°C	– – –	60 maximum 300 maximum 3.0 maximum	PPM/°C PPM/°C %	2.4.24	3.10.1.11
17. Thermal Resistance (Copper removed) A. T260 B. T288 C. T300	– – –	30 minimum 15 minimum 2 minimum	Minutes	2.4.24.1	3.10.1.12
18. CAF Resistance	–	AABUS	Pass/Fail †	2.6.25	3.12.1.4
19. Other	–	–			
PREPREG REQUIREMENTS					
Prepreg Requirement	Specification		Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90		Days	AABUS	3.17
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	1.5		%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	–		AABUS	AABUS	1.1.7
5. Flammability (as laminated)	V-0 minimum		rating	UL94	3.10.2.1
6. Other	–				

*See Slash Sheet 2 in IPC-4121.

† Pass or Fail are determined by Fail being ≥1 decade drop in the sample's initial insulation resistance value.

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SPECIFICATION SHEET						
SPECIFICATION SHEET #: IPC-4101/129						
REINFORCEMENT:	1: Woven E-glass	2: N/A	Keywords: (For Search Only)			
RESIN SYSTEM:	Primary: Epoxy		NOT Grade Requirement			
	Secondary 1: Multifunctional epoxy	Secondary 2: Modified Epoxy or Non-epoxy (max. wt. 5%)	See Section 7			
FLAME RETARDANT MECHANISM:	Bromine, RoHS Compliant	Minimum UL94 Requirement: V-0	Lead-Free FR-4			
FILLERS (≥5%):	N/A		Low Z-axis CTE			
ID REFERENCE:	UL/ANSI: FR-4/129		High Decomposition Temperature			
GLASS TRANSITION (T _g):	170°C minimum		CAF Resistant			
UL MAX. OPERATING TEMP:	130°C					
LAMINATE REQUIREMENTS						
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.	
1. Peel Strength, minimum						
A. Low profile copper foil and very low profile copper foil – all copper weights >17 μm [0.669 mil].	AABUS	AABUS	N/mm [lb/in]	2.4.8	3.9.1.1	
B. Standard profile copper foil				2.4.8.2	3.9.1.1.1	
1. After thermal stress	0.80 [4.57]	1.05 [6.00]		2.4.8.3	3.9.1.1.2	
2. At 125°C [257°F]	0.70 [4.00]	0.70 [4.00]			3.9.1.1.3	
3. After process solutions	0.55 [3.14]	0.80 [4.57]				
C. All other foil – composite	AABUS	AABUS				
2. Volume Resistivity, minimum						
A. C-96/35/90	10 ⁶	–	MΩ–cm	2.5.17.1	3.11.1.3	
B. After moisture resistance	–	10 ⁴				
C. At elevated temperature E-24/125	10 ³	10 ³				
3. Surface Resistivity, minimum						
A. C-96/35/90	10 ⁴	–	MΩ	2.5.17.1	3.11.1.4	
B. After moisture resistance	–	10 ⁴				
C. At elevated temperature E-24/125	10 ³	10 ³				
4. Moisture Absorption, maximum	–	0.5	%	2.6.2.1	3.12.1.1	
5. Dielectric Breakdown, minimum	–	40	kV	2.5.6	3.11.1.6	
6. Permittivity at 1 MHz, maximum (Laminate & prepreg as laminated)*						
1 MHz	5.4	5.4	–	2.5.5.2	3.11.1.1	
1 GHz	5.2	5.2		2.5.5.3		3.11.2.1
10 GHz	AABUS	AABUS		2.5.5.9		
7. Loss Tangent at 1 MHz, maximum (Laminate & prepreg as laminated)*						
1 MHz	0.035	0.035	–	2.5.5.2	3.11.1.2	
1 GHz				2.5.5.3		
10 GHz				2.5.5.9		
8. Flexural Strength, minimum						
A. Length direction	–	415 [60,190]	N/mm ² [lb/in ²]	2.4.4	3.9.1.3	
B. Cross direction	–	345 [50,040]				
9. Flexural Strength at Elevated Temperature, length direction, minimum	–	–	N/mm ² [lb/in ²]	2.4.4.1	3.9.1.4	
10. Arc Resistance, minimum	60	60	s	2.5.1	3.11.1.5	
11. Thermal Stress 10 s at 288°C [550.4°F], minimum						
A. Unetched	Pass Visual	Pass Visual	rating	2.4.13.1	3.10.1.2	
B. Etched	Pass Visual	Pass Visual				
12. Electric Strength, minimum (Laminate & prepreg as laminated)	30	–	kV/mm	2.5.6.2	3.11.1.7 3.11.2.3	
13. Flammability (Laminate & prepreg as laminated)	V-0 minimum	V-0 minimum	rating	UL94	3.10.2.1 3.10.1.1	
14. Glass Transition Temperature	–	170 minimum	°C	2.4.24 2.4.25	3.10.1.6	
15. Decomposition Temperature	–	340 minimum	°C	ASTM D3850 (5% wt loss)	3.10.1.10	

LAMINATE REQUIREMENTS (continued)					
Laminate Requirement	Specification <0.50 mm [0.0197 in]	Specification ≥0.50 mm [0.0197 in]	Units	Test Method	Ref. Para.
16. Z-Axis CTE A. Alpha 1 B. Alpha 2 C. 50 to 260°C	– – –	60 maximum 300 maximum 3.0 maximum	PPM/°C PPM/°C %	2.4.24	3.10.1.11
17. Thermal Resistance (Copper removed) A. T260 B. T288 C. T300	– – –	30 minimum 15 minimum 2 minimum	Minutes	2.4.24.1	3.10.1.12
18. CAF Resistance	–	AABUS	Pass/Fail †	2.6.25	3.12.1.4
19. Other	–	–			
PREPREG REQUIREMENTS					
Prepreg Requirement	Specification		Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90		Days	AABUS	3.17
2. Reinforcement	As per IPC-4412 or AABUS.				
3. Volatile content maximum	1.5		%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	–		AABUS	AABUS	1.1.7
5. Flammability (as laminated)	V-0 minimum		rating	UL94	3.10.2.1
6. Other	–				

*See Slash Sheet 2 in IPC-4121.

† Pass or Fail are determined by Fail being ≥1 decade drop in the sample's initial insulation resistance value.

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