IPC-4811
Working Draft 109

Specification for Embedded Passive Device Resistor Materials for Rigid and Multilayer Printed Boards

Embedded Component Materials Subcommittee (D-52)

Working Draft 108
(for Concall 061102)

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Forward:

IPC-4811 was developed based on industry knowledge at the time. Embedded passive devices may be made with a large variety of materials and cover a wide range of fabrication processes. At the time of writing this specification, use of these materials was not widespread. As such, it is anticipated that updates to this document will be needed in the future. In the meantime, the customer and supplier should work together to set the criteria for acceptance of embedded passive material products.

Table of Content

1 SCOPE

This document describes materials that can be used for the fabrication of embedded resistor devices within the finished printed circuit board substrate. For this document, embedded passive devices and the phrase embedded passives are considered to be equivalent. It provides information on general classifications and associated characteristics of embedded passive device (EPD) materials. The document **shall** be used as a qualification and conformance standard for designers and users when designing or constructing printed circuit boards containing EPD materials.

This document contains material designation, conformance (requirements), qualification (characterization) and quality assurance specifications. IPC-4811 should be used in conjunction with IPC-2000 series design standards and IPC-6000 series performance standards.

Embedded capacitor material designation, conformance (requirements), qualification (characterization) and quality assurance specifications are contained in IPC-4821.

1.1 General

This document covers the requirements for resistive materials that are used with conventional core materials for the manufacture of printed circuit boards containing embedded resistor functionality. Figures 1-1a & b show representations of how embedded resistors may appear in a PWB. The embedded resistor material spans the opening between conductors. The opening between conductors may actually be any shape. Figures 1-1a & b show a rectangular shape to the resistor material but other shapes are common such as serpentine, top-hat, and annular.

Embedded passive materials have advantages over typical leaded and surface mount passives such as:

- Embedded passives are used to enhance high speed, high frequency performance.
- Embedded passives are used to increase circuit density and simplify design of circuitry features such as decoupling capacitance and terminating resistors.
- Embedded passives are used to simplify assembly by mounting fewer components, thereby increasing functionality and/or reducing total board area.

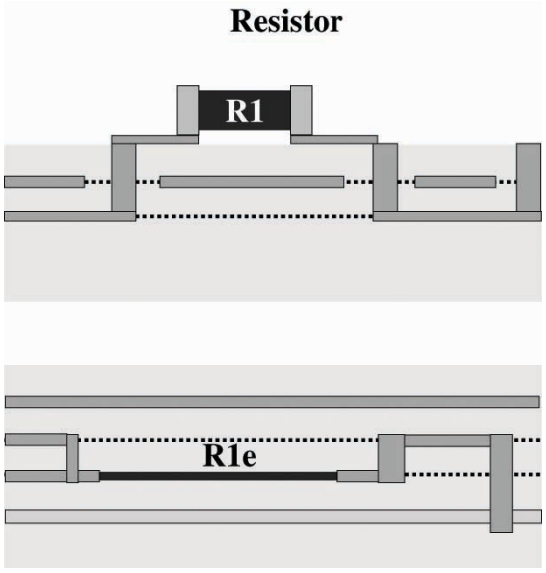

Figure 1-1a: Embedding passive resistor saves valuable surface real estate

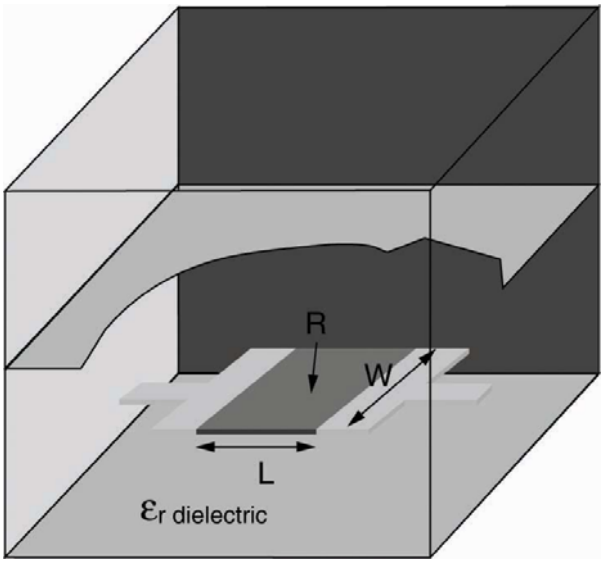

Figure 1-1b: Embedded resistor defined by number of squares Need to correct

1.2 Designation System

The following system identifies materials used for EPD resistor structures. This is a general identification system and does not in any way imply that all the permutations of properties and forms exist. See the series of specification sheets at the end of this document for the specific materials available. Each specification sheet outlines engineering and performance data for materials that can be used to manufacture printed boards incorporating EPD resistor materials. These materials include thin film resistor layers supplied as laminate, material applied to conductor foil, high and low viscosity pastes, and plating chemistry combinations. The specification sheets are provided with letters and numbers for identification and ordering purposes. For example, a user wishing to order from specification sheet 1 would substitute the number "1" for the "S" in the designation examples (i.e., IPC-4811/1) shown in 1.2.1 through 1.2.3. To start the ordering process, one can use the specification sheets in this document in combination with relevant IPC documents for each material set (i.e., IPC-CF-148, IPC-4562, IPC-4101, or IPC-4104).

The materials contained in this standard represent general material categories. As new materials become available, they will be added to future revisions. Users and material developers are encouraged to supply information on new materials for review by the IPC Embedded Component Materials Subcommittee (D-52). Users who wish to invoke this specification for materials not listed **shall** list a zero for the specification sheet number (IPC-4811/0).

The committee may approve new or revised specification sheets independent from revision of the document text. When this occurs, the new or revised specification sheet **shall** be printed and made available through IPC-4811. The effective date of the new or revised sheet **shall** be clearly indicated on the individual sheet. Specification sheets **shall** be transferred from IPC-4811 to the appropriate parent document whenever that document is revised.

Because there are embedded capacitor and inductor materials specified in other documents, the designation system recognizes them by using a first level of designation as shown in Level 1 below.

