# UL 746F

## STANDARD FOR SAFETY

Polymeric Materials – Flexible Dielectric Film Materials for Use in Printed Wiring Boards and Flexible Materials Interconnect Constructions

UL Standard for Safety for Polymeric Materials – Flexible Dielectric Film Materials for Use in Printed Wiring Boards and Flexible Materials Interconnect Constructions, UL 746F

Third Edition, Dated March 4, 2021

***Summary of Topics***

***This revision of ANSI/UL 746F dated June 27, 2025 includes the following changes in requirements:***

***– Clarification of the UL 94 VTM test method; Table 8.1 – Table 8.4, 8.1.4A – 8.1.4C, 8.1.13A, 8.3, 8.5.1.12, 8.6.12, 8.6.13, 8.7.17***

Text that has been changed in any manner or impacted by ULSE's electronic publishing system is marked with a vertical line in the margin.

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated April 18, 2025.

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**ANSI/UL 746F-2025**



**UL 746F**

# Standard for Polymeric Materials – Flexible Dielectric Film Materials for Use in Printed Wiring Boards and Flexible Materials Interconnect Constructions

First Edition – May, 2006
Second Edition – January, 2012

**Third Edition**

**March 4, 2021**

This ANSI/UL Standard for Safety consists of the Third Edition including revisions through June 27, 2025.

The most recent designation of ANSI/UL 746F as an American National Standard (ANSI) occurred on June 27, 2025. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

Comments or proposals for revisions on any part of the Standard may be submitted to ULSE at any time. Proposals should be submitted via a Proposal Request in the Collaborative Standards Development System (CSDS) at https://csds.ul.com.

No Text on This Page

## CONTENTS

### INTRODUCTION



### CONSTRUCTION



### PERFORMANCE

**MARKINGS**



**SUPPLEMENT SA – FOLLOW-UP INSPECTION**

## INTRODUCTION

### 1 Scope

1.1 Flexible materials shall be defined as films or materials exhibiting flexible properties.

1.2 These requirements cover short term and long term test procedures to be used for the evaluation of flexible material, film, base material, conductor adhesive material, bonding film, cover lay, and other thin film materials used for parts intended for specific applications in end products.

1.3 Together with the Standards mentioned in the Supplementary Test Procedures, Section 6, these requirements provide data with respect to the physical, electrical, flammability, thermal, and other properties of the materials under consideration and are intended to provide guidance to the material manufacturer, the fabricator, the end product manufacturer, safety engineers and other interested parties.

1.4 Compliance with these requirements does not indicate the product is acceptable for use as a component of an end product without further evaluation.

1.5 These requirements do not apply to the evaluation of rigid industrial laminates having a thickness greater than 0.25 mm (0.010 inch). For materials with thicknesses greater than 0.25 mm refer to the Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards, UL 746E.

1.6 For constructions and materials not specifically addressed in this Standard:

- The printed wiring board should provide safeguards not less than that generally afforded by this document and the principles of safety contained herein. This includes printed wiring boards with technologies, materials, or methods of construction, including the manufacturing process, not specifically addressed in this document.

- Propose for discussion with the Technical Committee the need for additional detailed requirements to address a new situation in a timely manner.



### 2 Abbreviations

2.1 The acronym "FMIC" appears throughout this Standard, and stands for "Flexible Materials Interconnect Construction." See 7.57 for the definition of FMIC.

2.2 The acronym "MOT" appears throughout this Standard, and stands for "Maximum Operating Temperature." See 7.70 for the definition of MOT.

2.3 The acronym "RTI" appears throughout this Standard, and stands for "Relative Thermal Index." See 7.81 for the definition of RTI.

### 3 Units of Measurement

3.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

### 4 Measurement Accuracy and Testing Conditions

4.1 A measuring device used to perform the tests required by this Standard shall be capable of measuring the specified parameter with an accuracy within 10 percent of the measured parameter.

4.2 Prior to all tests, subject all samples to a stabilization period in accordance with the Standard Practice for Conditioning Plastics for Testing, ASTM D618, and the Standard for Plastics – Standard Atmospheres for Conditioning and Testing, ISO 291, for a minimum of 40 hours at 23 ±2 °C (73.4 ±3.6 °F) and 50 ±10 percent relative humidity, unless specified otherwise in the individual test method.

4.3 During the test, the standard atmospheric conditions surrounding the samples shall be 25 °C ±10 °C (77 °F ±18 °F) and 50 ±10 percent relative humidity, unless specified otherwise in the individual test method.

4.4 Once samples are removed from the thermal or humidity pre-conditioning environment, samples shall be cooled in the desiccator for at least 4 hours at room temperature and tested within 30 minutes after removal from the desiccator.

## 5 References

5.1 Any undated reference to a code or standard appearing in the requirements of this standard shall be interpreted as referring to the latest edition of that code or standard.

5.2 The following publications are referenced in this Standard:

ASTM D 374 – Standard Test Methods for Thickness of Solid Electrical Insulation

ASTM D 618 – Standard Practice for Conditioning Plastics for Testing

ASTM D 5423 – Standard Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation

ASTM D 5374 – Standard Test Method for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation

ASTM E 3 – Standard Guide for Preparation of Metallographic Specimens

IPC TM-650 2.1.1 – Microsectioning Manual and Semi or Automatic Method

ISO 291 – Standard for Plastics – Standard Atmospheres for Conditioning and Testing



## 6 Supplementary Test Procedures

6.1 These requirements are intended to be used in conjunction with the following requirements or standards:

a) The Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, contains methods for evaluating the flammability of polymeric materials used for parts in electrical equipment.

b) The Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A, contains short term test procedures to be used for the evaluation of materials used for parts intended for specific applications in electrical end products.

c) The Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B, contains long term test procedures to be used for the evaluation of materials used for parts intended for specific applications in end products.

d) The Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, contain programs for evaluating polymeric materials. UL 746C is intended for the evaluations of polymeric materials in specific applications in end products.

e) The Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards, UL 746E, contain programs for evaluating polymeric materials. UL 746E is intended for the evaluation of polymeric materials in specific applications in printed wiring boards.

f) The Standard for Printed Wiring Boards, UL 796, contains the minimum performance requirements for printed wiring boards.

g) The Standard for Flexible Materials Interconnect Constructions, UL 796F, contains the minimum performance requirements for flexible printed wiring boards and interconnect constructions.

## 7 Glossary

7.1 For the purposes of this Standard, the following definitions apply.

7.2 ADHESIVE – A substance such as glue or cement used to join, bond, or fasten materials or objects together.

7.3 ADHESIVELESS – Sputtered on or Cast on film. Adhesiveless does not include Laminated materials.

7.4 AS-RECEIVED – Samples in an unconditioned state, prior to being subject to conditioning, or without a history of conditioning.

7.5 ASSEMBLY SOLDERING PROCESS – The process used for soldering components to a printed wiring board during the assembly process. The soldering process may include but is not limited to reflow, wave, selective soldering or other equivalent soldering techniques.

7.6 BASE DIELECTRIC MATERIAL – An organic or inorganic dielectric barrier material, used to support conductor material.

7.7 BASE MATERIAL – An organic or inorganic insulating material used to support a pattern of conductor material, with or without integral adhesive material, with or without integral conductor material.

7.8 BASE MATERIAL THICKNESS – The thickness of the base dielectric material excluding conductive foil or material deposited on the surfaces. If an adhesive is used for the base material, the adhesive thickness and number of sides is indicated separately.

7.9 BONDING FILM – The layer of insulation used to bond discrete layers during lamination of multilayer flexible printed wiring board constructions. A general term used to describe bondply and freefilm. See also Bondply and Freefilm.

7.10 BONDING LAYER – An adhesive layer used to bond discrete layers during lamination.

7.11 BONDPLY – See Bonding Film.

7.12 BUILD-UP THICKNESS – Overall thickness of a combination of materials. Unless otherwise indicated, the build-up thickness will refer to the overall thickness in the area of a flexible material where no internal or external conductor material resides.

7.13 CALCULATED THICKNESS – A thickness value determined by adding suggested material component thicknesses, or a thickness value determined by adding or subtracting one measured value to or from another measured value.

7.14 CAST ON COPPER – Resin is cast onto copper and then polymerized (cured). The process may require a "multilayer" resin to manufacture a double sided clad material.

7.15 CIRCUIT – Electrical devices and elements interconnected to perform a desired electrical function.

7.16 CIRCUITRY LAYER – Conductor layer or plane in or on an interconnect construction or printed board.

7.17 CLAD MATERIAL – Base material or base dielectric material with conductor material attached.

7.18 CLADDING – A deposited or plated metallic layer or laminated foil used for its protective and/or electrical properties. See Conductive Foil, 7.22.

7.19 COATING – A non-metallic substance applied by some process, such as dipping, curtain coating, film laminating, screening, spraying, or melt-flow.

7.20 CONDITIONING – The time related exposure of a test samples to a specified environment prior to or after testing and before evaluation.

7.21 CONDUCTIVE (ELECTRICAL) – The ability of a substance or material to conduct electricity.

7.22 CONDUCTIVE FOIL – A thin metal sheet intended for forming a conductor pattern on a base material.

7.23 CONDUCTOR – A single conductive in a conductive pattern.

7.24 CONDUCTOR ADHESIVE – Adhesive material used to attach conductor material to a base material, or base dielectric material.

7.25 CONDUCTOR AVERAGE TRACE WIDTH – The average width of a length of conductor trace.

7.26 CONDUCTOR BASE WIDTH – The width of a conductor at the interface of the conductor material and base material. See also Conductor Width.

7.27 CONDUCTOR LAYER – The total conductive pattern formed on one side of a single layer of a base material. (This may include all or a portion of ground and voltage planes.)

7.28 CONDUCTOR MATERIAL – An organic or inorganic substance capable of transmitting electricity, used for circuit conductors, including but not limited to copper, tin, nickel, gold, copper paste, silver paste, carbon paste, ruthenium oxide paste, etc.

7.29 CONDUCTOR PATTERN – The path, design, or configuration of conductor material on the base material, including but not limited to conductor traces, lands, through-holes, and vias.

7.30 CONDUCTOR THICKNESS – The thickness of the conductor and additional metallic platings or coatings, excluding non-conductive coatings.

7.31 CONDUCTOR TRACE – A linear conductor path of a conductor circuit.

7.32 CONDUCTOR WIDTH – The width of the conductor as viewed from a top view or at the plane of the surface of a base material, whichever is less. See Conductor Base Width.

7.33 CONSTRUCTION – A variation in flexible materials build-up, including but not limited to film, adhesive, base material, bonding film, cover lay, dielectric material, laminate, prepreg, or other insulation materials. Variations include singlelayer, multilayer, flexible, flex-to-install, rigid, and multilayer flex/rigid composite constructions.

7.34 CONTINUITY – An uninterrupted path for the flow of electrical current in a circuit.

7.35 CONVERTOR – Manufacturer who prepares materials, such as lamination of copper, adhesive, and base dielectric material for use in the fabrication of flexible materials.

7.36 CORE MATERIAL – The innermost material, interconnect construction, or printed wiring board which may be used to support a subsequent layer or layers of dielectric material and conductor pattern. Core material may be an organic or inorganic material, with or without integral dielectric material. Core material may be referred to as substrate material.

7.37 COVERCOAT – A material deposited as a liquid onto the circuitry that subsequently becomes a permanent dielectric coating. See Cover Material, 7.41.

7.38 COVERFILM – A film made from:

a) A homogenous, single component chemistry;

b) Separate layers of generically similar chemistries; or

c) A composite blend of chemistries.

See Cover Material, 7.41.

7.39 COVERLAY – Film and adhesive made from separate layers of generically different chemistries. See Cover Material, 7.41.

7.40 COVERLAY ADHESIVE – Adhesive used with film to prepare coverlay.

7.41 COVER MATERIAL – A thin dielectric material used to encapsulate circuitry, most commonly for flexible circuit applications. See Covercoat, 7.37, Coverfilm, 7.38, and Coverlay, 7.39.

7.42 CURRENT – The flow or movement of electrons in a conductor as a result of voltage difference between the ends of the conductive path.

7.43 DECLAD – A dielectric material from which the foil or conductive material has been removed by etching or other means.

7.44 DELAMINATION – A planar separation of materials between layers (i.e., separation between conductor and base material, bonding film and base material, cover film and conductor, etc.).

7.45 DIELECTRIC – A material capable of high resistance to the flow of electrical current and capable of being polarized by electric field.

7.46 DOUBLE-SIDED – A flexible material with a conductive layer on the two external sides of the base dielectric material.

7.47 END-PRODUCT – An individual part or assembly in its final completed state. See End-Use Product.

7.48 END-USE PRODUCT – A device or appliance in which an FMIC is installed as a component.

7.49 ETCHANT – A solution used to remove the unwanted portions of material from a base dielectric material or interconnect construction by a chemical reaction.

7.50 ETCHED – A laminate material in which the conductive layer has been removed by a chemical process.

7.51 ETCHING – The chemical, or chemical and electrolytic, removal of unwanted portions of conductive or resistive material.

7.52 EXTERNAL LAYER – The conductor pattern on the external surface of the interconnect construction.

7.53 FABRICATOR – A manufacturer, alternate manufacturer, subcontractor, or multi-site processor who may form the pattern of conductive material, laminate, coat, or process the materials for production of an interconnect construction or FMIC.

7.54 FILM – A sheet, thin coating, or membrane material having a thickness not greater than 0.25 mm (0.010 inch).

7.55 FLAMMABILITY RATED ONLY – A flexible material intended for use where the construction shall be evaluated for a flammability classification only, and the thermal, mechanical, and electrical capacity of the materials is not of concern and only the flammability classification of the resulting FMIC is of concern in the end-use product.

7.56 FLEXIBLE MATERIALS INTERCONNECT CONSTRUCTION – A sub-category interconnect construction intended for use where some portion of the interconnect construction shall be subject to flexing in the end-use product application. See the Standard for Flexible Materials Interconnect Construction, UL 796F.

7.57 FMIC – See Flexible Materials Interconnect Construction.

7.58 FOIL LAMINATION – A process for bonding a conductive foil to a dielectric base material or interconnect construction.

7.59 FREEFILM – An adhesive layer used to bond discrete layers during lamination of multilayer flexible printed wiring board constructions. See Bonding Film, Bondply, and Unsupported Bonding Film.

7.60 GRADE – A designation arbitrarily assigned to a material by the material manufacturer, converter, or vendor.

7.61 INCLUSIONS – Foreign particles, metallic or nonmetallic, entrapped (cannot be wiped off with a cloth) in the specified material and were not intended as part of the material formulation.

7.62 INFRARED REFLOW (IR) – Melting of platings such as tin/lead or remelting of solder using infrared heat as the primary source of energy.

