

# DuPont™ Riston® Aqueous Processable Photopolymer Films

## GENERAL PROCESSING GUIDE



### INTRODUCTION

DuPont offers a series of Riston® photopolymer resists for a wide range of applications that include the imaging of printed wiring boards, photochemical machining (chemical milling), and decorative applications. Many Riston® films are formulated for specific applications such as tenting, plating, innerlayer applications or alkaline etching. Other Riston® films are formulated as general purpose films.

This is a general guide for all the steps that could be involved in the processing of Riston® aqueous photopolymer film resists. Some sections may not apply to all films (e.g., the plating section). Specific processing conditions for a particular Riston® film type can be found in the specific data sheet for that film. Contact your DuPont Technical Representative for copies of the specific data sheets and technical publications.

The data in this guide is based on conventional commercial processing equipment similar to that used in most Printed Circuit Board fabrication facilities. However, since actual equipment and conditions vary from facility to facility, the data should be used only as a guide. Trends, such as slopes on graphs, are expected to be similar, while actual values may differ.

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## **PART 1: SURFACE PREPARATION**

Through mechanical, chemical, or electrochemical processing the copper surface's chemical composition and topography are prepared for optimal dry film adhesion and subsequent clean release. Processes will vary depending on the type of copper surface to be prepared (e.g. vendor copper; electroless; electroplated). Surface preparation processes typically roughen the surface to increase film contact area and remove chemical impurities and antitarnish coatings which could interfere with film adhesion.

Film contact area and chemical composition of the copper surface are critical variables. Contact area is normally not measured. It is a function of the copper topography, film thickness and flow characteristics, and lamination conditions.

Copper topography has been optimized empirically in a variety of mechanical and chemical processes. For example, in brushing operations, brush construction, grit, pressure, brush foot print etc. have been recognized as important variables. Likewise, for pumice operations, pumice type, size, spray pressure etc. are known to affect copper topography.

Attempts have been made to correlate surface profilometry values such as Rz or Ra with desirable topographies. Rz=1.5-3.0 (60-120 microinches) and Ra=0.15-0.3 micrometers (6-12 microinches) have been found to give good results. Microetched surfaces will have R-values at the lower end of this range, brushed and pumiced surfaces are likely to be in the middle to upper end of the range, and reverse treated foils are at the high end of the scale, occasionally exceeding the recommended upper limit. Non-contact profilometry (optical interferometry) has been used to quantify the total surface area.

Waviness in excess of Wt=4 micrometers may cause interfacial voids unless wet lamination is employed. The copper surface should be free from dents, pits, deep scratches, nodules or other particles to avoid conformation voids over recessed surfaces and resist thinning over protrusions.

The dry film resist adheres well to freshly cleaned copper surface, typically composed of copper, and hydrated cuprous and cupric oxides. Holdtimes between prelamination cleaning and lamination should not exceed about four hours. The chemical composition of the copper surface can be measured by sophisticated analytical techniques such as Auger, ESCA, or FTIR. However, these analyses are not in use as process controls but rather serve as tools in the development and characterization of surface preparation methods. Chemicals to be removed from the copper surface are usually organic contaminants, antitarnish coatings, or excessive copper oxide. A "water break test" will give some indication of the presence or absence of hydrophobic contaminants. Inhibition tests, such as the test to check for the presence

of conversion coatings by observing the inhibition toward uniform copper oxide or sulfide coating formation can be applied.

After cleaning, recontamination through oxidation and organics is controlled by controlling the cleanliness of the environment and restricting hold times. Drying of the copper surface, and especially in through-holes, is an important part of surface preparation to avoid undesirable accelerated re-oxidation or interactions with the dry film resist.

Some copper foils are designed to require minimal or no surface preparation: double treat copper typically does not require prelamination surface preparation. "Reverse Treated Foils" offer a rough copper surface suitable for dry film lamination but may require an acid cleaning step for best results. An antitarnish-covered surface (e.g. unscrubbed electroless copper) needs to be checked for compatibility with the resist to assure good adhesion.

After preparing the surface for resist application, it is important to prevent fumes and vapors from contaminating the surface of the panels. Do not locate cleaning equipment in corrosive environments, such as plating or etching areas. After cleaning, store the panels in a clean environment.

### **Print-and-Etch Applications**

The following surface preparation techniques can be used for cleaning copper foil for etching applications:

- Chemical cleaning (using a micro-etch)
- Brush pumice, aluminum oxide, or quartz (pumice: 3F or 4F grade, 10 - 20% %v)
- Jet pumice, aluminum oxide, or quartz.
- Compressed pad brushing (500 or 320 grit)
- Wet bristle brushing (500 or 320 grit)
- Brushing plus chemical cleaning

With jet pumice equipment, use non-fused pumice for good surface topography and contamination removal. With brush equipment, fused pumice is recommended for good abrasive action. Pumice-scrubbed surfaces should appear uniformly matte, with no discoloration or stains.

Pumice slurry may become alkaline with time. Additions of acid to the pumice slurry may be necessary to achieve good adhesion of aqueous resists. Generally, citric acid or sulfuric acid can be added to lower the pH to a value of less than seven. Check with the equipment manufacturer for the compatibility of machine parts with the acid used.

