FR406

Standard Loss, High Tg Epoxy Laminate and Prepreg

Processing Guide

The processing guidelines contained in this document were developed through in-house testing and field experience. However, they should be considered to be starting points that will require further adjustment. Read the following review of processes for applicability to your particular Printed Wiring Board (PWB) fabrication environment. Remember that the suggestions contained herein can not account for all possible board designs or processing environments. Additional adjustments by the fabricator will be necessary. Isola can and will assist with this process, but the fabricator, not Isola, is ultimately responsible for their process and the end results. ***Fabricators to verify that PWBs made using these suggestions meet all applicable quality and performance requirements.***

Part 1: Prepreg Storage and Handling

Isola Group's prepreg bonding sheets for use in multilayer printed circuit board applications are manufactured to specifications that include physical and electrical properties and processing characteristics relative to the laminating application. Handling and storage factors have an important influence on the desired performance of the prepreg. Some parameters are affected by the environment in which prepregs are stored. They can also deteriorate over extended periods of storage. The prepreg received by the customer is a glass fabric that has been impregnated with a stated quantity of low volatile, partially polymerized resin. The resin is tack-free but somewhat brittle. Many lamination problems arise from resin loss off the fabric due to improper handling. The fabric used is based on the order and supplies the required
thickness. In most cases the amount of resin carried by the fabric increases as the fabric thickness decreases.

Handling Suggestions

Handle all prepreg using clean gloves. Use sharp, precision equipment when cutting or paneling prepreg. Treat all prepreg as being very fragile. Use extreme care when handling very high resin content prepreg (glass fabrics 1080 and finer).

Storage Suggestions

Upon receipt, all prepreg should be immediately moved from the receiving area to a controlled environment. All prepreg should be used as soon as possible using a First-In-First-Out (FIFO) inventory management system. If not handled properly, FR406 prepreg will absorb moisture, which will lead to depressed Tg's and cure and affect flow in the press. If extended storage is required, separate facilities should be reserved with appropriate environmental control. Prepreg should be stored at <= 23 ºC and below 50% humidity.

Prepreg packages should be allowed to equilibrate to **layup room conditions before opening to prevent moisture condensation on the prepreg.**

Stabilization time will depend on storage temperature. In cases where storage temperature is significantly below room temperature, keep prepreg in package or plastic wrapping during stabilization period to prevent moisture condensation. Once the original packaging is opened, the prepreg should be used immediately. Remaining prepreg should be resealed in the original packaging with fresh desiccant. Storage should be in the absence of catalytic environments such as high radiation levels or intense ultraviolet light.

Part 2: Innerlayer Preparation

Isola Group's FR406 laminates are fully cured and ready for processing. It has been the experience of most fabricators that stress relief bake cycles are not effective in reducing any movement of high performance laminates such as FR406. Therefore, it is suggested that the movement of unbaked laminate be characterized and the appropriate artwork compensation factors are used.

Dimensional Stability

The net dimensional movement of laminate after the etch, oxide and lamination processes is typically shrinkage. This shrinkage is due to the relaxation of stresses that were induced when the laminate was pressed as well as shrinkage contribution from the resin system. Most of the movement will be observed in the grain direction of the laminate.

There are situations that have been known to alter the proportion of shrinkage in grain versus fill direction in some board shops. These include autoclave pressing and cross-plying laminate grain direction to that of prepreg. While both of these practices have their advantages,

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Table 1: Initial Artwork Compensation Factors

Base Thickness	Configuration	Direction	Comp (in/in)
≤ 0.005″	Signal/Signal	Warp (grain)	0.0007-0.0009
"	"	Fill	0.0001-0.0003
"	Signal/Ground	Warp (grain)	0.0005-0.0007
"	"	Fill	0.0001-0.0003
"	Ground/Ground	Warp (grain)	0.0002-0.0004
"	"	Fill	0.0000-0.0002
0.006-0.009″	Signal/Signal	Warp (grain)	0.0005-0.0007
"	"	Fill	0.0001-0.0003
"	Signal/Ground	Warp (grain)	0.0003-0.0005
"	"	Fill	0.0000-0.0002
"	Ground/Ground	Warp (grain)	0.0000-0.0002
"	"	Fill	0.0000-0.0002
0.010-0.014″	Signal/Signal	Warp (grain)	0.0002-0.0004
"	"	Fill	0.0000-0.0002
"	Signal/Ground	Warp (grain)	0.0001-0.0003
"	"	Fill	0.0000-0.0002
"	Ground/Ground	Warp (grain)	0.0000-0.0002
"	"	Fill	0.0000-0.0002