The first level of the designations system is the passive device type.

Level 1: Passive device type
Capacitor = C
Resistor = R
Inductor = L

For purposes of this specification only Level 1 "R" materials are included.

Table 1-1 illustrates the designation system for the resistor device types. The remaining designation levels are listed in Section 1.2.1.

1.2.1 Resistor Passive Device Designations

Table 1-1 Sample Resistor Passive Device Designation

IPC-4811	Level 1	Level 2	Level 3	Level 4	Level 5
4811/S	**R**	**1**	**A**	**1/1**	**N**
Where S is specification (slash) sheet number	Passive Type	Form of Resistor Material	Chemistry	Conductor Type	Encapsulant

Example The sample from Table 1-1 will be written as R 1 A 1/1 N.

Note The letter "X" **shall** be entered into the designation where an item is not specified and does not matter.

Level 1 Passive Type = R

Level 2 Form of Resistor Material
Sheet = 1
Paste = 2
Liquid = 3
Other = 9

Level 3 Chemistry
Metal Film = A
Ceramic = B
Conductive Polymer = C
Organometallic = D
Conductive particles in Organic Matrix = E
Other = O

Level 4 Termination (Conductor) Type (For the two terminations of the resistor the lowest will be considered Termination #1 and the second number will be considered Termination #2. For example, the level 4 designation of 1/2 signifies that one termination is copper foil and the other is a copper particle paste.)
Termination #1
Copper foil = 1
Copper Particle Paste = 2
Silver finish = 3
Silver Particle Paste = 4
Other Particle Paste = 5
Transient Liquid Phase Sintering = 6
Organometallic = 7
Conductive Polymer = 8
Other = 9

Level 5 Encapsulant Chemistry
Organic = A
Inorganic = B
Mixed = C
None = N

2 APPLICABLE DOCUMENTS

The following documents of the issue in effect at the time of order form a part of this specification to the extent specified herein. If a conflict exists between IPC-4811 and the listed applicable documents, IPC-4811 **shall** take precedence.

2.1 IPC[1]

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

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

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

IPC-TM-650 Test Methods Manual

2.4.1.3 Adhesion, Resistors (Hybrid Circuits)

[1] IPC, 3000 Lakeside Dr. Suite 309 S, Bannockburn, IL 60015-1249, 847-615-7100, www.ipc.org

2.4.8 Peel Strength of Metallic Clad Laminates

2.4.9 Peel Strength, Flexible Dielectric Materials

2.4.13.1 Thermal Stress of Laminates

2.4.22.1 Bow and Twist-Laminate

2.4.34 Solder Paste Viscosity - T-Bar Spin Spindle Method (applicable for 300,000 to 1,600,000 Centipoise)

2.4.34.1 Solder Paste Viscosity - T-Bar Spindle Method (Applicable at Less Than 300,000 Centipoise)

2.5.17.2 Volume Resistivity of Conductive Materials Used in High Density Interconnection (HDI) and Microvias, Two-Wire Method

2.6.2.1 Water Absorption, Metal Clad Plastic Laminates

2.6.16.1 Moisture Resistance of High Density Interconnection (HDI) Materials Under High Temperature and Pressure (Pressure Vessel)

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

IPC-4101 Specification for Base Materials for Rigid and Multilayer Boards

IPC-4562 Metal Foil for Printed Wiring Applications

IPC-4821 Specification for Embedded Passive Device Capacitor Materials for Rigid and Multilayer Printed Boards

IPC-6012 Qualification and Performance Specification for Rigid Printed Boards

IPC-9191 General Requirements for Statistical Methods

2.2 National Conference of Standards Laboratories (NCSL)

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

2.3 International Standards

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

2.4 International Electrotechnical Commission (IEC) Standards

IEC-61000-4-2 Electromagnetic compatibility (EMC)-Part 4-2: Testing and measurement techniques - Electrostatic discharge immunity test.

2.5 Military Standards

MIL-PRF-55182 Resistors, Fixed, Film, Non-established Reliability, Established Reliability and Space Level, General Specification For (Tom, can you get the rest of the title for this mil std?)

3 REQUIREMENTS

3.1 Terms and Definitions

Terms and definitions **shall** be in accordance with IPC-T-50G and as stated herein.

3.2 Specification Sheets

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

3.3 Supplier's Quality Profile

Suppliers of EPD materials **shall** assess their manufacturing capability and make such data available either electronically or in hard copy.

3.4 Qualification (Characterization) Testing

EPD resistor materials furnished under this specification **shall** be qualified as in Tables 3-1 and 3-2. The supplier **shall** retain on file data that supports that the material meets the requirements of this specification using the test methods described herein. Qualification testing **shall** be performed to demonstrate the supplier's ability to meet all of the requirements of each applicable specification sheet for each resistor material.

Qualification testing is synonymous with characterization of materials and is done one time to verify material properties.

Qualification and Conformance Testing Tables for Embedded Resistor Materials

Laminate-like resistor materials are generally made by applying a resistive film to copper or other metal cladding foil. The treated foil is then bonded to a dielectric. The specifications for the dielectric to which the treated foil is bonded are not addressed in this specification. The user must be satisfied that the dielectric supplied with the laminate-like resistor material meets his requirements. For purposes of this specification, only the resistive layer is addressed.