Acid chemical cleaning with some microetching yields a suitable surface without the dimensional distortion seen with mechanical processes on thin core laminate. An additional advantage is the low UV light reflectivity of the microetched surface compared with scrubbed copper. A persulphate or monopersulphate based solution is

commonly used. Less common are ferric chloride or cupric chloride microetchants. At least 1.0 µm (40 micro-inches) of copper should be removed from the surface, and the etching step should be followed by a sulfuric acid or high pressure water rinse and drying.

All panels should be laminated immediately after surface preparation. The ideal process has the lamination in line with surface preparation. A maximum hold time of four hours is recommended for panels treated otherwise. If panels are held longer, they should be re-cleaned.

#### Double-Treat Copper and DSTF

Double-treat copper does not require mechanical cleaning. However, precautions are required to prevent or eliminate contamination of the surface. Removing double-treat panels from the box and lamination directly through a tacky-roll cleaner is quite common and works well. DSTF (drain side treated foil) works best with an acid chemical clean process, but does not require a microetch. DSTF is occasionally used without precleaning.

#### Tent-and-Etch Applications

In this application resist is laminated to a panel plated surface. As plated, the copper is very pure and does not require chemical cleaning for the removal of contaminants or conversion coatings. However, a mild acid cleaning step may be required after a long holdtime to remove oxides. The plated surface tends to be very smooth, except for random "plating nodules". These nodules need to be removed by a brush or sanding operation. In addition, the plated surface should be roughened, e.g. by brush pumice. Avoid bristle brushing because it may cause dish-downs in the copper surface near the plated through-hole. Scrubbing may not be possible with thin buried via innerlayers.

#### Pattern Plate Applications

Unscrubbed Electroless Copper  
Most resists can be laminated to unscrubbed electroless copper surfaces without any other surface preparation. This requires thorough neutralization, rinsing and drying. Table 1 lists a recommended post-electroless rinsing process.

The electroless copper thickness should be 1.4 - 2.0 µm (50-80 microinches). Thinner deposits may not protect through-hole integrity during the preplate micro-etch cycle required for good copper-to-copper adhesion.

**TABLE I -  
POST ELECTROLESS RINSING**

Function	Comments
Drag out rinse	1 min. Removes gross copper solution to minimize the load on the waste treatment facility
Counterflow rinse	2 tanks, 2 min. each, air sparged
Heated rinse	(50 - 65° C) 3 min. completely reacts and removes residual electroless chemistry
Neutralization/ Passivation	5 min. 3% <sup>V</sup> /v sulphuric acid + 5% <sup>W</sup> /v citric acid or a commercial antitarnish
Counterflow rinse	2 tanks, 2 min. each, air sparged
Deionized water rinse	2 min.
Dry	Blow dry for uniform, stain-free copper. This may be followed by a 5-10 min. oven dry at 60 - 65°C to remove moisture from the holes.

For the unscrubbed electroless process, the maximum hold time between electroless deposition and resist lamination is four hours if the panels are stored in a clean environment. However, commercial antitarnish treatments can be applied after electroless deposition to extend the hold time. Check performance carefully; some treatments may be detrimental to resist performance. Failure is most likely with high antitarnish concentrations and poor rinsing after antitarnish.

If the panels are held beyond recommended hold times either use a scrubbed electroless process (see below) or regenerate the surface as follows:

1. Soak the panels for three minutes in a degreaser bath at the recommended temperature.
2. Rinse thoroughly.
3. Etch 0.13 µm of copper.
4. Rinse thoroughly.
5. Dip in 3% <sup>V</sup>/v sulfuric acid / 5% <sup>W</sup>/v citric acid.
6. Rinse thoroughly. The final rinse should be with deionized water.
7. Dry thoroughly.

#### Scrubbed Electroless Copper

With scrubbed electroless copper surfaces, the resulting quality depends on the cleaning method selected. The surface preparation techniques which can be used are as follows:

- Brush Pumice (3F or 4F grade, 10 - 20% <sup>V</sup>/v)
- Jet Pumice or jet aluminum oxide
- Compressed pad brushing (500 or 320 grit)
- Wet bristle brushing (500 or 320 grit)
- Brushing plus chemical cleaning

Scrubbing renews the surface, making resist performance less dependent upon neutralization, rinsing, drying effectiveness and hold times after electroless copper deposition. However, rinse and neutralization are still critical.

### Scrubbed Panel Plated Copper

In Asia and Europe partial panel plating after electroless copper is common for pattern plating operations. This surface is very smooth and some roughening of the surface is required for most resists. The most common surface preparation is some combination of compressed pad scrubbing, pumice and/or chemical cleaning. Since an antitarnish is usually applied after panel plating, a sulfuric acid or acid base microetch is required to remove the antitarnish.

### Direct Plate Processes

Direct Plate processes are replacing electroless copper in many shops. In most cases, resist can be laminated to the direct plate surface as it exits the equipment. Some have the direct plate process in line with the laminator. If the panels are held before lamination, keep the hold time to under 4 hours, unless an antitarnish is used.