Table 1 (for reference) illustrates the suggested approach to characterizing laminate movement and provides approximate artwork compensation factors for FR406 laminate when using a hydraulic press.

This table assumes that laminate and prepreg grain directions are oriented along the same dimension. Each shop must characterize material behavior given their particular lamination cycles, border designs and grain orientation of laminate to prepreg. It is also suggested that specific laminate constructions be specified and adhered to so that dimensional variations due to changes in construction are avoided.

Table 1 assumes that signal layers are either half or 1 ounce copper and ground layers are either 1 or 2 ounce copper.

Imaging and Etching

FR406 laminates are imaged using standard aqueous dry films and are compatible with both cupric chloride and ammoniacal etchants.

Bond Enhancement

Both reduced oxides and oxide alternative chemistries have been used successfully in fabricating FR406 multilayer boards to date. Users should make sure the oxide or oxide replacement coating exhibits a consistent, uniformly dark color. If reduced oxides are used, consult the chemical supplier for post oxide baking considerations as excessive baking may lead to lower pink ring resistance. It is generally suggested that post-oxide baking be performed vertically, in racks. Suggest mild bake of oxided innerlayers (15-30 minutes @ 80-100°C).

For conveyorized oxide replacements, an efficient dryer at the end of a conveyorized oxide replacement line should remove all moisture from the innerlayer surface. ***However, drying of layers for 30 minutes minimum @ 100°C (212°F) or higher is considered a "best practice".***

If immersion tin adhesion treatments are used, the fabricator should test the coating to verify adequate bond strength is developed with FR406 prepregs.

Part 3: Lamination

Standard Lamination

The amount of time at cure temperature, and to some extent the actual cure temperature of FR406, will be determined by the thickness of the multilayer package being produced. Very thick boards will require a longer cure time to assure optimum material performance.

Sequential Lamination

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Use a 50 minute cure for sub-assemblies depending on thickness and a 60-70 minute cure for the final assembly. This suggestion assumes a final assembly thickness ≥ 0.125″ (3.2 mm). Removal of FR406 flash should be performed by routing rather than shearing to minimize crazing along the panel edges.

Table 2 outlines general suggestions for lamination pressure based on press type used.

Table 2: FR406 Lamination Pressure

Lamination Method	Suggested Pressure Range
Hydraulic Pressing (without vacuum assist)	300-350 PSI 21-25 kg/cm^2
Hydraulic Pressing (with vacuum assist via vacuum frames or bags)	250-300 PSI 18-21 kg/cm^2
Hydraulic Pressing (vacuum enclosure)	200-250 PSI 14-18 kg/cm^2

Single-Stage and Dual-Stage Press Cycle Lamination

The following pages outline the suggested lamination parameters for the single-stage and dual-stage lamination cycles. The lamination cycle selected will be a function of board stack up, complexity and thickness as well as the lamination presses capability. Note that the following graphs are for reference purposes only and may require adjustment depending on the board size, thickness and complexity. ***Thicker boards may require additional dwell time at curing temperature to achieve full cure.*** See “Standard Lamination” previously discussed.

Choosing a dual stage or “kiss” cycle for FR406 multilayer boards may improve results in some applications. Use these cycles to enhance the wetting of the glass along the extreme edges and corners of the panel or to minimize circuit image transfer (“telegraphing”) on foil constructions.

