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EVALUATION OF ALKALINE ETCHANTS
FOR PRINTED WIRING BOARDS

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EVALUATION OF ALKALINE ETCHANTS FOR PRINTED WIRING BOARDS

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A proprietary alkaline, copper-ammonia-complex solution was evaluated for removing copper from the non-circuit areas of printed wiring boards. The process proved superior to the chromic-sulfuric acid etchant being used, and the alkaline etch process has been incorporated into the standard process for manufacture of printed wiring boards at Bendix.

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CONTENTS

Section	Page
SUMMARY.	4
DISCUSSION	5
SCOPE AND PURPOSE.	5
PRIOR WORK	6
ACTIVITY	6
ACCOMPLISHMENTS.	13
FUTURE WORK.	13
DISTRIBUTION	14

ILLUSTRATION

Figure	Page
1 Conductor Cross Section.	7

TABLES

Number		Page
1	Inspection Results of a Conductor Cross Section (Part Number 293958-204)	8
2	Comparison of Alkaline and Chromic-Sulfuric Acid Etchants.	9
3	Comparison of Upper and Lower Panel Sides (Part Number 291835)	10
4	Conductor Width Measurements	11
5	Conductor Spacing Measurements	12

SUMMARY

A proprietary, alkaline copper-ammonia complex etchant has been evaluated at Bendix for use in production of printed wiring boards (PWBs). A better etchant than the standard chromic-sulfuric acid etchant was needed because of the numerous disadvantages associated with use of the latter.

Testing of the alkaline etchant involved etching identical circuit patterns with both etchants, micro-sectioning samples, and measuring conductor widths. There was little dimensional difference between the two systems. Inspection of the panels etched in the alkaline etchant indicated that conductor widths were within dimensional tolerances and that undercutting of the masking was less than expected.

Parts masked with tin-lead plate and alkaline etched were tested for solderability; results were excellent.

Because of this evaluation, the production process was changed to incorporate the alkaline etchant. It has been used for production etching of PWBs since June 1973.

DISCUSSION

SCOPE AND PURPOSE

For many years the principal chemicals used for etching unwanted copper from PWBs were ferric chloride and chromic-sulfuric acid. When the circuitry was masked with tin-lead electroplate, only chromic-sulfuric acid etchant could be used because the tin-lead alloy was attacked by the ferric chloride etchant.

Disadvantages of chromic-sulfuric acid etching are numerous.

- It causes deterioration of the plastics used in construction of etching machines.
- The etch rate varies with the concentration of dissolved copper.
- It is not regenerable and must be replaced several times each week.
- The spent etchant is difficult to dispose of and creates severe environmental problems.
- Nickel-clad circuitry is pitted by the chromic-sulfuric acid etchant as copper concentration increases in the solution.

More recently, a new type copper etchant, formulated with an alkaline copper-ammonia complex, was developed for the printed circuit industry. This type etchant minimizes many of the disadvantages of the acid etchants:

- Tin-lead alloy can be used as the maskant;
- The etch machine is not attacked;
- The etchant can be automatically replenished, resulting in consistent etch rates;
- Dumping and recharging are seldom required;
- The spent etchant can be treated to remove the copper and poses no pollution hazards; and
- Nickel circuitry is unaffected by this etchant.

Because of these reasons, evaluation of alkaline etchants for use in production of PWBs was undertaken.

PRIOR WORK

Evaluation of alkaline etchants began at Bendix in February 1972, when a proprietary alkaline etchant was tested using the production etcher. After etching the tin-lead alloy-masked parts, examination revealed numerous areas where the etchant had attacked and pitted the tin-lead. A second trial with a fresh supply gave the same results, and no further efforts were made with this material.

