RT/duroid® 6002/6006/6010 High Frequency Laminates Fabrication Guidelines

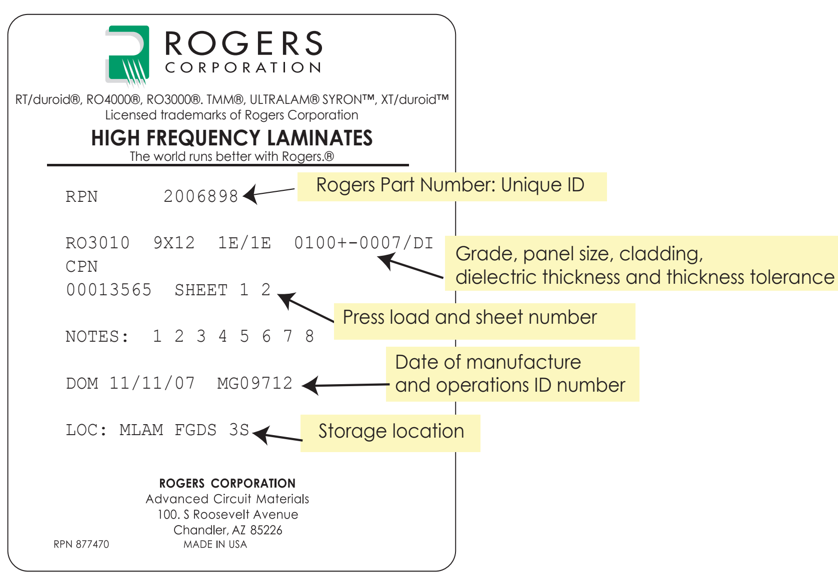
Notes on Packaging, Receiving, Storage, and Preparation for Processing

Packaging

High frequency circuit laminates are shipped in reinforced corrugated cardboard containers. Filler cardboard sheets, self-adherent polyethylene sheets, and vacuum-sealed poly bubble pack protect the materials against damage during shipping.

Receiving

1) Open the shipping cartons and inspect material immediately upon receipt.
2) Advise the carrier of any shipping damage noted. It is helpful to photograph the containers and contents to support your claim.
3) All quality problems should be reported to Rogers' Customer Service as soon as possible, and not later than 30 days after receipt of the product. You may contact by telephone or in writing:
4) Damaged or rejected material should not be returned without a proper return authorization obtained from the Customer Service Representative. Returns without proper authorization may be refused.
5) Every panel is packaged and labeled with the product identification and lot and sheet numbers. An example of a typical label is provided. Verify that this label is present on individual cores when the shipment is received.
6) Rogers Corporation maintains full traceability records for individual laminates based upon lot and sheet numbers. Maintaining traceability is often essential to understanding and correcting any problems that may arise. It is strongly urged that customers adopt an appropriate procedure for maintaining the identification of individual panels through storage, processing, and delivery of final product.



Storage

RT/duroid® 6000 PTFE-based laminates can be stored indefinitely at normal ambient room temperatures (65°F to 85°F, 18°C to 30°C) and normal humidity levels. At room temperature, the dielectric materials are inert to high humidity and atmospheric pollutants such as industrial gases and marine salts. However, metal claddings, such as copper foil or thick aluminum, brass, and copper backing, can be oxidized or corroded during direct exposure to

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high humidity, sulfur oxides, and marine salts. The adherent polyethylene cover sheet (thick cores) and polythelene bag (thin laminates) provide a large measure of protection from corrosive atmospheres. Normal cleaning procedures, covered later in this publication, readily remove traces of corrosion from properly stored materials.

Storage in Original Shipping Cartons

1) Stack cartons on a flat surface that is safely out of the way of mobile handling and moving equipment.
2) Cartons should be stacked to a maximum of five high to avoid excessive weight on the bottom packages.

