

# RT/duroid® 6002 High Frequency Laminate Direct Bonding

## *Discussion of Fusion Bonding Methods*

RT/duroid®6002 high frequency laminate is the preferred PTFE-based laminate for multilayer applications. With its low Z-axis thermal expansion (24 ppm/°C) and high melt point (620°F), RT/duroid 6002 laminates meet stringent reliability requirements. Commercially available bonding films are commonly used to bond fabricated circuit layers. Unfortunately, these bonding films generally have high thermal expansion coefficient (~200 ppm/°C) and melt points below 550°F. Delamination or fracture of plated through-holes can occur if the melt point of the adhesive is exceeded during soldering or testing. Also, fatigue failure of plated through-holes can occur during thermal cycling below the melt point because of these high thermal expansion films in multi-layer structure.

Fusion bonding solves these problems by eliminating the need for high thermal expansion bonding films. During fusion bonding, adjacent dielectric and circuit layers are fused directly by heating the RT/duroid 6002 laminate dielectric above its melt point, under pressure. The resulting structure has excellent thermal stability since RT/duroid 6002 laminate has low thermal expansion up to its melt point (620°F). Therefore, the multi-layer board can be exposed to common soldering and testing temperatures (500°F-550°F) without delaminating or fracturing plated through-holes.

	Hydraulic Press		Autoclave
	1700 psi	250 psi	250 psi
Direct Bond - (No blind cavities)	✓	✓	✓
Direct Bond - (Blind cavities)		✓ <sup>2</sup>	
Fusion Bond with Bond-Ply	✓ <sup>1</sup>		

Figure 1. Bonding options for plated through-hole boards (dielectric <sup>3</sup> 0.010" thick, copper £1 oz.).

- 1) Provides superior adhesion to copper ground planes.
- 2) Accelerated cycle (10-15 minute soak at 700°F)

The fusion bonding process also offers superior dielectric homogeneity, since it eliminates bonding films which generally have different dielectric constants ( $\epsilon_r \approx 2.1-2.3$ ). RT/duroid 6002 laminate has a  $\epsilon_r$  of 2.94.

There are two common approaches to fusion bonding. Either circuit layers are direct fusion bonded or bond-ply is used.

### Direct Fusion Bonding

With direct fusion bonding, etched circuit layers are stacked between tooling plates and bonded to each other. Either single sided circuit layers can be stacked on top of each other or a completely etched laminate can be incorporated between double sided circuit layers (figure 2, next page). During the fusion bonding process, dimensional change is minimal due to the extremely high melt viscosity of the PTFE composite. As a reference, the viscosity of PTFE above its melt point is approximately the same as lead (Pb) at room temperature.

Because of the limited flow during bonding, it is essential that dielectric thicknesses and bonding pressures be adequate to fill circuit features. To fill 1 oz. features with 10 mil dielectric thicknesses, bond pressure should be at least 250 psi. Higher pressures will yield better adhesion to copper ground planes. Pressures as high as 1700 psi are sometimes used.