To improve resist adhesion, some direct plated surfaces are mechanically scrubbed. Whether this is needed will depend on the direct plate surface and the photoresist. Note, that some direct plate processes don't recommend scrubbing or jetting of the surface to assure reliable through-hole metalization. A microetch step may also be part of the direct plate process sequence to remove catalyst particles (e.g. carbon, graphite, or palladium sulfide) from the surface. This could yield a relatively smooth surface, requiring the selection of a resist with very good adhesion to smooth surfaces.

### Chemical Milling and Other Non-copper Surfaces

Some Riston® photopolymer films can be used with non-copper surfaces such as stainless steel, Alloy 42, chromium, brass, aluminum, etc. Surface preparation will depend upon the nature of the metal substrate. However, the general recommendations for surface preparation outlined above still apply. Some metal surfaces may require specific surface treatments to enhance adhesion. Wet lamination has been used successfully to enhance adhesion of certain resists to non-copper surfaces.

## PART 2: LAMINATION

Riston® photopolymer films can be applied with all modern Hot Roll and Cut Sheet laminators. Lamination is a processing step where cleanliness is essential. The panels, lamination rolls, and surrounding area must be free from dirt and debris, which may cause pinhole defects.

Recommended lamination parameters depend on the profile and thickness of the substrate material and the imaging requirements. Fine-line applications may require decreased lamination speed to enhance resist flow into the substrate weave pattern and surface defects. Higher pressure will also promote resist flow, but should be carefully evaluated to ensure that increased tent breakage does not occur and that the resist is not forced into through-holes.

Although specific lamination parameters should be established empirically for each application, recommendations are shown in the data sheet for each individual product.

### Conditions and Parameters

Good conformation of the resist to the surface is required to achieve high yields. This is most critical for fine line applications and for surfaces that are rough (from glass weave, etc.).

Conformation can be increased by:

- Increasing lamination roll temperature
- Increasing pressure
- Laminating at slower speeds
- Adding preheat or increase preheater temperature

Of course, use only conditions that are within the specification for the equipment, and maintain conditions within recommendations in the Riston® data sheets.

High roll and preheat temperatures can induce resist wrinkling; the upper temperature limit for most resist is determined by tendency to wrinkling. Higher roll and preheat temperature, and increased roll pressure should be carefully evaluated to ensure that tent breakage does not occur due to photoresist being forced into through-holes. Reduced lamination roll pressure and/or temperature may be required in tenting applications to minimize tent breakage and photoresist flow into through-holes. Each application should be evaluated for hole size, weave pattern, and the tent reliability required.

### Board Exit Temperature

Board exit temperature is an excellent quality control measurement used to ensure lamination conditions are stable. The actual exit temperature will depend on laminate construction, measurement technique and instrument, amount of board preheat (if used), laminator roll temperature, and lamination speed. Because of this variability, it is best to determine the optimum board exit temperature for a given set of conditions and use it to detect changes in those conditions. We recommend using the temperature as a quality control measurement, but not as a specification.

Production experience has established a range of temperatures for use with most sets of conditions. These values have proven to be reasonable for most applications.

Innerlayer	60 - 70° C(140 - 160° F)
Outerlayer	43 - 55° C(110 - 130° F)
Outerlayer Gold Plating	48 - 55° C(120 - 130° F)

### Wet Lamination

Most Riston® films can be wet laminated on a DuPont YIELDMASTER® film laminator to enhance conformation to copper surfaces. Wet lamination is recommended for fine-line print and etch applications, especially when the

panels have rough substrate weave patterns or surface defects.

### Hold Times

Most Riston® photopolymer films can be exposed immediately after lamination without affecting line/space resolution or line reproduction. However, because both panels and phototools change size with temperature, panels should be racked and allowed to cool to room temperature prior to exposure. With an in-line system, an accumulator should be used between lamination and exposure to allow the panels to cool to room temperature.

Panels that have been wet laminated, or those with tented holes, should be processed through development without delay. Dry laminated panels without tented holes can be stored up to one week between lamination and development; however, processing times should be kept consistent. Maximum hold times should be determined empirically, as they will vary with the temperature and relative humidity of the yellow room area where laminated panels are stored.

In pattern plating applications, verify that the small through holes are dry before lamination. If water is present in the holes, resist can flow into the holes causing through-hole rim voids. These voids will increase with hold time, if the holes are not dry.

### Panel Handling After Lamination

Storing panels vertically in slotted racks keeps the panels separated. Racking is preferred for rigid panels. Panels also cool faster when racked.

Although racking is preferred, if panels must be stacked, stack them vertically (on edge) only after they have cooled to room temperature. The Riston® films are formulated to flow under pressure; pinholes can result if dust or dirt is trapped between laminated panels. On-edge stacking after cooling helps minimize pressed-in defects. Protect the panel next to the vertical support by inserting an unlaminated panel between the support and the first laminated panel. This extra panel should be at least as big as the largest panel normally stored on the rack.

Very thin innerlayers or flexible substrates can not be stacked vertically. These should be placed - NOT slid - into trays. If innerlayers are stacked horizontally in trays, the stack height should not exceed 10 panels. If the photoresist is thin and the circuitry is fine, then stacks are not recommended and in-line processing should be used. To minimize pressed-in defects, the cooling area must be clean.

