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CORPORATION

Technical Information

Chemcut CC8000 Etch Capability

Introduction

The Chemcut CC8000 etcher has many new features designed to reduce the cost of manufacturing and, just as importantly, the cost of ownership. Keeping the price of a new etcher to a minimum and making it as trouble free and easy to fix as possible while running is all well and good but it still has to deliver good etch quality in terms of line width uniformity, especially when line widths and spaces fall below 100 µm (4 mils). An inexpensive and easy to run etcher is still a bad investment if it doesn't etch well. One of the major changes in the Chemcut CC8000 etcher is a new spray system that is designed to give the maximum amount of spray coverage and etch uniformity with the least amount of solution sprayed on the surface of the panel. Reducing the number of nozzles reduces the amount of puddling on the panel surface, especially the top side, and increases etched line width uniformity. The Chemcut Sigma series etchers have 42 1.5 gpm nozzles spraying 63 gallons/ minute on each side of the panel to cover a thirty inch conveyor width while the Chemcut CC8000 etcher has 96 0.5gpm nozzles spraying 48 gallons/ minute per side to give the same coverage with better uniformity and no loss in conveyor speed. This bulletin gives the results of etch tests done to demonstrate the etch capability of the Chemcut CC8000 etcher for the standard conveyor, thin and flexible substrate conveyor and for half-etch (reducing 17 µm [½ oz.] foil to 9 µm [¼ oz.]or 5µm [$^{1}/_{8}$ oz.] foil).

Etch Test Cautions

It is important to note that the etched line width variation found after etching measures the variation *of the entire process*, not just the etcher. In addition to the variation introduced by the actual etching step, the line width variation found after etching also includes variations due to the type of foil and substrate used, cleaning, type of resist used, photo-tool manufacture and preparation, exposure of the etch resist and developing. All of these processes must be optimized in order to get a truer picture of the etcher capability. If all of the prior process steps have been optimized and run properly then approximately 70 to 80% of the line width variation found after etching is due to the etching step. If they are not done properly then only 30 to 40% of the variation may be due to the etch step, making it difficult to access the etcher performance properly. The etcher, by itself, cannot produce results that are better than what goes into the etcher in the first place. It is safe to assume for the etch test results shown here that the pre-etch processes have been optimized to the best of our abilities.

Etch Test Background

Evaluation of etch tests can vary according to the test method used so some explanation of test methods is necessary. Following is a brief summary of the method Chemcut uses to test etch capability.

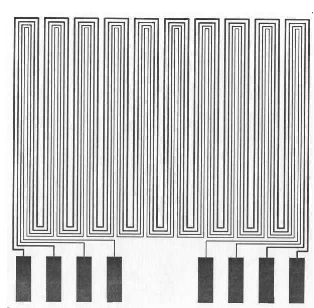
The main concern in etch quality is the uniformity of etched line widths over the entire panel surface. In order to evaluate the quality of etch results properly one needs enough data to get a reliable statistical base from which to make comparisons from one test to another. This requires more than just nine or ten readings per panel. It is desirable to have at least fifty data points on the surface and more is better. Doing this manually through an optical microscope is time consuming so many companies use automatic optical scanners to measure up to several hundred thousand points on the panel surface in a short amount of time. Chemcut also uses automatic optical scanning as part of its etch evaluation but we have found that optical scanning has resolution limits and other issues that may obscure subtle but important differences in etch quality.

In 1985 Chemcut started using an etch test pattern that allowed us to measure the electrical resistance of an etched line and, from the known length of the line and the thickness of the copper, calculate the line width. By etching many of these small test patterns in an array across the panel surface it was possible to get a reliable, repeatable etched line width map across the entire panel in a relatively short time. This allowed us to quickly see and identify the effects of any changes in the etcher design. In the early 1990's a test consortium, formed by several leading manufacturers to improve etch quality, independently developed a similar test pattern and method of calculating line widths. A company called Conductor Analysis Technologies (CATs) was formed to do the testing and analysis for the consortium and was soon offering their test and analysis as a paid service to the industry. Since then the CATs test and test patterns have become the de facto industry standard for etched line width and etch capability. Chemcut started using the CATs test pattern in 1995 so we had a common comparison to the industry and have used CAT to independently verify our test results. This pattern requires very precise etching to achieve good results and is very sensitive to any changes in the etch process.