7.63 INTERCONNECT CONSTRUCTION – An integral combination of film, adhesive, base material, conductor, bonding film, cover lay, dielectric material, and other insulation material, fabricated to form point-to-point connections in a predetermined arrangement. The interconnect construction does not include stiffener or adhesive (external bonding) materials.

7.64 INTERNAL LAYER – A conductor pattern contained entirely within a multilayer interconnect construction.

7.65 LAMINATE (n.) – A product made by bonding together two or more layers of material.

7.66 LAMINATE THICKNESS – The thickness of the base dielectric material (not including adhesive thickness) in a single-sided or double-sided singlelayer metal-clad base material.

7.67 LAMINATED – Typically a “Multilayer” resin build up and then laminated to copper. One option is to start with a prepolymerized film, the same as used for cast on type, and build up other types of resin, typically thermoplastic. The thermoplastic layer can be considered to be an adhesive, to hold the film to the copper.

7.68 LAMINATING ADHESIVE – A thin film, coating, or membrane material used to laminate multilayer FMIC’s and printed wiring boards.

7.69 LAYER-TO-LAYER SPACING – The thickness of dielectric material between adjacent conductor planes (i.e., the physical distance between adjacent conductor planes).

7.70 MAXIMUM OPERATING TEMPERATURE (MOT) – The maximum operating temperature is the maximum continuous use temperature that the FMIC may be exposed to under normal operating conditions.

7.71 METAL-CLAD BASE MATERIAL – Base material with integral metal conductor material on one or both sides with or without adhesive.

7.72 MULTILAYER – Interconnect construction category that consists of alternate layers of conductor and dielectric materials laminated or bonded together, including at least three conductor layers separated by two dielectric layers, with at least one internal conductor layer.

7.73 PATTERN – The configuration of conductive and nonconductive materials on a base dielectric material.

7.74 PERFORMANCE LEVEL CATEGORIES (PLC) – An integer defining a range of test values for a given electrical or mechanical property test.

7.75 PLATING (n.) – Chemical or electrochemical deposition of metal on an entire surface or on a conductive pattern.

7.76 PLATING-UP – The electrochemical deposition of a conductive material on a base dielectric material taking place after the base dielectric material has been made conductive.

7.77 PREPREG – A sheet of material impregnated with a resin cured to an intermediate stage (B-stage resin).

7.78 PRINTED (CIRCUIT) BOARD – A printed board produced from rigid industrial laminate material that provides point-to-point connections and printed components in a predetermined arrangement. See the Standard for Printed Wiring Boards, UL 796.

7.79 PRINTED WIRING BOARD – See Printed (Circuit) Board.

7.80 REINFORCEMENT MATERIAL – Any material (i.e. fibrous, continuous, sheet, etc.) capable of enhancing the base material mechanical or physical performance.

7.81 RELATIVE THERMAL INDEX (RTI) – Maximum service temperature for a material, where a class of critical property will not be unacceptably compromised through chemical thermal degradation, over the reasonable life of an electrical product, relative to a reference material having a confirmed, acceptable corresponding performance defined RTI.

7.82 RIGID – A sub-category construction intended for use where no portion of the interconnect construction shall be subject to flexing, bending, or flex-to-install in the end-use product application.

7.83 RIGID INDUSTRIAL LAMINATE – Fibrous reinforcement material impregnated or coated with a thermosetting resin binder, and consolidated under high temperature and pressure into a dense solid product.

7.84 RIGID PRINTED WIRING BOARD – A printed wiring board produced using rigid base dielectric materials.

7.85 ROLL MATERIAL – Flexible materials supplied on a supporting core for the purposes of off-winding for further processing.

7.86 SHEET MATERIAL – Flexible materials supplied cut to processing dimensions for further processing. May have been prepunched.

7.87 SINGLELAYER – Singlelayer flexible constructions are double-sided constructions with one layer of dielectric materials(s) separating the conductor planes, and single-sided constructions with a single conductor plane on one side of a dielectric material(s).

7.88 SINGLE-SIDED – Flexible material with conductive layer on one side of the base dielectric material(s).

7.89 SPUTTERED ON – Metallized pre-polymerized (cured) film. Typically the resin is a thermoset, but may be a thermoplastic.

7.90 STIFFENER – An organic or inorganic material used to provide support or strength to interconnect constructions as part of an FMIC.

7.91 SUBSTRATE – See Base Material.

7.92 SUPPORTED BONDING FILM – A combination of film with integral adhesive on two sides, and a dielectric material used to bond discrete layers during lamination of multiplayer flexible constructions and printed wiring boards. See also Bondply, Bonding Film, and Unsupported Bonding Film.

7.93 TEMPERATURE PROFILE – The depiction of the temperatures a select point traverses as it passes through a process involving multiple temperatures and dwell times.

7.94 TEST PATTERN – The conductor pattern intended for test and inspection purposes.

7.95 TEST SAMPLE – A complete (or portion of a) production flexible material formed by the production process incorporating specific features.

7.96 UL/ANSI TYPE MATERIAL – A specific type designation for materials defined in this Standard as having certain base material, resin, thermal index and profiles of minimum performance.

7.97 UNCLAD – A dielectric material without foil or conductive material (never copper clad.)

7.98 UNSUPPORTED BONDING FILM – A coating or membrane adhesive material used to bond discrete layers during lamination of multilayer constructions, FMICs and printed wiring boards. See also Bonding Film, Bondply, Freefilm and Supported Bonding Film.

7.99 VOID – The absence of metallic or nonmetallic substance in a localized area, in or on an interconnect construction or FMIC.

7.100 X-AXIS – A reference axis, usually horizontal or left-to-right direction in a two dimension coordinate system. The x and y axes are usually perpendicular to one another in a two or three dimension coordinate system.

7.101 Y-AXIS – A reference axis, usually vertical or bottom-to-top direction in a two dimension coordinate system. The x and y axes are usually perpendicular to one another in a two or three dimension coordinate system.

7.102 Z-AXIS – The axis perpendicular to the plane created by the x and y reference axes. This axis usually refers to the thickness of a flexible material.

## CONSTRUCTION

### 8 Flexible Dielectric Material Test Programs and Sample Requirements

#### 8.1 General

8.1.1 The test programs are divided into parts 1) Identification and Flammability, 2) Performance Profile and RTI, and 3) Metal Clad testing to evaluate the dielectric base film, bonding film, cover material, and other thin insulation materials.

a) Generic RTI values for dielectric materials based on field-test performance and chemical structure are listed in Section 7 of the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B.

b) Table 8.1 covers the evaluation to determine the material general composition and the flammability characteristics.

c) Table 8.2 covers the evaluation to determine the material RTI and profile of performance index.

d) Table 8.3 covers the evaluation to determine the acceptability of the metal clad film to be used in the construction of flexible printed wiring boards or flexible interconnect material constructions.

e) Table 8.4 covers the evaluation to determine the acceptability of flexible material combinations and flexible mass laminate test program and sample requirements

f) Table 8.5 covers the evaluation of direct support

g) Table 8.6 lists sample thickness tolerance.

## Table 8.1
## Dielectric Film Material Identification and Flammability Test Program and Sample Requirements

| Property | Sample dimensions length by width, mm (inch) | Film thickness | Adhesive thickness | Minimum number of samples | Applicable materials | For method refer to: |
|---|---|---|---|---|---|---|
| Identification and Flammability Tests | | | | | | |
| Infrared Analysis (IR) Film only | 125 x 13 (5 x 0.5) | Max | – | 5 | F, B, C, CF | UL 746F, 8.1.4, UL 746A |
| Infrared Analysis (IR) Adhesive only[a,b] | 125 x 13 (5 x 0.5) | – | Max | 5 (or 50 g) | FA, B, C, CF | UL 746F, 8.1.4, UL 746A |
| Infrared Analysis (IR) Film and Adhesive[a,b] | 125 x 13 (5 x 0.5) | Max | Max | 5 | FA, B, C, CF | UL 746F, 8.1.4, UL 746A |
| Thermogravimetric Analysis (TGA)[5] | 125 x 13 (5 x 0.5) | Max | – | 5 | F, B, C, CF | UL 746F, 8.1.4, UL 746A |
| Flammability Vertical[c] | 125 x 13 (5 x 0.5) | Min | – | 20 | F, B, C, CF | UL 746F, 8.1.4, UL 94 |
| Flammability Vertical[c] | 125 x 13 (5 x 0.5) | Max | – | 20 | F, B, C, CF | UL 746F, 8.1.4, UL 94 |
| Flammability Vertical[c] | 125 x 13 (5 x 0.5) | Min | Min | 20 | FA, B, C, CF | UL 746F, 8.1.4, UL 94 |
| Flammability Vertical [c] | 125 x 13 (5 x 0.5) | Min | Max | 20 | FA, B, C, CF | UL 746F, 8.1.4, UL 94 |
| Flammability Vertical[c] | 125 x 13 (5 x 0.5) | Max | Min | 20 | FA, B, C, CF | UL 746F, 8.1.4, UL 94 |
| Flammability Vertical[c] | 125 x 13 (5 x 0.5) | Max | Max | 20 | FA, B, C, CF | UL 746F, 8.1.4, UL 94 |
| Flammability VTM[c] | 200 x 50 (8 x 2) | Min | – | 20 | F, B, C, CF | UL 746F, 8.1.4, UL 94 |
| Flammability VTM[c] | 200 x 50 (8 x 2) | Max | – | 20 | F, B, C, CF | UL 746F, 8.1.4, UL 94 |
| Flammability VTM[c] | 200 x 50 (8 x 2) | Min | Min | 20 | FA, B, C, CF | UL 746F, 8.1.4, UL 94 |
| Flammability VTM[c] | 200 x 50 (8 x 2) | Min | Max | 20 | FA, B, C, CF | UL 746F, 8.1.4, UL 94 |
| Flammability VTM[c] | 200 x 50 (8 x 2) | Max | Min | 20 | FA, B, C, CF | UL 746F, 8.1.4, UL 94 |
| Flammability VTM[c] | 200 x 50 (8 x 2) | Max | Max | 20 | FA, B, C, CF | UL 746F, 8.1.4, UL 94 |
| Flammability Horizontal[c] | 125 x 13 (5 x 0.5) | Min | – | 6 | F, B, C, CF | UL 746F, 8.1.4, UL 94 |
| Flammability Horizontal[c] | 125 x 13 (5 x 0.5) | Max | – | 6 | F, B, C, CF | UL 746F, 8.1.4, UL 94 |
| Flammability Horizontal[c] | 125 x 13 (5 x 0.5) | Min | Min | 6 | FA, B, C, CF | UL 746F, 8.1.4, UL 94 |
| Flammability Horizontal[c] | 125 x 13 (5 x 0.5) | Min | Max | 6 | FA, B, C, CF | UL 746F, 8.1.4, UL 94 |
| Flammability Horizontal[c] | 125 x 13 (5 x 0.5) | Max | Min | 6 | FA, B, C, CF | UL 746F, 8.1.4, UL 94 |



**Table 8.1 Continued on Next Page**

## Table 8.1 Continued

| Property | Sample dimensions length by width, mm (inch) | Film thickness | Adhesive thickness | Minimum number of samples | Applicable materials | For method refer to: |
|---|---|---|---|---|---|---|
| Flammability Horizontal[c] | 125 x 13 (5 x 0.5) | Max | Max | 6 | FA, B, C, CF | UL 746F, 8.1.4, UL 94 |

Material Types:

F – Base Dielectric Film (film only, no adhesive. Includes adhesiveless “sputtered” or “cast on” materials.)

FA – Adhesive Coated Base Dielectric Film (film and adhesive)

B – Bonding Film (film and adhesive or adhesive only)

C – Cover material (film and/or adhesive, not intended to be used as a dielectric barrier)

CF – Coverfilm (film only, no adhesive)

NOTES:

1. All the samples shall be in the machine (grain) longitudinal direction unless specified otherwise.
2. All the samples shall be double sided unless single sided material is intended for production.
3. All the samples are to be prepared declad by completely etching a metal clad sheet, where applicable.
4. Infrared Analysis may be performed using Attenuated Total Reflectance (ATR) or other material appropriate test method.
5. Thermogravimetric Analysis samples shall be at least 50 microns minimum thickness.

[a] A cured or liquid adhesive only sample is to be provided. If not possible, cured adhesive on the film shall be provided for IR analysis.

[b] A cured sample is to be provided, if possible. As an alternative, a 50 gram (2 oz) liquid sample (with accompanying MSDS) shall be provided for IR analysis.

[c] See 8.1.4 for sample construction requirements when evaluating the properties of materials related to the intended application.

