561 Hillgrove Avenue • LaGrange, Illinois • 60525-5997 • U.S.A.
Phone: (708) 354-1040 • Fax: (708) 354-2820 • http://www.grayhill.com

# Lead Free Tin Whiskering Study

## Grayhill DIP Switches

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Revision A

Grayhill INC.
An ISO-9001 Company
561 Hillgrove Avenue • LaGrange, Illinois • 60525-5997 • U.S.A.
Phone: (708) 354-1040 • Fax: (708) 354-2820 • http://www.grayhill.com

# TABLE OF CONTENTS

1. Introduction ....................................................................................................3
2. Test Specification..............................................................................................4
  2.1. Intent..........................................................................................................4
  2.2. Preconditioning ..........................................................................................4
    2.2.1. Wave Temperature Processing .................................................................4
    2.2.2. Annealed Bases.......................................................................................4
  2.3. Test Conditions...........................................................................................5
    2.3.1. Storage Testing ......................................................................................5
    2.3.2. Accelerated Aging....................................................................................5
    2.3.3. Thermal Cycling.......................................................................................5
    2.3.4. Solderability ...........................................................................................5
    2.3.5. Testing with Bias......................................................................................6
3. Inspection .........................................................................................................6
  3.1. Optical Inspection........................................................................................6
  3.2. SEM Inspection ...........................................................................................6
4. Results.........................................................................................................6 – 7
5. Conclusion ........................................................................................................7
Appendix A...................................................................................................8 – 11

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1. Introduction

   In order to comply with the European ROHS directive, a study was conducted to qualify pure matte tin plating as a replacement for tin/lead plating currently used on Grayhill DIP switches. The main focus of this testing was to determine if tin whisker growth would occur and to ensure the solderability of the devices.

   Grayhill selected the 76 series for use in testing because it is representative of Grayhill's DIP product line. The samples used for testing were first plated with a 50 micro-inch thick layer of nickel and then a 100 – 175 micro-inch thick layer of 99.96% pure matte tin. The nickel provides a barrier between the copper substrate and the tin thereby preventing copper diffusion into the tin layer. This diffusion can create localized compressive stresses in the tin where tin whiskers can form.

   A group of plated bases in different stages of assembly as well as completed switches were subjected to various preconditioning and environmental test processes to determine if any of the processes had an impact on solderability or tin whisker growth. The different base assemblies used for testing represented several stages of terminal forming operations that the base is subjected to during processing. Since tin whisker growth is caused by mechanical compressive stresses in the material, it was essential that bases from each of the different processing stages were tested. This ensured that a specific stage could be isolated should any tin whiskers be found. The preconditioning included a group with no preconditioning, a group that was subjected to wave solder processing and, a group of bases that underwent an annealing process. The environmental processing included storage at room temperature, aging at elevated temperature and humidity and thermal cycling. Environmental and solderability testing was performed by Grayhill.

   All of the components used for testing were inspected by Grayhill for tin whiskers both before and after testing. Additional SEM (scanning electron microscope) inspection was conducted by McCrone Associates in Westmont, Illinois.

# 2. Test Specification

## 2.1. Intent

The Grayhill Quality Assurance Lab participated in this study by performing environmental conditioning, solderability testing and inspection of the test samples. The following components were used for this study:

76 series DIP switches and components with tin-plated leads
- 55 Switches
- 55 Bases
- 55 Annealed Bases
- 55 Frames

76 series DIP switches with tin/lead plating as a control group
- 55 Switches

The components were grouped and numbered as follows:

