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Advanced Circuit Materials

Fabrication Guidelines
RT4.4.1

Bonding PTFE Materials for Microwave Stripline Packages and Other Multilayer Circuits

There are three general types of bonding systems commonly used for bonding PTFE base laminates for microwave stripline packages and other multilayer circuits. The following introduction relates to the materials and methods commonly used. Contact the product manufacturers for additional data sheet and processing information.

Thermoplastic Films:

The most common method requires the use of interleaved film. Using film allows you to heat a clamped assembly of boards (in registration), interleaved with thermoplastic film having a melt point lower than the 327°C (620°F) of PTFE core laminates. Once the melt point of the film is surpassed, the film will laterally flow and fill between the copper features assisted by uniform pressure distribution applied to the package. Common film types include Rogers 3001 and Dupont FEP films. Choice will often depend on subsequent thermal exposures of the multilayer circuit vs. the meltpoint of the film type used.

Thermoset Prepregs:

The second method requires the use of thermoset bonding prepregs. The multilayer packet can be heated in a clamped assembly of boards (in registration), interleaved with thermosetting prepreg. Thermoset prepreg traditionally has a lower bond temperature than the 327°C (620°F) of the PTFE core laminates. During the temperature exposure, the prepreg resin will laterally flow and fill between copper features assisted by uniform pressure distribution applied to the package. The use of epoxy prepreg is common in mixed constructions where FR4 and PTFE based laminates are bonded together. However, location of epoxy prepreg should be carefully considered due to electrical performance reasons.

Gore Speedboard®C is a low loss, low Dk thermoset prepreg compatible with all commercial laminates. The product exhibits controlled X-Y resin flow for superior performance in cavity designs. The material consists of a BT resin in a continuous toughening matrix. Speedboard C is often considered as an alternative to thermoplastic films in a variety of printed circuit board applications including RF and microwave.

Direct Bonding:

The third method, which can be more difficult, is direct bonding (fusion bonding). This requires temperature above the melt point of the core material, omits the film, and directly fuses the softened PTFE surfaces together. In addition, Rogers offers a PTFE bond ply material based on Rogers RT/duroid® 6002 product grade that has been used to interleave between core layers increasing the dielectric flow at the bond line. Details of this process can be found in Rogers RT/duroid Technical Note RT 4.9.3. This method requires great care to control the clamp stress in addition to high temperature press capability.

Selection of Bonding System

Bonded assembly options may depend on the final application, lamination equipment, and subsequent post lamination thermal exposures of the bonded package.

When selecting a bonding system for PTFE base laminates consider the following:

System	Advantages	Disadvantages
Thermoplastic	Melt point to match needs. Done in readily available presses. Could be disassembled.	Fails above melt point. Surface etch recommended. Prepunch of film needed TFE-CTFE colpolymer has higher loss
Thermoset	Can be done as low as 23°C. Can be heat resistant. For example such bonds have served well in edge wise exposure to hypervelocity thermal ablation conditions.	Increased dielectric loss and poor match in dielectric constant. Pot life limitation with liquids. Cannot be disassembled. Surface etch required.
Direct Fusion	Function above 315°C (as much as 400°C). No special surface treatment. No need for concern about dielectric constant or loss of adhesive.	Needs care in clamp pressure during bonding. Cannot be disassembled. Must exclude air when bonding. High bond temperature (360°C+).

- Temperature available in a platen press or autoclave of suitable design.
- Subsequent thermal exposure of the bonded package through solder processes and thermal cycling requirements.
- Temperatures to be encountered by the device in service.
- Tolerance for dielectric losses and for dielectric constant match of the bond layer to the substrate material.
- Degree of copper cladding or ground plane present (3001 bonding film).