## Table 8.2
## Dielectric Film Material Performance Profile Index and Relative Thermal Index Test Program and Sample Requirements

| Property | Sample dimensions length by width, mm (inch) | Film thickness | Adhesive thickness | Minimum number of samples | Applicable materials | For method refer to: |
|---|---|---|---|---|---|---|
| Short Term Performance Profile Tests | | | | | | |
| High Current Arc Ignition (HAI)[d] | 125 x 13 (5 x 0.5) | Min | – | 10 | F, B | UL 746F, 8.1.4, UL 746A |
| High Current Arc Ignition (HAI)[d] | 125 x 13 (5 x 0.5) | Max | – | 10 | F, B | UL 746F, 8.1.4, UL 746A |
| High Current Arc Ignition (HAI)[d] | 125 x 13 (5 x 0.5) | Min | Min | 10 | F, FA, B | UL 746F, 8.1.4, UL 746A |
| High Current Arc Ignition (HAI)[d] | 125 x 13 (5 x 0.5) | Min | Max | 10 | F, FA, B | UL 746F, 8.1.4, UL 746A |
| High Current Arc Ignition (HAI)[d] | 125 x 13 (5 x 0.5) | Max | Min | 10 | F, FA, B | UL 746F, 8.1.4, UL 746A |
| High Current Arc Ignition (HAI)[d] | 125 x 13 (5 x 0.5) | Max | Max | 10 | F, FA, B | UL 746F, 8.1.4, UL 746A |
| Hot Wire Ignition (HWI)[d] | 125 x 13 (5 x 0.5) | Min | – | 10 | F, B | UL 746F, 8.1.4, UL 746A |
| Hot Wire Ignition (HWI)[d] | 125 x 13 (5 x 0.5) | Max | – | 10 | F, B | UL 746F, 8.1.4, UL 746A |
| Hot Wire Ignition (HWI)[d] | 125 x 13 (5 x 0.5) | Min | Min | 10 | F, FA, B | UL 746F, 8.1.4, UL 746A |
| Hot Wire Ignition (HWI)[d] | 125 x 13 (5 x 0.5) | Min | Max | 10 | F, FA, B | UL 746F, 8.1.4, UL 746A |
| Hot Wire Ignition (HWI)[d] | 125 x 13 (5 x 0.5) | Max | Min | 10 | F, FA, B | UL 746F, 8.1.4, UL 746A |
| Hot Wire Ignition (HWI)[d] | 125 x 13 (5 x 0.5) | Max | Max | 10 | F, FA, B | UL 746F, 8.1.4, UL 746A |
| Comparative Tracking Index (CTI) | 100 x 100 (4 x 4) | Max | – | c | F, B | UL 746F, 8.1.4, UL 746A |
| Comparative Tracking Index (CTI) | 100 x 100 (4 x 4) | Max | Max | c | F, FA, B | UL 746F, 8.1.4, UL 746A |
| Dielectric Strength (DS) | 100 x 100 (4 x 4) | Max | – | 10 | F, B | UL 746F, 8.1.4, UL 746A |
| Dielectric Strength (DS) | 100 x 100 (4 x 4) | Max | Max | 10 | F, FA, B | UL 746F, 8.1.4, UL 746A |
| Volume Resistivity (VR) | 100 x 100 (4 x 4) | Max | – | 10 | F, B | UL 746F, 8.1.4, UL 746A |
| Volume Resistivity (VR) | 100 x 100 (4 x 4) | Max | Max | 10 | F, FA, B | UL 746F, 8.1.4, UL 746A |
| Moisture Absorption (MA) | 75 x 25 (3 x 1) | Max | – | 5 | F, B | UL 746F, 8.1.4, UL 746A |
| Moisture Absorption (MA) | 75 x 25 (3 x 1) | Max | Max | 5 | F, FA, B | UL 746F, 8.1.4, UL 746A |
| Tensile Strength (Bias Cut)[a,b] | 250 x 25 (10 x 1) | Min | – | 10 | F, B | UL 746F, 8.1.4, UL 746A |

**Table 8.2 Continued on Next Page**

## Table 8.2 Continued

| Property | Sample dimensions length by width, mm (inch) | Film thickness | Adhesive thickness | Minimum number of samples | Applicable materials | For method refer to: |
|---|---|---|---|---|---|---|
| Tensile Strength (Bias Cut)[a,b] | 250 x 25 (10 x 1) | Max | – | 10 | F, B | UL 746F, 8.1.4, UL 746A |
| Tensile Strength (Machine Cut)[a,b] | 250 x 25 (10 x 1) | Min | – | 10 | F, B | UL 746F, 8.1.4, UL 746A |
| Tensile Strength (Machine Cut)[a,b] | 250 x 25 (10 x 1) | Max | – | 10 | F, B | UL 746F, 8.1.4, UL 746A |
| Long Term Thermal Aging Tests | | | | | | |
| 4 Point Thermal Aging Tensile Strength | 250 x 25 (10 x 1) | Min | – | 400 | F, B | UL 746F, 8.1.4, UL 746A and UL 746B |
| 4 Point Thermal Aging Dielectric Strength | 100 x 100 (4 x 4) | Min | – | 400 | F, B | UL 746F, 8.1.4, UL 746A and UL 746B |
| Secondary Flame | 125 x 13 (5 x 0.5) | Min | – | 60 | F, B | UL 746F, 8.1.4, UL 94 and UL 746B |
| Secondary Flame | 125 x 13 (5 x 0.5) | Max | – | 60 | F, B | UL 746F, 8.1.4, UL 94 and UL 746B |

Material Types:

F – Base Dielectric Film (film only, no adhesive. Includes adhesiveless “sputtered” or “cast on” materials.)

FA – Adhesive Coated Base Dielectric Film (film and adhesive)

B – Bonding Film (film and adhesive or adhesive only.)

NOTES:

1. All the samples shall be in the machine (grain) longitudinal direction unless specified otherwise.

2. All the samples shall be double-sided unless single sided material is intended for production.

3. All the samples are to be prepared declad by completely etching a metal clad sheet, where applicable.

[a] Film only shall be evaluated for Tensile Strength in the minimum and maximum thickness.

[b] Tensile Strength samples shall be prepared in the machine and transverse direction for non-reinforced or non-woven reinforced films. Tensile Strength samples shall be prepared in the bias and machine direction for woven reinforced films.

[c] If CTI samples are submitted at a thickness less than 2.5 mm (0.10 inch), the required number of samples varies depending on the thickness of the film. The number of samples shall be increased in order to provide 10 samples built up to the required 2.5 mm (0.10 inch) testing thickness.

[d] See 8.1.4 for sample construction requirements when evaluating the properties of materials related to the intended application.

**Table 8.3**
**Metal Clad Flexible Dielectric Material Test Program and Sample Requirements**

| Property | Sample dimensions length by width, mm (inch) | Film thickness | Adhesive thickness | Copper thickness | Minimum number of samples | For method refer to: |
|---|---|---|---|---|---|---|
| Metal Clad tests | | | | | | |
| Bond Strength/ Delamination | Figure 14.1 | Min | Min | Min | 10 | 8.1.4, Sections 14 and 15 |
| Bond Strength/ Delamination | Figure 14.1 | Min | Min | Max above 102 microns (3 oz) | 10 | 8.1.4, Sections 14 and 15 |
| Flammability Vertical with Thermal Stress[a] | 125 x 13 (5 x 0.5) | Min | Min | – | 20 | UL 746F, 8.1.4, UL 94 |
| Flammability Vertical with Thermal Stress[a] | 125 x 13 (5 x 0.5) | Min | Max | – | 20 | UL 746F, 8.1.4, UL 94 |
| Flammability Vertical with Thermal Stress[a] | 125 x 13 (5 x 0.5) | Max | Min | – | 20 | UL 746F, 8.1.4, UL 94 |
| Flammability Vertical with Thermal Stress[a] | 125 x 13 (5 x 0.5) | Max | Max | – | 20 | UL 746F, 8.1.4, UL 94 |
| Flammability VTM with Thermal Stress[a] | 200 x 50 (8 x 2) | Min | Min | – | 20 | UL 746F, 8.1.4, UL 94 |
| Flammability VTM with Thermal Stress[a] | 200 x 50 (8 x 2) | Min | Max | – | 20 | UL 746F, 8.1.4, UL 94 |
| Flammability VTM with Thermal Stress[a] | 200 x 50 (8 x 2) | Max | Min | – | 20 | UL 746F, 8.1.4, UL 94 |
| Flammability VTM with Thermal Stress[a] | 200 x 50 (8 x 2) | Max | Max | – | 20 | UL 746F, 8.1.4, UL 94 |
| Ambient Bend | Figure 17.1 | Min | Min | Min | 10 | 8.1.4, Section 17 |
| Ambient Bend | Figure 17.1 | Max | Max | Max | 10 | 8.1.4, Section 17 |
| Cold Bend | Figure 17.1 | Min | Min | Min | 5 | 8.1.4, Section 18 |
| Cold Bend | Figure 17.1 | Max | Max | Max | 5 | 8.1.4, Section 18 |
| Repeat Flex | Figure 19.1 | Min | Min | Min | 2 | 8.1.4, Section 19 |
| Repeat Flex | Figure 19.1 | Max | Max | Max | 2 | 8.1.4, Section 19 |

NOTES:

1. All the samples shall be double sided unless single sided material is intended for production.

2. All the flammability samples shall be prepared declad by completely etching a metal clad sheet.

[a] See 8.1.4 for sample construction requirements when evaluating the properties of materials related to the intended application.

**Table 8.4**
**Flexible Material Combinations and Flexible Mass Laminate Test Program and Sample Requirements**

| Property | Sample dimensions length by width, mm (inch) | Film thickness | Adhesive thickness | Copper thickness | Minimum number of samples | Applicable materials | For method refer to: |
|---|---|---|---|---|---|---|---|
| Cover Material and Bonding Film Evaluations with Metal Clad Flexible Dielectric Base Film | | | | | | | |
| Bond Strength/ Delamination | Figure 14.1 | Min | Min | Min | 10 | MF/B | 8.1.4, Sections 15 and 17 |
| Bond Strength/ Delamination | Figure 14.1 | Min | Min | Max above 102 mic (3 oz) | 10 | MF/B | 8.1.4, Sections 15 and 17 |
| Cover Material Lamination | Figure 14.1 | Min | Min | Min | 10 | MF/C, MF/B/C | 8.1.4, Section 20 |
| Cover Material Lamination | Figure 14.1 | Max | Max | Max | 10 | MF/C, MF/B/C | 8.1.4, Section 20 |
| Flammability Vertical with Thermal Stress[a] | 125 x 13 (5 x 0.5) | Min | Min | – | 20 | MF/C, MF/B/C | UL 746F, 8.1.4, UL 94 |
| Flammability Vertical with Thermal Stress[a] | 125 x 13 (5 x 0.5) | Min | Max | – | 20 | MF/C, MF/B/C | UL 746F, 8.1.4, UL 94 |
| Flammability Vertical with Thermal Stress[a] | 125 x 13 (5 x 0.5) | Max | Min | – | 20 | MF/C, MF/B/C | UL 746F, 8.1.4, UL 94 |
| Flammability Vertical with Thermal Stress[a] | 125 x 13 (5 x 0.5) | Max | Max | – | 20 | MF/C, MF/B/C | UL 746F, 8.1.4, UL 94 |
| Ambient Bend | Figure 17.1 | Min | Min | Min | 10 | MF/C, MF/B/C | 8.1.4, Section 17 |
| Ambient Bend | Figure 17.1 | Max | Max | Max | 10 | MF/C, MF/B/C | 8.1.4, Section 17 |
| Cold Bend | Figure 17.1 | Min | Min | Min | 5 | MF/C, MF/B/C | 8.1.4, Section 18 |
| Cold Bend | Figure 17.1 | Max | Max | Max | 5 | MF/C, MF/B/C | 8.1.4, Section 18 |
| Repeat Flex | Figure 19.1 | Min | Min | Min | 2 | MF/C, MF/B/C | 8.1.4, Section 19 |
| Repeat Flex | Figure 19.1 | Max | Max | Max | 2 | MF/C, MF/B/C | 8.1.4, Section 19 |
| Material Types:<br>MF – Metal Clad Dielectric Film (film with copper attached)<br>B – Bonding Film (film and adhesive or adhesive only)<br>C – Cover Material (film and adhesive) | | | | | | | |
| NOTES:<br>1. All the samples shall be double sided unless single sided material is intended for production.<br>2. All the flammability samples shall be prepared declad by completely etching a metal clad sheet. | | | | | | | |
| [a] See 8.1.4 for sample construction requirements when evaluating the properties of materials related to the intended application. | | | | | | | |



8.1.2 Flexible materials shall be defined as films or materials exhibiting flexible properties as further defined in this standard.

8.1.3 Material test samples shall be provided for each different manufacturer, each generic material type, and each different grade of material, for each material component.

8.1.4 Each material component, film, adhesive, base material, conductor material, bonding film, cover material and other insulation material, and combination of these materials shall be determined to be acceptable for use in the intended application.

8.1.4A The properties of materials can vary with thickness. Therefore, consideration is to be given to testing samples representative of the material and construction thickness range, and where applicable double sided and single sided constructions in accordance with production. See Table 8.1 – Table 8.4. Samples in intermediate thicknesses shall be tested if the results obtained on the minimum and maximum thickness indicate inconsistent test results.

*Exception No. 1: If the film material has been previously evaluated for flammability, performance index values and/or the electrical and mechanical thermal characteristics (if applicable) in the minimum and maximum thickness, testing of the film only is not required.*

*Exception No. 2: If the polyimide film has been previously evaluated for flammability in the minimum and maximum thickness and the flammability classification is V-0, flammability testing of the minimum film with the maximum adhesive thickness shall be required for a V-0 or VTM-0. Double sided constructions can be evaluated to represent single sided constructions.*

*Exception No. 3: If the polyimide film flammability classification is VTM-0, flammability testing of the minimum film with the maximum adhesive thickness shall be required for a VTM-0. Double sided constructions can be evaluated to represent single sided constructions.*

*Exception No. 4: If the polyimide film flammability classification is VTM-0 and the requested flammability classification of the film and adhesive combination is V-0, the following constructions require evaluation:*

*a) If single sided construction only:*

*1) Minimum film thickness and minimum adhesive thickness single sided;*

*2) Minimum film thickness and maximum adhesive thickness single sided.*

*b) If single sided and double sided construction:*

*1) Minimum film thickness and minimum adhesive thickness single sided;*

*2) Minimum film thickness and maximum adhesive thickness double sided.*

*Exception No. 5: If the polyimide film flammability classification is both VTM-0 and V-0 based on the thickness range, the above testing requirements shall be followed for each different flammability classification.*

*Exception No. 6: For HAI and HWI testing, if the polyimide film in the minimum and maximum thickness meets Direct Support values for HAI and HWI and the flammability classification is VTM-0 or V- 0, then electrical ignition testing of the minimum film with the maximum adhesive thickness shall be required. Double sided constructions can be evaluated to represent single sided constructions.*

*Exception No. 7: If the absolute minimum film with the absolute maximum adhesive thickness is not intended for production, two sets of samples shall be subject to flammability, HAI and HWI testing (if applicable). The first set of samples shall include for each material component the absolute minimum film thickness with the corresponding maximum adhesive thickness (which may not be the absolute maximum adhesive thickness to be used in production.) The second set of samples shall include for each material component the absolute maximum adhesive thickness with the corresponding minimum film thickness (which may not be the absolute minimum film thickness to be used in production.)*

8.1.4B The flammability and performance profile index values of the film only and film and adhesive combination shall be limited to the lowest rated individual values.

8.1.4C For multiple layers, multi-component and/or non-homogeneous composite films, samples in additional construction(s) and/or thickness(es) may be required to represent the intended application.

8.1.5 The thickness of the film and/or material combination build up shall be measured and tested in accordance with ASTM D 374, Method A or C. The deviation from the sample thickness shall be within the tolerance specified in Table 8.6.

8.1.6 If the base material, bonding film, and/or cover material consists of a dielectric material coated with adhesive on one or both sides, care should be taken so that the adhesive material is not included in the infrared analysis.

8.1.7 Infrared Analysis may be performed using Attenuated Total Reflectance (ATR) or other material appropriate test method.

8.1.8 Each material component, film, adhesive, base material, conductor material, bonding film, cover material, and other insulation material, and combination of these materials shall be evaluated for a flammability classification.

8.1.9 Vertical, Vertical Thin Material or Horizontal flammability testing shall comply with the desired flammability classification and the guidelines in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

8.1.10 Film, adhesive, bonding film, cover material, and other insulation material used as a base material, or dielectric barrier, shall be evaluated for electrical and mechanical relative temperature indices determined in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B.

