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# Temperature Cycle Report for 376 Ceramic Column Grid Array

## INTRODUCTION

This report summarizes the thermal cycle results of the 376 ceramic column grid array package with 80Pb/20Sn copper coil columns from 6Sigma. The 10bit 1GSPS Analog to Digital Converter, ADC10D1000CCMLS, is space qualified following Mil-PRF-38535 in a 376 ceramic column grid array package. The package's 256 external columns are 1.27mm pitch and are used for signal routing. The 120 1.00mm pitch columns attached to the heat sink in the center of the package are for heat removal and grounding the back side of the die (see figure 1).

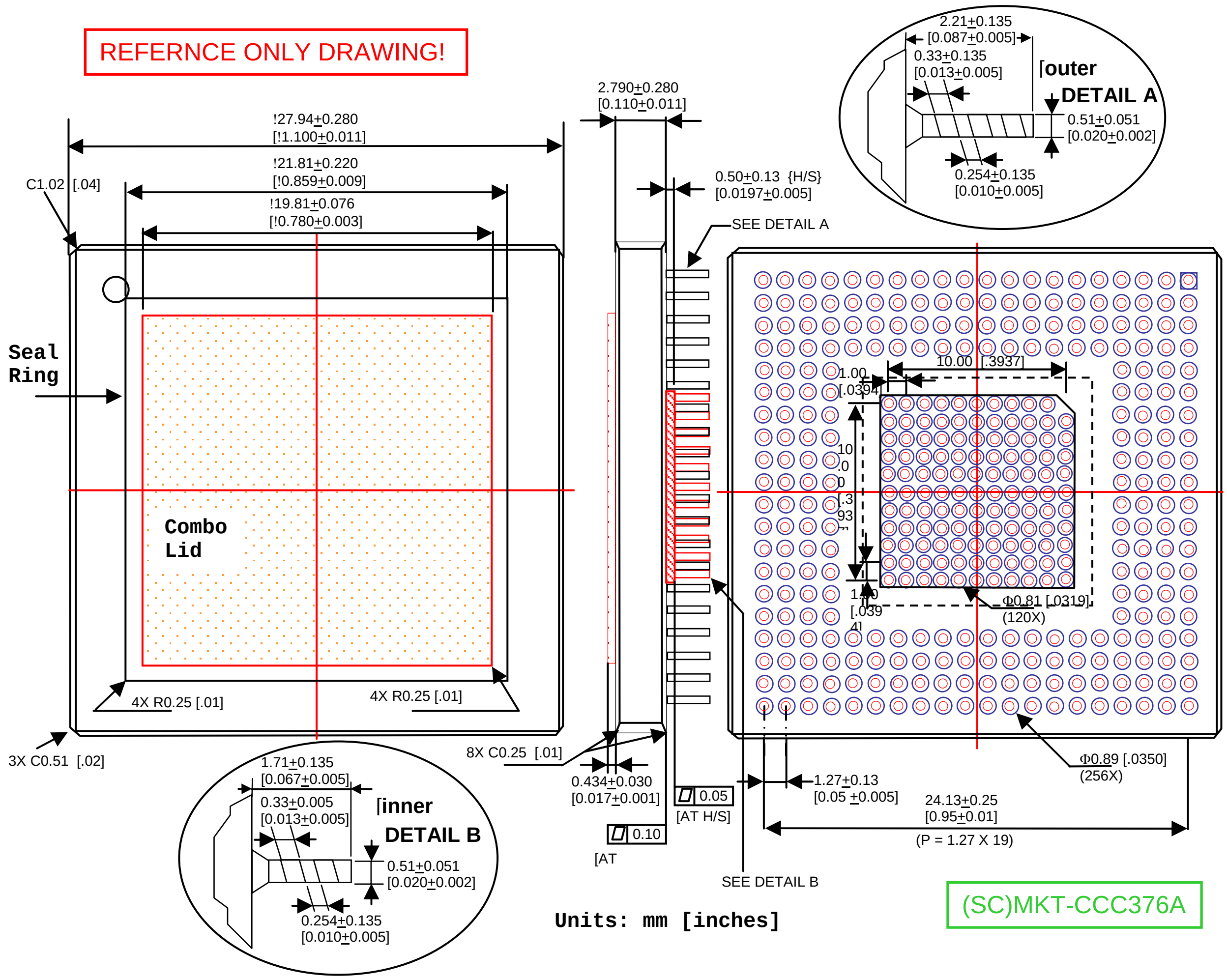



**Figure 1 – 376 CCGA**

Solder columns were attached to the ceramic package with eutectic solder (63 Pb/ 37 Sn) normal reflow. The column attach process flow shows the land pad gold metallization being removed before column attach (see figure 2). Removing the gold plating enhances the joint reliability by avoiding rich gold tin intermetallic formation. The columns are 0.51mm in diameter and 2.21mm in height from the board to the bottom of the package.

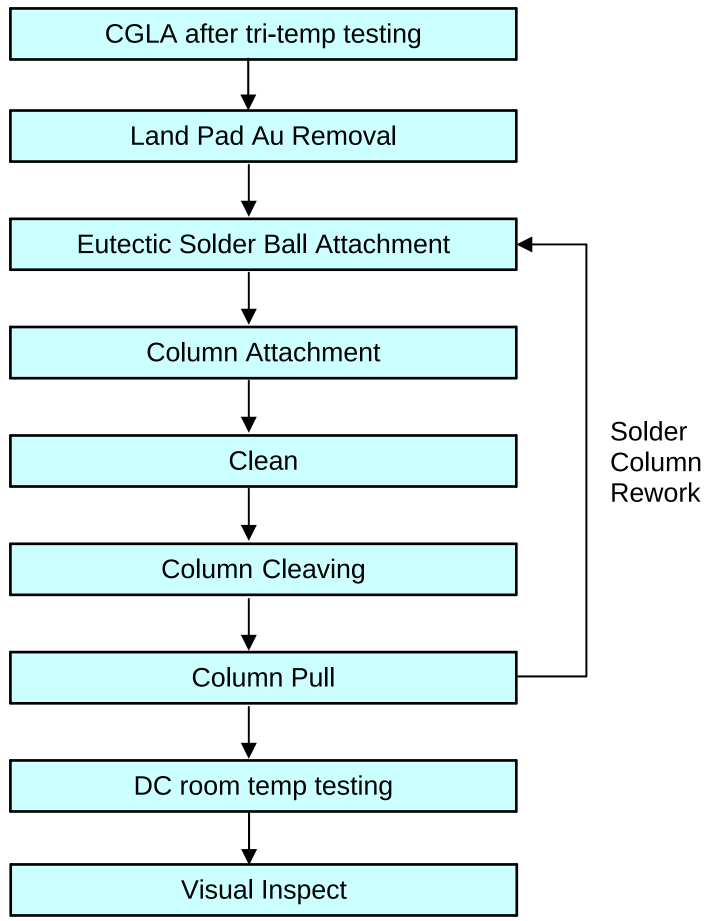
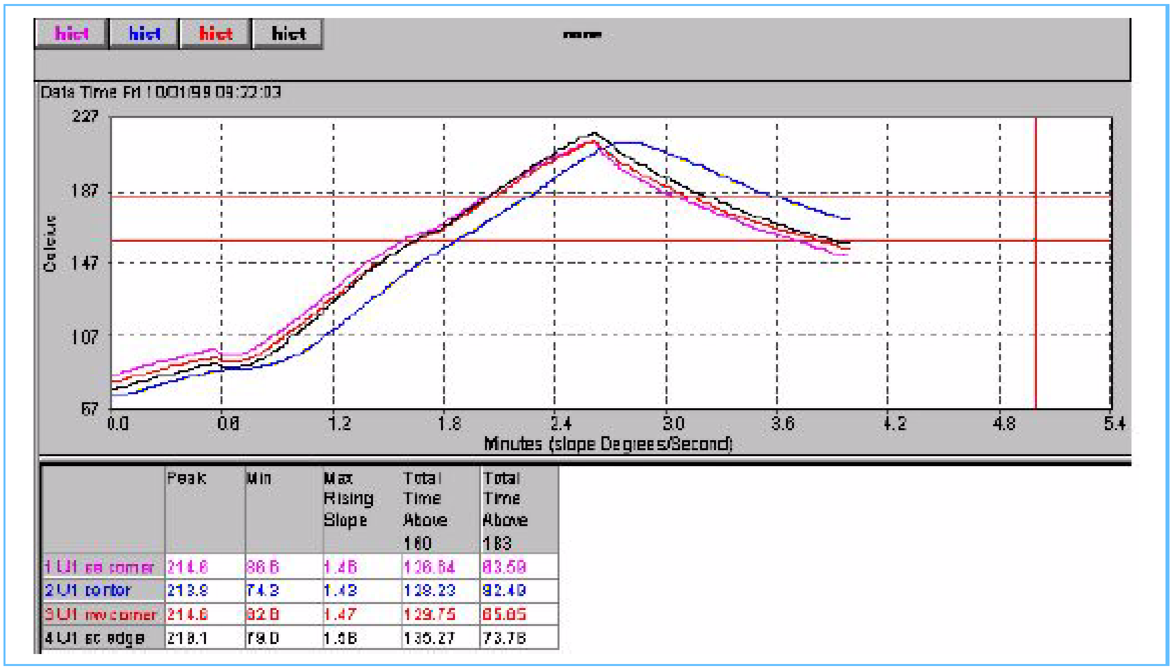