All cycles include a pressure reduction step in the lamination cycle, which facilitates stress relief of the package during the cure step.
Further, all cycles assume vacuum is maintained throughout the heating cycle and all cycles presume that the book is cooled to a temperature well below the Tg of the material before the press is opened. All three conditions are considered to represent “best practice” conditions during lamination by Isola.

While use of both the pressure drop cycle and cooling well below Tg in the “hot” press are strongly suggested, these steps are considered to be “optional” and the PCB fabricator may have equipment or capacity limitations which prevent following these suggestions.

Single-Stage Lamination (No “Kiss” Cycle)

1. Load/center the package as quickly as possible. Pull vacuum for 30 minutes on lifters.
2. Apply full pressure of 200-350 PSI (14.1-24.6 kg/cm^2) on the panels. Suggest 275 PSI (19.3 kg/cm^2 for initial pressure setting. See Table 2.
3. Adjust heat rise to ~4.5-6.7°C/min (8-12°F/min), as measured between 79-135°C (175-275°F) by controlling the platen ramp rate and/or by using the appropriate amount of pressure padding.
4. Cure for a minimum of 50 minutes @ 177°C (350°F) once the package center reaches the specified set point. NOTE: A 60-70 minute cure may be appropriate for high layer count boards or boards ≥ 0.125″ (3.2 mm) in thickness. Boards below 0.070″ in thickness may be cured for 50 minutes.
5. If possible, reduce the pressure to 50 PSI (3.5 kg/cm^2) after package has been at cure temperature for 15 minutes. This will relieve stress which may assist subsequent lead-free processing.
6. Cool material as slowly as possible or at 2.8°C/min (5°F/min),down from 185°C (365°F) through 135°C (275°F). Post baking is not required.

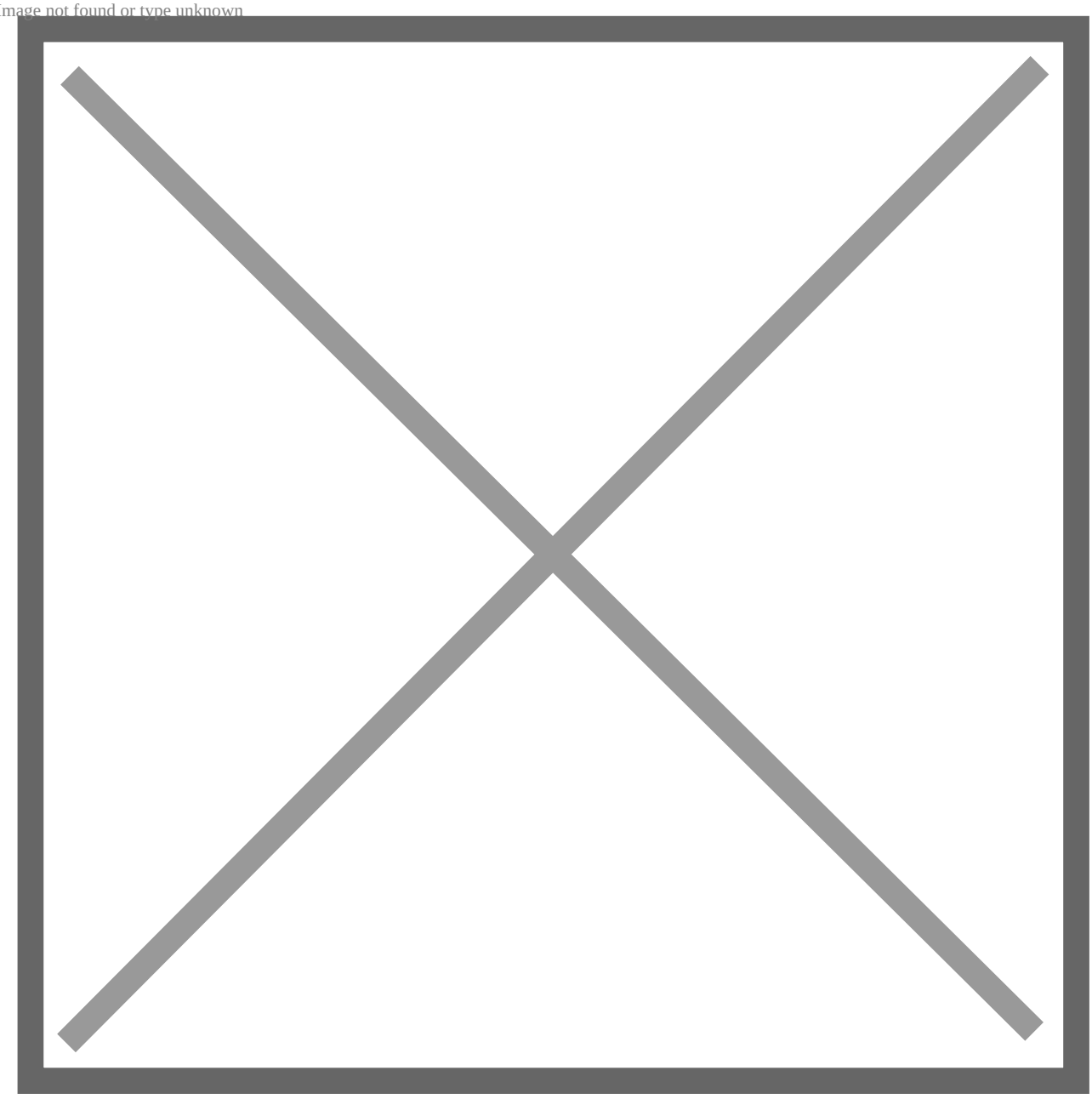
Suggested FR406 Single-Stage Pressure-Temperature Profile