ACTIVITY

In June 1973, another proprietary alkaline etchant from a different supplier was evaluated at Bendix for etching copper from PWBs. The new process required installation of a specific gravity sensor in the etching chamber and addition of a pumping console for automatically adding fresh etchant and withdrawing spent etchant. The etchant is contained in the reservoir of the etch machine and is heated to 120°F (49°C). Pumps force the solution through banks of spray heads which impinge on both sides of the PWBs as they pass through the etch chamber on a conveyor. After leaving the etch chamber, the parts pass through a water spray, a solder brightening solution spray, another water spray, and a blow dry. The etch machine operator visually monitors the operation to see that all unwanted copper is removed.

The cross section of a PWB conductor (Figure 1) as formed by chemical etching is generally in the shape of a trapezoid, with the longer of the parallel sides in contact with the base laminate and the shorter side in contact with the masking material. As the etchant etches downward toward the base laminate, it is to some extent etching laterally and undercutting the maskant, thus creating the trapezoid shape of the conductor cross section.

If the panels are exposed to the etchant for too long a time, over-etching will result, and the conductor width will be reduced below the width of the etch mask. Too short a time in the etcher will result in incomplete copper removal and a conductor width greater than the width of the etch mask.

Design Guide DG 10011, *Printed Wiring Boards*, WR, states, "Realistically, an experienced etch operator can probably stop the etch when the conductive pattern edge is within ± 0.002 inch of the edge of the etch resist mask. This means that the conductive path width can vary from the mask width by ± 0.004 overall."

Quality requirements for PWB manufacture include dimensions of conductor widths and the spacing between conductors. When parts are inspected, the width of the bottom of the conductor (the surface in contact with the laminate) is measured when viewed

Figure 1. Conductor Cross Section

normal to the board. The minimum conductor widths must be greater than the minimum called out on the part drawing. The maximum conductor widths must be such that the minimum spacing requirement of the part drawing is met.

In the design of PWBs, conductor widths are based on their electrical current carrying requirements, which are a function of the cross-sectional area. The Design Guide (DG 10011) suggests that, from a typical etch operation, the theoretical minimum copper width (top of trapezoid) will equal the measured conductor width (bottom of trapezoid) minus twice the total copper thickness.

A conductor cross section formed by alkaline etching was inspected (Table 1). Applying the data obtained from this inspection to the theoretical minimum dimensions suggested by the design guide, it can be readily seen that the cross-sectional area reduction is less than that theoretically expected.

- The theoretical trapezoid top for the conductor is $0.018 - 2(0.0031)$, or 0.0118 inch (0.2997 mm). The top actually measures 0.015 inch (0.381 mm).

Table 1. Inspection Results of a Conductor Cross Section (Part Number 293958-204)

Copper Thickness*		Conductor Widths*			
		Minimum Width Required	Measured		Mask Width
Minimum	Maximum		Top	Bottom	
Conductors					
0.00313	0.00319	0.016	0.015	0.019	0.020
0.00315	0.00320	0.016	0.015	0.018	0.020
0.00315	0.00319	0.016	0.015	0.018	0.020
0.00299	0.00304	0.016	0.015	0.018	0.020
0.00296	0.00312	0.016	0.015	0.018	0.020
Solder Tabs					
0.00326	0.00333	0.020	0.024	0.026	0.029
0.00310	0.00324	0.020	0.024	0.027	0.029
0.00310	0.00324	0.020	0.022	0.025	0.029
0.00313	0.00320	0.020	0.023	0.025	0.029
0.00319	0.00324	0.020	0.022	0.025	0.029
*Dimensions given in inches; 0.001 inch = 25.4 μ m.					

- The theoretical trapezoid top for the solder tabs is $0.026 - 2(0.0032)$, or 0.0196 inch (0.4978 mm). The top actually averages 0.023 inch (0.584 mm).

Samples from a group of PWB panels were etched in both the alkaline and standard production (chromic-sulfuric acid) etchants to compare their relative effectiveness. The alkaline etchant appears to provide an advantage in its smaller path width reduction below the mask width (Table 2).

Panels travel through the etch chamber horizontally with the etchant spray impinging on both the up and down surfaces. Because of differences in drainage and puddling of the etchant, differences in the etch characteristics from one side to the other are possible. These differences are minimized by maintaining a differential in spraying pressure between the two sides. The re-activity of the etch solution is also a factor in how etching of the two sides compares.