**Figure 2 – 6sigma Column Attach Process Flow**

## TEMPERATURE CYCLE EVALUATION PACKAGE & BOARD

In order to evaluate the thermal mechanical performance of the 376 column grid array package a daisy chain package was designed. The daisy chain package was design with the same number of layers as the production package, the same dimension, the same lid and the same heat sink. The daisy chain packages have no die or bond wires. The diameter of the columns were 0.51mm, the same as the production product. The 1.27mm pitched external signal path pins were connected through traces in the package in an alternating method to enable a complete daisy chain connection through the board. The 1.00mm pitched internal pins attached to the heat sink could not be connected in the daisy chain due to the fact they are electrically shorted. The columns attached to the heat sink are primarily for heat removal and provide a ground for the back of the die. The stress on these internal pins is less due to the short distance to the neutral point making them less susceptible to temperature cycle failures.

The temperature cycle boards were laid out on 4 layer PCB with landing pads sizes of 0.89mm for the 1.27mm pitch columns and 0.81mm for the 1.00mm pitched columns (see figure 4 and 5). In order to isolate any columns after a failure, probe pads were strategically connected to the daisy chain. The boards were able to accommodate 16 parts per board and were mounted using the recommended reflow profile from 6sigma (see figure 3).




| | Peak | Min | Max Rising Slope | Total Time Above 160 | Total Time Above 183 |
|---|---|---|---|---|---|
| 1 U1 se corner | 214.6 | 86.6 | 1.46 | 126.64 | 83.59 |
| 2 U1 center | 213.9 | 74.2 | 1.42 | 128.23 | 92.49 |
| 3 U1 nw corner | 214.6 | 82.6 | 1.47 | 129.75 | 85.85 |
| 4 U1 sc edge | 218.1 | 79.0 | 1.56 | 135.27 | 73.76 |