## PART 3: EXPOSURE

Riston® resists can be exposed on most commercial exposure units and are well suited for exposure in automated exposure units. Riston® photoresists respond best to UV light in the 350-380 nm wavelength range provided by most commercial exposure units. They have some sensitive from 300 to 450 nm; the higher wave-

length sensitivity is the reason that yellow light areas are required for processing.

For optimum resolution and resist sidewall quality, it is essential to have:

- Good quality phototools
- Excellent phototool/resist contact in the vacuum frame
- A light source suitable for the resist used
- An exposure intensity of 5 mW/cm<sup>2</sup> or higher incident on the resist (through phototool), and
- An exposure energy optimized for the processing equipment and conditions actually used.

Although optimum exposure should be achieved within the guidelines specified in Data Sheets for each resist, test over a broad range of exposure energies to determine the best performance throughout the process.

### Optimal Process Conditions

Both step held and exposure energy can be used to optimize and monitor the exposure process. Figure 1 shows the general interaction between step held and exposure energy; however, other factors also affect step held (in addition, not all radiometers will give the same millijoule reading). Specific data and the recommendations for each film are shown in the data sheets. The step held recommendations are based on the last resist step held after development (more than 50% remaining). To obtain the recommended range for copper step held, add one to the recommendation in the data sheets.

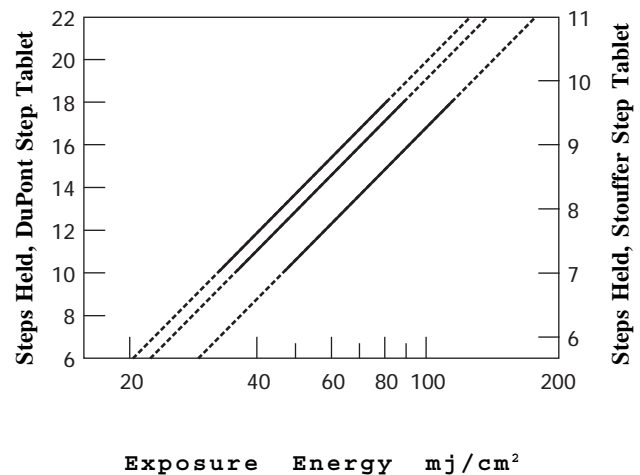


Figure 1: Riston® Film Steps Held vs. Exposure Energy

Graph of the general behavior for several resist thickness. ( Generic)

The best exposure energy is dependent on the resist and the specific process. Some general guidelines to help determine the best energy are:

Higher exposure energy:

- Increases polymerization, which increases the resistance to further processing chemistries
- Increases development latitude
- Decreases opens for etching and shorts for plating processes by preventing particles from resolving.

However, higher energy:

- Reduces the resolution capability of the resist, which increases shorts for etching and opens for plating processes.
- Increases the likelihood of off-contact exposure defects.

### Hold Times

Riston® photopolymer films can be exposed immediately after lamination. However, If panels are exposed while still warm, there may be a slight increase in the step held. Most Riston films can be developed immediately after exposure or held for several days. The individual Data Sheets for each resist will mention any specific hold time requirements.

### Line Width Reproduction

As exposure energy increases, the width of the resist line will also increase. The actual slope will depend upon the specific resist, phototool and exposure unit, and to a limited extent to the developer breakpoint. Generally, resist capable of higher resolution with show smaller increases in line width with exposure energy.

### Clean Rooms

To increase yields for high resolution applications, clean room conditions should be employed. The lamination and exposure processes are the most sensitive to particle contamination. Particles between the resist and copper (at lamination) reduce resist adhesion. Particles in the exposure areas can block light and prevent resist exposure. Both these problems will cause opens in etching applications and shorts in plating applications.

Particles 15 microns (0.5 mil) and larger are most likely to cause defects. Since particles this large do not stay suspended in air very long they are not usually removed by the clean room air handling. Therefore active cleaning around the exposure and lamination areas are required to remove these particles. In fact, cleaning boards just before lamination and exposure with tacky roll cleaners can decrease particle related defects. The exposure areas and phototools must be cleaned regularly during processing. Frequency of cleaning varies from after every panel to after every 30 panels.

### Off-Contact Exposure

Off-contact occurs when there is a separation between the phototool and the resist during exposure. This can cause shorts for etching, and opens for plating pro-

cesses. Even a separation between the phototool and the resist of 50 microns (2 mils) can prevent the resolving of 75 and even 100 micron spaces (3-4 mil). Off-contact is a major cause of defects for fine line applications and is the major reason lower exposure energies are used.

Recent Riston films are less sensitive to off-contact exposure defects. However, off-contact can cause defects even with these resists.

### Photoprinter Vacuum Frame Operation

Glass/Polyester (Mylar®)

Vacuum frames are necessary to achieve extremely close contact between the phototool and the resist surface. The appearance of small, immovable Newton Rings is the only way to be assured of good contact between the panel, phototool, and vacuum frame coversheet. Newton Rings have a rainbow-like appearance.

Air bleeder veins can be used to help channel air to the vacuum port and reduce vacuum drawdown time. Without them, air is likely to be entrapped between the vacuum frame coversheet and the frame glass, resulting in off-contact printing. The bleeder veins should be placed between the upper and lower phototools and within 6 mm of the panel edges to form a continuous path for air to escape to the vacuum port. Bleeder veins should be the same thickness as the panel.