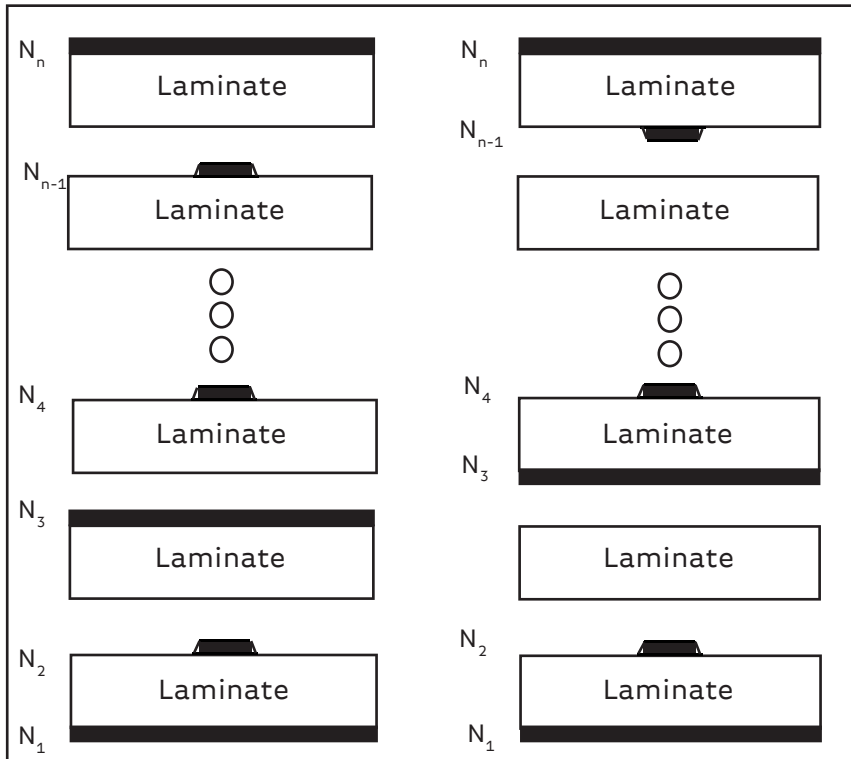


Figure 2.

### Fusion Bonding with Bond-Ply

Bond-ply is a lower density version of the RT/duroid 6002 laminate material. During the bonding process, bond-ply densifies to yield the same electrical and mechanical properties as the laminate. Bond-ply is often used in a manner analogous to prepreg in FR4 constructions (figure 3). The advantages of using bond-ply include improved adhesion to copper ground planes and better circuit feature fill. For microwave application, 1700 psi bonding pressure should be utilized with one hour dwell to obtain a uniform dielectric constant. Use of lower pressure will result in a lower effective dielectric constant. Only presses rated for at least 1700 psi should be used.

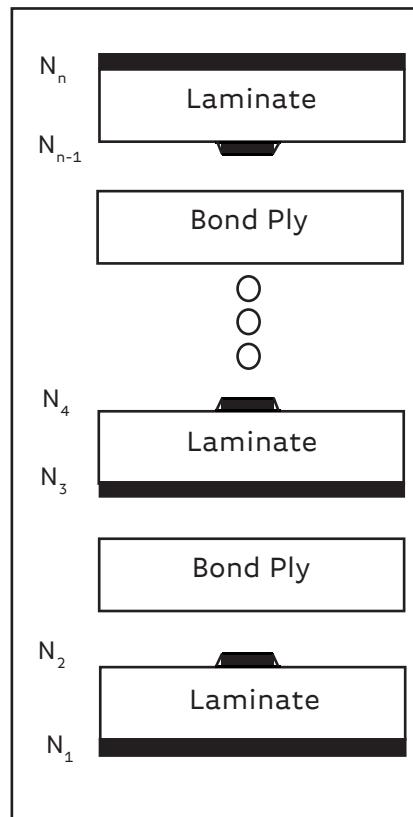


Figure 3.

In a study completed at the Rogers Lurie R&D Center, the use of 1700 psi bond pressures with bond-ply was found to yield average copper peel strengths of at least 7 lbs/linear inch (pli). With etched laminates, average smooth copper bond strengths were typically found to be above 4 pli when 250 psi pressure was used, and above 5 pli when 1700 psi was used.

Fusion bonding with bond-ply should be used if copper adhesion is a major concern or thin laminates with relatively thick cladding are being bonded. For examples, bond-ply should be used if 5 mil laminates with 1 oz. cladding are being bonded.

### Fusion Bond Cycle

A typical bond cycle is shown in figure 4. The dwell can be adjusted to account for thermal lags in the press for autoclave package. Fusion bonds have been successfully demonstrated with very short dwell times when reasonably thick, single parts were bonded. However, when thermal lags are significant or bond-ply is utilized, longer dwells are recommended.

