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Kansas City Division

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NEW FLEXIBLE CIRCUIT MATERIAL EVALUATION

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## ABSTRACT

A project has been undertaken to evaluate new sources of flexible circuit materials for use by Allied-Signal, Inc., Kansas City Division. The vast majority of current flexible circuits are fabricated from polyimide film and acrylic adhesive circuit materials. One new polyimide film was evaluated as an alternate dielectric film. Thirteen (13) suppliers of flexible circuit materials have been identified. The results of the mechanical and electrical properties evaluation study of some of the new sources of flexible circuit materials are discussed.

## 1. INTRODUCTION

Currently, over 90 percent of the flexible circuits produced at KCD are being fabricated from a single sourced material: Polyimide film and copper bonded together with an acrylic adhesive. The need exists to evaluate new dielectric films and adhesive systems that have recently been introduced on the market in order to eliminate the reliance on a single sourced material and to develop a database for materials to meet more demanding flexible circuit designs.

## 2. DISCUSSION

Today there are three competitive polyimide films that are available to laminators of flexible circuit materials. A survey of industry was made to

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determine new sources of flexible circuit materials. To date, thirteen different suppliers have been identified. Seven of the thirteen suppliers manufacture a complete system of laminates, covercoats and adhesives. Six suppliers supply metallized polyimide films without adhesive to bond the metal to the polyimide film. Two companies provide a polyimide coated metal laminate.

Three basic types of adhesive systems are currently offered by the various laminators of flex circuit materials. Most of these laminators may eventually supply laminates and covercoat materials with any of the three polyimide films and their own adhesive system.

Two laminators use a phenolic-butyral adhesive. Modified epoxy adhesives are available from two laminators and six suppliers of a modified acrylic adhesive systems similar to the acrylic system currently being used.

## 3. EVALUATION PROCEDURE

All of these suppliers will supply their products with standard thicknesses of copper, polyimide films and adhesive films as desired by the user. As a baseline for this project, the construction of the laminates and covercoats were standardized as follows: 1) double clad laminates as 1 oz/ft$^2$ copper bonded to both sides of a 25 micron (1 mil) polyimide film with a 25 micron thick adhesive; 2) single clad are same as double clad except the copper is bonded to only one side; 3) the covercoat is 25 micron polyimide film with 25 micron of adhesive on one side. Free-standing adhesive film with a thickness of 50 micron (2 mil) was chosen. Copper-clad laminates were fabricated to evaluate the properties of the covercoat and film adhesive materials.

Table 1 lists the properties and test methods used in this evaluation. Ten, 90° peel strength, test specimens were removed from the roll and transverse directions of the laminates. Both sides of the double clad laminates were tested. Each laminate was tested in the "as received", "after etching", and "after solder dip" conditions per the listed IPC test methods.

The electrical properties of interest were the volume resistivity and surface resistance as determined by IPC-TM-650, Method 2.5.17. Test specimens were 10 cm by 10 cm (4 in x 4 in) with the required test patterns etched into the copper. Dimensional stability of the covercoat material were determined per IPC-TM-650, Method A, which determines the change in dimensions after a 30 m bake at 150° C. The laminate materials were tested for dimension change after complete removal of copper (Method B) and after bake cycle of 30 M at 150° C (Method C).

## 4. RESULTS

Evaluation of one lot of material from eight different manufacturers has been completed. Four acrylic, two epoxy, one phenolic butyral adhesive systems and three different adhesiveless laminates have been tested.

### 90° Peel Strength

With only a few exceptions, no significant differences in any of the 90° peel strength values were found between the two laminates supplied or the laminate fabricated from the covercoat and film adhesive from the same manufacturer. Overall average values for the 90° peel strength for the material tested are listed in Table 2. Overall average values for the die cut (12mm wide) and the etched (3mm wide) test specimen tested in the as-received and after solder dipped conditions. These data show that the two epoxy and four acrylic adhesive systems meet the IPC value of 12.1 N/cm (7.0 lbs/in). Only one acrylic adhesive compares favorably with values reported for the currently used flexible circuit materials. One epoxy adhesive flexible circuit materials had exceptionally high average 90° peel strength values, 33 to 49 N/cm.

The phenolic-butyral adhesive had the lowest 90° peel strength values of the adhesive-based materials - 5.5 to 6.5 N/cm and did not meet the IPC requirement of 7.9 N/cm (5 lbs/in) minimum. As expected, the adhesiveless laminate had much lower 90° peel strength values.

### Electrical Properties

The volume resistivity and surface resistance data generated for six different materials (four acrylic, one epoxy and one phenolic butyral adhesive based laminates) are listed in Table 3. The values listed are the average of two tests run on samples from the two laminates supplied by the manufacturer and samples from laminates fabricated using the covercoat and film adhesive. All of the materials met the IPC requirement for the volume resistivity. The surface resistance values reported were less repeatable than the volume resistivity values. Surface contamination may have contributed to some of the low values.

Dimensional Stability

The results from the dimensional stability study are given in Table 4 for the supplied laminates and Table 5 for the covercoat materials. The values given in Table 4 are the average of roll and transverse directions values obtained from the single clad and double clad laminates. Due to the limited amount of data generated, no conclusion can be made except that all the laminates and covercoat material meet the IPC specification for dimensional stability.