**Figure 3 – Reflow Profile**

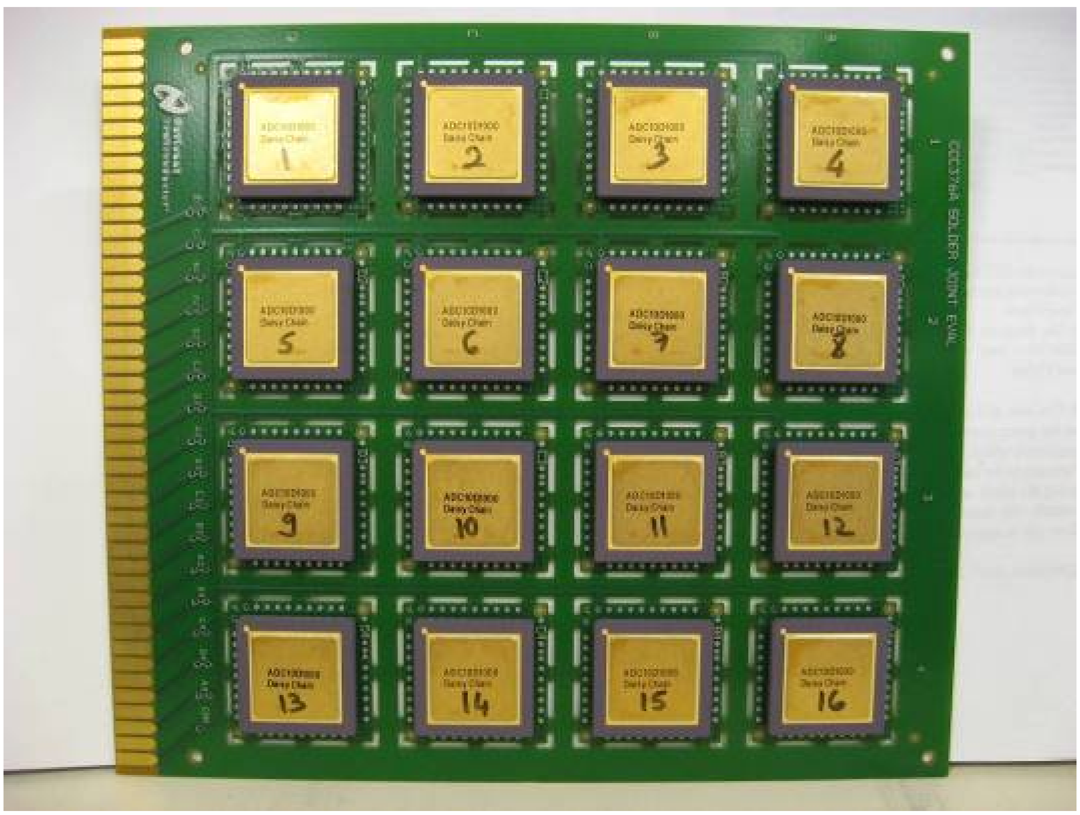



**Figure 4 – 376 CCGA Temperature Cycle Boards**

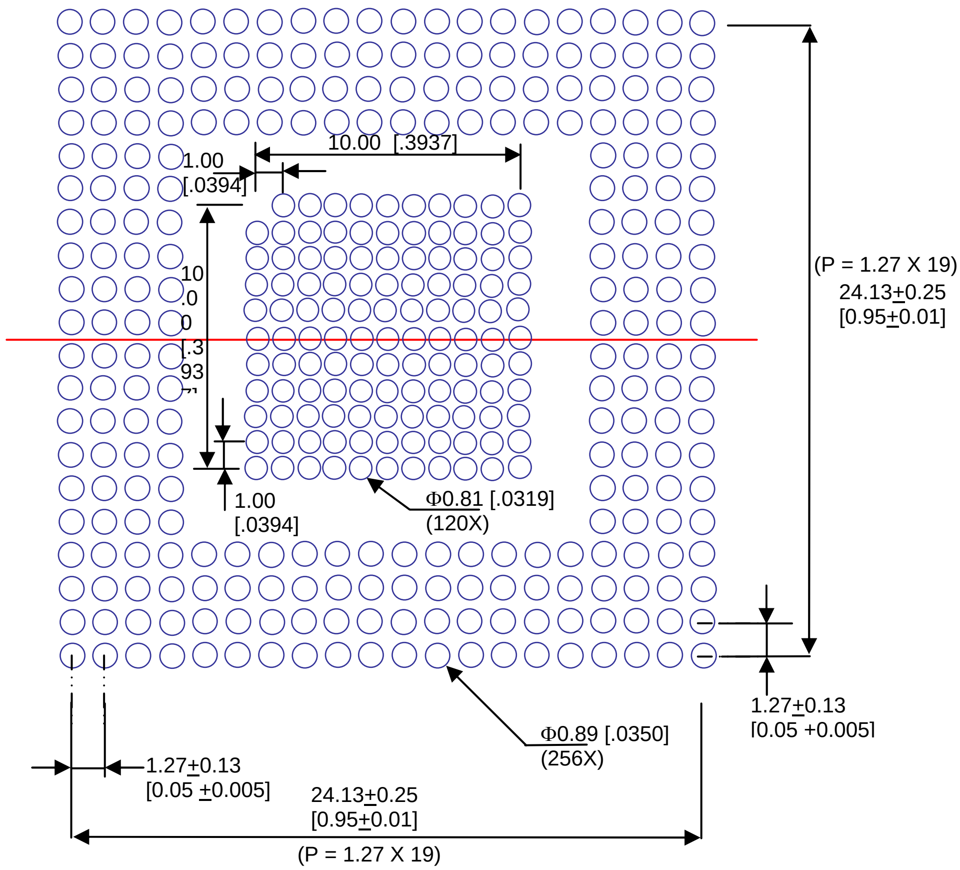



**Figure 5 – 376 CCGA Land Pattern**

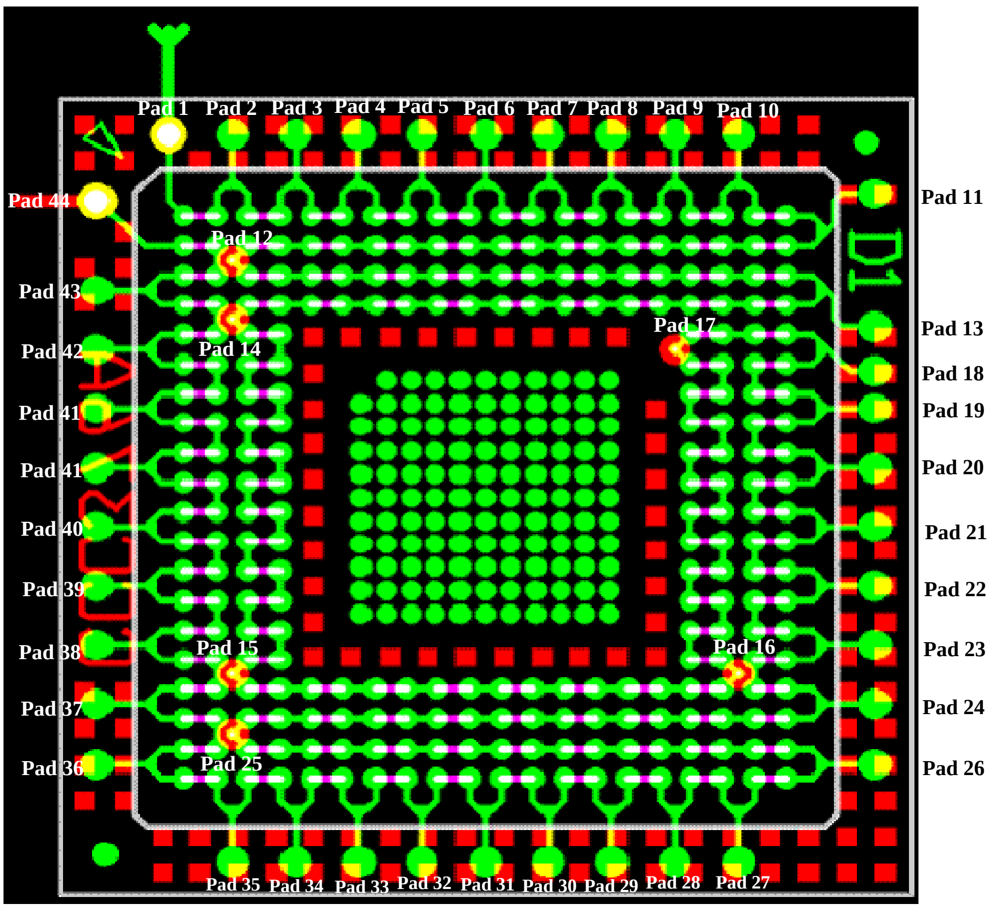



**Figure 6 – Temperature Cycle Board with Daisy Chain Package Superimposed**

## TEMPERATURE CYCLE METHODOLOGY

Two temperature cycle boards (16 parts per board) were used resulting in thirty two units for this evaluation. The thermal profile for this testing, following JEDEC Standard JESD22-A104C with test condition B and soak mode 3, was a -55°C to +125°C temperature range with a 10 minute soak time at temperature and a 36°C per minute ramp rate (see Figure 7). One cycle was