Since RT/duroid 6002 laminate is a thermoplastic material it does not cure during bonding like conventional multilayer board materials (thermosets). Therefore, heating rates do not affect properties. Heating rates should be defined based on the capability of the equipment utilized.

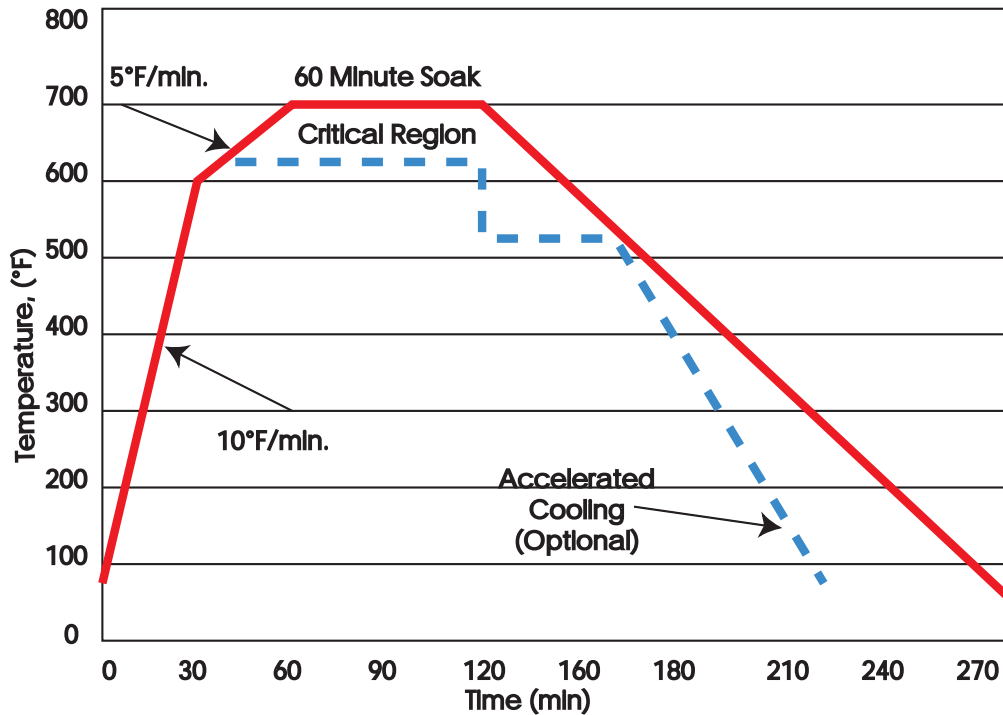


Figure 4.

Higher heating rates are acceptable if the equipment can maintain good part temperature uniformity and control at the higher rates. The period of time and temperature distribution above the melt point (620°F) are most critical. Part temperatures should be at or above 700°F for at least 10-15 minutes. Temperatures in excess of 730°F should be avoided. Parts should be bonded under vacuum or a nitrogen blanket to minimize copper oxidation.

### Surface Preparation

PTFE surface activation is not recommended prior to fusion bonding RT/duroid 6002 laminate. Copper surfaces should be clean and free of any contaminants. Oxide treatments (red or brown) can be used but are not required. Heavy oxide treatments should be avoided. All laminates should be completely dry prior to bonding. A 1 hour bake at 300°F is often used to insure that parts are dry.

### Bonding Package

Conventional tooling schemes can be used to bond RT/duroid 6002 laminate constructions. For any PTFE-based material, dimensional change can be minimized by using caul plates with similar in-plane thermal expansion coefficients. For RT/duroid 6002 laminate, 304 stainless steel has been found to yield good results. Aluminum caul plates should never be used for bonding RT/duroid 6002 laminate. When bonding in a platen press, press pads should be used to compensate for small imperfections in the press platen. Separator materials and press pad materials used in any fusion bonding package must be able to withstand the 700°F bonding cycle. Aluminum or copper foils are commonly used separator materials.

Additional information regarding specific applications is available upon request.

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