Table 3-1 Testing Requirements for Laminate-like Resistor Materials

	Properties	Section	Test Method	Qualification Testing	Conformance Testing Frequency	Samples per unit measure	Notes
	Visual	3.10.1					
1.	Metal cladding indentations and scratches.	3.10.1.1 3.10.1.2 3.10.1.3		✓	A	3	
2.	Wrinkles, and Creases	3.10.1.4		✓	A	3	
3.	Voids (Surface and internal) or pin holes	3.10.1.5.1		✓	A	3	
	Dimensional	3.11.1					
4.	Metal Cladding Weight	3.11.1.2		✓	D	3	
	Mechanical Requirements	3.12.1					
5.	Peel Strength	3.12.1.1	2.4.8 2.4.9	✓	A	3	Should this be tape test adhesion?
	Electrical Requirements	3.13.1					
6.	Sheet Resistivity	3.13.1.1	2.5.17.2	✓	A	per TM	
7.	Temperature Coefficient of Resistance (TCR)	3.13.1.2		✓	B	1	
8.	Power Density (milliwatts/cm^2)	3.13.1.3		✓			Need test frequency and number of samples.
	Environmental Requirements	3.14.1					
9.	Moisture and Water Absorption	3.14.1.2	2.6.2.1	✓	C	per TM	
10	Temperature and Humidity	?	?	✓	C	?	85/85 for up to 500 hours.
11.	Thermal Stress (Solder Float)	3.14.1.3	2.4.13.1	✓	B	per TM	

✓ Denotes qualification test required.
A Denotes conformance test required for every lot
B Denotes conformance test required every 3 months
C Denotes conformance test required every year
D Denotes conformance testing not required

Table 3-2 Testing Requirements for Non-laminate-like Materials

	Properties	Section	Test Method	Qualification Testing	Conformance Testing Frequency	Samples per unit measure	Notes
	Visuals	3.10.2					
1.	Foreign Material	3.10.2.1		✓	A	3	
2.	Voids (Surface and internal) or pin holes	3.10.2.2		✓	A	3	
3.	Delamination	3.10.2.3		✓	A	3	
	Dimensional	3.11.2					
	Mechanical Requirements	3.12.2					
5.	Adhesion Test (Tape Test)	3.12.2.1	2.4.1.3 (reference only)	✓	B	3	
6.	Viscosity	3.12.2.2	2.4.34 2.4.34.1 (reference only)	✓	A	1	
	Electrical Requirements	3.13.2					
7.	Sheet Resistivity of resistor	3.13.2.1	2.5.17.2	✓	A	per TM	
8.	Temperature Coefficient of Resistance (TCR)	3.13.2.2		✓	B	1	
9.	Power Density (milliwatts/cm^2)	3.13.2.3		✓			Need test frequency and number of samples.
	Environmental Requirements	3.14.2					
11.	Moisture and Water Absorption	3.14.2.2	2.6.2.1	✓	C	per TM	
12	Temperature and Humidity	?	?	✓	C	?	85/85 for up to 500 hours.
13.	Thermal Stress (Solder Float)	3.14.2.3	2.4.13.1	✓	B	per TM	

✓ Denotes qualification test required.
A Denotes conformance test required for every lot
B Denotes conformance test required every 3 months
C Denotes conformance test required every year
D Denotes conformance testing not requiredFor an explanation of frequency indicators, see Section 4.4.

3.4.1 Material Qualification

Material qualification **shall** be performed on test specimens that are produced with equipment and procedures normally used in production or in accordance with the test method procedure indicated. Material characterization provides the material suppliers with a method to specify the characteristics of their products, which may be useful for the designer or user to know. This group of tests is typically performed by the supplier a single time and reported on the applicable specification sheet. The PWB fabricator and/or user may also utilize this group of tests, if desired.

3.4.1.1 Samples
When required under the provisions of Tables 3-1 and 3-2, samples **shall** be selected from normal production for each material for which qualification is sought. The number of samples required for the individual test methods **shall** be as specified in the test method or as outlined in Tables 3-1 and 3-2 and sections 3.10 through 3.14.

3.4.1.2 Frequency
Each material (as outlined in the applicable specification sheet) **shall** undergo qualification once. The supplier, upon demand, **shall** provide certified data that the supplied material is qualified to this standard. Qualification retesting is not required unless agreed upon between user and supplier or as specified in Table 3-1 or 3-2.

3.4.1.3 Production Board Qualification Assessment of Materials
Production board system qualification is the responsibility of the printed board fabricator and/or user to confirm that the materials, production board system, and production process chosen are qualified for the appropriate application level.

3.5 Conformance Testing
Conformance testing **shall** be performed to demonstrate the supplier's ability to maintain his process to produce EPD materials with quality consistent with the qualification data. Conformance testing is performed at intervals as specified in Tables 3-1 and 3-2 to ensure that the manufacturing process and resulting product performance have not changed over time. EPD materials furnished under this specification **shall** undergo routine conformance testing as defined in Tables 3-1 and 3-2. The supplier **shall** retain on file data that supports that the material meets the conformance requirements of this specification using the test methods described herein.

3.5.1 Samples
When required under the provisions of Tables 3-1 and 3-2, samples **shall** be selected from normal production for each material for which conformance testing is sought. The number of samples required for the individual test methods **shall** be as specified in the test method or as outlined in Tables 3-1 and 3-2 and sections 3.10 through 3.14.

3.5.2 Frequency
Each material (as outlined in the applicable specification sheet) **shall** undergo conformance testing at least as frequently as shown in Tables 3-1 and 3-2. The supplier, upon demand, **shall** provide conformance testing data that shows the supplied material conforms to this standard. Conformance test frequencies other than those specified in Table 3-1 or 3-2 are permitted if agreed upon between user and supplier.

3.6 Verification of Supplier's Quality System
The verification of the supplier's quality system may be conducted to reduce risk to the buyer. The verification can be accomplished via several means, including internal assessment, individual customer audit, and/or third party assessment.

3.7 Conflict
In the event of conflict, the following order of precedence **shall** apply:
1. Purchase order as agreed upon between user and supplier
2. Master drawing
3. This specification
4. Applicable documents (see Section 2)

3.8 Materials

3.8.1 Resistor Materials in Laminate-like Form
Laminate-like resistor materials are thin layers of high resistance material that are placed between the copper foil and the dielectric material of the innerlayer panel. They could be on one or both sides of the double-sided laminate. The copper foil is etched to create the appropriate circuitry and resistor terminations. At this point the underlying resistor material, which was not removed during the copper etching, covers the entire panel. Photoresist is applied and imaged to prepare the panel for an etch step that will remove the unwanted resistor material. After this etch step, the photoresist is stripped, leaving resistor material between the copper terminations. The resistor material will

remain underneath all the remaining imaged copper. In some cases the resistor materials could be supplied as a coating on one side of copper foil. This could then be used to form an additional layer on a build-up multilayer, or the outerlayer of a multilayer board.