For those who are not familiar with CATs tests the following is a brief description of the test modules and test patterns Chemcut uses in our testing. If you are already familiar with the CATs method you may want to skip directly to the test results.

CATs Test Module

A typical CATs test module is illustrated below:

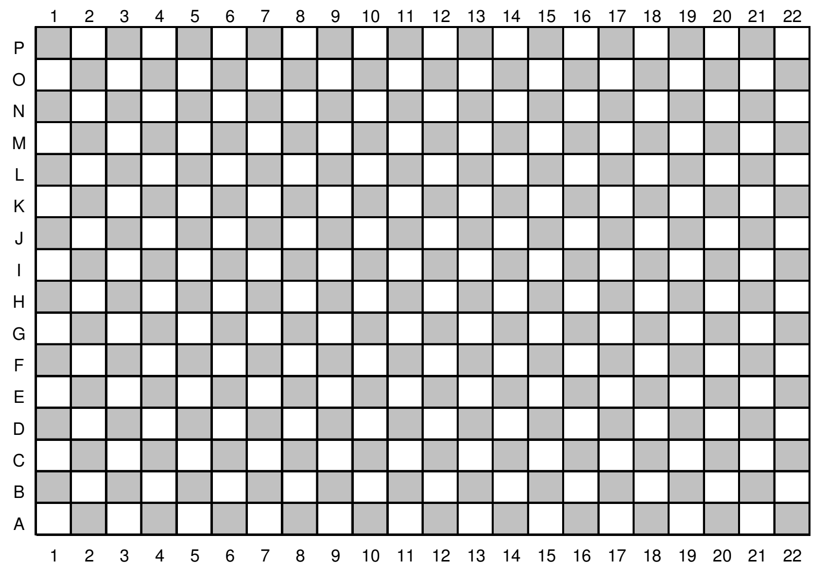


CATs multi-pitch Test Module

The CATs test module is multi-pitched with four different line widths and three different spaces between lines. They are offered in several different line widths ranging from 1 mil (25 µm) to 4 mil (100µm) lines with 1 mil to 3 mil spaces up to 8 mil (200 µm) to 11 mil (275 µm) lines with 8 mil to 10 mil spaces. Chemcut uses the pattern starting with a 3 mil (75 µm) line and space to a 6 mil (150 µm) line with 1 oz. foil. The module is approximately 1 inch (25mm) square and each of the line lengths is about 25 inches (63.5cm). The two innermost pads connect to the 3 mil line, the next two pads out connect to the 4 mil lines, etc.

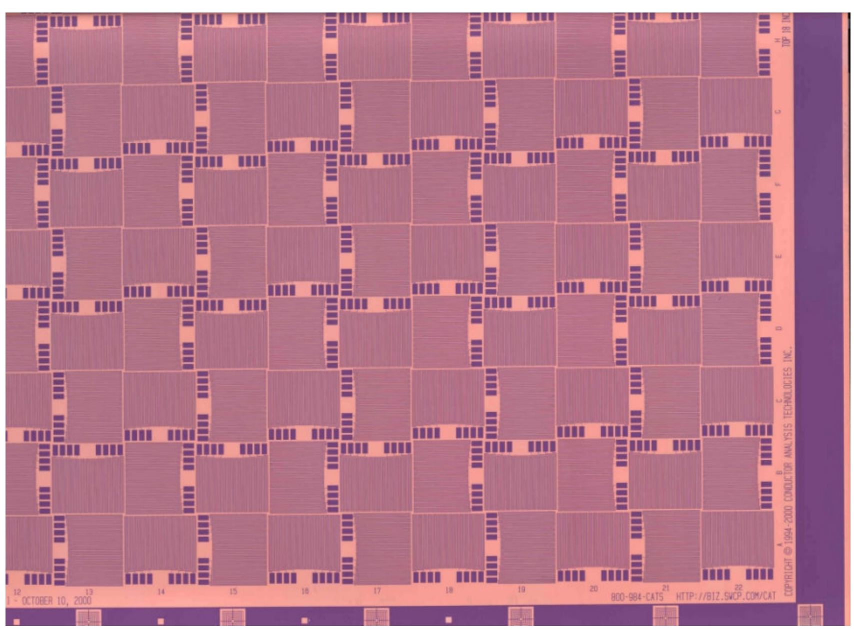
CATs Test Pattern

The test pattern is for an 18" x 24" (457 mm x 610 mm) panel. The test modules are arranged in a 16 x 22 grid (352 total modules) with every other module turned 90° in a checkerboard pattern as diagrammed below:



■ - Vertical Module ☐ - Horizontal Module

The lower right corner of a typical test panel ready for etching is illustrated below:



Section of Ready-to-Etch Test Panel

Once the panel has been etched and stripped a resistance meter is used to measured the resistance of each line and the individual line widths, average line width and standard deviation are calculated.