*Exception: Film, adhesive, base material, bonding film, cover material, and other insulation material used as a base material or dielectric barrier, evaluated for flammability classification only without consideration of an RTI or MOT, need not possess electrical and mechanical relative temperature indices.*

8.1.11 Variations in dielectric and adhesive material composition shall be evaluated in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A, Polymer Variations and the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B, Related Material – Coverage of Variations in Material Composition.

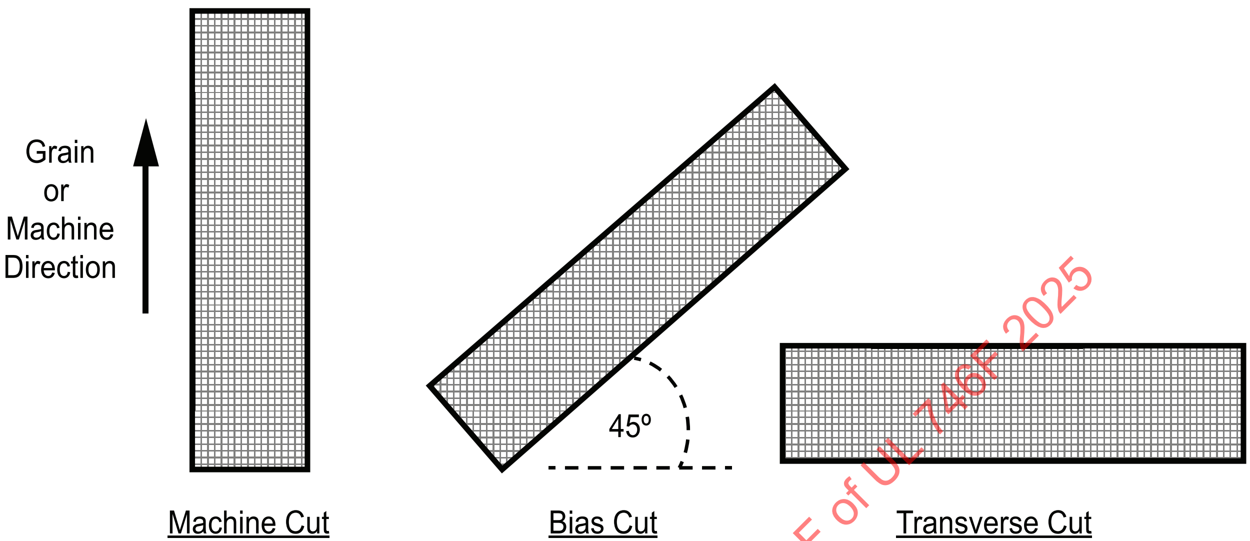
8.1.12 The film, adhesive, conductor, base material, bonding film, cover material, and other insulation material, in an "as-received" condition, shall be representative of typical production.

8.1.13 The material surface on the test samples should be smooth, even, and free of wrinkles, holes, voids, blisters, corrosion, or other imperfections which negatively impact the test results.

8.1.13A The properties of materials can vary with orientation. Therefore, when preparing samples, consideration is to be given to mechanical tests with samples cut lengthwise (machine), crosswise (transverse), and also in the bias direction of the material. See Figure 8.0.

**Figure 8.0**

**Example of Machine, Bias and Transverse Cut Samples – Used for Materials with Orientation Dependent Properties, such as Seen with Woven Fibers**

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8.1.13B Total halogen content testing (i.e. the total amount of chlorine and bromine) in base materials shall be conducted in accordance UL 746E.

8.1.14 The metal clad film, flexible material combinations and mass laminate construction samples shall be subjected to the Thermal Stress Test, Section 13, to determine the material assembly soldering process parameters.

8.1.15 Assembly Soldering Process (Solder limits) is described in the Assembly Soldering Process – Solder Limits section of the Standard for Flexible Materials Interconnect Constructions, UL 796F. The acceptability of the Assembly Soldering Process is determined by investigation of the metal clad material physical properties following the thermal stress test. The Assembly Soldering Process is not prescriptive and does not represent the exact assembly soldering process.

8.1.16 The board maximum surface temperature during the assembly soldering process determines the thermal stress test peak temperature.

8.1.17 Materials for use with reflow assembly processes shall be thermally stressed using the default 260 °C profile with thermal stress conditions of 260 °C peak temperature and six (6) cycles, unless specified otherwise. If a low temperature profile is being used in assembly, the manufacturer can specify the 245 °C or 230 °C profile for testing. If a lower number of cycles are being used in assembly, the manufacturer can specify three (3) cycles instead of six (6) cycles.

8.1.18 If special/unique thermal stress reflow conditions are defined by the manufacturer or OEM/ODM purchase order, the following parameters are needed: ramp rate (R1), cooling rate (C1), peak temperature (T2), dwell time (t2) and the number of cycles (X).

8.1.19 Materials for use with wave soldering and/or selective soldering assembly processes shall be thermally stressed using conditions specified by the manufacturer: the maximum temperature, maximum time, and maximum cycles. Unless specified otherwise, the default standardized conditions described in 8.1.17 for reflow assembly shall represent wave soldering and/or selective soldering processes.

## 8.2 Direct support requirements (DSR)

8.2.1 A dielectric material having an established electrical thermal index and acceptable performance profile characteristics as described in Table 8.5 meets the Direct Support Requirements (DSR) and may provide direct support of current carrying parts at 120 V rms or less and 15 A or less. Performance profile characteristics shall also be established for the dielectric material and adhesive combinations to meet the Direct Support Requirements.

**Table 8.5**
**Direct Support Requirements (DSR) of Dielectric Materials**

| Test[a] | Units or PLC | V-0, V-1, V-2, HB, VTM-0[b], VTM-1[b], VTM-2[b] | Thickness, mm (inch)[c] | |
|---|---|---|---|---|
| High current arc ignition (HAI) | Max PLC | 3 | Actual[d] | |
| Hot wire ignition (HWI) | Max PLC | 4 | Actual[d] | |
| Volume resistivity-dry | Min ohm-cm | 50 | 1.6[e] | (0.062) |
| Volume resistivity-wet | x 10[a] | 10 | 1.6[e] | (0.062) |
| Dielectric strength-dry | Min k volts | 6.89 | 1.6[e] | (0.062) |
| Dielectric strength-wet | per mm | 6.89 | 1.6[e] | (0.062) |
| Comparative tracking index (CTI) | Max PLC | 4 | 3.2[e] | (0.125) |
| Heat deflection | Degrees C | [f] | 3.2[e] | (0.125) |

[a] Testing is to be as described in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.

[b] VTM-0, VTM-1, VTM-2 ratings apply only to etched films.

[c] Test sample thickness on which the index value is based.

[d] Actual thickness or minimum thickness of group being considered.

[e] Test sample representative of all thicknesses.

[f] Not required for thermosets and films; for thermoplastics, at least 10 °C above rated operating temperature with 90 °C minimum value.

**Table 8.6**
**Sample Thickness Tolerance**

| Material nominal thickness mm | Material nominal thickness (in) | Thickness tolerance mm | Thickness tolerance (in) |
|---|---|---|---|
| Less than 0.025 | Less than (0.001) | ±0.005 | ±(0.0002) |
| 0.025 – 0.074 | (0.001 – 0.003) | ±0.008 | ±(0.0003) |
| 0.075 – 0.099 | (0.003 – 0.004) | ±0.01 | ±(0.0004) |
| 0.10 – 0.19 | (0.004 – 0.007) | ±0.02 | ±(0.0008) |
| 0.20 – 0.37 | (0.008 – 0.014) | ±0.03 | ±(0.001) |
| 0.38 – 0.62 | (0.015 – 0.024) | ±0.05 | ±(0.002) |
| 0.63 – 1.59 | (0.025 – 0.061) | ±0.08 | ±(0.003) |
| 1.60 – 2.54 | (0.062 – 0.100) | ±0.10 | ±(0.004) |
| Greater than 2.54 | Greater than (0.100) | ±0.13 | ±(0.005) |
| NOTE: The measured minimum build-up thickness and minimum film thickness shall not be less than the minimum calculated thickness, when employing the tolerance. | | | |

## 8.3 Polyimide ANSI-like flammability program

8.3.1 The program applies to flammability testing only. The full test program requires all electrical performance index tests and mechanical tests (if applicable) to be performed on each film, adhesive, base material, conductor material, bonding film, cover material, and other insulation material, and combinations of these materials.

8.3.2 When an adhesive has been previously evaluated for flammability classification in accordance with Table 8.1, Table 8.2, and/or Table 8.3 for use with a polyimide film with a V-0 or VTM-0 flammability classification, flammability testing is not required for the addition of the adhesive with an alternate polyimide film at the same parameter values when the alternate film meets the following requirements:

a) The alternate film shall be polyimide;

b) The alternate film shall have a VTM-0 or V-0, and the alternate film flammability classification shall be equal to the previously evaluated film;

c) The alternate film minimum thickness shall be equal to or less than the established film minimum thickness evaluated with the adhesive;

d) The alternate film maximum thickness shall be equal to or greater than the established film maximum thickness evaluated with the adhesive;

e) The adhesive and alternate film combination shall have a flammability classification not greater than the previous flammability classification of the alternate film unless flammability testing is performed; and

f) The adhesive and alternate film combination shall be identified by using a unique grade designation.

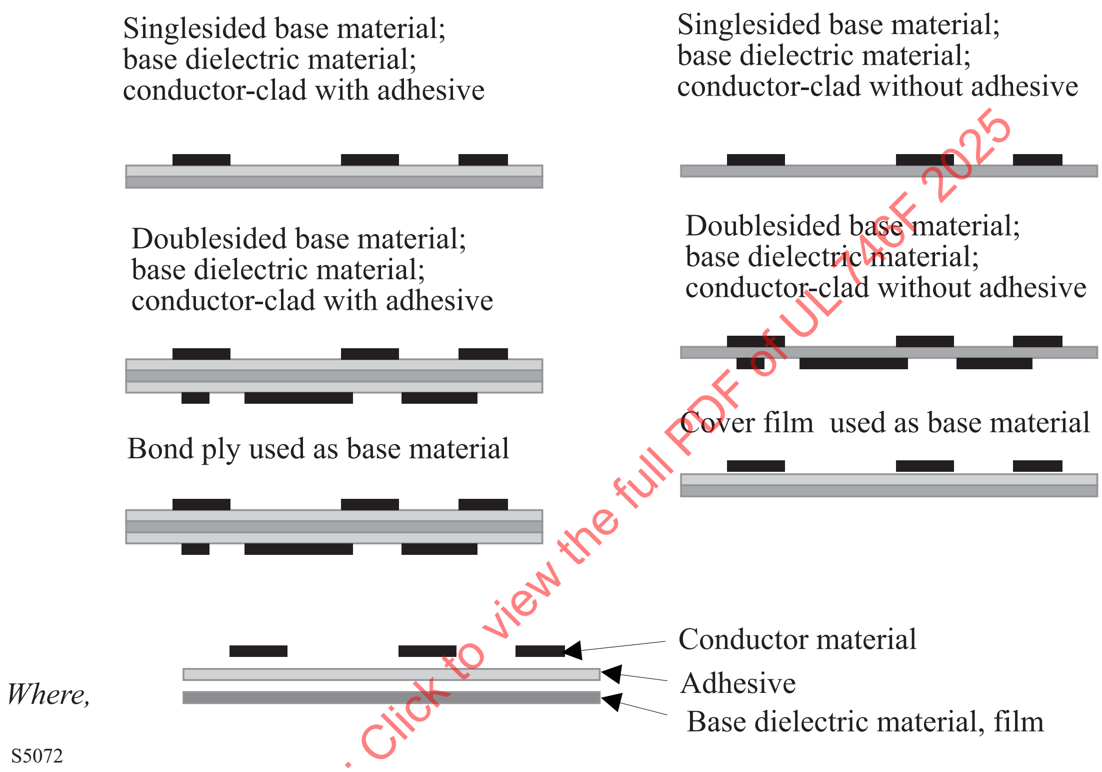
## 8.4 Base materials (Dielectric film material)

8.4.1 Reference to base materials in this Standard shall apply to materials used to support conductor materials, with or without the use of adhesive.

8.4.2 Base materials shall include but not be limited to base dielectric materials, films, and substrate materials supporting conductor material. Materials such as bonding film, cover material, laminate, prepreg, and other insulating material when used to support conductor material shall be considered base material. See Figure 8.1 for examples of base materials used in interconnect constructions.

**Figure 8.1**

**Examples of Base Materials, Used in Interconnect Constructions**






8.4.3 Base materials shall be identified by each constituent including primary and secondary resins, flame retardants, fillers, curing agents and reinforcement materials.

8.4.4 If reinforcement material is used, the orientation of the reinforcement material shall be specified.

8.4.5 Base materials shall be identified by the manufacturer and grade designation.

8.4.6 Base materials shall be identified by each core and each additional individual layer of the material if composed of multiple layers.

8.4.7 Base material thickness shall be specified at the minimum and maximum thickness including individual thickness of each layer of material, if composed of multiple layers.

8.4.8 Base material thickness describes the base material thickness only, without conductor material. Base material with conductor adhesive shall specify the base dielectric material and adhesive thicknesses separately.

8.4.9 Each base material shall be subject to identification by infrared analysis (IR) and thermogravimetric analysis (TGA) in accordance with Table 8.1.

*Exception: IR and TGA testing for the film only shall be waived, if the dielectric material IR and TGA have previously been established.*

8.4.10 If a base material is coated with conductor adhesive on one or both sides, the base material and adhesive shall be subject to identification by infrared analysis, independently.

8.4.11 Flammability testing in accordance with Table 8.1 shall be performed on each base material construction.

*Exception: Flammability testing for the film only shall be waived, if the dielectric material flammability classification has previously been determined at the requested thicknesses.*

8.4.12 The flammability classification of the base material is dependent on the most severe classification of the minimum and maximum thickness of the material.

8.4.13 Performance index testing in accordance with Table 8.2 shall be performed on each base material construction.

*Exception: Performance index testing for the film only shall be waived, if the dielectric material performance profile index values have previously been determined at the requested thicknesses.*

8.4.14 The electrical and mechanical RTI characteristics shall be determined in accordance with Table 8.2.

*Exception No. 1: Long term thermal aging for the film only shall be waived, if the dielectric material electrical and mechanical RTI characteristics have previously been determined at the requested thicknesses.*

*Exception No. 2: Long term thermal aging for the film only shall be waived, if the dielectric material IR spectra compares to the generic polymeric material IR reference spectra and the requested RTI is the same or less as the generic RTI listed in Section 7 of the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B. The electrical and mechanical RTI shall be assigned based on the generic RTI in Section 7 of UL 746B.*

8.4.15 The electrical RTI shall be determined using dielectric strength as the primary property.

8.4.16 The mechanical RTI shall be determined using tensile strength and elongation as the primary properties. Tensile strength samples shall be prepared in the bias direction for woven reinforced films and in the machine direction only for non-reinforced or non-woven reinforced films.

