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BDX-613-515 (Rev.)

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EFFECT OF SODIUM HYDROXIDE
ON ALUMINUM FOIL THICKNESS

PDO 6984694, Topical Report

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**Kansas City
Division**

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KANSAS CITY DIVISION
KANSAS CITY, MISSOURI

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ABSTRACT

A study was performed to evaluate the effect on aluminum foil thickness of a surface preparation etch with a sodium hydroxide solution. It was determined that a 20-second etch in a 20-gram-per-liter sodium hydroxide solution reduced a 0.00045-inch-thick aluminum foil by less than one percent.

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SUMMARY

This report covers investigations made from December 1970 through January 1971 to establish the amount of reduction in thickness of 1145 alloy aluminum foil as a result of the etching action of a 20 grams per liter sodium hydroxide solution. The samples studied were made from nominally 0.00045-inch-thick 1145-0 alloy aluminum foil bonded on 0.002-inch-thick polyester film.

The results of this test indicate that there is approximately a three percent decrease in thickness for a 120-second etch, and less than one percent decrease for a 30-second etch.

It was concluded that this process is usable as a surface preparation for etching precision elements.

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DISCUSSION

SCOPE AND PURPOSE

Evaluation of several potential techniques to obtain a matte type surface on specular finish aluminum foil prior to application of photoresist material resulted in the selection of a caustic rinse (20 grams per liter sodium hydroxide (NaOH) solution with 30 second immersion). This technique results in a finished panel etch quality within established requirements. The amount of aluminum the caustic solution removed from the exposed surface was not known, and this study was established to determine the amount of material removed.

PRIOR WORK

Techniques were recently established on a recent process development order which provided Bendix with a reliable method of measuring aluminum foil thickness on plastic substrates.

No prior work has been done at Bendix to study the effect of NaOH on the thickness of thin aluminum conductors.

ACTIVITY

Introduction

Bendix has a requirement to fabricate precision elements from a nominally 0.00045-inch-thick 1145-0 alloy aluminum bonded to a substrate of 0.002-inch polyester film. The material used was purchased according to Bendix Specification PS 43726-100-A, "Tentative Specification for Aluminum/Mylar/Mylar/Aluminum Laminate," which allows the vendor to apply the aluminum,

matte or specular finish, to the substrate. This degree of freedom is allowed so that the better surface for bonding can be selected to permit meeting the bond strength requirement defined in the specification. Normally the material purchased to this specification is received with the matte surface exposed; however, the lot of material for this order had the specular finish side exposed. These panels required approximately twice as much time in the etch solution and the resultant line definition was significantly poorer (Figures 1 and 2).

Several techniques to obtain a matte surface prior to application of photoresist material were evaluated. A caustic rinse (20 grams per liter NaOH solution with 30 seconds immersion) resulted in a finished panel etch quality which was within the requirements. What was not known was how much the aluminum foil was thinned as a result of the NaOH etching.

Experimental Procedure

Using material mentioned previously, a 6- by 6-inch panel with two patterns (Figure 3) was cleaned, exposed and etched in the usual manner.

Both patterns were measured for resistance to establish the original thickness. The measurements were repeated ten times each to establish the repeatability of the measuring package (Cimron digital milliohm system and the resistance fixture). All subsequent measurements were repeated ten times, with the largest error of repeatability (σ/mean) being 0.07 percent; five of the 20 repetitions were 0.00 percent.

One pattern was immersed in a 20 grams per liter NaOH solution for 30 seconds, then in intervals of 15 seconds up to 120 seconds accumulated time, and then immersed for an additional 4 minutes. After each interval, both patterns were given a cold-tap-water rinse, an alcohol rinse and air dry with large drops blotted with a Kimwipe. After each drying, measurements were taken. Thus, one pattern was used as a control sample.

Upon completion of the 6 minute accumulated immersion time, the roles of the test patterns were reversed and the original pattern was immersed in the NaOH solution for 120 seconds, washed and dried, and then measured.

Thickness Calculations

Using the test patterns mentioned before, a resistance measurement was taken using a multi-probe system (Figure 4). A constant current was put through the circuit using the two outboard leads and the voltage drop was measured using the inboard leads. The Cimron then displays a resistance.

Text continued on page 18.

Figure 1. Typical Etch Line Quality With No NaOH Surface Preparation (172X) (Average 4.3 minutes required to etch.)

Figure 2. Typical Etch Line Quality With 30-Second Immersion in 20 Grams per Liter NaOH Surface Preparation (172X) (Average 2.4 minutes required to etch.)

Figure 3. Foil Thickness Test Pattern, PS 6984383-9

Figure 4. Test Fixture, PS 44229-4

Using this resistance from the Cimron and the following equation

$$R = (\rho/t) * (L/W),$$

where ρ = volume resistivity
t = foil thickness
L = length
W = width

assuming that

$$L/W = 10$$

and that this ratio did not change significantly with exposure to the NaOH. Note length is the distance between voltage leads, and width is the distance 0.500 ± 0.0005 called out on the drawing PS 6984383-9.

$$\rho = 1.1133 \times 10^{-6} \text{ ohm inch*}$$

and that volume resistivity did not change significantly with exposure of the foil the NaOH.