Evaluating Etch Test Results

The etched line width results represent 75 µm (3 mil) lines with 75 µm spaces etched in 35 µm (1 oz.) foil. The data are in mils and are presented in tables and as 3-D surface charts. Included in the tables and charts will be information on average line widths, standard deviation, process capability potentials and high and low measurements. The average line width and high and low values are self-explanatory but the standard deviation and process capability potential (Cp) may need some explanation in order to make sense of the results.

The Standard Deviation is a common statistical calculation to express the amount of variation found in a group of numbers. The smaller the standard deviation the less the variation. When using the CATs method for evaluating etch results Chemcut uses the following guidelines:

Standard Deviation between 0.125 and 0.150 – Satisfactory etching, capable of 100 µm lines and spaces in volume.

Standard Deviation between 0.100 and 0.125 – Good etching, capable of 75 µm lines and spaces in volume.

Standard Deviation less than 0.100 – Excellent etching, capable of any line and width combination down to the limits of the process.

The Process Capability Potential, Cp, measures the potential of the process to meet specifications and is calculated by dividing the range between the upper and lower set limits of the line width variation by six times the standard deviation. The upper and lower set limits for these tests is ±20% of the average etched line width. A process with a Cp of 1.33 or greater is considered to be a fully viable process that can meet and maintain specifications reliably. To put the Cp's of the etch test results in perspective, the IPC and CATs recently released their $PCQR^2$ (Process Capability, Quality, and Relative Reliability) Industry Statistics for 1-ounce Innerlayer Conductors and Spaces. The Cp's for the 3 mil (75 µm) lines of the 15 manufacturers who submitted panels using the same CATs test pattern as used in our tests and the same ±20% line width variation ranged from a low of 0.33 to a high of 1.27 with a median value of 0.91

The 3-D surface chart is simply the average line width of the 75 µm lines in each test module plotted against its position on the panel.

The following sections contain the test results for the Chemcut CC8000 etcher for the standard conveyor, thin and flexible material conveyor, and half-etch results.

Etch Results with Standard Conveyor

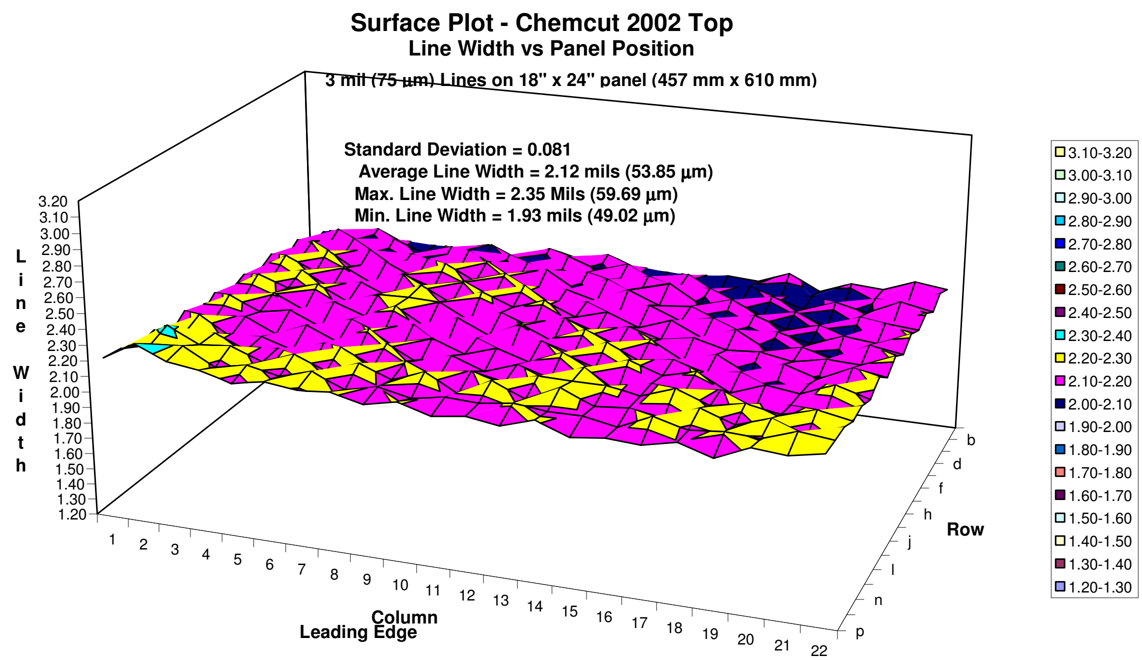
The standard conveyor is designed to transport rigid panels down to a substrate thickness similar that of 75 µm (3 mil) fiberglass with minimum shadowing by the conveyor wheels of the lower side of the panels. The test results are for 75µm (3 mil) lines and spaces on 457 mm x 610 mm (18" x 24") panels with 35 µm (1 oz.) foil and a 125 µm (5 mil) fiberglass core.