8.4.17 All materials requiring determination of a secondary property as indicated in the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B, are to be removed from the oven and tested at the same end-point time as the primary property.

8.4.18 Test samples as requested in the test program, Table 8.1 and Table 8.2, shall be provided for each different manufacturer and each different grade of base material.

*Exception: Testing may be waived for each different manufacturer of the same generic type of Polyimide material for Flammability Only Classification in accordance with the Polyimide ANSI-like program, Section 8.3.*

8.4.19 Materials used to bond or adhere conductor material to the base dielectric material shall comply with Section 8.5, Conductor adhesives and conductors.

### 8.5 Conductor adhesives and conductors

#### 8.5.1 Conductor adhesives

8.5.1.1 Reference to conductor adhesive in this Standard shall apply to materials used to bond or adhere conductor material to the base material. Conductor adhesive when applied by the converter is referred to as integral adhesive.

8.5.1.2 Conductor adhesive shall not be water soluble.

8.5.1.3 Conductor adhesive shall be identified by the adhesive manufacturer and grade designation.

8.5.1.4 Each combination of materials (i.e. base material, conductor adhesive and conductor) is limited to identification using a unique grade designation.

8.5.1.5 Conductor adhesive shall be specified as being on one side or both sides of the base material.

8.5.1.6 Table 8.1 and Table 8.2 indicate the tests and samples to be used in the evaluation of adhesive coated dielectric materials.

8.5.1.7 Conductor adhesive and base material shall be evaluated in the minimum and maximum thicknesses used in production. Conductive material is to be removed from the film by means of an etchant, where applicable.

*Exception: The testing described in Table 8.1 and Table 8.2 is not required for adhesiveless metal clad dielectric materials produced by sputtering copper on film or casting resin on copper when the RTI and performance profile indexing values have previously been determined.*

8.5.1.8 Each conductor adhesive shall be subject to identification by infrared analysis in accordance with Table 8.1.

8.5.1.9 If infrared analysis is not possible on the cured or liquid conductor adhesive only, samples with cured adhesive on the base material shall be subject to identification of the adhesive only by infrared analysis.

8.5.1.10 The minimum and maximum thickness of each adhesive shall be identified for each base material and base material thickness, and each conductor type and conductor thickness.

8.5.1.11 Flammability testing in accordance with Table 8.1 shall be performed on each base material in combination with each conductor adhesive.

8.5.1.12 The flammability classification of the base material and conductor adhesive combination is dependent on the most severe classification of the minimum and maximum thickness of these materials. See 8.1.

#### 8.5.2 Conductors

8.5.2.1 Reference to conductors in this Standard shall apply to materials used to create the circuit or conductive pattern of the FMIC.

8.5.2.2 Conductors shall include, but are not limited to additive-type, adhesive backed, aluminum, copper, copper alloy, silver, silver paste, and other conductive material having similar conductive properties.

8.5.2.3 The type of conductor material shall be identified for each base material and each conductor adhesive.

8.5.2.4 The minimum and maximum thickness of each type of conductor shall be identified for each base material type and thickness, and each conductor adhesive type and thickness.

8.5.2.5 Table 8.3 indicates the tests and samples to be used in the evaluation of the metal clad dielectric materials. The metal clad samples shall be double sided unless single sided only material is intended for production. Where samples are clad on both sides, the conductive patterns shall be directly opposite each other. The flammability samples shall be prepared declad by completely etching a metal clad sheet.

8.5.2.6 The base material or dielectric barrier shall have acceptable mechanical and electrical properties, at the MOT of the FMIC type. Suggested values for the RTI and MOT include 90, 105, 130, and 150 °C (194, 221, 266, and 302 °F), but the MOT shall not exceed the RTI established for the base material.

8.5.2.7 Each conductor, conductor adhesive, and base material combination shall comply with the mechanical tests specified in Table 8.3. The acceptability of the bond between the conductor, conductor adhesive (if employed) and the base film and performance characteristics of the combination shall be determined by this test program.

8.5.2.8 Representative test samples shall be provided for each conductor weight (thickness) range or conductor weight (thickness).

8.5.2.9 The minimum external copper weight shall be evaluated for Bond Strength, Blistering and Delamination. For external copper weights up to and including 102 mic (3 oz/ft$^2$), the minimum copper weight to be used in production may be considered representative of this copper weight range for evaluation of the Bond Strength, Blistering and Delamination property only.

8.5.2.10 If the minimum copper weight to be used in production for an external-surface conductor is less than 33 mic (1 oz/ft$^2$), the minimum copper weight shall be plated with copper as close as possible to a total thickness of 33 mic for Bond Strength test purposes.

8.5.2.11 For copper weights greater than 102 mic (3 oz/ft$^2$), an additional set of Bond Strength test samples including the heaviest copper weight to be used in production shall be evaluated. The heaviest copper weight may be considered representative of copper weights down to 102 mic.

8.5.2.12 The minimum and maximum external copper weight on the base film shall be evaluated for each of the tests listed in Table 8.3.

8.5.2.13 A retest is necessary if the weight of the conductive material is to be increased or reduced beyond the limits established for the base material grade. Testing shall be conducted in accordance with the Bond Strength, Blistering and Delamination test and the Ambient Bend, Cold Bend and Repeated Flexing tests.

8.5.2.14 A retest is necessary if an increase in the maximum area conductor diameter is desired. Testing shall be in accordance with the Delamination test. Samples shall include a pattern representing the maximum area conductor diameter. If base film, cover material and/or bonding film combination construction is to be evaluated, the combination will also require retest in accordance with Bonding film (supported and unsupported) and internal bonding materials and Cover material (coverlay, coverfilm, and covercoat), Sections 8.6 and 8.7 respectively. Multilayer interconnect constructions shall include an internal mirror image maximum area conductor diameter.

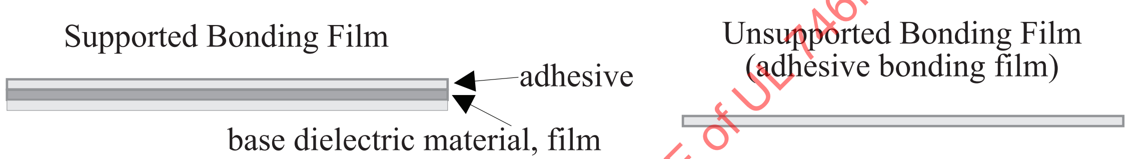
### 8.6 Bonding film (supported and unsupported) and internal bonding materials

8.6.1 Reference to bonding film in this Standard shall apply to materials used to laminate and adhere materials together.

8.6.2 Bonding film materials shall include film, adhesive, and other insulation materials used to laminate and adhere material layers together. Supported bonding film shall include materials such as base dielectric materials coated with adhesive on two sides, and unsupported bonding film materials shall include materials such as adhesive bonding film. See Figure 8.2 for examples of bonding film materials.

**Figure 8.2**

**Examples of Bonding Film, Supported and Unsupported**

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8.6.3 When conductor material is laminated or adhered directly to bonding film as a base dielectric material, the resultant combination of bonding film and conductor material is considered base material. See Base materials (dielectric film material), Section 8.4.

8.6.4 Supported bonding film made from base dielectric material with adhesive on two sides, the base dielectric material and adhesive thicknesses shall be specified separately.

8.6.5 Unsupported bonding film made from adhesive only, the thickness of the adhesive only shall be specified.

8.6.6 Bonding film shall be identified, including the manufacturer's name and grade designation of the dielectric material and adhesive.

8.6.7 The minimum and maximum thickness of dielectric material and adhesive shall be identified for each bonding film type and thickness.

8.6.8 Test samples as requested in the test program, Table 8.1 and Table 8.2, shall be provided for each different manufacturer and each different grade of film and/or adhesive.

*Exception: Testing, each different manufacturer of the same generic type of Polyimide material for Flammability Only Classification, may be waived in accordance with the Polyimide ANSI-like program, Section 8.3.*

8.6.9 Each bonding film, supported and unsupported, shall be subject to identification by infrared analysis and thermogravimetric analysis in accordance with Table 8.1.

8.6.10 If a supported bonding film consists of base dielectric material coated with adhesive on both sides, the base dielectric material and adhesive shall be subject to identification by infrared analyses, independently.

*Exception: IR and TGA testing for the film only shall be waived, if the dielectric material IR and TGA have previously been established.*

8.6.11 Flammability testing in accordance with Table 8.1 shall be performed on each bonding film.

8.6.12 Flammability testing in accordance with Table 8.4 shall be performed on each bonding film in combination with the base material, film, adhesive, bonding film, cover material, and other insulation material.

8.6.13 The flammability classification of the bonding film and material combinations is dependent on the most severe classification of the minimum and maximum thicknesses of these materials. See 8.1.

8.6.14 Performance index testing in accordance with Table 8.2 shall be performed on each bonding film construction.

*Exception: A dielectric material for which the profile of performance index values have previously been determined at the requested thicknesses, the performance index test program in Table 8.2 for the film only shall be waived.*

8.6.15 Bonding film, when used as a dielectric barrier between opposing conductor planes, the dielectric material and/or adhesive shall have been previously determined to have acceptable mechanical and electrical temperature indices, or long term thermal aging shall be conducted in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B.

*Exception: Bonding film evaluated for flammability classification only need not possess electrical and mechanical relative temperature indices.*

8.6.16 The electrical and mechanical RTI characteristics shall be determined for the bonding film in accordance with Table 8.2.

*Exception No. 1: A dielectric material for which the electrical and mechanical RTI characteristics have previously been determined, the long term thermal aging test program in Table 8.2 for the film only shall be waived.*

*Exception No. 2: A dielectric material for which the IR analysis compares to the generic dielectric material, the generic RTI shown in Section 7 of the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B shall be assigned and the long term thermal aging test program in Table 8.2 for the film only shall be waived.*

8.6.17 The electrical and mechanical RTI shall be determined in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B.

8.6.18 The electrical RTI shall be determined using dielectric strength as the primary property.

8.6.19 The mechanical RTI shall be determined using tensile strength and elongation as the primary properties. Tensile strength samples shall be prepared in the bias direction for woven reinforced films and in the machine direction only for non-reinforced or non-woven reinforced films.

8.6.20 All materials requiring a secondary property to be determined as indicated in the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B, are to be removed from the oven and tested at the time the end-point has been reached for the primary property.

8.6.21 Each bonding film in combination with the film, adhesive, base material, cover material, and other insulation material shall comply with the mechanical tests specified in Table 8.4.

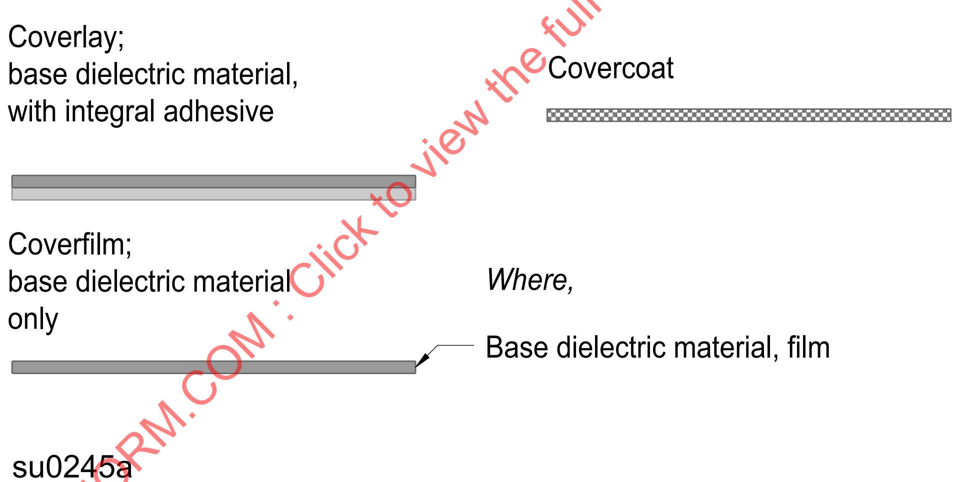
## 8.7 Cover material (coverlay, coverfilm and covercoat)

8.7.1 Reference to cover material in this Standard shall apply to insulating materials used to partially or entirely cover a conductive pattern on the outer surface(s) of an interconnect construction or FMIC.

8.7.2 Cover material shall be a coverlay, coverfilm or covercoat material, and shall include film, adhesive, coating, and other insulation materials. See Figure 8.3 for examples of cover materials.

**Figure 8.3**

**Examples of Coverlay, Coverfilm, and Covercoat**






8.7.3 When conductor material is laminated or adhered directly to cover material as base insulation material, the resultant combination of cover material and conductor materials is considered base material. See Base materials (dielectric film material), Section 8.4.

8.7.4 Coverlay made from insulation material with adhesive applied to one side, the base insulation material and adhesive thickness shall be specified separately.

8.7.5 Coverfilm and covercoat thickness describes the thickness of insulation material only, without conductor material.

8.7.6 Cover material shall be identified, including the manufacturer's name and grade designation of the insulation material and adhesive (if employed).

8.7.7 The minimum and maximum thickness of insulation material and adhesive (if employed) shall be identified for each cover material type and thickness.

8.7.8 Test samples as requested in the test program, Table 8.1 and Table 8.2, shall be provided for each different manufacturer and each different grade of film and/or adhesive.

*Exception: Testing, each different manufacturer of the same generic type of Polyimide material for Flammability Only Classification, may be waived in accordance with the Polyimide ANSI-like program, Section 8.3.*

8.7.9 Each cover material shall be subject to identification by infrared analyses in accordance with Table 8.1.

8.7.10 If the cover material is coated with adhesive on one side, the base dielectric material and adhesive shall be subject to identification by infrared analyses, independently.

*Exception: IR testing for the film only shall be waived, if the dielectric material IR and TGA have previously been established.*

8.7.11 Each covercoat shall be subject to identification by infrared analysis on each color tested for flammability. A cured sample is to be provided, if possible. As an alternative, a 50 g (4 oz) liquid sample (with accompanying MSDS) is to be provided for this purpose.

8.7.12 If the covercoat material is a multi-component coating (i.e. resin and hardener) each component shall be subject to identification by infrared analysis unless a cured sample employing all components is provided.

8.7.13 Flammability testing in accordance with Table 8.1 shall be performed on each cover material.

*Exception: Flammability testing for the film only shall be waived, if the insulation material flammability classification has previously been determined at the requested thicknesses.*

8.7.14 If a cover material is to be evaluated in a range of colors, samples representing this range shall be provided for flammability testing.