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FR406

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Please note: This is not a press control program! The graph represents the preferred pressure/temperature profile panels are subjected to during the lamination program cycle. ***Note that the actual high pressure setting and cure duration chosen may differ from the 275 PSI suggested setting shown in this graph. Press pressure and cure duration selected may depend upon board design as well as other factors.***

Dual-Stage Lamination (With "Kiss" Cycle)

Choosing a dual-stage or "kiss" cycle for FR406 may improve results in some applications. Use these cycles to enhance the wetting of the glass along the extreme edges and corners of the panel or to minimize circuit image transfer ("telegraphing") on foil constructions.

Develop dual-stage cycles based on the temperature of the stack at various locations. It is essential that the temperatures of the top and bottom panels in the stack be below full fluidity temperature when high pressure is applied. ***Ensure that the temperature* difference between the center and outside of the stack is less than 22°C (40°F) when full pressure is applied.**

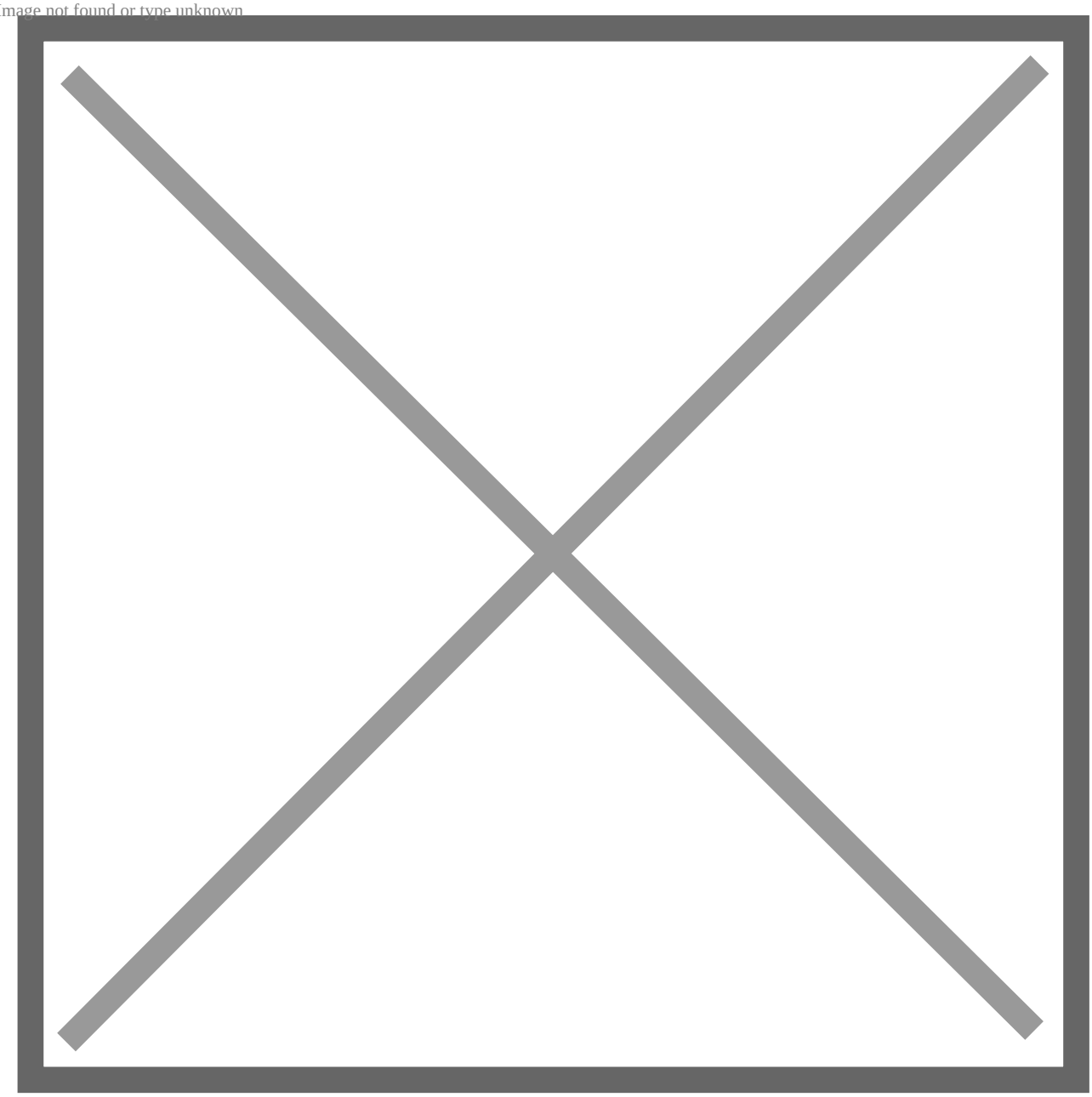
1. Load/center the package as quickly as possible. Pull vacuum for 20 minutes on lifters.
2. Close press and apply 50 PSI (3.5 kg/cm^2) pressure. Adjust heat rise to ~4.5-6.7°C/min (8-12°F/min), as measured between 79-135°C (175-275°F) by controlling the platen ramp rate and/or by using the appropriate amount of pressure padding.