3.8.2 Resistor Materials in Non-Laminate-like Form

Resistor materials in non-laminate-like form are generally supplied as paste, liquid, powder, or vapor deposited material. These materials are generally applied by the printed wiring board fabricator by a variety of methods to form discrete resistor devices. The materials could be metal or non-metal based. Resistor terminations will be copper foil or other conductive material.

3.8.3 Encapsulant Materials in Non-Laminate-like Form

Encapsulant materials are generally organic-based and applied to already formed discrete embedded resistors to protect them from the subsequent printed wiring board chemistries and processes. The chief intent is to ensure correct resistance values after complete fabrication of the board. These materials have been incorporated in some cases to improve the capability for trimming of resistors. They are applied by the same methods used to form the discrete resistors.

3.8.4 Conductor/Termination Materials

Conductor and termination materials provide the conductive elements of the embedded passive devices. For the most part they are the conventional copper foil that exists as part of the laminate used to make the layers of the printed circuit board. In other cases, conductors are needed and cannot be made from the existing copper foil. In these cases, they are conductive materials applied by the printed wiring board fabricator at the time of creating the embedded passive device.

3.8.4.1 Copper Foil or Other Metal Cladding

Copper foil or other metal cladding **shall** meet the requirements of IPC-4562, IPC-CF-148, IPC-CF-152, or as agreed upon between user and supplier. For alternate metal claddings not covered by industry standards, requirements **shall** be as agreed upon between user and supplier. The treatment applied to the metal cladding may be of interest to the circuit designer depending on the signal integrity and electrical performance desired.

3.8.4.2 Plated Copper

Plated copper will be applied by the printed circuit board fabricator and should meet the requirements of IPC-6012.

3.8.4.3 Conductive Paste

Conductive paste materials are metal filled and are applied by a variety of methods. These conductive pastes may be used for resistor terminations. In general conductor pastes have an organic phase.

3.8.4.4 Other Plated Metals

Plated metals other than copper may be incorporated into the embedded passive device. Some embedded resistor terminations require immersion silver plating of the termination to improve performance. Other metal terminations such as immersion nickel/gold may also be used.

3.9 General Acceptability

Materials used for embedded resistor devices **shall** be considered acceptable if they meet the minimum requirements listed below and in the applicable specification sheet, or as agreed upon between user and supplier.

3.9.1 General Acceptability of Resistor Materials

Resistor material qualification and conformance are required to be performed by the material supplier but may, by appropriate agreement, also be used as an incoming material inspection procedure by the PWB user. The tests the supplier **shall** perform to determine the properties of each material are outlined in sections 3.10 through 3.14. A summary of the results for critical tests is indicated on the applicable specification sheet for each material that has been qualified to this specification. Other qualification and conformance test results may be obtained from the material supplier.

3.9.2 General Acceptability of Conductive Paste Materials

Conductive paste material qualification and conformance are required to be performed by the material supplier but may, by appropriate agreement, also be used as an incoming material inspection procedure by the PWB user. The tests the supplier **shall** perform to determine the properties of each material are outlined in section 3.13.2.4. A summary of the results for critical tests is indicated on the applicable specification sheet for each material that has been qualified to this specification. Other qualification and conformance test results may be obtained from the material supplier.

3.9.3 Inspection

3.9.3.1 Inspection Lot

Inspection lot **shall** be as defined in IPC-T-50G or as agreed upon between user and supplier.

3.9.3.2 Preparation of Samples

Unless otherwise specified herein, samples and test specimens **shall** be prepared in accordance with the appropriate IPC-TM-650 test method or as described in this specification. If a referee method is required, it **shall** be as outlined herein or as agreed upon between user and supplier.

3.9.3.3 Standard Laboratory Conditions

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

3.10 Visual Requirements

3.10.1 Visual Requirements of Laminate-like Resistor Materials

Laminate-like resistor materials **shall** be tested in accordance with Table 3-1 and sections 3.10.1.1 through 3.10.1.5.1 using the test methods described therein and in the applicable specification sheets. Any defect within 6.35 mm of the outside edges of the sheet or roll **shall** be disregarded. Unless otherwise specified, the working area of the specimen **shall** be a 300 mm x 300 mm [11.81 in x 11.81 in] area examined with normal 20/20 vision. The worst 50 mm x 50 mm [1.97 in x 1.97 in] area **shall** be examined at 10X magnification unless otherwise specified. Visual inspection **shall** be carried out under ambient temperature and humidity conditions.

3.10.1.1 Metal Cladding Indentations

When tested in accordance with 3.10.1, metal cladding indentations **shall** be located visually using 20/20 vision. The longest dimension of each foil indentation in a specimen **shall** be measured with a suitable reticule on a minimum 4X magnifier, with referee inspections at 10X. The point value system shown in Table 3-3 **shall** be used to determine the point count for any 300 mm x 300 mm [11.81 in x 11.81 in] area:

Table 3-3 Point Value System for Metal Indentations

Longest Dimension	Point Value
0.13 mm to 0.25 mm [5.12×10^{-3} in to 9.84×10^{-3} in]	1
0.26 mm to 0.50 mm [1.02×10^{-2} in to 1.97×10^{-2} in]	2
0.51 mm to 0.75 mm [2.01×10^{-2} in to 2.95×10^{-2} in]	4
0.76 mm to 1.00 mm [2.99×10^{-2} in to 3.937×10^{-2} in]	7
greater than 1.00 mm [greater than 3.937×10^{-2} in]	30

Class of foil indentations **shall** be as specified on the purchase order in accordance with Class list below. The class **shall** be determined by a point count when examined in accordance with the point value versus longest dimension chart, Table 3-3 Point Value System for Metal Indentations, and the provisions below.

There **shall** be no adherent material in an indentation or exposure of the underlying dielectric or resistor material. Requirements for foil indentations do not apply to copper that has been treated on both sides or to the exterior 25-

mm [0.984-in] border on full-size sheets and 13-mm [0.512-in] border on cut panels. Class A applies, unless otherwise specified.