8.7.15 The cover material color range shall be represented by evaluating the:

a) Unpigmented color;

b) Most heavily pigmented light color; and

c) Most heavily pigmented dark color.

In addition, the color with the highest organic pigment level shall be evaluated unless the most heavily pigmented light and dark colors include the highest organic pigment level.

8.7.16 Flammability testing in accordance with Table 8.4 shall be performed on each cover material in combination with the base material, film, adhesive, bonding film, cover material, and other insulation material.

8.7.17 The flammability classification of the cover material and material combinations is dependent on the most severe classification of the minimum and maximum thicknesses of these materials. See 8.1.

8.7.18 Each cover material in combination with each applicable combination of base material, film, adhesive, bonding film, dielectric material, and other insulation material intended in the interconnect construction shall comply with the mechanical tests specified in Table 8.4.

## 8.8 Flexible material combinations and flexible mass laminate

8.8.1 Multilayer mass laminate constructions shall include multiple planes of base dielectric material and three or more conductor planes.

8.8.2 Multilayer constructions shall consist of base materials with conductor materials on one or two sides, laminated or bonded together with additional base materials with conductor materials on one or two sides. See Figure 8.4 for examples of multilayer (dielectric) constructions.

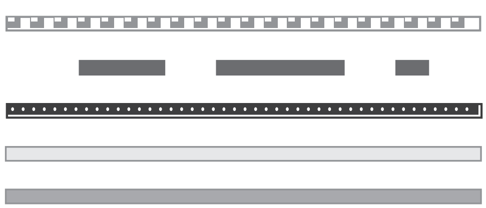
**Figure 8.4**

**Examples of Multilayer (Dielectric) Interconnect Constructions**

Various multilayer interconnect constructions (pre-lamination) with 3 conductor planes:

Various multilayer interconnect constructions (pre-lamination) with 4 conductor planes:

*Where:*



= cover coat

= conductor

= conductive paste

= adhesive

= base dielectric material, film

S5078

8.8.3 Test samples as requested in the test program, Table 8.4, shall be provided for each different manufacturer and each different grade of base material, bonding film, cover material, and other applicable insulation materials.

8.8.4 Flammability samples shall be prepared declad by completely etching a metal clad sheet.

8.8.5 The conductor pattern shall be included on internal and both external sides of a sample with good layer registration, if multilayer interconnect constructions are intended for production.

8.8.6 Each combination of materials or interconnect constructions shall be provided for each type and grade of material, unless otherwise indicated. A representative multilayer interconnect construction shall include film, adhesive, base material, conductor, bonding film, cover material, and other applicable insulation and conductor material.

8.8.7 A representative multilayer interconnect construction shall include two or the minimum number of internal patterned conductor layers, whichever is greater.

8.8.8 A representative multilayer interconnect construction shall include at least one internal patterned conductor layer of the maximum weight intended in production.

8.8.9 If a bonding layer is the sole separation between conductors, the bonding layer shall have been previously evaluated for performance profile indexing values and Relative Temperature Indices (RTI's).

8.8.10 Intermixing of base material, bonding film, and cover material, where cover material is used as a dielectric barrier, is limited to generically identical materials.

8.8.11 Intermixing of dissimilar materials that are not generically identical shall be subjected to the Dissimilar Dielectric Materials Thermal Cycling Test, Section 16 and the Flammability Tests, Section 11. Each individual base dielectric material in the dissimilar material combination shall have been previously evaluated for flammability rating, performance profile indexing values and Relative Temperature Indices (RTI's).

8.8.12 The electrical and mechanical RTI assigned to the combination of dissimilar materials shall not exceed the lowest thermal rating electrical and mechanical RTI of the dissimilar base dielectric materials in the combination.

8.8.13 When performance profile indices are not determined for the dissimilar materials combination, the indices are to be assigned based on the lowest performance rating values of the base dielectric materials in the dissimilar materials combination. Performance profile indexing tests shall be conducted if higher values are to be assigned. The performance values assigned shall be limited to the construction(s) tested, and the outer surface base dielectric material shall be defined.

8.8.14 The flammability rating assigned to the combination of dissimilar materials shall not exceed the lowest flammability rating of the individual dielectric materials.

8.8.15 A multilayer interconnect construction shall be considered representative of an identical multilayer mass-laminated prefabricated package interconnect construction with a representative conductor pattern, if the mass-laminated prefabricated package interconnect construction has the same base material, conductor, bonding film, cover material, and other insulation material thickness, parameter profile indices, and a production process which is considered equal to or less severe than the multilayer interconnect construction production process.

8.8.16 A multilayer interconnect construction is not considered representative of a singlelayer interconnect construction, and a singlelayer interconnect construction is not considered representative of a multilayer interconnect construction or mass-laminated prefabricated package construction.

8.8.17 For multilayer interconnect constructions evaluated to the requirements for direct support of live parts, each base material to which conductors are adhered, bonded, or supported shall comply with the requirements for direct support of live parts.

*Exception: If a multilayer interconnect construction is intended for flammability classification only, the acceptability of the multilayer interconnect construction shall involve only flammability tests.*

## PERFORMANCE

### 9 Short Term Performance Profile Tests

9.1 The IR, TGA, and short term performance profile test method requirements are described as follows or in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.

### 10 Long Term Thermal Aging Tests

10.1 The long term thermal aging test method requirements are in the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B.

### 11 Flammability Tests

11.1 The purpose of this test method is to provide a consistent procedure for assessing the flammability on dielectric film materials. In addition, the test method provides a consistent procedure for assessing the flammability following exposure to solder limits. The test is designed to measure and describe the flammability properties of materials in response to heat and flame under controlled laboratory conditions.

11.2 Flammability tests shall be conducted in accordance with the Standard for Test for Flammability of Plastic Materials for Parts in Devices and Appliance, UL 94.

11.3 Each combination of film, adhesive, base material, bonding film, cover material, and other insulation in the construction shall be subject to flammability tests in the minimum and maximum build-up thickness.

11.4 Flammability tests shall be conducted on the minimum and maximum build-up thickness.

11.5 Flammability tests shall also be conducted after thermal stress for metal clad evaluation.

11.6 Flammability samples shall be preconditioned as described in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, or shall be preconditioned using the alternate conditions of 125 ±2 °C for 24 ±1 hours instead of 70 ±2 °C for 168 ±2 hours, unless otherwise specified.

### 12 Microsection Analysis

#### 12.1 General

12.1.1 The purpose of the microsection examination is to evaluate and determine compliance of the materials, construction, and test pattern of the metal clad laminate, film and prefabricated multilayer laminate with the applicable standard and test method sample coupon construction requirements. The same basic procedures may be used to evaluate other areas of the sample construction.

12.1.2 Guidelines for preparing microsection samples are described in the Standard Practice for Preparation of Metallographic Specimens, ASTM E 3, and Microsectioning, Manual and Semi or Automatic Method, IPC TM-650 2.1.1.

## 12.2 Test samples

12.2.1 The microsection samples shall be cut from the test coupon to include representative areas of the parameters to be measured. This may require multiple microsections. All samples must maintain required traceability. Three common types of cutting tools are diamond saws, routers, and punching dies. Samples shall be cut perpendicular to the evaluation surface with enough clearance to prevent damage to the examination area. The recommended minimum clearance is 2.5 mm (0.1 inch). Depending on the test coupon design, care shall be exercised in choosing a microsection location such that a complete examination can be made.

12.2.2 Samples sizes are generally not more than 12 to 25 mm (0.5 to 1.0 inch) square. The sample height shall be determined for convenience in handling during polishing.

12.2.3 Samples shall be cleaned thoroughly with isopropyl or ethyl alcohol to remove all greases, oils, and residue from the cutting tools. Dry the sample thoroughly.

Note: Cleanliness during sample preparation is important for good adhesion of the mounting resin. Poor adhesion of the mounting resin can cause gaps between the sample and the mounting material which make proper examination difficult.

12.2.4 Samples shall be mounted prior to grinding and polishing in a castable resin/potting material. A release agent shall be applied to the plate and mount mold. The sample shall stand in the mount perpendicular to the base with the surface to be evaluated facing the mounting surface. Clips or tape may be used to support the sample until the potting material is cured.

12.2.5 The mount mold shall be filled with potting material carefully to reduce bubbles in the potting material. Allow samples to cure and remove mount mold.

12.2.6 A description of the basic grinding and polishing steps is outlined in 12.2.7 – 12.2.9.

12.2.7 The samples shall be rough planar ground using an abrasive medium. ANSI 180 – 240 grit abrasive paper (or equivalent) may be used as a starting grit size using metallographic equipment to remove the sectioning/cutting damage. The sample shall be held firmly in contact with the rotating wheel in a circular path against the rotation of the wheel. Rinse the sample with running water and dry. Wheel speeds of 200 to 300 rpm are generally used during grinding. Rotate the sample 90 degrees planar between successive grit size and grind to remove the scratches from the previous step. The successive grinding time may be three times longer than the previous step. Scratches are grooves in the surface of the sample produced by the abrasive particles in the grinding paper. The surface of the sample shall be flat with one set of unidirectional grinding scratches. Water flow must be maintained for removal of grinding debris and to prevent overheating and damage to the sample.

12.2.8 Continue grinding the samples with fine grit size. ANSI 400 – 1200 grit (or equivalent) may be used in successive order to remove the rough and finer grinding damage/scratches. Less time shall be spent on the larger grit and more time on the smaller grit for better sample quality. The scratch removal can be verified by microscopic inspection between steps. Rinse and dry samples between each step to avoid contamination by grinding particles.

12.2.9 Polish the samples to remove the scratches from intermediate steps. Diamond polish is preferred. Smearing of the test material or potting material may occur if lubrication levels are too low or if excessive load is used during grinding. Increase or change the lubricant and reduce the applied load to reduce smearing.

### 12.3 Micro-etching the sample surface

12.3.1 When the required microsection quality has been achieved, the sample shall be etched to allow examination of the copper foil and plating interface.

12.3.2 The etching solution shall be prepared daily and is a mixture of 7 drops Ammonium Hydroxide solution and 9 drops Hydrogen Peroxide solution. The Ammonium Hydroxide solution is 1:1 ratio solution of reagent grade Ammonium Hydroxide and deionized water. The Hydrogen Peroxide solution is 1:1 ratio solution of stabilized Hydrogen Peroxide (3 percent by volume) and deionized water.

12.3.3 The etching solution shall be applied for 2 to 3 seconds. If necessary, repeat the application of the etchant 2 to 3 times to show the plating surface. Rinse in running tap or deionized water to remove etchant.

Note: Over etching may obscure the demarcation line between the copper foil and electroplate copper, preventing accurate evaluation. Thin copper foil and special plating processes require the etching time to be modified.



### 12.4 Material and test pattern parameter examination

12.4.1 The microsection sample shall be evaluated at a minimum 100X magnification with bright field illumination.

12.4.2 All parameters required by the standard shall be measured and observed including, but not limited to, overall construction build up thickness, laminate layer thickness, bonding layer thickness, number and thickness of reinforcement layers, conductor thickness (weight), conductor base width, etc.

## 13 Thermal Stress Test

### 13.1 Purpose

13.1.1 The purpose of this test method is to evaluate the physical fatigue of test samples exposed to assembly soldering. See Table 13.1 for the test methods to be conditioned using the thermal stress test.

**Table 13.1**
**Test Methods Requiring Thermal Stress Conditions**

| Test | Section |
|---|---|
| Flammability test | 11 |
| Delamination test | 14 |
| Delamination test | 15 |
| (Ambient) bend test | 17 |

### 13.2 Compliance criteria

13.2.1 There shall be no presence of any wrinkling, cracking, blistering, loosening, or delamination of any conductor, adhesive, base material, bonding film, cover material, or other insulation material as a result of the thermal stress test.

### 13.3 Test samples

13.3.1 Samples shall include all material components for the desired construction.

### 13.4 Test apparatus and material

13.4.1 A fixture for racking samples can be used for this test. The fixture shall not interfere with the test area of or heat transfer to the samples. The entire sample shall be exposed to the preconditioning and thermal stress temperatures. A tab or area of the sample used to secure the sample in a rack shall not interfere with the heat transfer to the test area of the sample during preconditioning or thermal stress.

13.4.2 A preconditioning (convection) oven capable of maintaining the intended temperature for the desired time, and calibrated to the Standard Test Method for Forced-Convenction Laboratory Ovens for Evaluation of Electrical Insulation, ASTM D 5374, and the Standard Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation, ASTM D 5423, shall be used for this test.

13.4.3 A dry storage device or desiccator capable of maintaining the preconditioned samples at 20 percent RH or less at room temperature shall be used for this test.

13.4.4 Thermal stress reflow conditions shall be conducted using the following apparatus:

Reflow Oven – The reflow system shall have adequate environmental controls to maintain the tolerance range and limits in the designated reflow profiles. IR reflow requires attention to the uniformity of temperature across the sample due to the susceptibility of the materials to infrared absorption.

13.4.5 Thermal stress shall be conducted using one of the apparatus specified below for other soldering processes:

a) Convection Oven – Attention shall be directed to maintaining the test temperature, when introducing and removing the samples into and from the oven chamber.

b) Sand Bath – Attention shall be directed to the uniformity of temperature throughout the fluidized bed, and avoid mechanical damage imposed by an inadequately fluidized sand bath. Samples shall be prepared to prevent adhesion of sand. Samples shall not be tested for flammability if sand adheres to the sample.

c) Solder Pot – Attention shall be directed to the samples when removing them the solder pot so the solder does not join with the conductor traces. Samples shall be prepared so as not to have solder resist or excess solder on conductor traces.

### 13.5 Procedure

13.5.1 Precondition the samples to remove moisture. The samples shall be baked at 121 °C ±2 °C (250 °F ±3.6 °F) minimum for 1.5 hours minimum prior to being subjected to the thermal stress unless specified otherwise.

13.5.2 Subject the samples to a thermal stress within 30 minutes after removal from the 121 °C oven. If not conducted within 30 minutes, the samples shall be stored in a desiccator to prevent moisture absorption.

13.5.3 All samples shall be subjected to reflow soldering conditions or equivalent process specified by the manufacturer. The standardized thermal stress conditions described in Table 13.2 shall be used for this investigation.

**Table 13.2**
**Sample Thermal Stress Standardized Conditions**

| Assembly Process | Maximum Peak Temp | Dwell Time | Cycles |
|---|---|---|---|
| Reflow 260 °C, 245 °C or 230 °C | T1<br>(default 260 °C) | IPC TM-650 2.6.27 | X<br>(default 6) |
| Reflow Special | T2 | t2 plus profile conditions | X |
| Wave / Selective soldering | T3 | t3 | X |

Notes:

1 – Default reflow conditions are 260 °C peak temperature and 6 cycles. Manufacturer shall specify alternate conditions if necessary, for the thermal stress test.