Film Type	Teflon	3001 Bonding Film	Speedboard C Prepreg
Distributor	DuPont	Rogers	Gore Electronics
Description	Fluorinated ethylenepropylene copolymer	copolymer chlorotrifluoroethylene	BT Resin
Melt Point, Tg, °C	260	200	220
Dielectric Constant	2.1	2.28	2.6
Dissipation Factor	0.003	0.003	0.004

***NOTE**: Do not use 3001 Bonding Film when bonding to metal ground planes or where inner layers are mostly metal.*

Preparation of PTFE Dielectric Surface for Bonding

Following etching and stripping of the etch resist, copper circuitry should be treated with a light microetch to ensure complete removal of resist residues and to provide sufficient topography for sound mechanical adhesion. DO NOT mechanically clean.

All surfaces to be bonded should be free of contaminants that impair adhesion, including dust, grease, oil, fingerprints, non-adherent oxides, salts or other process chemical residues. A final rinse of deionized water may be followed by a dip in clean isopropyl alcohol. Avoid use of compressed air which can deposit airborne contaminates such as oil.

Hot air oven baking should be used to assure removal of all solvent residues. This can be as little as 45 to 60 minutes at 121°C (250°F) but, with some solvents such as acetone, methylene chloride or trichlor as much as 2 hours at 150°C (302°F) may be needed to assure complete solvent removal. Incomplete removal of such absorbed solvents may swell the PTFE surface to a small degree or create corrosion problems later in the assembly since chlorinated solvents in contact with moisture may form corrosive hydrochloric acid by hydrolysis.

The PTFE surface as initially exposed by etching away electrodeposited foil is typically water-wettable (hydrophilic) and capable of forming a bond without additional surface treatments. However, almost any kind of solid surface contact by scrubbing, swabbing, rubbing or normal stacking and handling will destroy that wettability by distorting the microscopic surface topography left from the imprint of the copper foil cladding. When distortion of the surface topography occurs, the surface will become non–wettable (hydrophobic) and will need to be treated to return to its water wettable state. There are two common approaches to this process:

Sodium Napthelene

Chemically altering the PTFE surface by replacing fluorine groups with polar groups raises the surface energy and makes the surface wettable. The very high fluorine-carbon bond of PTFE resists all but very strong chemical treatments. The effectiveness of a treatment is tested by observing whether water forms a film rather than beaded-up droplets on the surface. Treating the surface with one of the commercially available elemental sodium solutions such as Poly-Etch®, NATREX25™ or FluoroEtch® can be used to render the dielectric surface hydrophilic. Please contact the manufactures of these products for additional reference.

Contact Information:

Poly-Etch®	NATREX25™	Fluoro-Etch®
Matheson Gas Products	ABB Etching Service Inc	Acton Associates, Inc
61 Grove St	55 2nd Street	100 Thompson St
Gloucester, MA 01930	Maxwell, TX 78656	Pittston, PA 18640
978/283-7700	800/344-3644, Direct: 512/357-2499	570/654-0612
Fax: 978/283-6177	Fax: 512/357-2846	Fax: 570/654-2810

Plasma etch

Use of plasma has also been proven to increase the wettability of a PTFE surface. Plasma etched surfaces have also been noted to help develop bonds exceeding the strength of the substrate in a peel test. Equipment for plasma etching offers advantages of a single step process and alleviates some of the environmental concerns associated with Sodium based Products. It is important to note the gas mixture used for PTFE surface activation is not what is commonly used for epoxy desmear processes. The following conditions have been found to yield good results for treating a PTFE surface: Hydrogen or a hydrogen-nitrogen mix with 60 to 80% hydrogen. With a flow rate of 0.5 to 2.5 standard litres per minute, pressure at 175 to 250 millitorre, and RF power at 1 to 4.5.

Please contact the plasma gas and equipment manufacturers for additional product information.