Metal Cladding Indentation Class List:
a. Class A. The total point count **shall** be 29 maximum for any 300 mm x 300 mm [11.81 in x 11.81 in] area.

b. Class B. The total point count **shall** be 17 maximum for any 300 mm x 300 mm [11.81 in x 11.81 in] area.

c. Class C. The total point count **shall** be 5 maximum for any 300 mm x 300mm [11.81 in x 11.81 in] area. There **shall** be no foil indentations with a maximum dimension >0.38 mm.

d. Class D. The total point count **shall** be 0 (zero) for any 300 mm x 300 mm [11.81 in x 11.81 in] area. Foil indentations $\geq$125 µm [4.921 mil] **shall** not be acceptable. Resin spots **shall** be 0 (zero) as inspected with 20/20 vision. If Class D is specified, other quality related features are also required of this quality class per IPC-4562.

e. Class X. Requirements **shall** be as agreed upon between user and supplier.

3.10.1.2 Scratches.
When tested in accordance with 3.10.1, scratches are not permitted where any part of the defect is greater than or equal to 20% of the nominal foil thickness (i.e., 3.4 µm [1.34 x 10^{-4} in] for 17 µm [6.69 x 10^{-4} in] copper). No more than five scratches may occur in any 300 mm x 300 mm [11.81 in x 11.81 in] area. Any scratch with a depth less than 5% of the nominal foil thickness **shall** not be counted, regardless of length. Acceptability criterion for scratch length within the 5 to 20% depth range is a maximum of 100 mm [3.937 in].

3.10.1.3 Surface Finish of Foil after Curing - Except Double Treat.
Unless otherwise specified, discoloration of the copper surface as a result of the curing process **shall** be acceptable.

3.10.1.4 Wrinkles and Creases
When tested in accordance with 3.10.1, wrinkles and creases **shall** not be permitted unless as agreed upon between user and supplier.

3.10.1.5 Surface and Subsurface Imperfections
Etched panels **shall** be inspected to verify surface or subsurface imperfections conform to the requirements described below. Any 300 mm x 300 mm [11.81 in x 11.81 in] area may be inspected. The panels **shall** be inspected using an optical apparatus or aid that provides a minimum magnification of 4X. Referee magnification **shall** be accomplished at 10X. Lighting conditions of inspection **shall** be appropriate to the type, grade, and thickness being inspected or as agreed between user and supplier.

3.10.1.5.1 Voids, Cracks or Pin Holes in the Resistive Layer
When laminate-like resistor materials are tested in accordance with paragraph 3.10.1.5, no voids, cracks or pin holes **shall** be permitted within the 300 mm x 300 mm [11.81 in x 11.81 in] inspection area of the resistive layer(s) of resistor materials. The resistive layer of laminate-like resistor materials can be a very thin film. When supplied as a foil, inspection of the resistive layer can be done easily since the resistive layer can be seen. When supplied as a laminate with the resistive layer bonded to the dielectric of the laminate, the metal foil must be removed by etching.

3.10.2 Visual Requirements of Non-Laminate-like Resistor and Associated Materials
Non-laminate-like resistor materials **shall** be tested in accordance with Table 3-2 and sections 3.10.2.1 through 3.10.2.3 using the test methods described therein and in the applicable specification sheets. Visual inspection **shall** be carried out under ambient temperature and humidity conditions.

3.10.2.1 Foreign Material
Non-laminate-like resistor materials **shall** be applied to a glass plate in an area of 6 cm x 6 cm [2.4 in. x 2.4 in.] and dried. Full curing may not be possible when applied to a glass plate. The sample **shall** be examined under 10X magnification. If the sample is light in color foreign material is likely to be seen as dark in color. If the sample is

dark in color, the foreign material is likely to be seen as light in color. Some formulations may intentionally have dark or light ingredients that should not be confused with foreign material. Since foreign material may be introduced during the deposition and drying of the sample, special care should be exercised in sample preparation. The presence of foreign material is not necessarily a cause for rejection since it may be non-conducting in nature. The acceptable level of foreign material present **shall** be as agreed upon between user and supplier.

3.10.2.2 Voids or Pin Holes in the Resistive Layer

Non-laminate-like resistor materials **shall** be applied to a glass plate in an area of 6 cm x 6 cm [2.4 in. x 2.4 in.] and dried. Full curing may not be possible when applied to a glass plate. After application in accordance with the supplier's recommended process and examined under 10X magnification, no voids or pinholes **shall** be visible.

3.10.2.3 Delamination

The supplier **shall** apply the non-laminate-like resistor material to an appropriate substrate according to his recommended process. After application in accordance with the supplier's recommended process, the sample **shall** be inspected for delamination from the substrate. No delamination **shall** be permitted.

3.11 Dimensional Requirements

3.11.1 Dimensional Requirements of Laminate-like Resistor Materials

Laminate-like resistor materials **shall** be tested in accordance with Table 3-1 and sections 3.11.1.1 through 3.11.1.2 using the test methods described therein and in the applicable specification sheets. Length, width, thickness, and other dimensional characteristics **shall** be measured with equipment capable of accuracy to verify the requirements of this specification.

3.11.1.1 Thickness

Thickness of laminate-like resistor material is generally of the thin film variety. The attribute of importance is sheet resistivity. Sheet resistivity **shall** govern and the thickness shown on the applicable specification sheet **shall** indicate a nominal value for reference purposes only.

3.11.1.2 Metal Cladding Weight

For copper or other metal cladding, all foil **shall** meet the requirements specified in IPC-4562, Metal Foil for Printed Wiring Applications.

3.11.2 Dimensional Requirements of Non-Laminate-like Resistor Materials

Laminate-like resistor materials **shall** be tested in accordance with Table 3-1 and section 3.11.2.1 using the test methods described therein and in the applicable specification sheets.

3.11.2.1 Metal Cladding Weight

For copper or other metal cladding used in the process of fabricating the non-laminate-like resistors, all foil **shall** meet the requirements specified in IPC-4562, Metal Foil for Printed Wiring Applications.

3.12 Mechanical Requirements

3.12.1 Mechanical Requirements of Laminate-like Resistor Materials

Laminate-like resistor materials **shall** be tested in accordance with Table 3-1 and sections 3.12.1.1 through 3.12.1.2 using the test methods described therein and in the applicable specification sheets.