Storage of Panels Removed from Cartons

1) Thin panels should remain sealed within the polyethylene bags, and the adherent polyethylene sheets should remain on thicker cores. These packaging materials deter oxidation and corrosion of the metal layers and provide a measure of protection against mechanical damage (i.e., scratches, pits, dents, etc.).
2) Store panels on edge in slotted shelving units, keeping the clad surfaces vertical. This provides easy access with low risk of damage to the metal surfaces.
3) If storage facilities do not permit vertical stacking:
   A) The shelf must be flat, smooth, and clean.
   B) The shelf must extend beyond the full area of the panels being stored.
   C) Surfaces of the laminates must be free of debris.
   D) Shelf loading should be kept below 50 pounds per square foot.
   E) Panels should be interleaved with soft, non-abrasive separator sheets.

Handling

PTFE-based materials are softer than most other rigid printed wiring board laminates and are more susceptible to handling damage. Cores clad only with copper foils are easily creased. Materials bonded to thick aluminum, brass, or copper plates are more prone to scratches, pits, and dents. Proper handling procedures should be followed.

1) Wear gloves of knit nylon or other non-absorbent material when handling panels. Normal skin oils are slightly acidic and readily corrode copper surfaces. Fingerprints are difficult to remove as normal brighteners dissolve the corrosion, but leave corrosive oils in the copper to cause the fingerprint to reappear hours or days later. The following procedure is recommended to remove fingerprints:
   A) Bright dip in dilute hydrochloric acid.
   B) Degrease in acetone, methyl ethyl ketone, or vapor degrease with chlorinated solvents.
   C) Water rinse and bake dry for 60 minutes @ 250°F (125°C).
   D) Repeat bright dip.
2) Keep work surfaces clean, dry, and completely free of debris.
3) Leave the polyethylene bag or sheet in place through initial processes such as shearing, sawing, blanking, and punching.
4) Only pick panels by two edges. Thin cores in particular lack the stiffness required to support themselves by one edge or corner, handling them in that manner may dimensionally distort the dielectric or impart a permanent crease.
5) During processing, cores should be transported between work stations on flat carrying trays, preferably interleaved with a soft, sulfur-free paper. Vertical racks should not be used unless they are slotted and provide adequate vertical support.

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Single- and Double-Sided PCB Fabrication Guidelines

Surface Preparation

For panels protected by self-adhering polyethylene sheet, use the following steps to remove it and any adhesive residue. This should be done prior to drill (double-sided process) or just before the final copper cleaning step that immediately precedes the application of photoresist in a single-sided process. As previously mentioned, gloves should be worn.

1) Lay the panel on a flat clean surface.
2) Peel back the film at one corner and extend the starting peel across the short edge.
3) Hold the exposed panel end against the flat surface and gently peel off the film in a horizontal direction away from the starting edge.
4) Turn the panel over and remove the film on the other side in a similar manner. Make sure that the work surface remains clean.
5) Remove adhesive residue by wiping with a lint-free cloth soaked in an alcohol solvent. Isopropanol, 70% to 100%, is recommended for low toxicity and flammability. Ketones, such as acetone or MEK, or halogenated hydrocarbon degreasing solvents are not particularly effective for removing adhesive spots.
6) The solvent clean should be followed with a clean water rinse.
7) Remove copper oxides using commercially available cleaners and microetchants.
8) **Abrasive cleaning (e.g., pumice powder or conveyorized brush scrubbing) is not recommended.** Mechanical surface preparation tends to cause microscopic scratches in copper. These scratches become stress risers that can lead to thermal stress cracks in some environmental conditions. While strongly recommending against abrasive cleaning, we recognize that in some circumstances that abrasive cleaning is necessary. When abrasive cleaning is required, it should be performed with minimal pressure and knowledge of the risks involved. Brush scrubbing may cause material distortion.

Tooling Holes

Pinning or tooling holes can be punched, drilled, or routed using normal procedures.

Drilling

Avoiding Smear

Smear on drilled via walls is a well-known problem with epoxy-glass laminates. Overheated tools can thermally decompose the epoxy resin system causing it to soften. The softened resin system stretches slightly during drilling, causing a connected "flap" of resin to form. Furthermore, small pieces of debris may become lodged during drilling between the hole wall and the tool when they become shear-deformed and are loosely re-deposited. Resin flaps and re-deposited debris can be removed during plasma or permanganate desmear processes.