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3. Apply full pressure of 200-350 PSI (14.1-24.6 kg/cm^2) on the panels when the center of the stack reaches 93°C (200°F). Suggest 275 PSI (19.3 kg/cm^2) for initial pressure setting. See Table 2. NOTE: The exterior (top and bottom) panel temperature must be ≤ 110°C (230°F) when full pressure is applied. Cure for a minimum of 50 minutes @ 185°C (365°F) once the package center reaches the specified set point. NOTE: A 60-70 minute cure may be necessary for boards ≥ 0.125″ (3.2 mm) in thickness.
4. Use stress relief and cooling cycles as with single-stage lamination. Post baking is not required.

Suggested FR406 Dual-Stage Pressure-Temperature Profile

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Please note: This is not a press control program! The graph represents the preferred pressure/temperature profile panels are subjected to during the lamination program cycle. ***Note that the actual high pressure setting and cure duration chosen may differ from the 275 PSI suggested setting shown in this graph. Press pressure and cure duration selected may depend upon board design as well as other factors.***

Part 4: Drill

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General

Standard drill bit geometries have been used with FR406 with good results. However, to assure effective removal of the resin debris during drilling, undercut drill geometries and high helix tools are suggested. On high layer count technologies and thicker overall board thicknesses, peck drilling parameters may be necessary. Suggested parameters are outlined below for typical multilayer designs.