3.12.1.1 Peel Strength

For Laminate-like embedded resistor materials that have been laminated to a dielectric, peel strength **shall** be tested in accordance with IPC-TM-650, Method 2.4.8 and be as shown in the applicable specification sheet.

For laminate-like resistor materials supplied as resistor material on foil, the peel strength **shall** be tested based on the supplier's test method and be as shown in the applicable specification sheet or as agreed upon between user and supplier.

In all cases where the metal foil is less than 1 ounce, it may be plated to 1 ounce for the peel strength test.

3.12.2 Mechanical Requirements of Non-laminate-like Resistor Materials

Non-laminate-like resistor materials **shall** be tested in accordance with Table 3-2 and sections 3.12.2.1 through 3.12.2.2 using the test methods described therein and in the applicable specification sheets.

3.12.2.1 Adhesion

Non-laminate-like resistor materials **shall** be tape tested for adhesion to an appropriate substrate using IPC-TM-650, Method 2.4.1.3 as a reference. The supplier **shall** apply the sample material to a typical substrate using the supplier's recommended process. The sample size **shall** be such that the tape spans at least two edges of the sample. After removing the tape, examine both the tape and the sample. Shadowing and speckling **shall** be permitted but "chunks," visible pits in the sample, and pieces of sample completely removed from the substrate **shall** not allowed.

3.12.2.2 Viscosity

Viscosity will play a roll in the ability of the non-laminate-like resistor material to be applied to a substrate. Viscosity in the range of 300,000 to 1,600,000 Centipoise may be measured in a manner similar to that described in IPC-TM-650, Method 2.4.34. Viscosity in the range of 300,000 or less may be measured in a manner similar to that described in IPC-TM-650, Method 2.4.34.1. Viscosity may be tested in an alternate manner if agreed upon between user and supplier. The viscosity **shall** be as shown in the applicable specification sheet.

Non-laminate-like resistor materials supplied as solution chemistry **shall** be exempt from this requirement.

3.13 Electrical Requirements

3.13.1 Electrical Requirements of Laminate-like Resistor Materials

Laminate-like resistor materials **shall** be tested in accordance with Table 3-1 and in sections 3.13.1.1 through 3.13.1.3 using the test methods described therein and in the applicable specification sheets.

3.13.1.1 Sheet Resistivity

When laminate-like resistor materials are tested in accordance with IPC-TM-650, Method 2.5.17.2, the volume resistivity can be calculated. For purposes of this specification, the thickness is assumed constant for a given supplier's material and sheet resistivity in Ohms/square **shall** be as indicated in the applicable specification sheet.

3.13.1.2 Temperature Coefficient of Resistance (TCR)

When laminate-like resistor materials are tested in accordance with the supplier's test method, the temperature coefficient of resistance **shall** be as indicated in the applicable specification sheet. Testing **shall** be done between -55°C and +125°C and results reported as ppm/°C. Alternate test methods may be used as agreed upon between user and supplier.

3.13.1.3 Power Density

Power density, expressed as milliwatts/cm^2, is the maximum power dissipation rating for the resistor material. The power density rating is used to calculate the resistor area of the embedded resistor element. When laminate-like resistor materials are tested in accordance with the supplier's test method, the power density **shall** be as indicated in the applicable specification sheet. Alternate test methods may be used as agreed upon between user and supplier.

3.13.2 Electrical Requirements of Non-laminate-like Resistor Materials

Non-laminate-like resistor materials **shall** be tested in accordance with Table 3-2 and sections 3.13.2.1 through 3.13.2.4 using the test methods described therein and in the applicable specification sheets.

3.13.2.1 Sheet Resistivity

When non-laminate-like resistor materials are tested in accordance with IPC-TM-650, Method 2.5.17.2, the volume resistivity can be calculated. For purposes of this specification, the thickness is assumed constant for a given supplier's material and sheet resistivity in Ohms/square **shall** be as indicated in the applicable specification sheet.

3.13.2.2 Temperature Coefficient of Resistance (TCR)

When non-laminate-like resistor materials are tested in accordance with the supplier's test method, the temperature

coefficient of resistance **shall** be as indicated in the applicable specification sheet. Testing **shall** be done between -55°C and +125°C and results reported as ppm/°C. Alternate test methods may be used as agreed upon between user and supplier.

3.13.2.3 Power Density

Power density, expressed as milliwatts/cm^2, is the maximum power dissipation rating for the resistor material. The power density rating is used to calculate the resistor area of the embedded resistor element. When non-laminate-like resistor materials are tested in accordance with the supplier's test method, the power density **shall** be as indicated in the applicable specification sheet. Alternate test methods may be used as agreed upon between user and supplier.

3.13.2.4 Conductivity of Conductor Paste

When non-laminate-like conductor materials are tested in accordance with the supplier's test method, the conductivity **shall** be as indicated in the applicable specification sheet. Alternate test methods may be used as agreed upon between user and supplier.

3.14 Environmental Requirements

3.14.1 Environmental Requirements of Laminate-like Resistor Materials

Laminate-like resistor materials **shall** be tested in accordance with Table 3-1 and in 3.14.1.1 through 3.14.1.3 using the test methods described therein and in the applicable specification sheets.

3.14.1.1 Moisture Resistance by Pressure Vessel Test (Optional)

When laminate-like resistor materials are tested in accordance with IPC-TM-650, Method 2.6.16.1 the material grade number after test **shall** be as indicated in the applicable specification sheet or as agreed upon between user and supplier. For purposes of this test refer to Alternate Method B for sample preparation. Sample preparation **shall** be modified such that metal cladding **shall** be removed from one side of the test material and laminated with prepreg of nominal 0.05mm thickness to each side of a 0.4mm etched core. After lamination, the exterior metal cladding **shall** be completely removed by etching.

Totally inorganic laminate-like capacitor materials **shall** be exempt from this test.

3.14.1.2 Moisture and Water Absorption

When laminate-like resistor materials are tested in accordance with IPC-TM-650, Method 2.6.2.1, the moisture absorption **shall** be as indicated in the applicable specification sheet.