Similar types of smear occur when drilling PTFE composites. While re-deposited debris can be dislodged using vapor honing, a proven way does not exist to remove the flap-style smear that is connected to a hole wall. As smear cannot be readily removed, it must be avoided by employing tightly controlled drilling parameters and conservative tool life expectations.

Stack Construction

RT/duroid® 6000 cores can be drilled individually or in stacks using pressed phenolic composite boards for entry and exit. The total thickness of the core material plus entry material and penetration into exit material should not exceed 75% of the drill's flute length. For most applications, the maximum stack height should be less than 0.240 inch (6.1 mm).

Drill Type

Carbide drills should be used to minimize wear of cutting edges. Standard style drills with an included lip angle of 130° are recommended. Undercut style drills where the flute diameter is reduced 0.025" (0.65 mm) from the cutting end may help to reduce re-deposited smear. The use of new drills is strongly urged. Re-pointed drills, if used, must be precision ground and visually inspected prior to use.

Drill Parameters

The optimum tool surface speed and infeed rates are 250-300 surface feet per minute (60 to 90 meters per minute) and 0.002" (0.045 mm) to 0.003" (0.070 mm) per revolution. The retract rate should be maintained between 400 and 500 inches per minute (10 and 13 meters per minute). The drill bit should be changed once it has drilled 12" (30 cm) of dielectric.

Equations for using surface speed, infeed rate, and tool diameter to calculate spindle and infeed speeds are provided below along with a quick-reference table:

Entry	Phenolic Composite	0.010"-0.030" (0.25-0.75 mm)
Exit	Phenolic Composite	>0.060" (1.5 mm)
Chip Load		0.002"-0.003" (0.045-0.070 mm)
Surface Speed		200-300 ft/min (60-90 m/min)
Retract Rate		400-500 inch/min (10-13 m/min)

Tool Life Estimate:	Stack Height	Maximum Hit Count
	0.060" (1.5 mm)	300
	0.120" (3.0 mm)	250
	0.180" (4.5 mm)	100

Equations for calculating spindle speed and infeed rate:

Spindle Speed (RPM)=950/Tool Dia (inch)

Infeed (IPM)=Spindle Speed (RPM) X 0.002 (inch)

Tool Size		Spindle Speed	Infeed	
(in)	(mm)	(RPM)	(IPM)	(m/min)
0.0197	0.50	48200	96.4	2.4
0.0256	0.65	37100	74.2	1.9
0.0295	0.75	32200	64.4	1.6
0.0394	1.00	24100	48.2	1.2
0.0492	1.25	20000	40.0	1.0
0.0625	1.59	20000	40.0	1.0
0.1250	3.18	20000	40.0	1.0

Deburring

The use of flat, rigid entry/exit materials, conservative drilling parameters, and limited hit counts with new drills should minimize the risk of copper burring. When drilled properly, the cores should be ready for subsequent processing. Chemical preparation is preferred, but if mechanical or hand pumice scrubbing processes are used to deburr boards, the force applied must be minimized to prevent gouging and dimensional distortion.

Hole Preparation

Loosely re-deposited debris in the holes can be removed using vapor- or hydro-honing processes. These processes involve directing abrasive particles carried in water or air streams through drilled holes. The soft laminates must be adequately supported through these processes.

Drilled holes in PTFE-based laminates must be treated prior to the deposition of a conductive seed layer (e.g., electroless copper or direct metallization). Not performing a surface activation treatment will most likely result in poor metal adhesion or plated voids. Two common pre-treatments for PTFE materials are sodium treatment and plasma treatment. Either can be used for treating RT/duroid 6000 materials.

Sodium treatments consist of highly reactive sodium naphthalene compounds in glycol ether solution. They are very effective at making PTFE surfaces wettable prior to metal deposition. Recommended application procedures available from the vendors of sodium treatment products are applicable when processing RT/duroid 6000 materials with one exception. The treatment time must not exceed thirty seconds. Controlling exposure time is required to reduce the risk of absorption of chemicals into the dielectric material surrounding the drilled holes. Sodium treated RT/duroid 6000 cores should be baked at 125C for 60 minutes just prior to metallization.