completed every 30 minutes resulting in 48 cycles per day. The resistive interconnect of the units under test was continuously monitored. The average resistance measure was 15Ω and a device was considered a failure if the resistance changed more than 10% or 1.5 Ω. The units were stressed until a cumulative 25% failure rate was achieved.

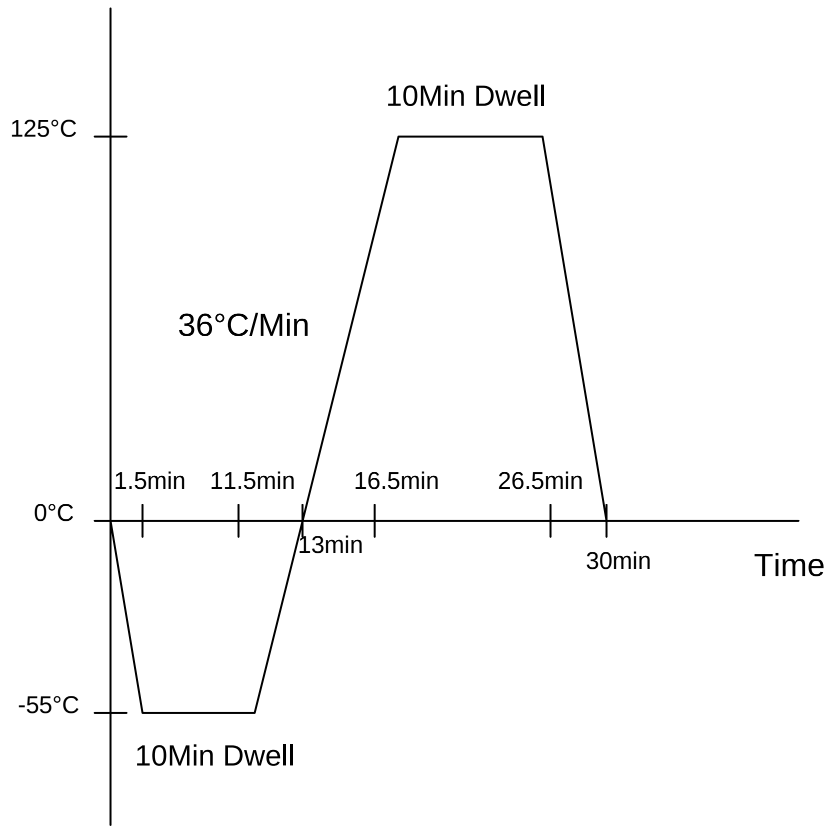



**Figure 7 - TMCL PROFILE**

## TEMPERATURE CYCLE RESULTS

| Temperature Cycle Results | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1000 Cycle | | 2000 Cycles | | 3000 Cycle | | 3809 Cycles | | 4022 Cycles | |
| Pass | Fail | Pass | Fail | Pass | Fail | Pass | Fail | Pass | Fail |
| 32 | 0 | 32 | 0 | 32 | 0 | 29 | 3 | 24 | 5 |

Three units failed after 3809 cycles displaying cracks between the column and the pad of the package. The twenty nine units passing were placed back on test and were pulled at 4022 cycles with an additional five units failing. These failing units displayed the same cracks between the column and the pad of the package. Failure analysis was performed on the eight units and summarized in this report (see Appendix FAILURE ANALYSIS).

Based on the raw data from the above table a plot of cumulative failures vs. temperature cycle (see Figure 8) was derived using regression analysis on a loglog probability distribution scale. The analysis generates an $N_{.01}$ of 3600 which was used to predict mission life (see Thermal Cycle Projections).