Totally inorganic laminate-like resistor materials **shall** be excluded from this test.

3.14.1.3 Thermal Stress (Solder Float)

When laminate-like resistor materials are tested in accordance with IPC-TM-650, Method 2.4.13.1, samples **shall** have copper etched from both sides unless the material will not stand alone when the metal cladding is removed. If the supplied dielectric will not stand alone when the metal cladding is removed from both sides, these materials may be tested with metal cladding etched from only one side, the side containing the resistive layer. Completely etched or single-side etched samples **shall** be free of charring, surface contamination, blistering, propagation of imperfections, crazing or voids.

3.14.2 Environmental Requirements of Non-laminate-like Resistor Materials

Non-laminate-like resistor materials **shall** be tested in accordance with Table 3-2 and sections 3.14.2.1 through 3.14.2.3 using the test methods described therein and in the applicable specification sheets.

3.14.2.1 Moisture Resistance by Pressure Vessel Test (Optional)

When non-laminate-like resistor materials are tested in accordance with IPC-TM-650, Method 2.6.16.1 the material grade number after test **shall** be as indicated in the applicable specification sheet or as agreed upon between user and supplier. Sample preparation **shall** be according to section 3.1.3, "Coated Dielectrics."

Totally inorganic non-laminate-like capacitor materials **shall** be exempt from this test.

3.14.2.2 Moisture and Water Absorption

When non-laminate-like resistor materials are tested in accordance with IPC-TM-650, Method 2.6.2.1, the moisture absorption **shall** be as indicated in the applicable specification sheet.

Totally inorganic non-laminate-like capacitor and resistor materials **shall** be exempt from this test.

3.14.2.3 Thermal Stress (Solder Float)

When non-laminate-like resistor materials are tested in accordance with IPC-TM-650, Method 2.4.13.1, the sample material **shall** be applied to copper foil and cured according to the supplier's recommended process. After testing, samples **shall** be free of charring, surface contamination, blistering, propagation of imperfections, crazing or voids. Measure resistance before and after thermal stress. Percent change in resistance to be incorporated into slash sheet.

3.16 Workmanship

All embedded passive materials **shall** be supplied in such a manner as to be uniform in quality and free of defects that will affect life, serviceability, processability, or appearance as specified in 3.4 through 3.14.2.3

3.17 Material Safety Data Sheets

All embedded passive materials suppliers **shall** have available a material safety data sheet (MSDS) and other additional safety information as appropriate.

3.18 Shelf Life

The shelf life for all embedded passive materials **shall** be as specified by the supplier.

3.19 Marking

All embedded passive materials **shall** have a unique lot number traceable to all raw materials and processing parameters. Evidence of compliance for each lot **shall** be available from the supplier upon request.

4 QUALITY ASSURANCE PROVISIONS

4.1 Quality System

A quality system **shall** be documented to support the conformance testing frequency selected by the supplier.

4.2 Responsibility for Inspection

Unless otherwise specified in the purchase order, the supplier is responsible for the performance of all the inspection requirements as specified herein. Except as otherwise specified in the purchase order, the supplier may use his own or any other facility suitable for the performance of the inspection requirements herein, unless disapproved by the procuring authority. The procuring authority reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and service meet the prescribed requirements.

4.2.1 Test Equipment and Inspection Facilities

Test and measuring equipment and inspection facilities of sufficient accuracy, quality, and quantity to permit performance of the required inspection **shall** be established and maintained by the supplier or be available to the supplier. The establishment and maintenance of a calibration system to control the accuracy of the measuring and test equipment **shall** utilize methodology acceptable to all concerned parties. A calibration system that controls the accuracy of measuring and test equipment **shall** be in accordance with ANSI/NCSL Z540-1-1994 or ISO 10012-1.

4.2.2 Standard Laboratory Conditions

All inspection/testing **shall** be performed in accordance with the conditions specified in the applicable test method(s) or specification(s). Where inspection/test conditions are not specified, a standard laboratory condition of 15ºC to 35ºC at ambient pressure and RH **shall** apply.

4.3 Qualification (Characterization) Testing

4.3.1 Samples
When required under the provisions of Tables 3-1 and 3-2, samples **shall** be selected from normal production for each supplier's brand type for which qualification is sought. The number of samples required for the individual test methods **shall** be as specified in the test method or as outlined in Tables 3-1 and 3-2 and sections 3.10 through 3.14. Unless otherwise specified herein, samples **shall** be prepared in accordance with standard in-house procedures. If a referee method is required, it **shall** be as agreed upon between user and supplier.

4.3.2 Structurally Similar Construction
Certain tests may require changing the thickness in order to obtain an accurate measurement of a material property. The changed thickness is permitted for those tests where the measured property is thickness independent..

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

4.4.1 Frequency
Quality conformance inspection **shall** consist of group A, B, and C inspection as follows:

Group A	On a lot basis
Group B	Every 3 months
Group C	Every 12 months

The frequency of conformance testing **shall** be as specified in the supplier's quality system, as specified in Tables 3-1 or 3-2, or by the purchase order. Where lot is indicated in Tables 3-1 or 3-2, only random samples are to be selected for testing. Additional samples may be taken to satisfy the terms of the purchase order.

4.4.2 Inspection of Product for Delivery
Inspection of product for delivery consists of testing material as defined by the method of examination in sufficient quantity to achieve statistical confidence or by process control documentation of key process parameters correlated to product performance testing. The sample specimens **shall** be subjected to the inspections specified in Tables 3-1 and 3-2. Inspection of product for delivery **shall** consist of group A, B and C inspections. Products that have passed Group A inspection may be shipped prior to obtaining the results of Groups B or C inspections.

4.4.3 Acceptance Criteria
All sampled units **shall** meet the requirements defined in 3.10 through 3.14, as required when tested in accordance with Tables 3-1 and 3-2.