Sources for sodium treatment chemicals:

FluoroEtch® Etchant
Acton Technologies, Inc
100 Thompson St
Pittston, PA 18640
570-654-0612

W.L. Gore Tetra-Etch® etchant 500 ML available from
R.S. Hughes Company, Inc
1162 Sonora Court
Sunnyvale, CA 94086
408 739 3211

Sources for sodium treatment services:

FluoroEtch Etchant
Acton Technologies, Inc
100 Thompson St
Pittston, PA 18640
570-654-0612

G & S Associates
1865 Sampson Ave.
Corona, CA 92879
http://www.gsassociates.com
951 739 7513

A recommended plasma treatment prior to metal desposition would use a 70/30 H2/N2 blend, NH3, or N2 gases. Plasma conditions would be:

Pressure:	100 mTORR Pump-down
	250 mTORR Operating
Power:	4000 Watts
Frequency:	40 KHz
Voltage:	500-600 V
Cycle Time:	10-30 Minutes

Metallization

Electroless copper processes or electroless copper alternatives such as Crimson, Shadow, and Black Hole may be used to deposit a conductive seed layer once the PTFE surface has been properly treated (and baked if a sodium treatment process was used). As the PTFE resin system is soft and somewhat compressible, a flash plate build-up of copper 0.0001"-0.0003" (0.0025-0.0076mm) thick should be applied prior to preparing metal surfaces for photoresist.

Resist Strip, Cu Etch, Sn or Sn/Pb Strip

Standard etchants and strip solutions may be used. Thin cores may require the support of leader boards or frames through conveyorized processes. Complete rinsing (preferred: 20-30 minutes in 70F+ distilled or de-ionized water) and baking (preferred: 125°C for 60 minutes in air or for 30 minutes under vacuum) of cores should immediately follow the final strip process.

The post-etched surface of the cores will retain the imprint of the copper cladding's dendritic tooth structure. This surface, if left undisturbed, provides adequate surface area for mechanical bonding of most soldermasks and adhesive systems used for multi-layer bonding. Not wiping or scrubbing the etched surfaces will allow the cores to proceed through soldermask application or multi-layer bonding without requiring special surface pre-treatments.

Soldermask Application

Epoxy-based soldermasks such as Hysol® SR1000 are preferred if the soldermask will be selectively silver screened. Most photoimageable soldermasks have been found to provide adequate adhesion providing the post-etch surface has been preserved and the cores have been baked prior to application of the coating.

Final Metal Surface

All final metal surface options (i.e. HASL, Sn, Sn/Pb, Ni/Au, Ag, OSP, etc.) have been successfully applied to circuits on RT/duroid 6000 materials. Exposure time to fluxes should be less than 30 seconds prior to HASL or reflow. Any processes requiring flux or oil should be immediately followed by a thorough rinse (hot water is preferred, a 15-minute rinse in clean solvents such as methanol, ethanol, or isopropyl alcohol may be required if dielectric has been exposed to water insoluble solvents) and bake (30-60 minutes at 125°C). Electroless nickel/immersion gold (ENIG) finishes should be used on RT/duroid 6010 materials only when absolutely required. ENIG processes can stain the surface of the high dielectric constant materials.

Final Circuitization

Individual circuits in RT/duroid 6000 materials can be routed, scored, punched, or lased depending upon edge quality requirements. Detailed recommendations for routing are provided below:

These guidelines were developed to minimize burrs and maximize tool life when routing stacks of double sided boards. This information should also be applicable to most bonded assemblies.

Guideline Summary:

Chip Load:	0.00125”- 0.00250”/rev. (32 mm - 64 mm/rev.)
Speed:	200 - 600 sfm (61 - 183 m/min)
Peripheries:	Conventional Cut
Internal Cut-outs:	Climb-cut
Tool Type:	Double fluted spiral endmill-carbide
Exit/Entry:	Phenolic or composite board
Tool Life:	20 - 30 linear feet (6 - 9 meters)

* Pre-route vacuum channels in the backer board to provide adequate air flow through the channels during routing.
* Double pass (opposite directions) when two clean edges are required.