### Glass/Glass Frames

Glass/Glass exposure frames are quite common because of faster productivity and accurate registration. However, achieving good contact between the phototool and the resist can be more difficult because of the rigid glass. It is critical to optimize the gasket material location and thickness to the board size and thickness. For frames with fixed gaskets use shims for boards smaller than normal for the frame. Typically, the best shim thickness is slightly thicker than the resist coated board (75 to 125 microns, 3 to 5 mil).

## PART 4: DEVELOPMENT

Riston® photopolymer films develop in carbonate-based solutions using conveyerized spray processors.

### Development Conditions

Table II shows generic development conditions for Riston® films. See the specific data sheet for recommendations.

**Table II. Development Conditions**

Condition	Preferred	Acceptable
Developer Pressure	1.7 bar	1.4 to 2.4 bar (20-35 psig)
Developer Temperature	28°C (85 F).	25 - 32°C (75 - 90 F).
Chemistries, (wt%)		
Sodium Carbonate	0.85	0.7 - 1.0
Sodium Carbonate Monohydrate	1.0	0.8 - 1.1
Potassium Carbonate	1.0	0.8 - 1.1
Breakpoint	50 - 65 %	(Resist dependent)
Rinse Spray Pressure	> 1.5 bar	1.2 - 2.7 bar
Rinse Temperature	20°C (70 F)	15 - 25°C (60-80 F)
Effective Rinse Length	= Developer	> 1/2 of Developer Chamber length

**Chemistry/Make-up**

For all three developer chemistries, sodium carbonate, sodium carbonate monohydrate, and potassium carbonate, use these equations to make up the solution.

$$\begin{aligned} \text{kg of carbonate} &= \text{wt\%} \times \text{sump size (liters)} \times 0.01 \\ \text{lb of carbonate} &= \text{wt\%} \times \text{sump size (gallons)} \times 0.083 \end{aligned}$$

Follow the vendor recommendations for using proprietary developers based on liquid concentrated potassium carbonate.

Verify developer concentrations using methyl orange end point with the following equation:

$$\text{wt\%} = (N \times V_a \times FW) \div (V_s \times 20)$$

where N is acid normality, V<sub>a</sub> is volume of acid, V<sub>s</sub> is volume of sample, and FW is carbonate formula weight: sodium carbonate = 106, sodium carbonate monohydrate = 124, and potassium carbonate = 138. (Recommended concentrations are 0.07-0.08 Molarity.)

**Breakpoint (Wash-off point)**

The developer speed should be set based on the recommended breakpoint for each resist. Breakpoint is expressed as the percentage of the distance through the developer chamber where unexposed resist clears. (Alternatively, if the developing machine does not have an even spacing of spray arms through the developing section, it may be better to express the breakpoint as a percentage of the number of spray arms rather than chamber length.) The recommended breakpoint is generally 50- 65%, but refer to the specific film data sheet

for details. Breakpoint should be determined on unexposed panels that are the same size as production panels.

The easiest method for determining the breakpoint is: Mark several copper panels with non-permanent water soluble felt tipped (such as Staedler Lumocolor 355 Non-permanent or Vis-a-Vis Overhead pen.) Laminate the panels with resist. Remove the polyester coversheet and develop the panel. When the panel is at about 65% of the developing chamber length, stop the sprays and conveyor. The marking ink will be washed off the panel surface as soon as the resist has been developed, thus indicating the breakpoint. In some cases, the machine must be opened to see the breakpoint. To change the breakpoint, calculate the speed required to achieve the desired breakpoint using the equation:

$$\text{Bp(desired)} \times \text{Speed\#1} \div \text{Bp\#1} = \text{Desired speed}$$

where speed #1 refers to the speed for the initially determined breakpoint (Bp1)

Adjust the conveyor speed and repeat the test until the breakpoint is correctly set.

**Development Time versus Developer Conditions**

The developing time required to achieve a desired breakpoint will depend on the developer solution. Development time decreases with increasing developer concentration. However, at high concentrations, the time can actually increase. For wider development latitude, especially for fine line applications, use lower developer concentrations. Development time decreases with temperature but higher temperatures do not always provide the best result or widest latitude.

The developing time varies considerably with development equipment. The developing time should be determined for each film and machine combination individually. The actual developing time may be influenced by: the type and number of nozzles, spray pressures, type and number of rollers, distance between nozzles and boards, size of panels being processed etc.

**Resist Loading: Batch Operation**

As the photoresist loading increases in the developer solution, the breakpoint increases. Therefore, to maintain consistent developing conditions the conveyor speed must be decreased. A batch solution should be replaced when the time-to-clean becomes 50% longer than that for fresh solution.

Figure 2 shows the generic response of time-to-clean versus resist loading. Most Riston® films perform well across a wide loading range, without significantly affecting the development time or the conveyor speed.

Photoresist loading up to 0.2 m<sup>2</sup>/1(38 µm film) or 12 mil-ft<sup>2</sup>/gal do not significantly affect sidewall quality, artwork reproduction, or line / space resolution.

To determine when the developer solution must be replaced because of high loading, use these guide lines:

- Change solution once pH drops below 10.2
- Replace solution based on board count. The board capacity will be affected by size, and % resist developed.
- Change solution once developer speed is too slow to achieve correct breakpoint.