Contact Information:

March Plasma Systems Florida

12000 28th St. N.
St. Petersburg, FL 33716
(727) 573-4567
www.marchplasma.com

Plasma Etch

3522 Arrowhead Drive
Carson City, NV 89706
(775) 883-1336
www.plasmaetch.com

General Guidelines for Multilayer Lay-Up

Film Preparation

Boards prepared for bonding should be stored in a clean, dry environment. Generally layup and bonding should be done within 24 hours of surface preparation. Assemble boards to be bonded interleaved with bonding film between dielectric layers. In cases where registration is critical, the plates should be provided with pins and the boards and film with holes. Films should be pre-punched with registration holes matching the boards to be bonded. Film thickness should typically be equal to copper thickness to adequately flow and fill.

Bonding Note

Bonding material must be moved from the copper pattern areas to the non-copper areas during bonding. As the ratio of pattern area to total area is increased more clamp stress is required. Inadequate clamp stress will be evident if voids between copper areas are present as noted through destructive inspection. With direct bonding the dielectric substrate is the material that must move to accommodate copper areas.

The type of bonding system and temperature exposure will determine how low a melt viscosity is attained. Clamp stress combines with the normal wetting action of the adhesive to promote the intimate contact of surfaces needed for dependable bond.

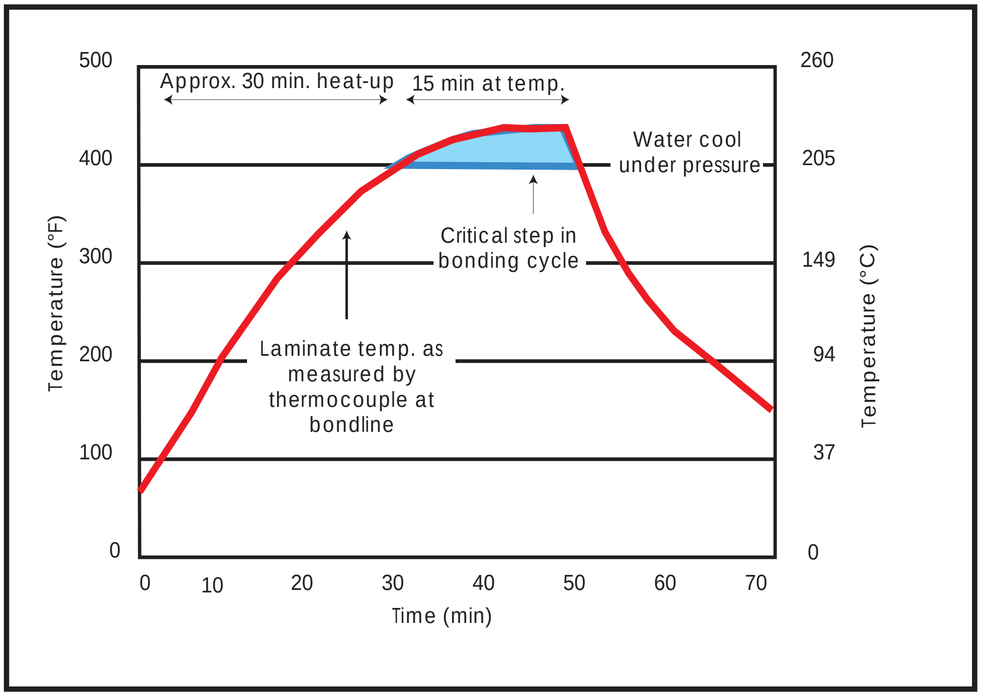
Bonding Cycles

The assembly with the plates is held under constant clamp pressure. The temperature is raised to the required value for bonding. After a suitable dwell the assembly is cooled under clamp pressure before removal.