Recommended Tool Type:

The machining parameters provided were developed using an Excellon EX200 Driller/Router at Megatool's Buena Park, CA facility. Best results were obtained with a double fluted spiral endmill (Megatool RP series).

Other carbide endmills (ie. single flute, three flute, etc.) may also be used without significantly impacting quality. However, conventional diamond cut and chip breaker router bits should not be used since they generally yield inferior quality and poor effective tool life.

Machining Parameters:

Tool Diameter	Spindle Speed	Lateral Feed Rate
1/32"	40 KRPM (327 sfm)	75 IPM (0.0019/rev.)
1/16"	30 KRPM (491 sfm)	75 IPM (0.0025"/rev.)
3/32"	20 KRPM (491 sfm)	50 IPM (0.0025"/rev.)
1/8"	15 KRPM (491 sfm)	37 IPM (0.0025"/rev.)
1,0 mm	40 KRPM (125 m/min)	2.0 m/min (50 mm/rev.)
1.5 mm	32 KRPM (150 m/min)	2.0 m/min (63 mm/rev.)
2.5 mm	19 KRPM (150 m/min)	1.2 m/min (63mm/rev.)
3.0 mm	16 KRPM (150 m/min)	1.0 m/min (63 mm/rev.)

Entry/Exit/Interleaving Material and Table Configuration:

Burrs and loose debris can be minimized by using entry and exit material, compressible interleaving sheets, and open vacuum channels. The entry and exit material provide the support necessary to minimize material deflection and obtain cleanly cut edges. The interleaving material (often 2-4 sheets of Kraft paper) conforms around metal features and offers support to etched dielectric surfaces. Open channels in the backer material significantly increase the effectiveness of the routing machines vacuum system by allowing air to flow up through channels during routing. This minimizes the need for deburring and debris removal after routing by preventing flute and channel clogging. The vacuum measured at the spindle should be at least 30 in. H2O for best results.

Vacuum channels are prepared by pre-routing the backer material with a tool that is 1.5 to 2.0 times the diameter of the tool used to rout the panels. Channel depth is usually about 0.060" to 0.100" (1.5 - 2.5 mm). The routed peripheries and cut-outs in the backer material are joined with channels that extend to areas outside the panel periphery. This allows air to be drawn through the channels during routing.

Figure #1 (previous page) is an example of a pre-routed backer board. There are two boards per panel. Each board has an internal cut-out. Three connecting channels extend to areas outside the periphery of panels to be routed.

When routing parts, "entry material" is placed above and below the stack of panels.

The "entry material" placed below the stack prevents deflection of material into the oversized vacuum channels in the backer board. During routing, the tool cuts through the thin channel overlay (0.015" to 0.025" entry) to provide access to the vacuum channels.