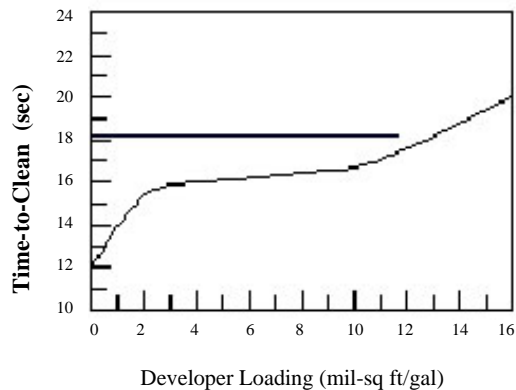


Figure 2. Wide Loading Latitude of Riston® Series Films (Generic)

Data was generated with a 38 µm thick film developed in 0.85 wt% Na<sub>2</sub>CO<sub>3</sub>, 2 bar spray pressures. Note the rapid change during initial loading, the conveyor breakpoint should be adjusted accordingly

#### Resist Loading : Feed-and-Bleed

The relatively small change in development time with photoresist loading also makes Riston® films ideal for automatic replenishment operation. In a feed and bleed system, the loading is held relatively constant by feeding fresh developer based on the amount of resist developed. The feeding of fresh solution is controlled by either:

- pH control (usually pH 10.6)
- board count (adjusting for board size and % resist developed)

Both methods work well if optimized correctly and monitored; but have problems if not. (Board count is common in Europe, while pH control is popular in North America.)

Most feed systems work by mixing concentrated carbonate liquid and water. Some systems use a pump for the concentrate and line water pressure for the water to mixed the two. With this system concentration can be difficult to control. System that premix the two to working strength are usually best. Concentration of fresh solution can be check with titration or by conductivity.

The loading may be corrected by adjusting the overall feed rate. The required concentration may vary depending on the resist type, and the optimum loading level will vary according to the technology of the work being processed. Loading recommendations are given in the specific data sheets.

During resist development carbonate is converted to bicarbonated by the acid functional groups in the resist. The resist loading can be estimated by determining the active carbonate concentration. The activity of the solution based on the ratio of carbonate to bicarbonate may also be used as the basis for controlling the replenishment. Active carbonate can be determined by titration using the equation shown earlier but the 20 is replaced by 10. The end point is set with phenolphthalein or a pH of 8.2.

#### Antifoams

The need for an antifoam will depend upon the specific film being processed, along with other factors such as machine design and water quality. Refer to the data sheet for specific antifoam recommendations. Avoid antifoams that are difficult to rinse or can cause sludge in the developer sump.

The actual antifoam level will depend upon water quality, resist loading and equipment design. For automatic replenishment systems the antifoam should be added directly to the sump at a predetermined rate with a dosing pump. Do not add antifoam to the carbonate concentrate feed tank.

#### Rinsing and Drying

Rinsing is an extremely important part of the development process. To clean between circuit traces and to remove all active development chemistry, the panels must be well rinsed with sufficient water of temperatures from 15 - 25°C (60 - 80°F). Poor rinsing may result in ragged edges, rough plating, step plating, lifting, or pruned tents. Hard water between 150 to 300 ppm (calcium carbonate equivalent) or 8 - 15 dH works best for rinsing. Water spray pressures should be above 1.5 bar (20 psig) using high impact direct-fan nozzles..

Rinsing in softened, de-ionized, RO or UF water is not recommended for most resist as the developing process tends to continue in such rinse waters and generally results in poor sidewall quality. If water of the required hardness is not available, it may be hardened artificially by dosing small quantities of magnesium sulphate solution. Some new Riston® films can be successfully rinsed in soft water.

The boards should be dried thoroughly after rinsing. Water left in the resist traces and allowed to evaporate will reduce line quality because the residual developer chemistry will attack the resist sidewall. This can result in non-uniform plating and ragged lines. Oxidation also occurs on areas that are not dried immediately after development. Heavy oxidation may cause etching residues, especially in alkaline etch.

#### Developer Design

Riston® films have wide processing latitude and yield good results in most commercial developer designs. Good spray patterns, high pressures, and high impact spray nozzles, as well as consistent temperatures and chemistries are all necessary to obtain the optimum performance from the film.

Best results are generally obtained if the resist is developed efficiently and quickly. However, it may be necessary to slow the conveyor to match other in-line equipment. In these cases, maintain the recommended breakpoint at the required conveyor speed by adjusting the carbonate concentrations. Lowering the developer concentration does not adversely affect the film performance within the recommended range. Lowering temperature within the recommended range will also allow slower development speeds. If necessary, nozzles at the front of the developer can be plugged. Do not lower spray pressures as this may affect sidewall quality.

#### Developer Maintenance

The developer chambers should be cleaned at least once per week to remove resist residue, calcium carbonate scale, and antifoam. Resist residues are best removed with 3-5 wt% NaOH or KOH solution, however, scale residues caused by the use of very hard water will require cleaning with dilute acids. Several proprietary equipment cleaners are now available. Many of this work very well and are sometimes easier and faster.