Then the foil thickness is

$$t = 1.113 \times 10^{-5} / R \text{ (meas).}$$

The results of such data are displayed in Figures 5 and 6. Analysis of the data is given in Appendix A.

A hypothesis was proposed that the etch rate should be constant with time. A computer program (Appendix B) was constructed using the resistance of pattern 04-01 starting at time = 0 and using the resistance at time = 360 seconds. The display of this hypothesis is plotted as line 5 of Figure 5 and line 6 of Figure 6.

ACCOMPLISHMENTS

The experiment was successful in providing data to support the hypothesis that NaOH solutions could be used for surface preparation of specular finished aluminum foils. The data indicates that a 30-second immersion in

* Charles D. Hodgman, Handbook of Chemistry and Physics, 35th Edition, Chemical Rubber Publishing Company.

Figure 5. Resistance Versus Etch Time for Test Pattern Etched in 20 Grams per Liter NaOH Solution

Figure 6. Calculated Thickness Versus Etch Time of Test Pattern

a 20 gram per liter NaOH solution will reduce the thickness of a 0.00045-inch 1145-0 alloy aluminum foil by 0.8 percent. This decrease in thickness meets the requirement for present precision elements.

FUTURE WORK

The NaOH etch appears to prepare the surface such that present etching parameters are satisfied; however, photoresist adherence to specular aluminum surfaces and the mechanism causing the difference in etch time between specular and matte finish aluminum foils will be investigated.

Until results from these investigations are obtained, purchases under the existing specifications will be limited to material with matte surface of the foil exposed.

Appendix A

DATA ANALYSIS FOR TEST PATTERN RESISTANCE VERSUS ETCH TIME

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Table A-1. Analysis of Data for Resistance of Test Pattern Versus Etch Time in 20 Grams per Liter NaOH Solution

PATTERN	TOTAL ETCH TIME (SECONDS)	N	MEAN ($10^{-5}\Omega$)	SIGMA ($10^{-6}\Omega$)	SIGMA/MEAN (PERCENT)	MIN ($10^{-5}\Omega$)	MAX ($10^{-5}\Omega$)	ORIGINAL DATA ($10^{-5}\Omega$)									
								1	2	3	4	5	6	7	8	9	10
04-1-1	0	10	2232	8.433	0.04	2230	2232	2232	2232	2232	2232	2232	2232	2232	2232	2230	2230
04-2-1	0	10	2229	5.271	0.02	2229	2230	2230	2230	2230	2230	2230	2229	2229	2229	2229	2229
04-1-2	30	10	2237	0.000	0.00	2237	2237	2237	2237	2237	2237	2237	2237	2237	2237	2237	2237
04-2-2	0	10	2230	4.217	0.02	2229	2230	2230	2230	2230	2230	2230	2230	2230	2230	2229	2229
04-1-3	45	10	2242	0.000	0.00	2242	2242	2242	2242	2242	2242	2242	2242	2242	2242	2242	2242
04-2-3	0	10	2228	12.52	0.06	2225	2229	2229	2229	2229	2225	2227	2227	2227	2228	2228	2228
04-1-4	60	10	2248	9.661	0.04	2246	2249	2249	2249	2249	2249	2249	2249	2246	2248	2248	2248
04-2-4	0	10	2230	4.832	0.02	2229	2230	2229	2230	2230	2230	2230	2230	2230	2230	2229	2229
04-1-5	75	10	2248	16.19	0.07	2245	2250	2250	2250	2245	2247	2247	2247	2249	2249	2249	2249
04-2-5	0	10	2223	6.667	0.03	2222	2224	2222	2223	2223	2223	2224	2222	2223	2223	2223	2223
04-1-6	90	10	2260	9.190	0.04	2259	2261	2261	2261	2261	2260	2260	2259	2259	2259	2259	2259
04-2-6	0	10	2229	0.000	0.00	2229	2229	2229	2229	2229	2229	2229	2229	2229	2229	2229	2229
04-1-7	105	10	2271	4.217	0.02	2270	2271	2271	2271	2271	2271	2271	2271	2271	2271	2270	2270
04-2-7	0	10	2231	3.163	0.01	2230	2231	2230	2231	2231	2231	2231	2231	2231	2231	2231	2231
04-1-8	120	10	2273	0.000	0.00	2273	2273	2273	2273	2273	2273	2273	2273	2273	2273	2273	2273
04-2-8	0	10	2230	7.072	0.03	2229	2231	2229	2231	2231	2230	2230	2230	2231	2231	2231	2231
04-1-9	360	10	2446	0.000	0.00	2446	2446	2446	2446	2446	2446	2446	2446	2446	2446	2446	2446
04-2-9	0	10	2231	11.97	0.05	2229	2232	2229	2230	2230	2230	2230	2232	2232	2232	2232	2232
*04-1-10	360	10	2446	9.661	0.04	2445	2447	2447	2447	2447	2447	2447	2447	2447	2445	2445	2445
**04-2-10	120	10	2264	4.218	0.02	2263	2264	2263	2263	2264	2264	2264	2264	2264	2264	2264	2264
* AT THIS POINT 04-1 BECAME THE CONTROL SAMPLE																	
** AT THIS POINT 04-2 BECAME THE TEST SAMPLE																	