Figure 1
Pre-Rout Channels in Backer Board

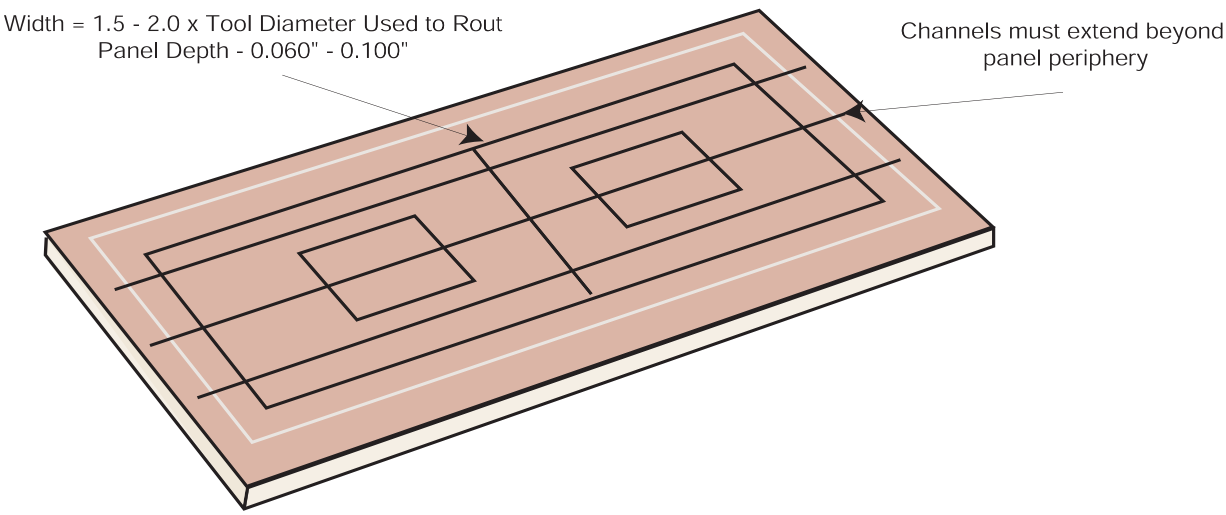


Figure 2

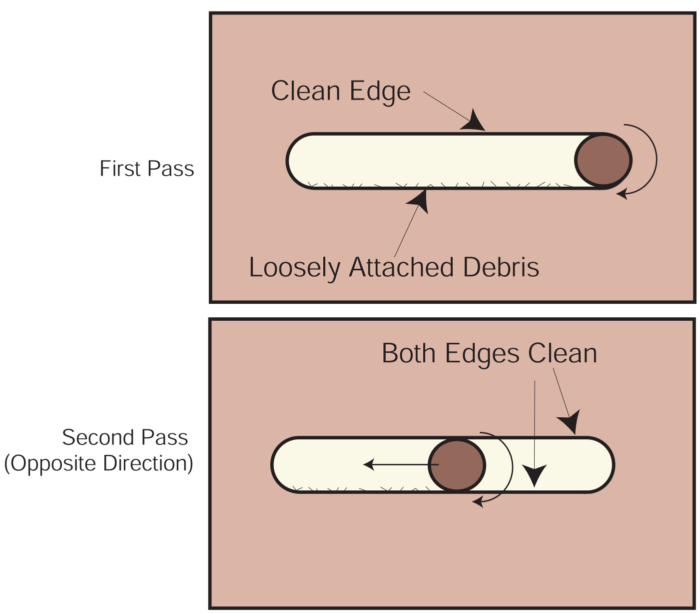


Figure 3
Routing Peripheries
Conventional Cut

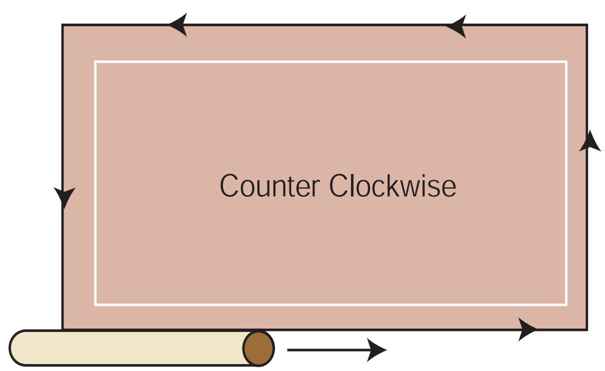
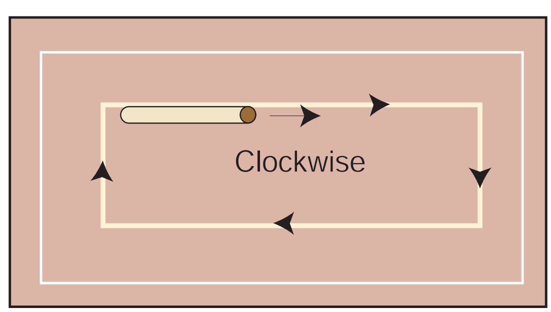


Figure 4
Routing Internal Cut-Outs
Climb Cut



Climb-Cut vs. Conventional Cut:

The leading edge of a routed channel is typically cleaner than the trailing edge (figure #2-previous page). Therefore, peripheries should be conventional cut and internal cut-outs should be climb-cut to maximize edge quality on the finished part (figures 3 & 4). If both edges of a routed channel need to be cleanly cut, the tool direction should be reversed for a second pass through the channels. This will remove most of the debris left on the trailing edge during the first pass (figure #2 - previous page).