## 5. CONCLUSION

Test data has been generated for one lot of flexible circuit materials from nine manufacturers (six adhesive-based and three adhesiveless systems). Additional lots of materials from some of these manufacturers are currently being tested. The third polyimide film will be used by some of the laminators in the second lot of material to be evaluated. Flexible circuit materials from different laminators will also be evaluated.

## 6. BIOGRAPHY

The author is a staff engineer in the Materials Engineering department of Allied-Signal Inc., Kansas City Division, Kansas City, Missouri. He received his BSChE from the University of Colorado (1962) and MSChE from the University of Missouri-Columbia (1972).

TABLE 1

PROPERTIES TESTED

| PROPERTY | TEST METHOD* | # OF TEST SPECIMENS |
|---|---|---|
| 90° Peel Strength | 2.4.9 | |
| Die cut - As received | Method B | 5 |
| Die Cut - Solder dipped | Method D | 5 |
| Etched - As received | Method A | 5 |
| Etched - Solder dipped | Method C | 5 |
| Volume resistivity | 2.5.17 | 2 |
| Surface resistance | | |
| Dimensional stability | 2.2.4 | 1 |
| Covercoat | Method A | |
| Laminates | Method B & C | |

* IPC-TM 650 Test Methods

TABLE 2

AVERAGE 90° PEEL STRENGTH RESULTS

| Adhesive Type | Average 90° Peel Strength, N/cm* Width | | | | |
|---|---|---|---|---|---|
| | As Received | | Solder Dipped | | |
| | Die Cut | Etched | Die Cut | Etched | Average |
| Epoxy | 13.1 | 18.9 | 13.1 | 17.2 | 15.6 |
| Epoxy | 32.9 | 49.0 | 32.0 | 43.4 | 39.3 |
| Acrylic | 10.8 | 10.3 | 12.8 | 15.8 | 12.4 |
| Acrylic | 9.8 | 13.0 | 14.2 | 16.4 | 13.3 |
| Acrylic | 18.4 | 20.6 | 16.1 | 22.0 | 17.3 |
| Acrylic | 12.6 | 16.4 | 12.1 | 18.7 | 15.0 |
| Ph-Butyral | 6.1 | 6.5 | 5.6 | 6.0 | 6.0 |
| None | ** | ** | 7.0 | 4.6 | 5.8 |
| None | 0.5 | 0.5 | 0.5 | 0.6 | 0.5 |
| None | ** | ** | 7.9 | 7.0 | 7.4 |
| Acrylic*** | 21.0 | 20.0 | 20.0 | 19.0 | 20.0 |

* 1 N/cm = 0.57 lbs/in.
** Could not get copper/polyimide separated to start test
*** Typical values

TABLE 3

AVERAGE ELECTRICAL PROPERTIES

| Polyimide Film | Adhesive Type | Surface Resistance Megohms | Volume Resistivity Megohms-cm |
|---|---|---|---|
| Polyimide 1 | Epoxy | 4.7 E+2 | 2.3 E+7 |
| Polyimide 1 | Acrylic | 1.9 E+5 | 3.2 E+8 |
| Polyimide 1 | Ph-Buty. | 1.1 E+5 | 1.7 E+7 |
| Polyimide 2 | Acrylic | 8.8 E+3 | 2.9 E+8 |
| Polyimide 2 | Acrylic | 2.8 E+5 | 3.6 E+8 |
| Polyimide 1 | Acrylic | 2.2 E+4 | 3.4 E+8 |
| Polyimide 1* | Acrylic | 1 E+7 | 1 E+6 |
| Polyimide** | Acrylic | 1 E+5 | 1 E+6 |

* Typical value

** Minimum values required by IPC specifications, varies with type of adhesive.

TABLE 4

AVERAGE DIMENSIONAL STABILITY OF LAMINATES*

| Polyimide Film | Adhesive Type | Change, % (Etched) | Change, % (Baked) |
|---|---|---|---|
| Polyimide 1 | Epoxy | -0.05 | -0.09 |
| Polyimide 1 | Acrylic | -0.04 | -0.08 |
| Polyimide 1 | Ph-Buty. | -0.04 | -0.08 |
| Polyimide 1 | None | -0.04 | -0.08 |
| Polyimide 1 | Acrylic | -0.05 | -0.14 |
| Polyimide 1 | None | -0.04 | -0.08 |
| Polyimide 1 | None | -0.02 | -0.06 |
| Polyimide 2 | Acrylic | -0.04 | -0.07 |
| Polyimide 2 | Acrylic | -0.05 | -0.08 |
| Polyimide 1** | Acrylic | -0.07 | -0.08 |
| Polyimide*** | Acrylic | -0.15 | -0.20 |

* Average of machine and transverse direction and 2 laminates

** Typical values

*** Maximum required values per IPC specification

TABLE 5

AVERAGE DIMENSIONAL STABILITY OF COVERCOAT MATERIAL*

| Polyimide Film | Adhesive Type | Change, % (Baked) |
|---|---|---|
| Polyimide 1 | Epoxy | -0.11 |
| Polyimide 1 | Acrylic | -0.20 |
| Polyimide 1 | Ph-Buty. | -0.16 |
| Polyimide 1 | Acrylic | -0.04 |
| Polyimide 2 | Acrylic | -0.12 |
| Polyimide 2 | Acrylic | -0.10 |
| Polyimide 1** | Acrylic | -0.04 |
| Polyimide*** | Acrylic | 0.20 |

* Average of machine and transverse direction

** Typical values

*** Maximum required value per IPC specifications