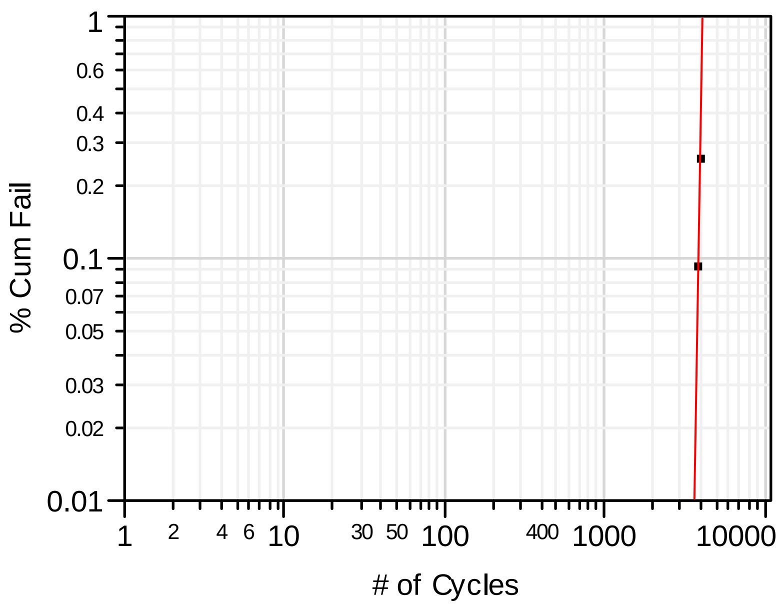



**Figure 8 – Percent Cumulative Failure vs. Number of Cycle to Failure**

## TEMPERATURE CYCLE PROJECTIONS

Using the test results on the daisy chain packages, field life reliability projections can be made (see Table 2). Projecting the life of the product under given conditions can be achieved using the Coffin-Manson equation and the derived $N_{.01}$ from the testing. The Coffin Manson equation is shown below.

A. $F. = (\Delta T_t * DNP_t / \Delta T_f * DNP_f)^{1.9} \times (F_f/F_t)^{1/3} \exp[1414(1/T_{maxf} - 1/T_{maxt})]$

$\Delta T_t$ = Test Cycle Temperature Range
$\Delta T_f$ = Field Cycle Temperature Range
$DNP_t$ = Test Distance to Neutral Point
$DNP_f$ = Field Distance to Neutral Point
$F_t$ = Test Cycle Frequency
$F_f$ = Field Cycle Frequency
$T_{maxt}$ = Maximum Test Temperature
$T_{maxf}$ = Maximum Field Temperature
CPD = Cycle Per Day

**Table 1 - Test Conditions for 376 CCGA TMCL**

| | Test Cycle (CPD) | Test Temp Range °C | $DNP_t$ (mm)_ | Test Max Temp °C |
|---|---|---|---|---|
| Test Conditions | 48 | -55°C to 125°C | 17.1 | 125°C |

**Table 2 - Projected yeas of life for four typical space applications**

| | Field Cycle (CPD) | Field Temp Range °C | Delta Temp | $DNP_f$ (mm) | Field Max Temp °C | $N_{.01}$ Test Cycles | Acceleration Factor | Projected Field Cycles | Years of Life |
|---|---|---|---|---|---|---|---|---|---|
| CCGA 376 | 12 | 10°C to 40°C | 30 | 17.1 | 40 | 3600 | 49.8 | 179107.6 | 41 |
| CCGA 376 | 18 | 65°C to 85°C | 20 | 17.1 | 85 | 3600 | 69.7 | 251055.6 | 38 |
| CCGA 376 | 12 | 70°C to 85°C | 15 | 17.1 | 85 | 3600 | 105.2 | 378840.5 | 86 |
| CCGA 376 | 18 | 70°C to 85°C | 15 | 17.1 | 85 | 3600 | 120.5 | 433664.1 | 66 |

## Summary and Conclusions

National has completed the qualification of the Ceramic 376 Column Grid Array package and the ADC10D1000CCMLS to Mil-PRF-38535. The CCGA376 package using the 6sigma 0.51mm column at 1.27mm pitch exceeds the typical satellite program application. The density of failures exhibited during the temperature cycle testing were located near the corners of the package. These failures were the result of the columns detaching from the package pad. The design of the ADC10D1000CCMLS and layout used the corner pin locations for non-critical no connect pins, more tolerant digital control pins and redundant Ground and Supply connections to further reduce the risk of failures in the typical satellite program application.