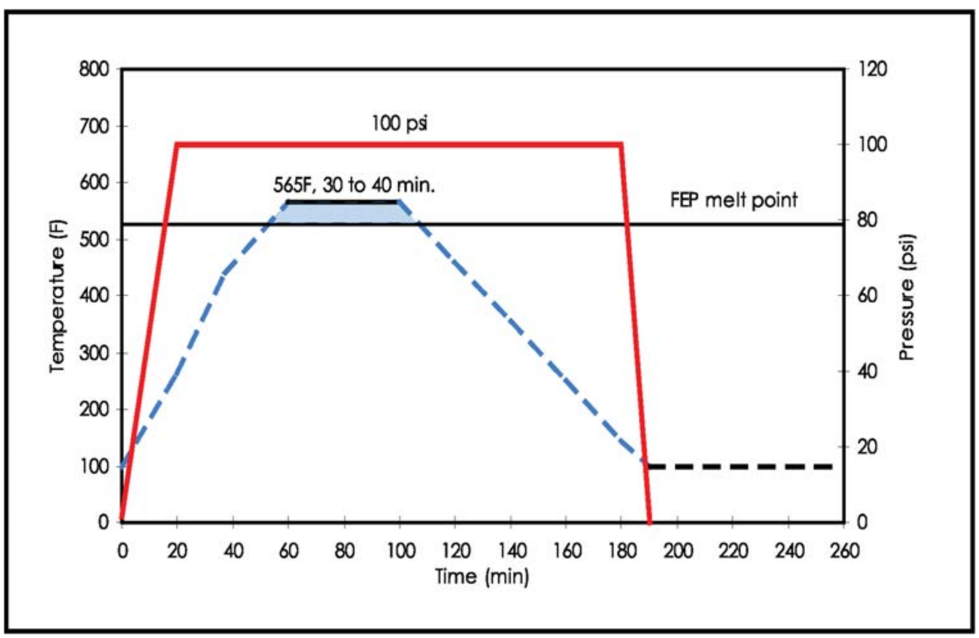
The following tables summarize suggested starting points for bonding cycles for thermoplastic films, Speed Board C thermoset system, and direct bonding. Epoxy grade thermoset bond cycles are too numerous to be shown here. Generally the vendor’s recommendation should be followed.

Thermocouples should be used in prototype work and occasionally in production to audit the temperature actually attained in the bonding cycle.