	Ave. LW	Standard Deviation	Cp	High	Low
Top Side	2.12 mils	0.081	1.71	2.35 mils	1.93 mils
Bottom Side	1.98 mils	0.058	2.27	2.14 mils	1.82 mils

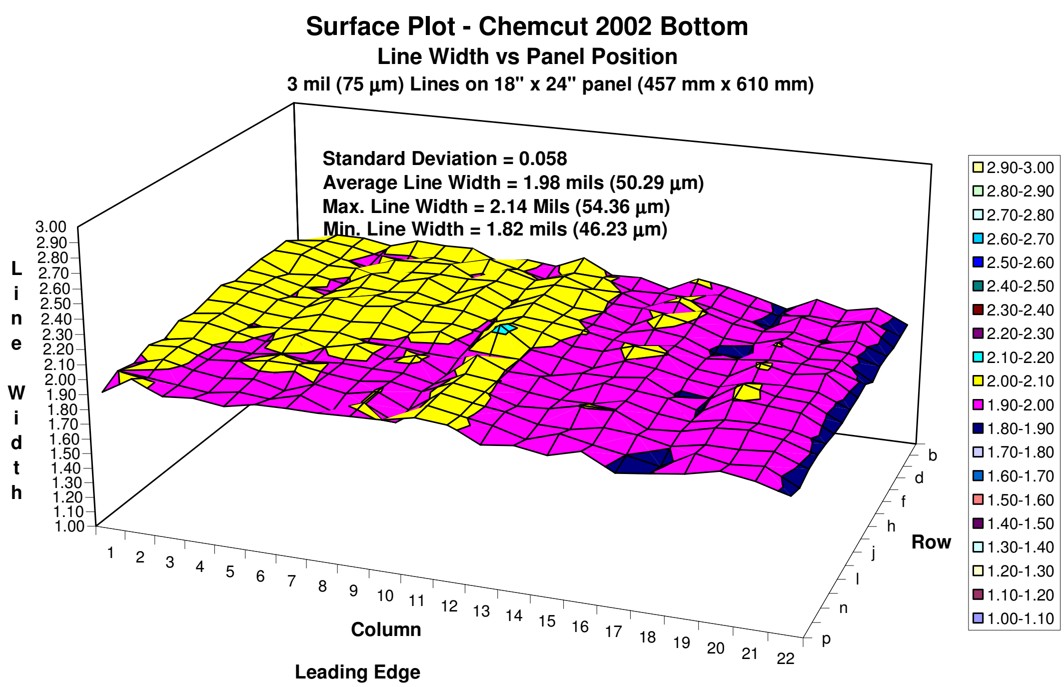
3-D surface charts are on the next page. Each color represents a difference of 2.5 µm (0.1 mils) in the average line width.