Table 2. Comparison of Alkaline and Chromic-Sulfuric Acid Etchants

Alkaline Etchant			Chromic-Sulfuric Acid Etchant		
Conductor Width*			Conductor Width		
Top	Bottom	Reduction**	Top	Bottom	Reduction
Side 1					
0.011	0.016	0.002	0.014	0.014	0.004
0.012	0.015	0.003	0.014	0.014	0.004
0.012	0.016	0.002	0.014	0.015	0.003
0.012	0.016	0.002	0.014	0.015	0.003
0.012	0.016	0.002	0.014	0.014	0.004
Side 2					
0.012	0.016	0.002	0.015	0.016	0.002
0.012	0.016	0.002	0.015	0.016	0.002
0.013	0.014	0.004	0.014	0.016	0.002
0.013	0.016	0.002	0.015	0.017	0.001
0.012	0.016	0.002	0.015	0.016	0.002
*Conductors masked with tin-lead plate; copper thickness averaged 0.0039 inch (99.1 μ m); dimensions given in inches; 0.001 inch = 25.4 μ m. **Reduction determined by subtracting bottom width from mask width of 0.018 inch (0.457 mm).					

Table 3 shows that conditions can be balanced, when using alkaline etchant, so that there is very little difference between conductor dimensions on the upper side and those on the lower side. Inspection results of conductor widths and spacing for several production PWBs etched with the alkaline etchant are given in Tables 4 and 5.

In one early evaluation, a group of parts, masked with tin-lead plate were alkaline etched and then inspected. The results indicated excessive undercutting with this group. Further tests of this type using parts from many lots, including nickel-clad laminate, did not repeat the over-etched condition. It was concluded that the discrepant etching resulted from a too-slow conveyor speed and could be avoided with proper operator control.

Table 3. Comparison of Upper and Lower Panel Sides
(Part Number 291835)

Upper			Lower		
Mask Width (inch)**	Conductor* Width		Mask Width (inch)	Conductor Width	
	Top (inch)	Bottom (inch)		Top (inch)	Bottom (inch)
0.100	0.097	0.099	0.100	0.097	0.098
0.100	0.096	0.099	0.100	0.097	0.100
0.100	0.097	0.099	0.099	0.096	0.099

*Conductors masked with tin-lead plate; copper thickness averaged 0.0026 inch (66.04 μm).

**0.001 inch = 25.4 μm .

The weld tabs of PWBs fabricated from nickel-clad laminate and subjected to the alkaline etchant were examined microscopically. The surface of the nickel was unaffected by the etchant. There was no evidence of pitting as was commonly experienced when using chromic-sulfuric acid as the etchant.

The alkaline etchant discolored the surface of the tin-lead plate maskant less than had been common with the chromic-sulfuric acid etchant. However, close examination of the parts masked with tin-lead revealed a salt deposit at the edge of some conductors that was not removed in the washing steps. This problem was resolved by soaking the parts after etching in a tank of solder brightening solution for 3 minutes and then rinsing. Today, with the new production circuit board etch machine in use, this problem does not occur. The new machine is designed so that as the parts exit the etch chamber they are sprayed with the etchant's replenisher solution which washes off the etchant before the salts can form.

Samples of tin-lead plated parts that were etched in alkaline etchant were subjected to solderability tests. In one test, gold-plated lead frames were pre-tinned and soldered to pads and through holes of the PWBs. All joints were examined and found to exhibit excellent wetting. Solderability was also checked by determining the spread factor, a quantitative measure of the ability of a solder preform to wet the material in question. The spread factors of the boards submitted were in excess of 98 percent, which is considered excellent.