2 – Reflow - The peak temperature (T1) and number of cycles (X) shall be specified.

3 – Reflow Special - Unique conditions defined by manufacturer for ramp rate (R1), cooling rate (C1), peak temperature (T2), dwell time (t2) and cycles (X).

4 – Wave / Selective - The peak temperature (T3) and dwell time (t3) shall be specified.

5 – The peak temperature shall be measured on the material surface.

6 – See reflow profile figures in IPC TM-650 2.6.27.

13.5.4 Materials for use with reflow assembly processes shall be thermally stressed using one of the standardized profile conditions Reflow 260 °C, Reflow 245 °C, Reflow 230 °C, or Reflow Special in accordance with IPC TM-650 2.6.27. The thermal stress maximum temperature and maximum cycles shall be specified by the fabricator. The Reflow 260 profile using six (6) cycles shall be the default thermal stress unless specified otherwise.

13.5.5 Materials for use with wave solder and/or selective soldering assembly processes shall be thermally stressed using the maximum temperature, maximum time, and maximum cycles specified by the fabricator. One (1) cycle shall be the default unless specified otherwise.

13.5.6 Cool the test samples to room temperature.

13.5.7 Examine the samples using normal or corrected 20/20 vision, and record any presence of any wrinkles, cracks, blisters, or loose conductors, or any delamination, wrinkles, cracks, blisters, or loose film, adhesive, base material, bonding film, cover material, or other insulation material.

## 13.6 Data collection

13.6.1 Record and report the following test conditions and equipment:

a) The preconditioning temperature(s) and time(s) used to remove moisture from the samples.

b) The thermal stress temperature(s), time(s) and cycle(s) subjected to the samples.

c) The apparatus used for the thermal stress operation.

13.6.2 Record and report the following test results prior to preconditioning to remove moisture, and following the thermal stress operation and cooling to room temperature:

a) The presence of any wrinkles, cracks, blisters, or loose conductors or

b) Any delamination, wrinkles, cracks, blisters, or loose film, adhesive, base material, bonding film, cover material, or other insulation material.

## 14 Delamination Test

### 14.1 Purpose

14.1.1 The purpose of this test method is to provide a consistent procedure for assessing the physical endurance of material, following exposure to solder limits and thermal conditioning based on the maximum operating temperature. The test is designed to assess physical fatigue of test samples exposed to the anticipated production soldering temperatures and anticipated service temperatures via elevated temperature conditioning.

### 14.2 Compliance criteria

14.2.1 There shall be no presence of any wrinkling, cracking, blistering, or loosening of any conductor, or any delamination, wrinkling, cracking, blistering, or loosening of any film, adhesive, base material, bonding film, cover material, or other insulation material as a result of the pre-conditioning, thermal stress, oven conditioning, or cooling.

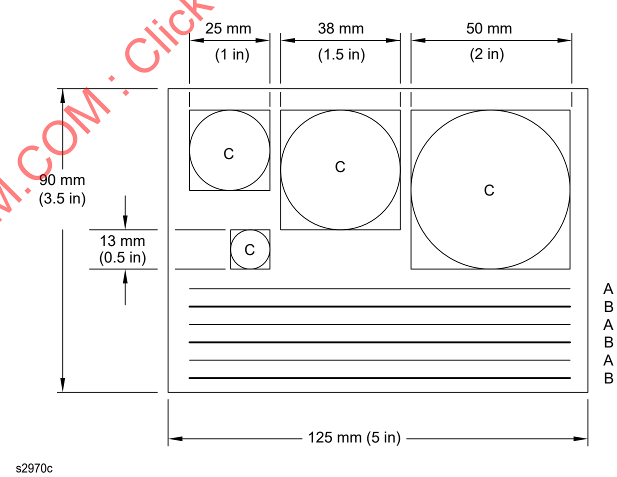
### 14.3 Test samples

14.3.1 Four (4) samples shall include all material components representing a minimum build-up construction.

14.3.2 A representative conductor pattern is shown in Figure 14.1.

**Figure 14.1**

**Typical Bond Strength Test Sample Pattern**




A – Conductor trace 0.8 ±0.13 mm (0.031 inch) wide.

B – Conductor trace 1.6 mm (0.062 inch) conductor with an absolute minimum width not less than 1.47 mm wide.

C – Large conductor areas: Shall be 13 mm (0.5 inch), 25 mm (1.0 inch), 38 mm (1.5 inch) and 50 mm (2.0 inch) diameters, square or circular shape.

14.3.3 External conductors of the initial minimum weight shall be provided on samples for test.

14.3.4 Cover material and solder resist materials shall not be present on the external surfaces of the samples.

## 14.4 Apparatus or material

14.4.1 A conditioning (convection) oven capable of maintaining the specified conditioning temperatures.

## 14.5 Procedure

14.5.1 *Deleted*

14.5.2 Measure the sample build-up thickness in three separate areas where no conductor material resides on the internal or external surfaces of the construction of the four (4) minimum build-up construction samples.

14.5.3 Measure the maximum area conductor diameter(s) on the samples.

14.5.4 Examine the (as-received) samples using normal or corrected 20/20 vision, and record any presence of any wrinkles, cracks, blisters, or loose conductors, or any delamination, wrinkles, cracks, blisters, or loose film, adhesive, base material, bonding film, cover material, or other insulation material.

14.5.5 Subject the samples to the Thermal Stress Test, Section 13.

14.5.6 Place two (2) of the minimum build-up construction samples in a full-draft circulating-air oven for 240 consecutive hours (10 days), maintained at a temperature determined by the following formula:

$$t_2 = 1.076(t_1 + 288) - 273$$

in which

$t_2$ is the oven conditioning temperature in °C for 240 hours oven conditioning, and

$t_1$ is the MOT in °C of the material grade.

See Table 14.1 for the 240 hours oven conditioning temperatures corresponding to the desired or established MOT.



**Table 14.1**
**Corresponding Oven Conditioning Temperatures for the Desired (or Established) MOT**

| $t_1$, Desired (or established) MOT (°C) | $t_2$, Oven temperature (°C) for 240-hour oven conditioning | $t_3$, Oven temperature (°C) for 1344-hour oven conditioning |
|---|---|---|
| 90 | 134 | 113 |
| 105 | 150 | 128 |
| 120 | 167 | 144 |
| 125 | 172 | 149 |
| 130 | 177 | 154 |
| 150 | 199 | 174 |
| 155 | 204 | 179 |
| 160 | 210 | 184 |

14.5.7 An alternate 1344 hours (56 days) oven conditioning temperature may be used if the 240 hours (10 days) oven conditioning program is considered too severe for the evaluated product. Place two of the minimum build-up construction samples in a full-draft circulating-air oven for 1344 consecutive hours (56 days), maintained at a temperature determined by the following formula:

$$t_3 = 1.02(t_1 + 288) - 273$$

in which

$t_3$ is the oven conditioning temperature in °C for 1344 hours oven conditioning, and

$t_1$ is the MOT in °C of the FMIC type.

See Table 14.1 for the 1344 hours oven conditioning temperatures corresponding to the desired or established MOT.

14.5.8 Cool the samples to room temperature at standard ambient laboratory conditions. The samples shall be placed on a ceramic plate or tile, hung, or racked such that the samples are not adversely affected by the mechanism used to hold or retain the samples during cooling.

14.5.9 *Deleted*

14.5.10 Examine the samples using normal or corrected 20/20 vision, and record any presence of any wrinkles, cracks, blisters, or loose conductors, or any delamination, wrinkles, cracks, blisters, or loose base material, film, adhesive, bonding film, cover material, or other insulation material.

### 14.6 Data collection

14.6.1 Record and report the following measurement test data:

a) The three overall construction build-up thickness measurements in accordance with 14.5.2;

b) The measured maximum area conductor diameter(s) in accordance with 14.5.3;

c) The 240-hour oven temperature; and

d) The 1344-hour oven temperature.

14.6.2 Record and report the following test results:

a) The presence of any wrinkles, cracks, blisters, or loose conductors, or any delamination, wrinkles, cracks, blisters, or loose film, adhesive, base material, bonding film, cover material, dielectric material, or other insulation material in accordance with 14.5.4,

1) After the thermal stress in accordance with 14.5.5;

2) After the 240 hours oven conditioning at temperature $t_2$ or cooling to room temperature in accordance with 14.5.6; and

3) After the 1344 hours oven conditioning at temperature $t_3$ or cooling to room temperature, in accordance with 14.5.7.

## 15 Bond Strength Test

### 15.1 Purpose

15.1.1 The purpose of this test method is to provide a consistent procedure for assessing the physical endurance and bond strength of metallic conductors on base materials, following exposure to solder limits and thermal conditioning based on the maximum operating temperature. The test is designed to assess physical fatigue of test samples exposed to the anticipated production soldering temperatures and anticipated service temperatures, via elevated temperature conditioning.

### 15.2 Compliance criteria

15.2.1 The average bond strength between the conductor and base material shall not be less than:

a) 0.525 N/mm (3 lbf/inch) for each individual conductor trace, for the as received bond strength after being subject to thermal stress; and

b) 0.525 N/mm (3 lbf/inch) for each individual conductor trace, for the 240 hours (10 day) bond strength after being subject to thermal stress and 240 hours (10 day) oven conditioning; or

c) 0.350 N/mm (2 lbf/inch) for each individual conductor trace, for the 1344 hours (56 day) bond strength after being subject to thermal stress and 1344 hours (56 day) oven conditioning.

15.2.2 There shall be no presence of any wrinkling, cracking, blistering, or loosening of any conductor, or any delamination, wrinkling, cracking, blistering, or loosening of any film, adhesive, base material, bonding film, cover material, dielectric material, or other insulation material as a result of the pre-conditioning, thermal stress, oven conditioning, or cooling.

### 15.3 Test samples

15.3.1 Eight (8) samples shall include all material components representing a minimum build-up construction.

15.3.2 A representative conductor pattern is shown in Figure 14.1.

15.3.3 External conductors of the initial minimum weight shall be provided for the bond strength test. For initial conductor weights less than 33 mic (1 oz/ft$^2$), the conductors shall be plated up to 33 mic for the purpose of pulling the conductor for bond strength.

15.3.4 Conductors on the samples for bond strength test shall be continuous, and may be tapered at one end to aid initiating the bond strength pull.

15.3.5 Cover materials shall not be present on the external surfaces of the base material. The bond strength test shall be conducted by peeling the conductor from the base material without obstruction of cover materials.

### 15.4 Apparatus or material

15.4.1 Double-faced adhesive tape or an adhesive system with an adhesive strength capable of attaching a rigid supplemental reinforcement material to the test sample for bond strength testing. (Or other equipment set up preventing the base material from tenting during the conductor pull.)

Note – The double-faced adhesive tape or adhesive system should be compatible with the materials used in the construction, and should not be detrimental to or adversely affect the materials in the construction.

15.4.2 A rigid supplemental reinforcement material to be bonded to the test samples. The rigid supplemental reinforcement material is intended to eliminate tenting and flexing of the sample during the bond strength test.

Note – The reinforcement material should be compatible with the materials used in the construction, and should not be detrimental to or adversely affect the materials in the construction.

15.4.3 A pry tool, such as a knife or scalpel, capable of separating the conductor from the substrate adhesive or film material to initiate the conductor bond strength pull.

15.4.4 A conditioning (convection) oven capable of maintaining the specified conditioning temperatures.

15.4.5 A bond strength tester capable of providing and measuring the force required to separate the conductor material from the substrate material with an accuracy within 10 percent of the measured force value.

15.4.6 A ceramic plate or tile, rack, or hanging device capable of being maintained at standard ambient laboratory conditions to hold or retain oven conditioned samples for cooling.

Note – The material of the ceramic plate or tile, rack, or hanging device should be compatible with the materials used in the construction, and should not be detrimental to or adversely affect the materials in the construction.



## 15.5 Procedure

15.5.1 *Deleted*

15.5.2 Measure the sample build-up thickness in three separate areas, where no conductor material resides on the internal or external surfaces of the construction of seven (7) minimum build-up construction samples.

15.5.3 Measure and verify the conductor trace average widths of the following conductors:

a) A 0.8 mm (0.031 inch) wide conductor;

b) A 1.6 mm (0.062 inch) wide conductor; and

c) The conductor circle diameters.

15.5.4 Examine the (as-received) samples using normal or corrected 20/20 vision, and record any presence of any wrinkles, cracks, blisters, or loose conductors, or any delamination, wrinkles, cracks, blisters, or loose film, adhesive, base material, bonding film or other insulation materials.

15.5.5 Subject the samples to the Thermal Stress Test, Section 13. The samples shall be subjected to the Thermal stress test without any reinforcement attached; a supplemental reinforcement material shall be applied to these samples only after the Thermal stress test.

15.5.6 Attach a rigid reinforcement material to the back-side, the side of the sample not being subjected to the bond strength test using double-faced adhesive tape or adhesive system.

15.5.7 Separate the conductor from the base material and measure the force required to pull the conductor from the base material on four (4) of the samples.

15.5.8 Separate or pry the end of the conductor from the base material, so that the conductor can be grasped for the bond strength pull.

*Exception: After attempting to pry up an end of a conductor, if the conductor material and base material interface remain intact, the base material rips or tears when the bond strength pull is conducted, and the forces imparted to the conductor material exceeds 0.525 N/mm (3 lbf/inch), the bond strength of that conductor shall be considered greater than 0.525 N/mm.*

15.5.9 Peel a uniform width of the conductor from the sample surface for a distance of at least 6.4 mm (0.25 inch) at a uniform rate of approximately 300 mm/min (12 inches/min) [or, approximately 6.4 mm (0.25 inch) in 1.25 seconds]. The angle between the conductor and the sample surface shall be maintained at not less than 85 degrees during the test. Three force determinations are to be made on each conductor width described below:

a) Two 0.8 mm (0.031 inch) wide conductors and

b) Two 1.6 mm (0.062 inch) wide conductors.