Chemcut CC8000 Etch Capability – Standard Conveyor Etch Results

3-D Surface Chart – Top Side



3-D Surface Chart – Bottom Side

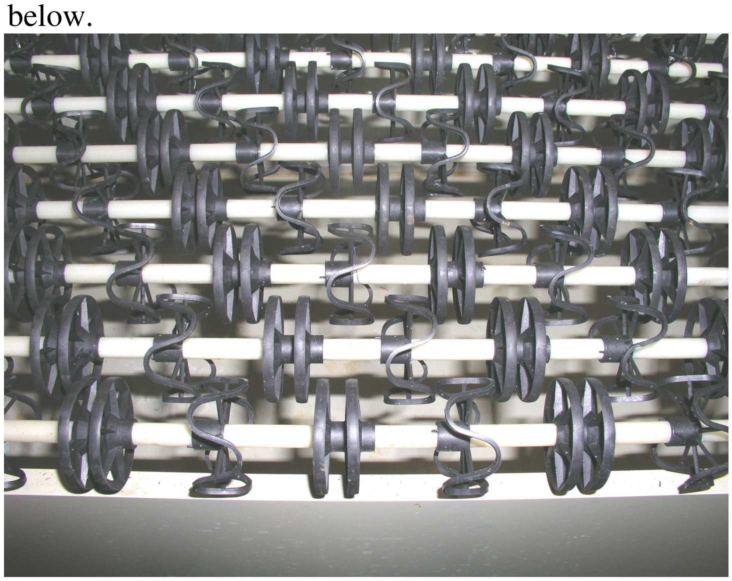


Etch Results with Thin and Flexible Material Conveyor

As substrate materials have become thinner and more flexible, transporting and etching these substrates in horizontal conveyorized etchers without damage and without resorting to leaders is a major problem. Increasing the density of the wheels solves the transport problem but causes major interference with etch speed and quality. Chemcut has developed a Thin Material Transport (TMT) conveyor that will transport the most flexible substrates without leaders with minimal loss of conveyor speed and excellent etch quality.

Description

Chemcut's conveyor rods are spaced 1 $^5/_8$ inches (41 mm) apart. By using 2 inch (50 mm) diameter conveyor wheels, slightly offset from rod to rod, the wheels overlap each other from rod to rod, making it impossible for the leading edge of a flexible panel to slide down between them to the bottom of the etcher. The problem has been to provide enough support between wheels on a rod without interfering with the etching. The heart of the TMT design is the patented 'S' wheel. The rim of the 'S' wheel snakes back and forth around the circumference of the wheel in an S pattern rather than a straight line. The width of the pattern is 1 inch (25.4 mm) so that the most support with the least masking of the lower spray is offered. However, it is difficult to get the 'S' wheels close enough together to provide reliable transport of very flexible materials without interfering with the wheels on the next rod. This problem is resolved by alternating the 'S' wheel on every rod with two soft wheels with a straight, rather broad, rim on each conveyor as in the photo below.



Transport Tests

Initial tests with water in the spray modules has shown that this system is capable of transporting a wide variety of thin and flexible circuit board materials without leaders and without skewing or damage to the boards. Materials tested included 2 mil (50 µm) fiberglass, 3.5 mil (90 µm) Teflon, and 1 mil (25 µm) Kapton with both 1 oz. (35 µm) and ½ oz. (17 µm) unetched copper, with a typical signal/signal pattern etched on the panel, and with no copper left on the surface at all. Even under the worst case conditions of the lower pressure 15 psi (1 bar) higher than the top and no upper idler wheels to hold the material down, all the material transported through the spray modules with no jamming or skewing, including the 1 mil Kapton with no copper. There were no impressions from the wheels in any of the copper clad materials. These tests showed that this conveyor design would run most of the industry's problem materials without leaders or damage but, as you can see from the photograph, the density of the wheels has to have some effect on the etching from the bottom side. A series of etch tests was run to find out what price, in terms of etch uniformity and speed, was paid in order to transport the material through the etcher.

Thin Material Transport Etch Tests

The test results are again for 75 µm lines and spaces but the panels for this test measured 457 mm x 305 mm (18" x 12") with 35 µm foil and a 75 µm Teflon core.

Chemcut's latest etcher with standard conveyor wheels was used for the etching. Once the speed and pressures were set, one panel was etched and stripped with the standard wheels in place. The standard wheels were then removed and replaced with the TMT wheels. The conveyor speed and upper and lower spray pressures were adjusted so the etched line widths matched those for the standard conveyor and one more panel was etched and stripped. The line widths on the panels were then measured and compared using the CATs method. The panels were then optically scanned using an AEI TOMM optical scanner.

Etch Test Results

The comparison of the conveyor speeds and spray pressures for the two sets of conveyor wheels are shown below. The denser wheel pattern of the TMT conveyor did cause enough shadowing to slow the conveyor speed from 25 inches per minute (0.64 M/min.) to 22 ipm (0.56 M/min.) in order to maintain the same line widths. This is an acceptable trade-off to ensure reliable transport of thin material.