Table 4. Conductor Width Measurements

Part Number	Minimum Width Required*	Mask Width*	Measurements*			
			Side 1		Side 2	
			Top	Bottom	Top	Bottom
281571	0.018	0.025	0.019	0.022	0.021	0.025
	0.018	0.025	0.022	0.025	0.021	0.026
	0.038	0.050	0.046	0.051	0.046	0.049
	0.038	0.050	0.046	0.051	0.046	0.049
281585	0.022	0.025	0.025	0.027	0.023	0.026
	0.022	0.025	0.025	0.028	0.023	0.026
	0.044	0.050	0.046	0.049	0.046	0.050
	0.044	0.050	0.046	0.050		
293677	0.046	0.050	0.046	0.047	0.048	0.051
	0.046	0.050	0.046	0.047	0.047	0.050
	0.046	0.050	0.047	0.048		
293431		0.052	0.049	0.052		
		0.062	0.058	0.062		
		0.050			0.048	0.051
		0.075			0.073	0.078
279909	0.017	0.020	0.018	0.020	0.017	0.020
	0.017	0.020	0.016	0.018	0.016	0.019
281571	0.018	0.025	0.021	0.026	0.019	0.026
	0.018	0.025	0.022	0.026	0.019	0.026
	0.038	0.050	0.045	0.049	0.043	0.050
	0.038	0.050	0.045	0.049	0.043	0.049

*Dimensions given in inches; 0.001 inch = 25.4 μ m.

One limitation in the use of alkaline etchant is with printed wiring boards made from Teflon laminate. This type of laminate is made with a heavy copper oxide layer to promote adhesion between the copper and the Teflon. The alkaline etchant will not dissolve this copper oxide layer. These parts are still being etched with ferric chloride solution.

Alkaline etchant has been used in production of PWBs and flexible cables for over 2 years. Relatively few operational difficulties have been experienced. The automatic replenishing system has been trouble-free. On one occasion, after several months use,

Table 5. Conductor Spacing Measurements

Part Number	Minimum Spacing Required*	Narrowest Masked Dimension*	Spacing Measurement*
281571	0.015	0.020	0.030
	0.015		0.022
	0.015		0.025
281585	0.020	0.025	0.024
	0.020		0.036
	0.015		0.035
293677	0.050	0.055	0.055
	0.050		0.054
		0.050	0.063
293431	0.025	0.040	0.053
	0.025		0.044
	0.025		0.049
	0.025		0.047
279909	0.008	0.015	0.016
	0.008		0.014
281571	0.015	0.020	0.025
	0.015		0.023
	0.015		0.019
	0.015		0.017

*Dimensions given in inches; 0.001 inch = 25.4 μm .

the sprays of the etcher ceased to function. After decanting the etch solution a heavy deposit of salts was found on the bottom of the etcher. It was learned that excessive amounts of water added to the solution will cause precipitation of copper salts.

Some water leakage from the spray rinse chamber into the etch chamber was discovered. These leaks were stopped, the defective solution was discarded, the etcher was recharged with spent etchant, some fresh etchant was added to restore ammonia concentration, and etching was resumed. On another occasion, after an extended period in which the etcher had not been used, the salting out condition again occurred. In this instance, it was concluded that the solution had evaporated to the point where the concentration of the copper salts had exceeded their solubility and salt precipitation began. This solution was discarded, the etcher was recharged, and etching was back to normal. This

condition is now avoided by making sure the etcher is turned on every day to allow the replenishing system to add chemicals to maintain the proper concentration balance. If the etcher is not used for an extended period, the solution is pumped into drums for storage.

Very little maintenance is required for the alkaline etching process. When a barrel of replenisher is emptied it is replaced with a new barrel, and the barrel of spent etchant is sent for copper reclamation. About once every 6 weeks the etch solution is decanted, the etcher cleaned, and the same etchant returned to the etcher.

ACCOMPLISHMENTS

A proprietary alkaline etchant was evaluated for production etching of printed wiring boards. The process was found to be satisfactory from the standpoint of quality and economics. This alkaline etchant is now used in all production etching of PWBs at Bendix.

FUTURE WORK

As chemical suppliers modify their present products or develop new etchants, these will be evaluated for applicability in PWB manufacture at Bendix.

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