*Exception No. 1: As an alternative to using three force determinations, one force determination can be made on each conductor tested by peeling a uniform width conductor from the sample surface for a distance of at least 19 mm (0.75 inch).*

*Exception No. 2: When the characteristics of the conductor material of unconditioned (i.e., no thermal stress and no oven conditioning) or conditioned (i.e., thermal stress or oven conditioning) samples inhibit measurement of the bond strength with test equipment, the bond strength shall be evaluated manually. A reference material previously evaluated with test equipment and found to have bond strength greater than 0.525 N/mm (3 lbf/inch) for each individual conductor trace of similar average width shall be used to compare with the bond strength of each individual conductor trace of similar average width on unconditioned and oven conditioned samples. A tool can be used to pry the conductor from the base material surface and the bond strength shall be evaluated manually. The same conductor traces on unconditioned and oven conditioned samples shall be evaluated in the same manner as described above, and the bond strength of the unconditioned, oven conditioned, and reference samples shall compare favorably with one another.*

15.5.10 Place two (2) of the minimum build-up samples subjected to thermal stress in a full-draft circulating-air oven for 240 consecutive hours (10 days), maintained at a temperature determined by the following formula:

$$t_2 = 1.076(t_1 + 288) - 273$$

in which

$t_2$ is the oven conditioning temperature in °C for 240 hours oven conditioning, and

$t_1$ is the MOT in °C of the material grade.

See Table 14.1 for the 240 hours oven conditioning temperatures corresponding to the desired or established MOT.

15.5.11 When the fabricator so requests, a longer oven conditioning time at a lower temperature than described in 15.5.10 shall be used. Place two (2) of the minimum build-up samples subjected to thermal stress in a full-draft circulating-air oven 1344 consecutive hours (56 days), maintained at a temperature determined by the following formula:

$$t_3 = 1.02(t_1 + 288) - 273$$

in which

$t_3$ is the oven conditioning temperature in °C for 1344 hours oven conditioning, and

$t_1$ is the MOT in °C of the material grade.

See Table 14.1 for the 1344 hours oven conditioning temperatures corresponding to the desired or established MOT.

15.5.12 Cool the test samples to room temperature at standard ambient laboratory conditions after being oven conditioned. The samples shall be placed on a ceramic plate or tile, hung, or racked such that the samples are not adversely affected by the mechanism used to hold or retain the samples during cooling.

15.5.13 *Deleted*

15.5.14 Examine the samples using normal or corrected 20/20 vision, and record any presence of any wrinkles, cracks, blisters, or loose conductors, or any delamination, wrinkles, cracks, blisters, or loose film, adhesive, base material, bonding film, or other insulation materials.

15.5.15 Attach a rigid reinforcement material to the back-side of the samples using double-faced adhesive tape or an adhesive system so the samples do not flex or tent during the bond strength test.

The test samples shall be oven conditioned without any supplemental reinforcement attached. A supplemental reinforcement material shall be applied to the test samples only after the oven conditioning and cooling.

15.5.16 The force required to separate the conductor from the base material shall be initiated and measured.



### 15.6 Data collection

15.6.1 Record and report the following measurement test data:

a) Flexible material build-up thickness;

b) A 0.8 mm (0.031 inch) wide conductor;

c) A 1.6 mm (0.062 inch) wide conductor; and

d) The conductor circle diameters.

15.6.2 Record and report the following test data:

a) The presence of any wrinkles, cracks, blisters, or loose conductors, or any delamination, wrinkles, cracks, blisters, or loose film, adhesive, base material, bonding film, or other insulation materials:

1) Prior to thermal stress;

2) After the 240 hours oven conditioning at temperature $t_2$ or cooling to room temperature;

3) After the 1344 hours oven conditioning or cooling to room temperature;

4) The type of supplemental reinforcement attached to the samples; and

5) The forces required to separate the conductors from the base material after thermal stress (if applicable) and after oven conditioning.

15.6.3 Record and report the following test data for samples subjected to 240 hours oven conditioning at temperature $t_2$:

a) Oven conditioning temperature ($t_2$).

b) The forces required to separate the conductors from the base material after 240 hours oven conditioning at temperature $t_2$.

15.6.4 Record and report the following test data for samples subjected to 1344 hours oven conditioning at temperature $t_3$:

a) Oven conditioning temperature ($t_3$).

b) The forces required to separate the conductors from the base material after 1344 hours oven conditioning at temperature $t_3$.

15.6.5 Indicate if the bond strength was conducted manually in accordance with the Exception to 15.5.9. If the bond strength test was conducted manually, the forces required to separate the conductors from the base material shall be noted as being obtained manually.

15.6.6 Calculate the average bond strength in force per unit width (lbf/inch; N/mm) for the forces recorded:

a) After thermal stress and before 240 hours or 1344 hours oven conditioning, for each corresponding conductor average width;

b) After 240 hours oven conditioning, for each corresponding conductor average width; and

c) After 1344 hours oven conditioning, for each corresponding conductor average width.

## 16 Dissimilar Dielectric Materials Thermal Cycling Test

### 16.1 Purpose

16.1.1 The dissimilar dielectric materials thermal cycling test is designed to evaluate the physical fatigue of dissimilar material constructions exposed to thermal cycling environments, including elevated and reduced temperature conditioning and high humidity.

### 16.2 Compliance criteria

16.2.1 There shall be no wrinkling, cracking, blistering, or loosening of any conductor or any delamination of any film, adhesive, base material, bonding layer, cover material, or other insulation material as a result of the thermal cycling test.

### 16.3 Test samples

16.3.1 Six (6) samples constructed with all material components for the desired construction(s) using the conductor pattern shown in Figure 14.1.

a) Three (3) samples shall include all material components representing a minimum build-up construction, and

b) Three (3) samples shall include all material components representing a maximum build-up construction.

### 16.4 Apparatus

16.4.1 A thermal conditioning convection oven capable of maintaining the specified conditioning temperature used for this test.

16.4.2 A cold conditioning chamber capable of maintaining the specified conditioning temperature used for this test.

16.4.3 A humidity conditioning chamber capable of maintaining the specified conditioning temperature and relative humidity used for this test.

### 16.5 Procedure

16.5.1 Subject three (3) minimum build-up construction samples and three (3) maximum build-up construction samples to the following thermal cycle conditions for three cycles. A programmable conditioning chamber can be used instead of manual cycling. The programmable chamber shall have the software ramp rate and cooling rate set at the chamber maximum limitation for rapid rates. If a manual process is used, the samples shall be stored at 23 ±2 °C (73.4 ±3.6 °F) and 50 ±10 percent RH between each cycle.

a) 48 hours at 10 °C above the mechanical RTI rating of the lowest thermal rating material in the construction, or 10 °C above the maximum operating temperature specified by the manufacturer, whichever is greater,

b) 64 hours at 35 ±2 °C (95 ±3.6 °F) at 90 ±5 percent RH,

c) 8 hours at 0 °C (32 °F), and

d) 64 hours at 35 ±2 °C (95 ±3.6 °F) at 90 ±5 percent RH.

16.5.2 Examine the samples using normal or corrected 20/20 vision, and record any presence of loosening, wrinkles, cracks, blisters, or delamination in the conductors or insulation material.

## 17 Ambient-bend Test

### 17.1 Purpose

17.1.1 The purpose of this test method is to provide a consistent procedure for bending and assessing the integrity and physical endurance of materials intended for flexible applications at ambient conditions following exposure to solder limits and thermal conditioning based on the maximum operating temperature. The test is designed to provide a limited assessment of the bend-ability and physical fatigue at ambient conditions of test samples exposed to the anticipated production soldering temperatures and anticipated service temperatures, via elevated temperature conditioning.

### 17.2 Compliance criteria

17.2.1 There shall be no presence of any wrinkling, cracking, blistering, or loosening of any conductor, or any delamination, wrinkling, cracking, blistering, or loosening of any film, adhesive, base material, bonding film, cover material, or other insulation material as a result of the pre-conditioning, thermal stress, oven conditioning, or cooling.

### 17.3 Test samples

17.3.1 Ten (10) samples shall include all material components representing a minimum build-up construction, and ten (10) samples shall include all material components representing a maximum build-up construction.

17.3.2 The test samples shall include the same material components and component thickness used to prepare the minimum and maximum build-up construction samples for the Cold-bend Test, Repeated Flexing Test, and Cover Material Test (if applicable) described in Sections 18, 19, and 20 respectively.

17.3.3 The test sample conductor pattern is shown in Figure 17.1.

**Figure 17.1**

**Ambient-Bend and Cold-Bend Test – Sample Configuration**


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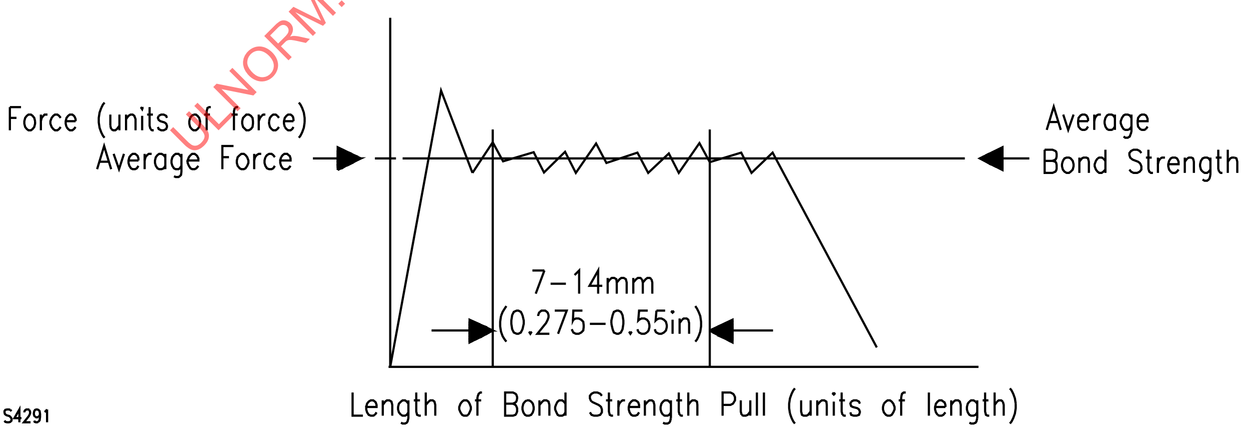
**Figure 17.2**

**Determining Average Bond Strength from the Average Force**

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### 17.4 Apparatus or material

17.4.1 A conditioning (convection) oven capable of maintaining the specified conditioning temperatures shall be used for this test.

17.4.2 A 6.4 mm (0.25 inch) diameter rigid mandrel, maintained at standard ambient laboratory conditions.

### 17.5 Procedure

17.5.1 *Deleted*

17.5.2 Measure the overall build-up thickness on each of five (5) minimum build-up construction samples and on each of five (5) maximum build-up construction samples in three separate areas, where no conductor material resides on the internal or external surfaces of the constructions.

17.5.3 Verify the 13 mm (0.5 inch) conductor trace average width.

17.5.4 Examine the samples using normal or corrected 20/20 vision, and record any presence of any wrinkles, cracks, blisters, or loose conductors, or any delamination, wrinkles, cracks, blisters, or loose film, adhesive, base material, bonding film, cover material, or other insulation material.

17.5.5 Subject the samples to Thermal Stress Test, Section 13.

17.5.6 Place five (5) of the minimum build-up construction samples and five (5) of the maximum build-up construction samples subjected to the thermal stress test in a full-draft circulating-air oven for 240 consecutive hours (10 days), maintained at a temperature determined by the following formula:

$$t_2 = 1.076(t_1 = 288) - 273$$

in which

$t_2$ is the oven conditioning temperature in °C for 240 hours oven conditioning, and

$t_1$ is the MOT in °C of the material grade.

See Table 14.1 for the 240 hours oven conditioning temperatures corresponding to the desired or established MOT.

17.5.7 Place the remaining five (5) minimum build-up construction samples and five (5) maximum build-up construction samples subjected to the thermal stress test in a full-draft circulating-air oven for 1344 consecutive hours (56 days), maintained at a temperature determined by the following formula:

$$t_3 = 1.02(t_1 + 288) - 273$$

in which

$t_3$ is the oven conditioning temperature in °C for 1344 hours oven conditioning, and

$t_1$ is the MOT in °C of the material grade.

See Table 14.1 for the 1344 hours oven conditioning temperatures corresponding to the desired or established MOT.

17.5.8 Cool the test samples to room temperature at standard ambient laboratory conditions following oven conditioning. Place the samples on a ceramic plate or tile, or hang or rack them such that the samples are not adversely affected by the mechanism used to hold or retain the samples during cooling.

17.5.9 *Deleted*

17.5.10 Examine the samples using normal or corrected 20/20 vision, and record any presence of any wrinkles, cracks, blisters, or loose conductors, or any delamination, wrinkles, cracks, blisters, or loose film, adhesive, base material, bonding film, cover material, or other insulation material.

17.5.11 Bend a sample around a 6.4 mm (0.25 inch) diameter rigid mandrel for five completely closed turns, noting where the first turn is completed. The first bend shall be initiated at least 25 mm (1 inch) away from the end of the sample. Bending of the sample around the mandrel shall be initiated at an angle to the mandrel, such that overlap of the sample is maximized, the sample is intimately wrapped onto the mandrel and previous wrap of sample, and the number of completely closed turns can be easily counted. If a sample has asymmetrical construction, one set of samples will be tested with a surface wrapped to the inside, and another set of samples will be tested with a surface wrapped to the outside.

Note – Due to sample thickness or material rigidity, six turns may be required to establish five completely closed turns; in this case, note where the first turn is initiated and completed.



17.5.12 Release the completely closed turns of the sample wrapped around the mandrel without altering the resulting configuration or condition of the sample due to the bending around the rigid mandrel.

17.5.13 Examine the sample using normal or corrected 20/20 vision, and record any presence of any wrinkles, cracks, blisters, or loose conductors, or any delamination, wrinkles, cracks, blisters, or loose film, adhesive, base material, bonding film, cover material, or other insulation material.

Note – In the case when six turns are required to establish five completely closed turns, where the first turn was initiated and where the first turn was completed shall be noted. Disregard examination of the sample in the area between where the first turn was initiated and where the first turn was completed, and examine the area of the five completely closed turns following the completion of the first turn.

17.5.14 Slowly and carefully flatten the sample by hand, being careful not to crease or fold the sample, and allow the sample to relax.

17.5.15 Examine the sample using normal or corrected 20/20 vision, and record any presence of any wrinkles, cracks, blisters, or loose conductors, or any delamination, wrinkles, cracks, blisters, or loose base material, film, adhesive, bonding film, cover material, or other insulation material, after the sample has been flattened, without creases or folds, and allowed to relax.

Note – In the case when six turns are required to establish five completely closed turns, where the first turn was initiated and where the first turn was completed shall be noted. Disregard examination of the sample in the area between where the first turn was initiated and where the first turn was completed, and examine the area of the five completely closed turns following the completion of the first turn.

17.5.16 Repeat the procedure steps outlined in 17.5.11 – 17.5.15 for the remaining samples.

### 17.6 Data collection

17.6.1 Record and report the following measurement test data:

a) Flexible material build-up thickness and

b) Verification of the 13 mm (0.5 inch) conductor trace average width.