Cutting Speed and Chipload

Maximum cutting speeds of 550 to 600 SFPM are suggested. Chiploads should not exceed 3.5 mils for bit diameters of .040″ and above. ***Table 3*** gives drill parameters by bit diameter for a maximum cutting speed of 550 SFPM and maximum chipload of 3.0 mils.

Cutting speeds and chiploads in excess of those in ***Table 3*** have been successfully implemented on all of Isola's FR-4 products in 6 to 12 layer .060″ (1.6 mm) thick boards. The parameters in Table 3 provide a moderate initial starting point for typical board designs. Thick boards with heavy copper or special cladding such as invar will require more conservative drill parameters.

Stack Height and Hit Count

Stack heights and hit counts will vary according to construction and overall thickness of the boards being drilled. Standard .060″ thick boards have been successfully stacked 3 high for bit diameters down to 13.5 mils. As a general guideline, the sum of the board thickness in a multilayer drill stack should not exceed 200 mils. Maximum hit count for a small drill diameter is 1000. For drill diameters of 13.5 mils and greater, maximum hit count is 1500.

Table 3: Suggested Drilling Parameters For Initial FR406 Setup

Drill Size		Spindle Speed	Surface Speed Per Minute		Infeed		Chipload		Retract	
in	mm	RPM	SFPM	SMPM	in/min	m/min	mil/rev	mm/rev	in/min	m/min
0.0098	0.25	120,000	309	94	75	1.91	0.63	0.016	600	15
0.0118	0.30	105,000	325	99	82	2.08	0.78	0.020	800	20
0.0138	0.35	100,000	361	110	90	2.29	0.90	0.023	800	20
0.0157	0.40	91,000	375	114	96	2.44	1.05	0.027	1000	25
0.0197	0.50	92,000	474	145	100	2.54	1.09	0.028	1000	25
0.0256	0.65	84,000	563	172	130	3.30	1.55	0.039	1000	25
0.0295	0.75	70,000	541	165	140	3.56	2.00	0.051	1000	25
0.0354	0.90	58,000	538	164	145	3.68	2.50	0.064	1000	25
0.0394	1.00	52,000	536	163	155	3.94	2.98	0.076	1000	25
0.0500	1.27	42,000	550	168	125	3.18	2.98	0.076	1000	25
0.0591	1.50	35,000	541	165	105	2.67	3.00	0.076	1000	25
0.0787	2.00	26,000	536	163	78	1.98	3.00	0.076	1000	25

Part 5: Hole Wall Preparation

General

Good desmear and electroless copper deposition performance are more easily achieved when the drilled hole quality is good. The generation of smooth, debris free hole walls is influenced by the degree of resin cure, drilling conditions and board design considerations. The elimination of 7628 or similar heavy glasses (whenever possible), coupled with properly adjusted drill parameters on fully cured boards has been shown to improve overall drilled hole quality. This helps reduce smear generation, which improves desmear performance and can ultimately help to reduce copper wicking.

Factors which influence chemical desmear rates, and therefore the suggestions in this document, include: resin type, chemistry type, bath dwell times, bath temperatures, chemical concentrations in each bath and the amount of solution transfer through the holes.

Factors which influence the amount of solution transfer through the holes include: hole size, panel thickness, work bar stroke

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length, panel separation in the rack and the use of solution agitation, rack vibration and rack “bumping” to remove air bubbles from the holes.

Chemical Desmear
Conventional permanganate desmear systems are effective for removal of FR406 resin from interconnect posts. Dwell times and temperatures typically used for most high performance materials should be satisfactory. Consult the chemical supplier for suggested conditions.

Plasma Desmear
If available, plasma can be used with or without a single permanganate pass (to be determined by each fabricator). Plasma processing tends to improve overall hole quality, particularly in thick and/or high aspect ratio boards. Standard plasma gas mixtures and cycles are satisfactory. ***Care must be exercised to avoid excessive resin removal if both plasma and permanganate are employed together.***

3-Point Etchback
True 3-point “etchback” exposes the innerlayer “post” on all three sides for subsequent plating processes. This will require a more robust approach compared to simple desmear, which is designed only to remove resin smear from the vertical surface of the innerlayer interconnect “posts”.