| Group | Precondition | Test Condition | Frames | Bases | Annealed Bases | Switches | Tin-Lead Switches |
|---|---|---|---|---|---|---|---|
| I | None | Storage | 101-105 | 201-205 | 301-305 | 401-405 | 501-505 |
| II | None | Aging | 106-110 | 206-210 | 306-310 | 406-410 | 506-510 |
| III | None | Thermal Cycle | 111-115 | 211-215 | 311-315 | 411-415 | 511-515 |
| IV | None | Solderability after storage | | 216-220 | 316-320 | 416-420 | 516-520 |
| V | Wave Temp | Storage | 116-120 | 221-225 | 321-325 | 421-425 | 521-525 |
| VI | Wave Temp | Aging | 121-125 | 226-230 | 326-330 | 426-430 | 526-530 |
| VII | Wave Temp | Thermal Cycle | 126-130 | 231-235 | 331-335 | 431-435 | 531-535 |
| VIII | None | Solderability after aging | | 236-240 | 336-340 | 436-440 | 536-540 |
| IX | Wave Temp | Storage - With Bias | | 241-245 | 341-345 | 441-445 | 541-545 |
| X | Wave Temp | Aging - With Bias | | 246-250 | 346-350 | 446-450 | 546-550 |
| XI | Wave Temp | Thermal Cycle - With Bias | | 251-255 | 351-355 | 451-455 | 551-555 |

## 2.2. Preconditioning

### 2.2.1. Wave Temperature Processing

This preconditioning operation was performed to subject the components to temperature extremes encountered during wave solder. A solder pot was used for this operation. The tips of the leads of the switches and bases were inserted into 245°C molten solder for a period of 30 seconds. Only the tips of the leads were soldered so the remainder of the leads could be inspected for tin whisker growth. No flux or steam aging was used for this operation.

### 2.2.2. Annealed Bases

A group of bases was preconditioned by baking at 125°C for a period of 1 hour. The purpose of this was to determine if the annealing process would affect tin whisker growth.

## 2.3. Test Conditions

### 2.3.1. Storage Testing

The components were stored at room temperature for a period of 1,000 hours (42 days).

### 2.3.2. Accelerated Aging

The components were aged in a temperature/humidity chamber for a period of 1,000 hours (42 days). The chamber was set to 60°C with 93% relative humidity.

### 2.3.3. Thermal Cycling

Thermal cycling was performed in Grayhill’s thermal shock machine. This machine has two chambers: a hot chamber positioned above a cold chamber. A motorized carriage moves test samples rapidly between the chambers to allow fast ramp times. For this test the hot chamber was set to 85°C and the cold chamber was set to -55°C. 500 hot/cold cycles were run with a dwell time of 10 minutes at each temperature. The test lasted seven days.

### 2.3.4. Solderability

Solderability tests were performed on bases and switches after storage and aging. Solderability testing was performed in accordance to MIL-STD 202, Method 208H and carried out as follows:

- Steam Aging: Half of the components were aged for a period of 8 hours. The other half the components were aged for a period of 16 hours.
- Solder Pot: Component leads were dipped in type ROL1 rosin flux for 5 seconds, air-dried for 5 seconds, dipped in 245°C molten solder for 5 seconds. After cooling, the leads were cleaned with isopropyl alcohol.
- Hand Solder: A soldering iron with a tip temperature of 350°C was applied to the test lead for 5 seconds. Solder was applied to the device lead. Tests were performed with rosin-core and no-clean type solders.
- Optical inspection under magnification: Solder must cover 95% of the area and be free of pits and voids.

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2.3.5. Testing with Bias

The switches and bases requiring bias were mounted in sockets on a printed wiring board. A current of 12.5 milliamperes at 5 volts was passed through alternating positions of each DIP. The other switch positions were closed and at ground potential. The leads of the components were partially inserted into the sockets so remaining section of the leads could be inspected for tin whiskers.

## 3. Inspection

The components were inspected for tin whisker growth before and after environmental conditioning.

### 3.1. Optical Inspection

The components were inspected by Grayhill using an optical microscope.

### 3.2. SEM Inspection

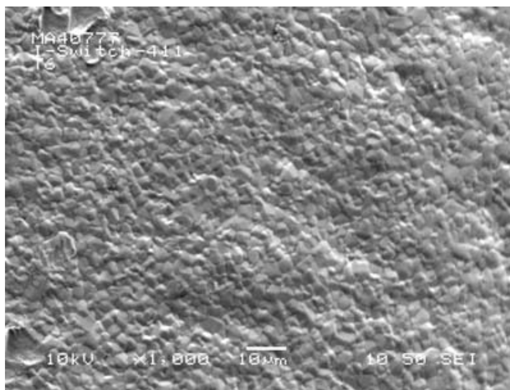
The components were also inspected using scanning electron microscope. This inspection was performed by McCrone Associates in Westmont, Illinois.