## PART 5: ETCHING

### Acid Etch

Riston® films perform well in cupric chloride, hydrogen peroxide/sulfuric acid, and ferric chloride etchants. The free hydrochloric acid (HCl) normality should be - 3.0 N to optimize etched track edge acuity.

Cupric chloride etchers can build up organic residue over time that can cause excess copper and shorts. This residue is best removed with continuous carbon filtration.

### Alkaline Etch

Alkaline etchants can be used with some photopolymer films. The data sheet should be checked to determine if the type being used is suitable. The replenisher flood rinse should be well vented during operation to minimize ammonia vapors which may attack the resist.

## PART 6: PLATING

Riston® films are excellent for pattern plating in electrolytic acid plating baths common to the printed circuit industry, including copper sulphate, tin-lead, matte acid tin, bright acid tin, nickel, and acid gold.

### Preplate Cleaning

To obtain good adhesion between the electroless copper or direct metallization surfaces, and the plated metal, the boards should be cleaned using standard acidic preplate cleaning techniques, such as those described in Table III.

Hot alkaline and electro-cleaners, sometimes found in preplate cleaning lines should not be used.

**Table III. Preplate Cleaning**

Recommended Process Sequence	Time ( min. )
Acidic Cleaner, 30 - 50 C (90-120 F)	2 - 4
Spray and/or Tank Rinse (two suggested)	2 total
Micro Etchant	to remove 0.1 - 0.4 μm copper (5 to 15 microinches)
Spray and/or Tank Rinse (two suggested)	2 total
Sulphuric Acid 5-10% v/v	1 - 2
(Optional) Spray Rinse	1 - 2

### Hot Soak Cleaner Conditions

Low temperature soak cleaners are preferred; high temperatures can attack the resist, and cause tent failure. Avoid the use of soak cleaners that contain solvents: Check with the supplier for the presence of solvents which may attack resists. Cleaners with a pH of 1.5 or below are preferred.

### Micro Etch Conditions

An acidic micro-etch at 25 - 30°C is recommended to ensure that the copper surface is thoroughly cleaned, and will form a good bond with the plated metal. The amount of copper removal required will depend upon the Riston® film used; see the data sheet for specific recommendations. Most require 0.15-0.25 microns (5 to 10 micro-inches). Some films may produce rough edges if too much copper is removed. Acceptable etchants are:

- Hydrogen peroxide-sulfuric acid
- Potassium peroxy-monopersulfate compound
- Sodium persulfate with 1% sulfuric acid

Etch depth should be checked regularly.

### Rinse Conditions

Good rinsing is essential to prevent contamination of the micro-etch and plating baths. High density boards require more intense rinsing as they tend to have smaller tracks and through - holes and more of each so that they retain more solution by capillary action.

Water flow rate and/or frequency of total exchange should be sufficient to prevent build up of color, foam or solids in the rinse tank. Warm water (>15°C) may provide improved rinsing performance.

### Preplate Acid Conditions

Acids that are compatible with subsequent plating baths are commonly used to condition panels just before plating. However, high acid concentrations (20%) can shrink and lift some Riston® films, especially when combined

with an antitarnish treated surface. Long contact times should be avoided, and these solutions should not be used as a holding tank for panels in the plating process.

### Tenting

Riston® films are tough and flexible, and can also be used in tenting applications. Photoresist thickness selection should be based on the diameter of the hole to be tented, the severity of the processing conditions, and the hold time between lamination and exposure. For demanding applications, such as large holes, slots or extended hold times 50 µm (2.0 mil) thick films may be required. For best results, minimize the hold time between lamination and exposure.

## PART 7: STRIPPING

Riston® photopolymer films strip in aqueous and proprietary stripping solutions, and are suitable for conveyorized processes. Actual stripping time for plated panels will depend upon several factors, including stripping equipment, degree of over-plating, resist thickness, and exposure level.

The stripping time for Riston® films increases with high exposure levels, post-development baking, and prolonged exposure to white light after development or plating.

### All Aqueous Stripping

The equipment configuration and process requirements will influence the choice of solution composition and temperature. In general, 1.0 % to 4.0 % (by weight) potassium hydroxide (KOH) or sodium hydroxide (NaOH) can be used in conveyorized processors or stripping tanks. The equipment should be designed to break up or filter resist skins from stripper solution.

All stripping operations should be set up with a breakpoint of 50% or less. Later breakpoints increase the likelihood that the resist will not be completely removed. As the stripper becomes loaded, the stripping rate will decrease. To maintain a 50% breakpoint, the conveyor speed must be reduced.

To minimize attack of the stripping solution on the metals of the PCB, the breakpoint can be set to 70% - 80%, but it must be ensured that the resist is completely removed. Thorough rinsing is essential.

The data sheets list specific recommended ranges for each resist, but the optimum conditions will vary between operations. Using the recommendations as a starting point, the basic rules described below will help to determine the best conditions.

- The fastest stripping times occur at a medium caustic concentration.
- Higher and lower concentrations can result in slower stripping.

- Higher caustic concentrations produce larger skins sizes
- Potassium hydroxide generally produces smaller skin sizes than sodium hydroxide.
- A higher stripping temperature will increase the stripping rate, but may increase the attack on tin or cause more oxidation of the copper surface (Within equipment limitations)
- Higher impact pressure (using high manifold pressure or high-impact nozzles) increases the stripping rate.