	Standard Conveyor	TMT Conveyor
Conveyor Speed	25 inches/min.	22 inches/min.
Upper Spray Pressure	36 psi	25 psi
Lower Spray Pressure	25 psi	33 psi

The same shadowing also caused a change in the pressure balance between the upper and lower spray tubes. With the standard conveyor the upper spray pressure was 11 psi higher than the bottom to get even etching on both sides of the panel. With the TMT conveyor the bottom pressure had to be run 8 psi higher than the top to achieve the same results. While this may seem alarming at first glance in terms of transport capability, our testing has shown that the panel stays on track with bottom pressures as high as 15 psi greater than the top with no upper hold down wheels. In fact, 3.5 mil Teflon cores with ½ oz. foil showed no signs of wandering during the etch process. The weight of the cupric chloride solution on the top of the panel is more than enough to hold the panel down on the conveyor until the bottom pressure is at least 15 psi higher on the bottom.

The table below shows the etch results on the bottom sides for the 3 mil lines for the two sets of panels run using the CATs measurement method. The topside results for both conveyors were in the 0.090 to

0.096 range for standard deviation and didn't change since no changes were made that affected the topside etching.

Etch Results for 3 mil Lines – Bottom Side

	Standard Conveyor			TMT Conveyor		
	Ave. LW	Standard Deviation	Cp	Ave. LW	Standard Deviation	Cp
Bottom Side						
3 mil Teflon, 35 µm Foil	2.36 mils	0.079	1.99	2.35 mils	0.087	1.80

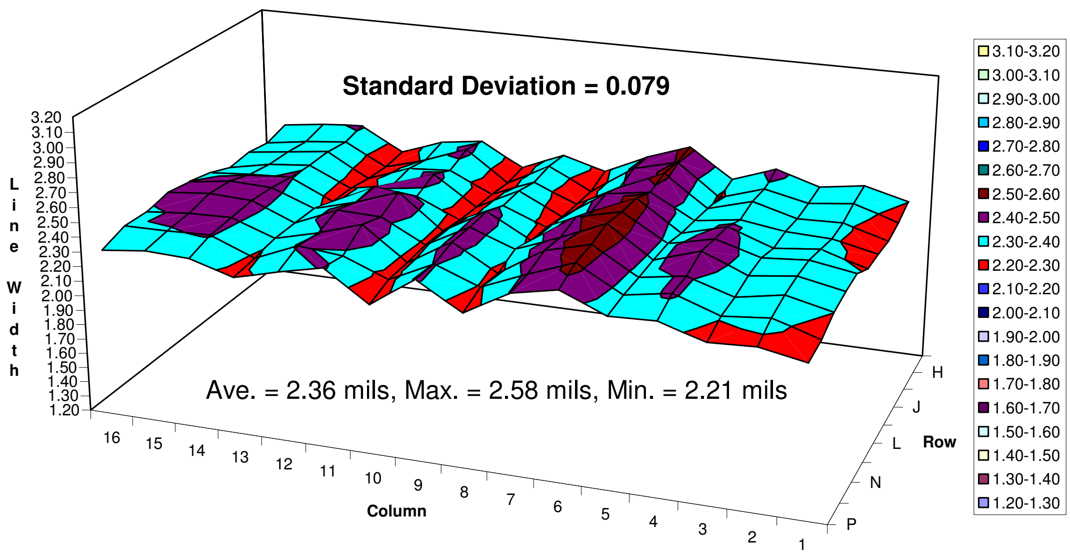
While the TMT conveyor caused some increase in the standard deviation of the panels run they still remained well within the excellent etching range.

3-D surface charts are on the next page. Each color represents a difference of 2.5 µm (0.1 mils) in the average line width.