Plasma will readily etch back FR406 resin. Standard plasma gas mixtures and process cycles designed for conventional FR-4 epoxy are satisfactory and are suggested for use as initial starting parameters for etchback of FR406. The practice of following the plasma process with a chemical process is suggested rather than plasma alone to increase hole wall texture and remove plasma ash residues.

If plasma is not available, chemical etchback for 3-point connections can usually be accomplished using a double-pass through the permanganate line. Some fabricators have found a post-drill bake for 2 hours @ 375°F with boards racked (not stacked) accelerates resin removal rates with permanganate systems. Care must be taken when using a double-pass to minimize copper wicking. Consult the chemical supplier for suggested conditions.

Secondary Drilling
The use of entry and backer material may be necessary during the secondary drilling of larger hole sizes to avoid crazing/fracturing at the hole perimeter. Additionally, sharper plunge point angle geometries may be necessary to avoid crazing around secondary drilled hole perimeters.

Routing and Scoring
Modifications of the final PWB route fabrication process may be necessary. Table 4 lists initial starting parameters using chip breaker or diamond cut tool designs. Note that parameters listed may require further adjustment.

Table 4: Suggested Routing Parameters for Initial FR406 Setup

Tool Diameter		Spindle Speed	Spindle Travel Speed	
in	mm	RPM	in/min	m/min
0.062	1.57	45,000	20	0.51
0.093	2.36	35,000	40	1.02
0.125	3.18	25,000	50	1.27

Chip breaker or diamond cut tool designs recommended.

For PWB designs requiring scored geometries, the testing of various Tg’s and resin content materials has determined that adjustments to the process will be necessary. As the modulus strength of materials increases, the maximum resultant web thickness (dependent on the scored edge depth) must be decreased to avoid excessive fracturing upon breaking away the scored materials. Individual board designs/stack-ups may require adjustment of score depth geometries. Thinner web thicknesses are typically required. This is influenced by layer count, glass types and retained copper in the design. The customer should contact the scoring equipment and/or bit supplier for application specific suggestions for use with FR406 materials. Your Isola Technical Account Manager may also be able to provide some initial suggestions, but these should be validated through testing by the individual PWB fabricator.

Part 6: Packaging and Storage

FR406 finished boards have low moisture sensitivity and good shelf life. However, Isola recommends using best practices in storage

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and packaging, as noted below, to reduce risk during lead-free assembly.

FR406 boards should be dry prior to packaging to ensure the most robust lead-free performance. For some complex, high reliability designs, baking prior to solder mask application can be implemented to ensure maximum floor life in assembly processing. Printed boards made for high temperature assembly from FR406, which require a long shelf life, the best protection is provided using a Moisture Barrier Bag (MBB) with a Humidity Indicator Card (HIC) and adequate drying desiccant inside the MBB to prevent moisture absorption during shipment and
long-term storage.

Upon opening the MBB, the boards should be processed within 168 hours when maximum shop floor conditions are at < 30°C (85°F)/60% RH. MBB bags that are opened for inspection should be resealed immediately to protect the boards from moisture uptake.

Part 7: Health and Safety

Always handle laminate with care. Laminate edges are typically sharp and can cause cuts and scratches if not handled properly. Handling and machining of prepreg and laminate can create dust (see FR406 Material Safety Data Sheet).

Appropriate ventilation is necessary in machining/punching areas. The use of protective masks is suggested to avoid inhaling dust. Gloves, aprons and/or safety glasses are suggested if individuals have frequent or prolonged skin or eye contact with dust.

Isola Group does not use polybromidebiphenyls or polybromidebiphenyloxides as flame retardants in any product. Material Safety Data Sheets are available upon request.

Part 8: Ordering Information

Contact your local sales representative or contact: ***info@isola-group.com*** for further information.

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NOTES

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