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

4.5 Statistical Process Control (SPC)
SPC utilizes systematic statistical techniques to analyze a process or its outputs. The purpose of these analyses is to take appropriate action to achieve and improve process capability. The primary goal of SPC is to continually reduce variation in processes, products, or services in order to provide product meeting or exceeding real or important customer requirements. Implementation of SPC **shall** be in accordance with IPC-9191. Depending on the progress made in implementing SPC on a particular product, an individual supplier may demonstrate compliance to specification with any of the following:

- Quality conformance evaluations

- End-product control
- In-process product control
- Process parameter control

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

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

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

5 PREPARATION FOR DELIVERY

5.1 Packaging
Materials **shall** be packed in a manner that will afford adequate protection against corrosion, deterioration, and physical damage during shipment and storage. Containers **shall** conform to the requirements of the consolidated freight classification rules in effect at the time of shipment, except that fiberboard, when used, **shall** be able to withstand storage, re-handling, and reshipment without the necessity of repackaging.

6 NOTES

6.1 Ordering Data
Purchase orders should specify the following:

A. Title, number, and revision letter of the specification
B. Specification sheet number and revision level
C. Specific exemptions to the specifications, if any
D. Title, number, and date of any applicable drawing
E. Information for preparation of delivery, if applicable (see section 5)
F. Part identification and matching instructions
G. Production inspection if applicable (see 4.4)
H. Dimensions of material. This could be thickness, width and length, weight, or other dimension of material (see section 3.11)
I. Other exceptions as agreed upon between user and supplier

6.2 References
[This is a place holder in case we decide to add any references.]

6.3 Electrostatic Discharge (ESD) Testing
Embedded resistor materials regardless of form may be required to meet the IEC-61000-4-2 Human Body Model standard. This requirement is normally tested in finished board form. It is suggested the supplier, fabricator and OEM coordinate testing as appropriate.

6.4 Short Time Overload
The short time overload test measures change in resistance before and after an applied overload. Test method MIL-R.10509, Method 4.6.6 may be used for this test. Results should be as agreed upon between user and supplier.

[Noted that this section needs redefining. Bill Borland agreed to work on this.]

Specification Sheets for Embedded Passive Device Materials

Following this appendix are the specification (slash) sheets for Embedded Resistor Materials, as outlined in 1.2. Each specification sheet outlines engineering and performance data for the material that it represents. The specification sheets identify the type of material by following the format of Section 1.2.

The specification sheets are based on information available at the time that this document was created. As new materials become available, they will be added to future amendments or future revisions. Specification sheets will be added by the Embedded Passive Device Materials Task Group (D-52), independent from revision of the document text. The reference paragraphs are listed in column 2, the IPC-TM-650 Test Methods employed are listed in Column 3, Typical Values for the designation type, where they exist, are listed in Column 4. This column is intended to reflect a range of values for each designation type. It is based on information provided by the suppliers of the various designation types of materials. For example, IPC-4811 Classification ID: R1A1/1N refers to an embedded resistor device type deposited on foil, the chemistry is a metal film, termination #1 is copper, and termination #2 is copper and there is no encapsulant needed. There are several suppliers of this type of embedded resistor material and their specific materials have a range of values for each listed property. Yet, all fall within this designation type.

The user of these slash sheets is encouraged to specify specific values of properties that may be of special interest. The most obvious example of this is sheet resistivity. Within a given designation type, suppliers offer materials with different sheet resistivities.

Effective date

SPECIFICATION SHEET	
Specification Sheet #:	IPC-4811/1
Passive Type:	Resistive
Form of Dielectric:	Paste
Chemistry:	Ceramic
Conductor Type:	Copper/Copper
Encapsulant Chemistry:	Mixed
IPC-4811 Classification ID:	~~R4B1~~R2B1/1A
Date:	

EMBEDDED PASSIVE MATERIAL QUALIFICATON AND CONFORMANCE REQUIREMENTS

PROPERTY	Reference Paragraph	Test Method	Typical Values
Viscosity (Pascal Seconds)	3.12.2.2	2.4.34 2.4.34.1 (reference only)	150 - 250
Sheet Resistivity (Ohm/square)	3.13.2.1	2.5.17.2	10 - 10K
Temperature Coefficient of Resistance (ppm/°C)	3.13.2.2		-170 - 140
Power Density (milliwatts/cm^2)	3.13.2.3		50
Change of resistance after thermal stress	3.14.2.3	2.4.13.1	

Effective date:

SPECIFICATION SHEET	
Specification Sheet #:	IPC-4811/2
Passive Type:	Resistive
Form of Resistive Material:	~~Deposition on Foil~~Sheet
Chemistry:	Metal film
Conductor Type:	Copper/Copper
IPC-4811 Classification ID:	R1A1/1N
Date:	

EMBEDDED PASSIVE MATERIAL QUALIFICATON AND CONFORMANCE REQUIREMENTS

PROPERTY	Reference Paragraph	Test Method	Requirement	Typical Values
Peel Strength (Kg/M) (we think a tape test of the resistor material on the metal foil is more appropriate - see comments in tables 3-1 and 3-2)	3.12.1.1	2.4.8 2.4.9		55 - 72
Sheet resistivity (Ohms/square)	3.13.2.1	2.5.17.2		1 to 1000
Temperature Coefficient of Resistance (ppm/°C)	3.13.2.2			-50 to +400
Power Density (milliwatts/cm^2)	3.13.2.3			7 - 50
Change of resistance after thermal stress	3.14.2.3	2.4.13.1		

SPECIFICATION SHEET	
Specification Sheet #:	IPC-4811/3
Passive Type:	Resistive
Form of Resistive Material:	~~Solution Deposition~~Liquid
Chemistry:	Metal film
Conductor Type:	Copper/Copper
Encapsulant Chemistry:	Organic
IPC-4811 Classification ID:	R3A1/1A
Date:	

EMBEDDED PASSIVE MATERIAL QUALIFICATON AND CONFORMANCEREQUIREMENTS

PROPERTY	Reference Paragraph	Test Method	Requirement	Typical Values
Sheet Resistivity (Ohm/square)	3.13.2.1	2.5.17.2		10 - 100
Temperature Coefficient of Resistance (ppm/°C)	3.13.2.2			< 100
Power Density (milliwatts/cm^2)	3.13.2.3			50