## 4. Results

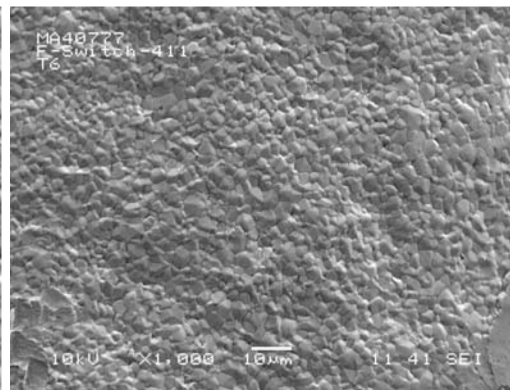
All samples passed solderability testing and no tin whisker growth was detected on any of the samples.

| Test Condition | Results |
|---|---|
| Solderability | Pass |
| Tin Whisker Growth | None |

See Table I in appendix A for more detailed information regarding the SEM inspection performed by McCrone Associates.  Sample before and after images from the SEM inspection are shown below.



Switch #411 before thermal cycling



Switch #411 after thermal cycling

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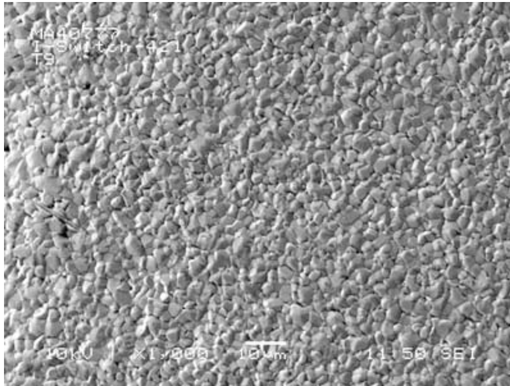
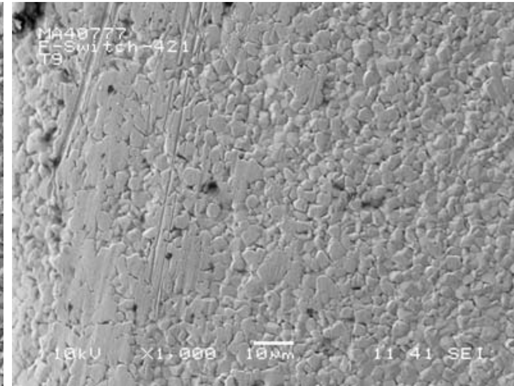


Switch #421 before wave solder and storage



Switch #421 after wave solder and storage

5. Conclusion

This testing has shown that tin whiskering on pure tin plated terminals is not an issue in Grayhill's DIP product lines when used with a nickel under plating. The testing has also shown that Grayhill's terminal forming operations do not have an impact on the formation of tin whiskers. Pure tin solder plating is therefore an acceptable alternative to the tin lead solder plating currently in use.