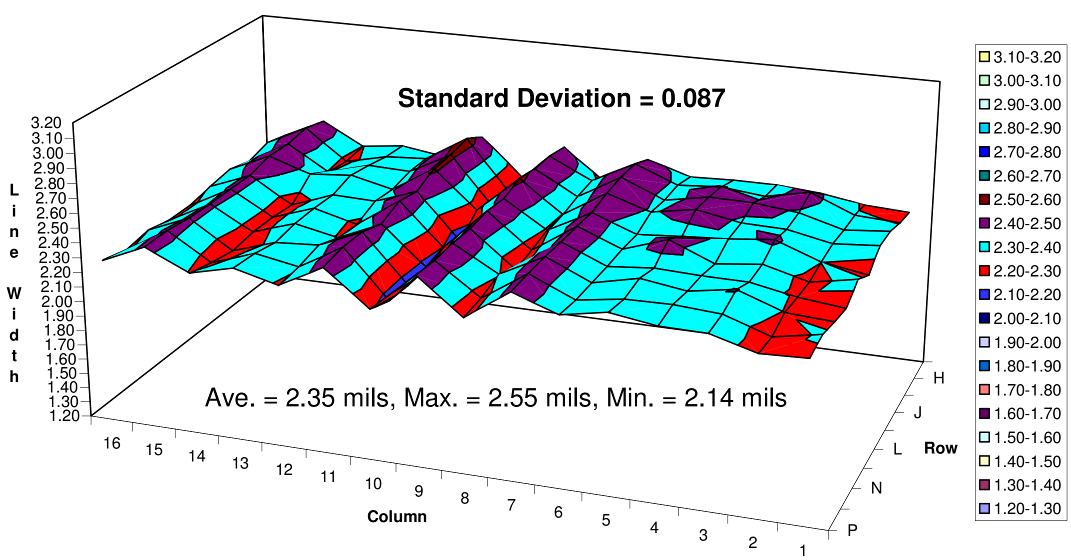
Etch maps from the optical scanner are on the page following the 3-D scans. Each color here represents a difference of 1.25 µm (0.05 mils) in the average line width.

Chemcut CC8000 Etch Capability – Thin and Flexible Material Conveyor Etch Results