Rogers 3001 Thermoplastic Film Bonding Cycle

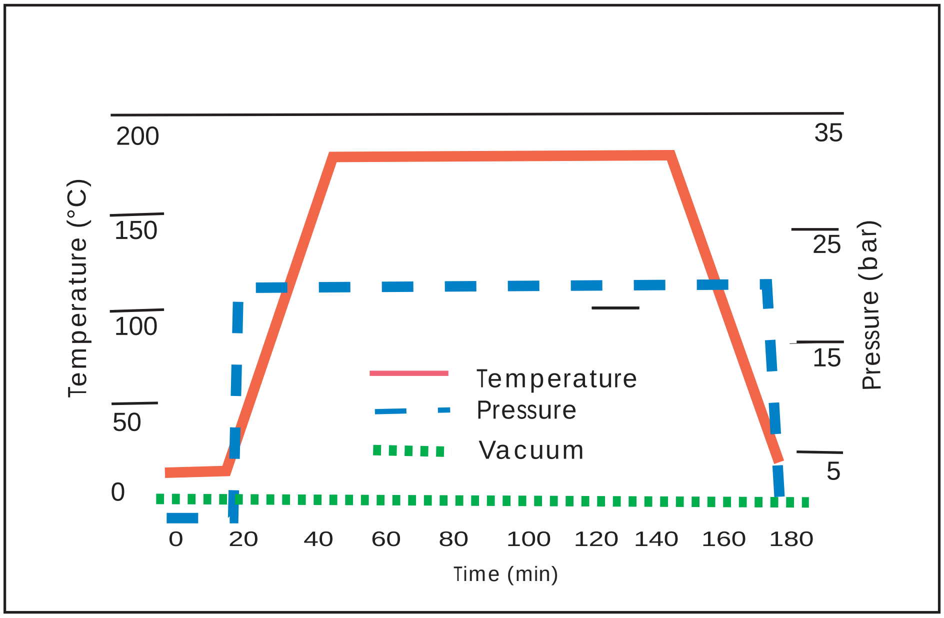


Dupont FEP Fluorocarbon



W.L.Gore Speedboard C Bonding Cycle

Air Exclusion in Direct Bonding

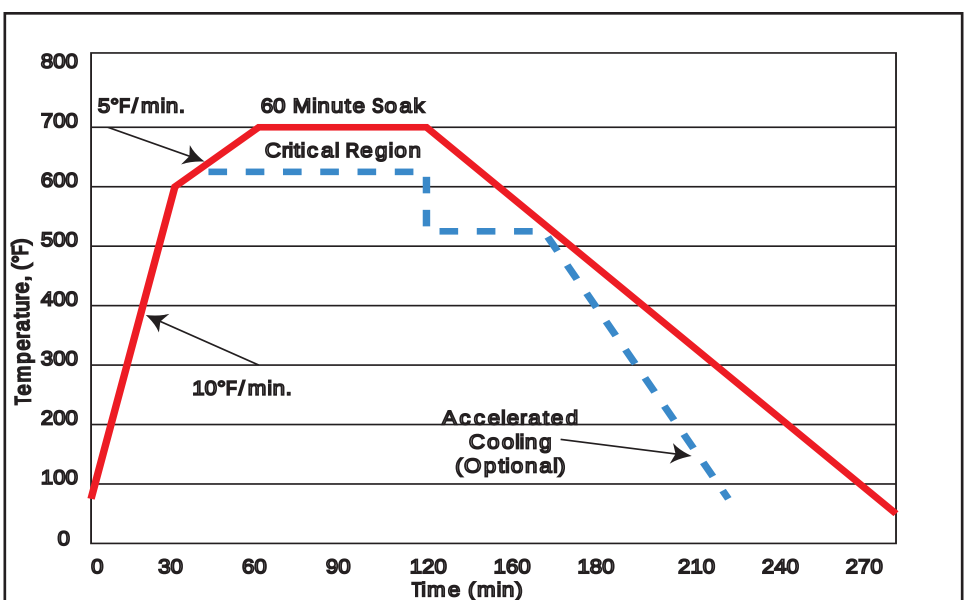


The high temperature requirement for direct bonding requires exclusion of air to avoid copper oxidation that destroys the bond of copper to base material. Air also causes degradation of the PTFE evident as a whitened or bleached appearance and may increase dissipation factor.

Air is satisfactorily excluded by enveloping the assembly with tooling in heavy aluminum foil. Seal by crimping or rolling foil edges together at least two times. A preferred alternative would be to enclose the apparatus in an inert atmosphere.

Aluminum anneals at the direct bonding temperature. Use plates of stainless steel rather than aluminum for long runs on the same tooling.

Rogers Direct Bonding Cycle



The Autoclave as an Alternative to the Press

An autoclave for applying clamping force to the assembly layup has the advantage of more uniform clamping stress without concern for parallelism of platens. Autoclaves are avoided in direct bonding because of the temperature limit of the sealing blanket. Layup for autoclave bonding resembles pressing except that the assembly is sealed in a gas-tight metal box by a silicone rubber blanket clamped to the box's flange by a perforated metal cover plate. A tubing connection to the box allows evacuation of the work while autoclave gas pressure is being applied.

Contact information:

Rogers 3001 Bonding Film
Rogers Corporation
100 S. Roosevelt Avenue.
Chandler, Arizona 85226
480-961-1382
www.rogerscorporation.com

FEP Fluorocarbon Film
Dupont High Performance Films
P.O. Box 89 Route 23 South Dupont Blvd.
Circleville, Ohio 43113
800-967-5607
www.dupont.com

SPEEDBOARD®C
W.L. Gore & Associates, Inc
501 Vieve's Way
Elkton, Maryland 21921
410-506-3605
www.goreelectronics.com

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Korea:	Rogers Korea Inc.	Tel: 82-31-716-6112	Fax: 82-31-716-6208
Singapore:	Rogers Technologies Singapore Inc.	Tel: 65-747-3521	Fax: 65-747-7425

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Revised 7/2003 2.5 ON **Publication #92-441**