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# APPENDIX A

## TABLE I

Summary of Final SEM Examination

| Sample | Terminal | Comment | Result |
|---|---|---|---|
| Frame 101 | 2 | Some abrasions ~ mid point to end. Imaged near center on widest part of terminal. | No tin whiskers found. |
| Frame 106 | 5 | Some abrasions. Imaged where terminal narrows to a constant width left of center. | No tin whiskers found. |
| Frame 111 | 12 | Some abrasions. Imaged right of center where terminal narrows. | No tin whiskers found. |
| Frame 116 | 3* | Some abrasions. Imaged left of center on widest part of terminal. | No tin whiskers found. |
| Frame 121 | 11* | Some abrasions. Imaged inside surface left of center where terminal narrows. | No tin whiskers found. |
| Frame 126 | 13 | Some abrasions. Imaged inside surface near right edge, narrow part of terminal. | No tin whiskers found. |
| Base 201 | 1 | Heavy abrasions. Imaged near left edge on narrowest part of terminal. | No tin whiskers found. |
| | 5 | Heavy abrasions. Imaged right of center. | No tin whiskers found. |
| Base 206 | 2 | Heavy abrasions. Imaged right of center where terminal narrows. | No tin whiskers found. |
| | 6 | Some abrasions. Imaged right of center where terminal narrows. | No tin whiskers found. |
| Base 211 | 3 | Some abrasions. Imaged left of center where terminal narrows. | No tin whiskers found. |
| | 7 | Some abrasions. Imaged left of center where terminal narrows. | No tin whiskers found. |
| Base 221 | 9 | Some abrasions. Imaged left of center where terminal narrows closest to plastic. | No tin whiskers found. |
| | 13 | Some abrasions. Imaged right of center where terminal narrows closest to plastic. | No tin whiskers found. |
| Base 226 | 2* | Some abrasions. Imaged near right edge on widest part of terminal. | No tin whiskers found. |
| | 8* | Some abrasions. Imaged right of center where terminal narrows closest to plastic. | No tin whiskers found. |
| Base 231 | 4* | Some abrasions. Imaged left of center just below where terminal narrows. | No tin whiskers found. |
| | 7* | Some abrasions. Imaged near left edge on widest part of terminal. | No tin whiskers found. |
| Base 241 | 12 | Some abrasions. Imaged left of center just below where terminal narrows. | No tin whiskers found. |
| | 15 | Some abrasions. Imaged left of center where terminal narrows. | No tin whiskers found. |

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# APPENDIX A

TABLE I - Continued

Summary of Final SEM Examination

| Sample | Terminal | Comment | Result |
|---|---|---|---|
| Base 246 | 2* | Some abrasions. Imaged near left edge on widest part of terminal. | No tin whiskers found. |
| | 6* | Some abrasions. Imaged near left edge on widest part of terminal. | No tin whiskers found. |
| Base 251 | 1* | Some abrasions. Imaged left of center where terminal narrows closest to plastic. | No tin whiskers found. |
| | 8* | Some abrasions. Imaged right of center just below where terminal narrows. | No tin whiskers found. |
| Annealed Base 301 | 10 | Some abrasions. Imaged near left edge on widest part of terminal. | No tin whiskers found. |
| | 16 | Some abrasions. Imaged near left edge on widest part of terminal. | No tin whiskers found. |
| Annealed Base 306 | 9 | Some abrasions. Imaged near right edge on widest part of terminal. | No tin whiskers found. |
| | 11 | Some abrasions. Imaged left of center just below where terminal narrows. | No tin whiskers found. |
| Annealed Base 311 | 4 | Some abrasions. Imaged near left edge on widest part of terminal. | No tin whiskers found. |
| | 7 | Some abrasions. Imaged right of center where terminal narrows closest to plastic. | No tin whiskers found. |
| Annealed Base 321 | 4* | Some abrasions. Imaged near left edge on widest part of terminal. | No tin whiskers found. |
| | 5* | Some abrasions. Imaged near right edge on widest part of terminal. | No tin whiskers found. |
| Annealed Base 326 | 13* | Some abrasions. Imaged left of center where terminal narrows closest to plastic. | No tin whiskers found. |
| | 14* | Some abrasions. Imaged near left edge on widest part of terminal. | No tin whiskers found. |
| Annealed Base 331 | 12* | Some abrasions. Imaged near left edge on widest part of terminal. | No tin whiskers found. |
| | 15* | Some abrasions. Imaged near right edge on widest part of terminal. | No tin whiskers found. |
| Annealed Base 341 | 3* | Some abrasions. Imaged near right edge on widest part of terminal. | No tin whiskers found. |
| | 6* | Some abrasions. Imaged left of center where terminal narrows closest to plastic. | No tin whiskers found. |
| Annealed Base 346 | 2* | Some abrasions. Imaged left of center just below where terminal narrows. | No tin whiskers found. |
| | 5* | Some abrasions. Imaged left of center where terminal narrows closest to plastic. | No tin whiskers found. |