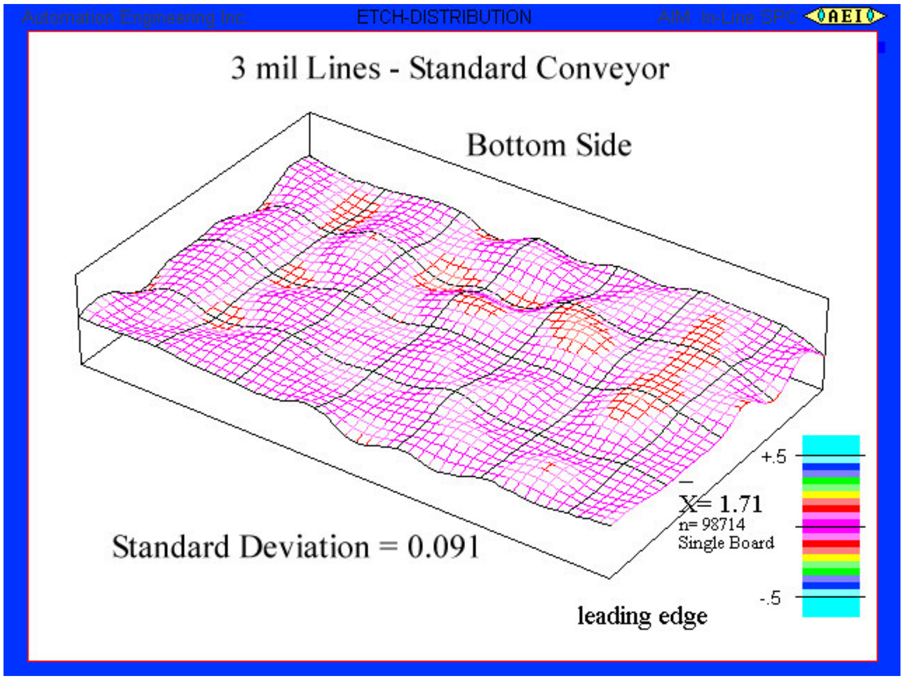
Bottom Side Results - Standard Conveyor

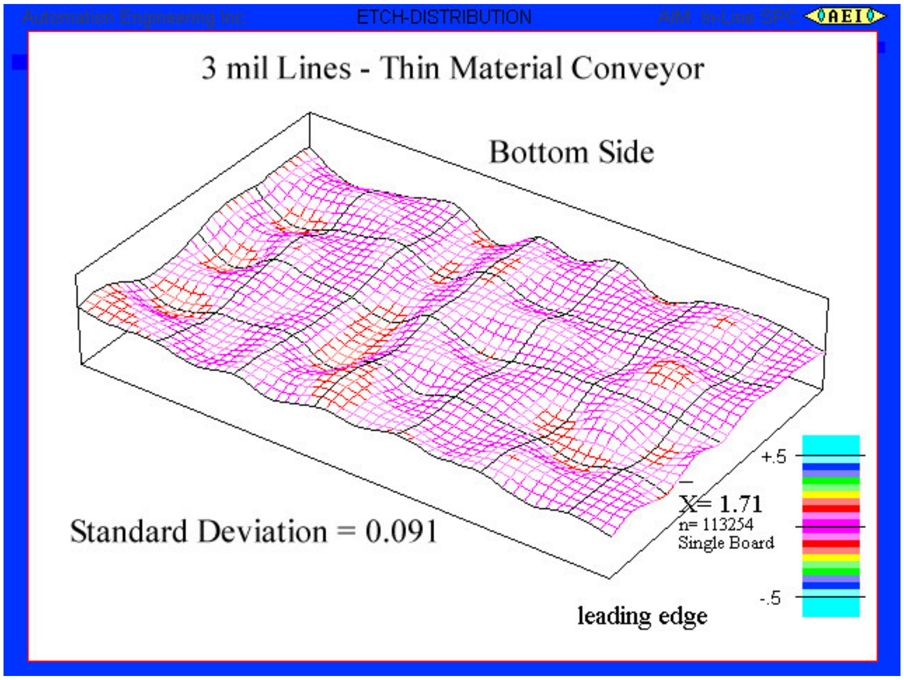


Bottom Side Results - Thin Material Transport Conveyor



Chemcut CC8000 Etch Capability – Thin and Flexible Material Conveyor Etch Results
Optical Scan Etch Maps





Half Etch Results

As line width requirements approach 50 µm (2 mils) and even 25 µm (1 mil) it would be desirable to etch them in thinner foils than 17 µm (½ oz.). 17 µm foil is readily available in quantity but 9 µm (¼ oz.) foil is only available in limited quantities and at a high price. One way around this is to etch 17 µm foil down to 9 µm to take advantage of the price and availability of 17µm foil.

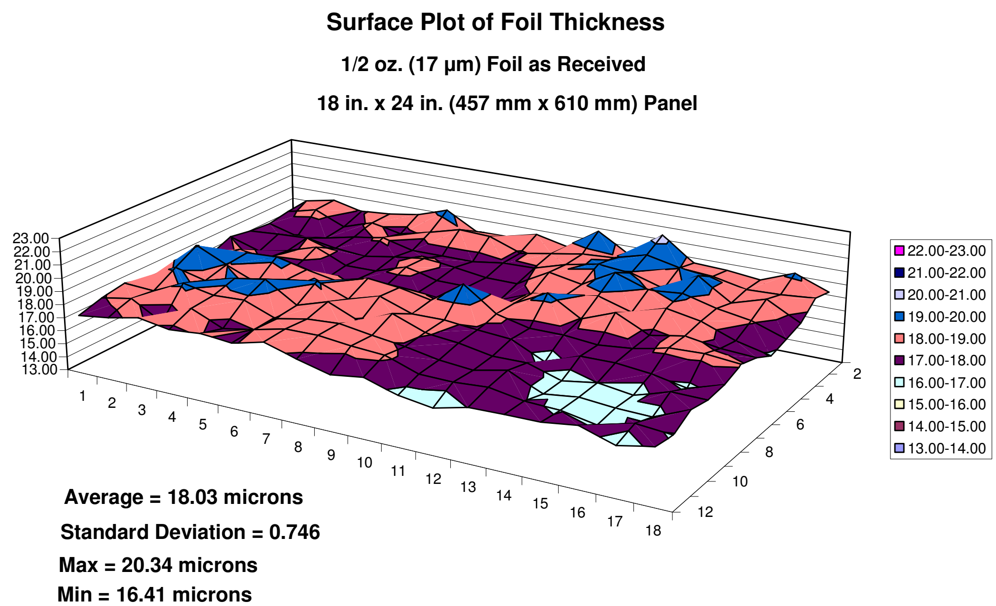
Test panels were 457 mm x 610 mm. The copper thickness was measured before and after half etch using x-ray fluorescence at 25 mm intervals over the panel surface.

	Foil before Half Etch	After Half Etch
Thickness	18.03 µm	9.30 µm
Standard Deviation	0.746	0.526
Maximum Thickness	20.34 µm	10.77 µm
Minimum Thickness	16.41 µm	7.98 µm

3-D surface charts of the foil thickness data before and after half etch are shown on the next page. Each color represents a thickness difference of 1µm.

Chemcut CC8000 Etch Capability – Half Etch Test Results

3-D Surface Chart – 17 µm foil thickness as received



3-D Surface Chart – 9 µm foil after etching down from 17 µm