Appendix B

COMPUTER PROGRAM AND OUTPUT TO PREDICT
THINNING OF ALUMINUM FOIL,
ASSUMING CONSTANT ETCH RATE

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PROGRAM (XTRAN)

```

DIMENSION R(100),T(100),TIM(100),RNORM(100)
RHO=2.828E-8*39.37
DISPLAY /, 'RHO = ', RHO, ' OHM IN. '
RZRO=2.232E-2
R(360)=2.446E-2
ALOW=10.
B=RHO*ALOW
TZRO=B/RZRO
A=(TZRO/360.)-(B/(360.*R(360)))
DISPLAY 'T(0) = ', TZRO, ' IN. '
DISPLAY 'B = ', B, ' OHM IN. '
DISPLAY 'A = ', A, ' IN. /SEC. '
DISPLAY /, 'TIME          THICKNESS          RESISTANCE          RNORM'
DO 100 I=1, 50
ITIM=10*I
TIM(I)=FLOAT(ITIM)
T(I)=TZRO-A*TIM(I)
R(I)=B/T(I)
RNORM(I)=TZRO/T(I)
100 DISPLAY TIM(I), T(I), R(I), RNORM(I)
STOP
END

```

OUTPUT

```

RHO =      1.1133836E-06 OHM IN.
T(0) =      4.988277778E-04 IN.
B =      1.1133836E-05 OHM IN.
A =      1.212287004E-07 IN./SEC.

```

TIME	THICKNESS	RESISTANCE	RNORM
10	4.976154908E-04	0.022374376	1.002436192
20	4.964032038E-04	0.022429017	1.004884284
30	4.951909168E-04	0.022483926	1.007344361
40	4.939786298E-04	0.022539105	1.009816514
50	4.927663428E-04	0.022594555	1.01230083
60	4.915540558E-04	0.022650278	1.0147974
70	4.903417687E-04	0.022706277	1.017306315
80	4.891294817E-04	0.022762554	1.019827666
90	4.879171947E-04	0.02281911	1.022361547
100	4.867049077E-04	0.022875948	1.02490805
110	4.854926207E-04	0.022933069	1.02746727
120	4.842803337E-04	0.022990477	1.030039304
130	4.830680467E-04	0.023048173	1.032624247

140	4.818557597E-04	0.023106159	1.035222196
150	4.806434727E-04	0.023164438	1.037833251
160	4.794311857E-04	0.023223012	1.04045751
170	4.782188987E-04	0.023281882	1.043095075
180	4.770066117E-04	0.023341052	1.045746045
190	4.757943247E-04	0.023400523	1.048410525
200	4.745820377E-04	0.023460298	1.051088617
210	4.733697507E-04	0.023520379	1.053780427
220	4.721574637E-04	0.023580769	1.056486058
230	4.709451767E-04	0.023641469	1.05920562
240	4.697328897E-04	0.023702483	1.061939219
250	4.685206027E-04	0.023763813	1.064686963
260	4.673083157E-04	0.023825461	1.067448965
270	4.660960287E-04	0.023887429	1.070225334
280	4.648837417E-04	0.023949721	1.073016183
290	4.636714547E-04	0.024012339	1.075821625
300	4.624591677E-04	0.024075284	1.078641776
310	4.612468806E-04	0.024138561	1.081476751
320	4.600345936E-04	0.024202171	1.084326667
330	4.588223066E-04	0.024266117	1.087191644
340	4.576100196E-04	0.024330403	1.0900718
350	4.563977326E-04	0.024395029	1.092967257
360	4.551854456E-04	0.02446	1.095878136
370	4.539731586E-04	0.024525318	1.098804562
380	4.527608716E-04	0.024590985	1.101746659
390	4.515485846E-04	0.024657006	1.104704554
400	4.503362976E-04	0.024723381	1.107678374
410	4.491240106E-04	0.024790115	1.110668248
420	4.479117236E-04	0.024857211	1.113674306
430	4.466994366E-04	0.02492467	1.11669668
440	4.454871496E-04	0.024992496	1.119735504
450	4.442748626E-04	0.025060693	1.122790911
460	4.430625756E-04	0.025129263	1.125863039
470	4.418502886E-04	0.025198209	1.128952024
480	4.406380016E-04	0.025267535	1.132058007
490	4.394257146E-04	0.025337243	1.135181127
500	4.382134276E-04	0.025407336	1.138321526

STOP
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