Routing Through Copper Cladding:

Routed edge quality is usually superior when routing through the copper foil since it helps constrain the dielectric material. However, good results can generally be obtained with or without copper cladding.

Stack Height:

At least 20%-30% of the flute should be exposed above the entry material to allow for debris removal. This leaves 70%-80% of the flute length available for routing the panels, entry material and exit material. The maximum stack height can be calculated by subtracting the entry thickness and exit penetration depth from the available flute length (70%-80% of the actual flute length).

Example:

0.0625" endmill with 0.260" flute length
0.015" entry and vacuum channel overlay
0.020" penetration into vacuum channels

0.75 x 0.260" (available flute length)
- 0.015" (entry material)
- 0.015" (exit overlay)
- 0.020" (vacuum channel penetration)
0.145" (maximum stack height)

Estimated Tool Life:

Edge quality will slowly degrade as the tool wears. Fabricators should base tool life on the edge quality requirements for a particular job. In general, 20 - 30 linear feet (6-9 meters) of material can be routed with the same tool without sacrificing edge quality. This estimate is basically the same with or without a second pass. Since flute and channel clogging will significantly impact edge quality, vacuum channels are usually needed to minimize the need for tool changes.

* Rogers Corporation would like to thank Megatool, Inc. for helping us develop these guidelines.

Multilayer Considerations

Inner-Layer Preparation

Standard photoresist and etch procedures are used. Care should be taken to preserve the as-etched dielectric surface. Selection of an appropriate copper surface treatment is dependent upon the adhesive selected. All layers should be baked for 30 minutes at 100-125°C prior to bonding.

Adhesive Systems

Two categories of adhesive systems, thermoplastic and thermoset, have been used when bonding RT/duroid 6000 multilayers. Thermoplastics, such as Dupont's FEP film or Rogers 3001 film, are typically selected when electrical properties of the adhesive layers are critical. The dielectric constant and dissipation factor of FEP is 2.1 and 0.0003. The dielectric constant and dissipation factor of 3001 film is 2.28 and 0.003. As the PTFE resin system is a thermoplastic, direct bonding (see RT 4.9.3, "RT/duroid 6002 High Frequency Laminate Direct Bonding") can be used to manufacture homogeneous multiplayer constructions.

Thermosets, such as FR-4 prepreg or Speedboard C from W.L.Gore, can be chosen when electrical properties are less critical.

Thermoplastics

Melting point is an important consideration when selecting a thermoplastic adhesive system. FEP melts at 500°F (260°C) and is therefore stable through most PCB and assembly processes. The 390°F (200°C) melting point of 3001 film can result in a re-melting if subsequent PCB or assembly processes are higher in temperature and longer in duration than a few minutes. Copper surfaces should be prepared using a microetch, brown oxide, red oxide, or one of the subtractive process oxide alternatives. 3001 film should not be used against a continuous copper plane.

The thermoplastic adhesives should be bonded with applied pressure between 50 and 250 PSI. The ramp to temperature (525-550°F, 275-290°C) for (FEP; 425-450°F, 220-230°C for 3001) can be 6-8°F/min (3.5-4.5°C/min) and the dwell at temperature should be 20-30 minutes. Cooling to 250°F (120°C) at a rate of 2-4°F/min (1.4-2.5°C/min) should be completed under pressure as transfer cooling can result in delamination.

Thermosets

Refer to vendor recommendations for appropriate oxide types and bond conditions when using thermoset adhesive systems.

Post-Bond PCB Processing

Guidelines for double-sided circuit processing would apply to multilayer through hole and outer-layer processing.

The information in this fabrication guideline is intended to assist you in fabricating Rogers' circuit materials. It is not intended to and does not create any warranties express or implied, including any warranty of merchantability or fitness for a particular purpose or that the results shown on this fabrication guideline will be achieved by a user for a particular purpose. The user should determine the suitability of Rogers' circuit materials for each application.

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