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# APPENDIX A

TABLE I - Continued

Summary of Final SEM Examination

| Sample | Terminal | Comment | Result |
|---|---|---|---|
| Annealed Base 351 | 10* | Some abrasions. Imaged near right edge on widest part of terminal. | No tin whiskers found. |
| | 16* | Some abrasions. Imaged near right edge on widest part of terminal. | No tin whiskers found. |
| Switch 401 | 13 | Some abrasions. Imaged near right edge ~2 mm from housing. | No tin whiskers found. |
| | 16 | Some abrasions. Imaged near left edge ~2 mm from housing. | No tin whiskers found. |
| Switch 406 | 2 | Some abrasions. Imaged near right edge ~2 mm from housing. | No tin whiskers found. |
| | 7 | Some abrasions. Imaged near left edge ~2.5 mm from housing. | No tin whiskers found. |
| Switch 411 | 1 | Some abrasions. Imaged near left edge ~2.5 mm from housing. | No tin whiskers found. |
| | 6 | Some abrasions. Imaged near right edge ~2 mm from housing. | No tin whiskers found. |
| Switch 421 | 9 | Some abrasions. Imaged near left edge ~2 mm from housing. | No tin whiskers found. |
| | 15 | Some abrasions. Imaged near left edge ~2 mm from housing. | No tin whiskers found. |
| Switch 426 | 4* | Some abrasions. Imaged near right edge ~1.2 mm from housing. | No tin whiskers found. |
| | 8* | Some abrasions. Imaged near right edge ~1.2 mm from housing. | No tin whiskers found. |
| Switch 431 | 10* | Some abrasions. Imaged near right edge ~1.1 mm from housing. | No tin whiskers found. |
| | 14* | Some abrasions. Imaged near left edge ~1 mm from housing. | No tin whiskers found. |
| Switch 441 | 2 | Some abrasions. Imaged near right edge ~2 mm from housing. | No tin whiskers found. |
| | 6 | Some abrasions. Imaged near left edge ~2 mm from housing. | No tin whiskers found. |
| Switch 446 | 11* | Some abrasions. Imaged near right edge ~1.4 mm from housing. | No tin whiskers found. |
| | 16* | Some abrasions. Imaged near left edge ~1.3 mm from housing. | No tin whiskers found. |
| Switch 451 | 3* | Some abrasions. Imaged near left edge ~0.8 mm from housing. | No tin whiskers found. |
| | 5* | Some abrasions. Imaged near left edge ~0.8 mm from housing. | No tin whiskers found. |

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# APPENDIX A

TABLE I - Continued

Summary of Final SEM Examination

| Sample | Terminal | Comment | Result |
|---|---|---|---|
| Switch 501 | 2 | Some abrasions. Imaged near left edge ~2 mm from housing. | No tin whiskers found. |
| Switch 505 | 13 | Some abrasions. Imaged near left edge ~2 mm from housing. | No tin whiskers found. |
| Switch 511 | 6 | Some abrasions. Imaged near right edge ~2 mm from housing. | No tin whiskers found. |
| Switch 521 | 8 | Some abrasions. Imaged near left edge ~2 mm from housing. | No tin whiskers found. |
| Switch 526 | 5* | Some abrasions. Imaged near right edge ~2 mm from housing. Bumps along edge may be due to uneven solder flow. | No tin whiskers found. |
| Switch 531 | 12* | Some abrasions. Imaged near left edge ~2 mm from housing. Bumps along edge may be due to uneven solder flow. | No tin whiskers found. |
| Switch 541 | 11 | Some abrasions. Imaged near left edge ~2 mm from housing. | No tin whiskers found. |
| Switch 546 | 3* | Some abrasions. Imaged near left edge ~2 mm from housing. | No tin whiskers found. |
| Switch 551 | 10* | Some abrasions. Imaged near right edge ~2 mm from housing. | No tin whiskers found. |

Note: Asterisk (*) denotes terminals that contained solder from testing following the initial SEM inspection. Locations of SEM images may vary slightly due to the soldering process.