### Proprietary Stripper

Most proprietary commercial strippers contain chemicals that allow them to strip faster and last longer than all- aqueous strippers. These strippers may also offer minimized chemical attack on tin and tin/lead, and reduce discoloration due to copper oxidation. These strippers have become common for pattern plating applications because of the reduced attack on tin/lead and tin.

### Continuous Replenishment

As photoresist loading slows the stripping process, continuous replenishment (feed-and-bleed) is recommended to keep the stripping speed constant. Typically the feed-and-bleed system is set by board count.

### Filtration Systems

Spray stripping equipment should contain a filtration system that collects resist skins that are generated in most stripping operations. The filters prevent skins from clogging nozzles, and help prevent resist skins from reaching the rinse systems.

Some filter systems actively remove resist skins from the stripping solution. This increases stripper solution loading capability since dissolved resist does most of the depleting of the stripper solution. Most active filter systems are based on either cyclones, drum filters, or slanted screens, or some combination of these.

Filter has become more important because most new Riston films have been formulated to dissolve very slowly in stripper solution. This helps extend the life of the stripper by increasing the amount of resist that can be removed undissolved. However, the stripper must have a system to remove resist skins to prevent over accumulation in the sump.

### Antifoams

The need for an antifoam will depend upon the specific film being processed, along with other factors such as machine design and water quality. Refer to the specific data sheet for recommendations.

### Equipment Cleaning

Strippers should be cleaned on a regular basis. Proprietary equipment cleaners work well as does 5 wt% sodium or potassium hydroxide.

## **PART 8: REWORKING PANELS**

Unexposed panels should be reworked by either developing, or by blanket exposing and stripping. However, developer replenishment systems that use board count can be overwhelmed if too many unexposed boards are developed together. This could lead to higher loading than the equilibrium position

Exposed panels should be reworked by developing and stripping, or blanket exposing and stripping. Never strip unexposed resist. This leads to heavy loading of the stripper solution and can also cause stripper residues on the copper, if the resist is exposed to white light.

Panels that have been reworked may have organic residues on the surface from the photoresist or antifoams. These panels should be sent through the prelamination surface preparation again to ensure a good surface for resist adhesion. For processes that do not have any surface preparation, either a mechanical or chemical surface cleaning must be incorporated into the process for reworked boards, to regenerate a clean copper surface. Chemical treatment should consist of at least an acid soak cleaner followed by good rinsing and drying. If the panels are heavily oxidized a light microetch may also be required.

## **PART 9: SAFE LIGHTING**

Riston® photoresists polymerize and harden when exposed to ultraviolet (UV), violet, or blue light. Resist sensitivity to UV light peaks near 366 nm and extends to 450 nm in the blue portion of the spectrum. To prevent premature and unwanted polymerization, handle resists under yellow, amber, or gold fluorescent “safe lights” that do not have any light below 450 nm. Use safe lights in all process areas from lamination through to development.

Protect panels from all sources of white light, unless these sources are carefully checked to ensure that they will not cause polymerization. Possible sources of white light include exposure units, inspection tables, incompletely shielded windows and light fixtures, and light from outside the yellow room. Improper storage could result in partial polymerization of unexposed resist, leading to scumming and incomplete development. Prolonged exposure to white light, especially daylight, in all processing steps should be avoided as this may increase the stripping time.

Bright yellow light may also affect the resist performance. Yellow safe light intensities above 70 foot-candles (measured with a General Electric Light Meter Model 214) can cause change in step held. Very high intensities that can be encountered on a yellow light inspection table can cause changes in a very short time. It is particularly important to protect step tablet test panels from the influence of intense yellow light.

## **PART 10: STORAGE**

Store Riston® films between 5°C and 21°C (40°F and 70°F ) and a relative humidity between 30% and 70%.

Product that experiences storage conditions outside of the above recommendations should not automatically be discarded. We recommend inspecting material for signs of physical damage then running a small production test to confirm full functionality.

## **PART 11: SAFETY & HANDLING PRECAUTIONS**

Please note the safety and handling precautions in DuPont publication (TB-9944) “Handling Procedures for DuPont Photopolymer Films”, and the MSDS for each individual product. Normal industrial hygiene should be practiced, as well as, the use of adequate local exhaust as described in the publication.

## **PART 12: WASTE DISPOSAL**

Waste treatment for spent process solutions will depend on state and local regulations, and the type of stripper composition used. Please consult your local regulations. We have taken steps wherever possible to eliminate or minimize use and presence of materials that are specifically regulated under the Federal Clean Water Act of 1987. EPA has published two lists including (1) the 129 priority water pollutants and (2) the substances comprising total toxic organics, TTO, (40 CFR 413.02 - FR July 15, 1983, pg 32483). None of these materials are used in Riston® photopolymer resists. All DuPont Riston photopolymer resists are also tested for compatibility with the biological treatment used in most sewage treatment plants. Copies of these reports may be obtained from DuPont.

Disposal of scrap or unused film is also governed by local regulations, however, Riston photopolymer resists do not contain any materials listed on the “D” or Toxicity Characteristic list (TCLP) under RCRA (40CFR261.24).

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