# FR402

**Tetrafunctional 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, FR402 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 FR402 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 FR402. 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, material movement must be uniquely characterized.

**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 FR402 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**

FR402 laminates are imaged using standard aqueous dry films and are compatible with both cupric chloride and ammoniacal etchants.

**Oxide Treatment**

The following treatments are acceptable for adequate bonding of these epoxies: black oxide, brown oxide, red oxide and double treat copper. If black oxide is used, the oxide should be self limiting to avoid excessive oxide crystal. The various reduced and alternative oxides available on the market have also provided adequate bond strength.

Innerlayers should be thoroughly dried in an oven prior to lay-up. The typical bake cycles, which fall between 200-250°F for 30 to 60 minutes are acceptable. If reduced or alternative oxides are used, consult the chemical supplier for post oxide baking considerations as excessive baking may lead to lower pink ring resistance. It is recommended that baking is performed in vertical racks with panels supported in an upright position.

**Table 2: FR402 General Lamination Parameters**

| Process | Recommendation |
|---|---|
| Vacuum Time | 20 minutes (no pressure, product on risers) |
| Curing Temperature | 180°C (350°F) |
| Curing Time | 50 minutes above 180°C (350°F)<br>70 minutes for thicker boards (>3 mm) |
| Resin Flow Window | 80-135°C (180-280°F)<br>Maintain heat ramp in this temperature range. |
| Heat Ramp | 4.5-6.5°C/min (8-12°F/min) |
| Pressure | 200-250 PSI 14-18 kg/cm$^2$ |
| Pressure Application | Single Stage Apply pressure after vacuum dwell time. - Dual Stage 3.5 kg/cm$^2$ (50 PSI) after vacuum dwell time, switch to high pressure ≤ 90°C (194°F) product temperature. |
| Pressure Drop | After 20 minutes at cure temperature, reduce pressure to 3.5 kg/cm$^2$ (50 PSI) in hot press (optional). |
| Cool Down | Cool to 135-140°C (275-285°F) at 2.8°C/min (5.0°F/min) with 3.5 kg/cm$^2$ (50 PSI) pressure prior to removing or transferring the load. |

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

## Part 3: Lamination

### Standard Lamination

The amount of time at cure temperature, and to some extent the actual cure temperature of FR402, 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.

Removal of FR402 flash should be performed by routing rather than shearing to minimize crazing along the panel edges.

### Single-Stage and Dual-Stage Press Cycle Lamination

The suggested lamination parameters for the single-stage and dual-stage lamination cycles are shown in ***Table 2***. 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 FR402 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.

## Part 4: Drill

### General

Standard drill bit geometries have been used with FR402 with good results. Drill wear for FR406 should be identified independently from FR402 or IS402.

### 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 4 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 4: Suggested Drilling Parameters For Initial FR402 Setup**

| Drill Size | | Spindle Speed | Surface Speed Per Minute | | Infeed | | Chipload | | Retract | |
|---|---|---|---|---|---|---|---|---|---|---|
| in | mm | RPM | SFPM | SMPM | in/min | m/min | mil/rev | m/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 | 375 | 110 | 90 | 2.29 | 0.90 | 0.023 | 800 | 20 |
| 0.0157 | 0.40 | 91,000 | 474 | 114 | 96 | 2.44 | 1.05 | 0.027 | 1000 | 25 |
| 0.0197 | 0.50 | 92,000 | 563 | 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 |
| 0.0787 | 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 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 FR402 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.

### Etchback of FR402

A positive etchback of several tenths of a mil can be achieved on FR402 with most standard permanganate processes. Some shops have identified that a double pass permanganate process assures a more repeatable etchback when processing tetrafunctional epoxy blends.

## Part 6: Packaging and Storage

FR402 finished boards have low moisture sensitivity and good shelf life. However, Isola recommends using best practices in storage and packaging, as noted below, to reduce risk during lead-free assembly.

FR402 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 FR402, 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 FR402 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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## Tetrafunctional Epoxy Laminate and Prepreg