# Appendix

## FAILURE ANALYSIS

ELECTRICAL VERIFICATION:

Curve tracing found an open between the pads on the PCB board as indicated in the diagram below.

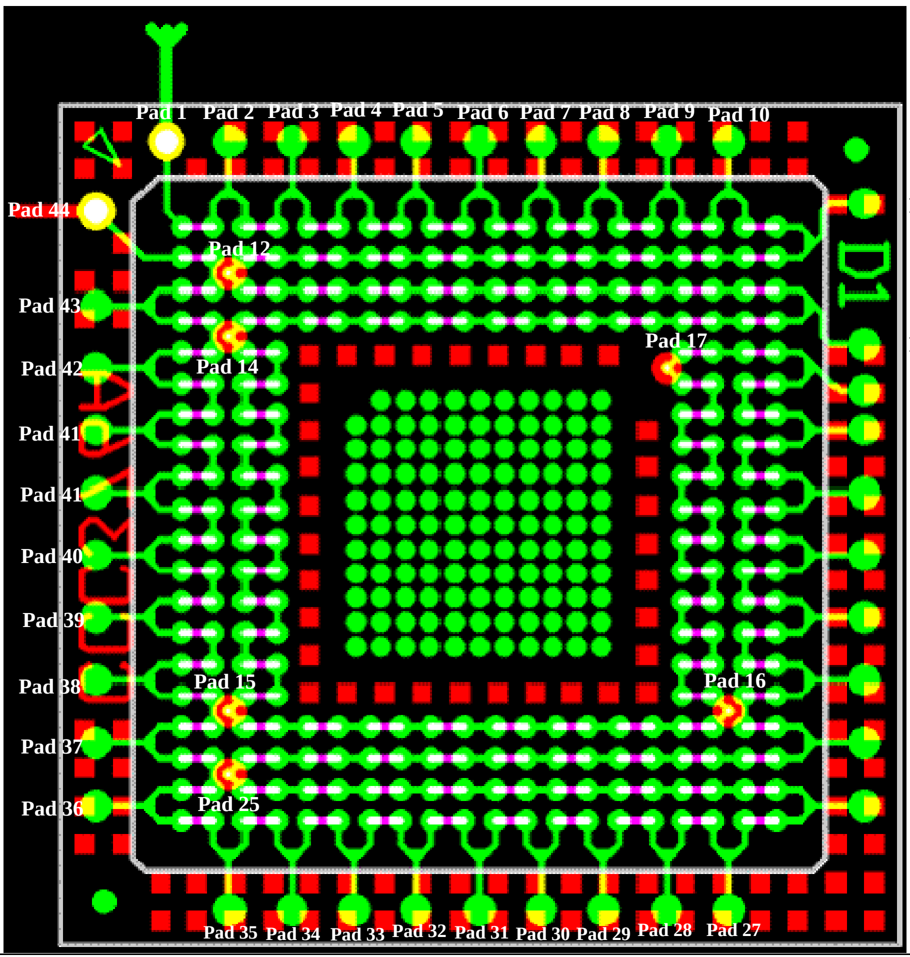
3809 Cycles

SN 4: between pad 1 and pad 2, pad 10 and pad 11, and pad 11 and pad 12.
SN18: between pad 36 and pad 37, and pad 38 and pad 39.
SN20: between pad 26 and pad 27.

4022 Cycles

SN 3: between pad 35 and pad 36.
SN 15: between pad 10 and pad 11, and pad 25 and pad 26.
SN 21: between pad 25 and pad 26, pad 36 and pad 37, and pad 43 and pad 44.
SN 27: between pad 15 and pad 16, and pad 36 and pad 37.
SN 29: between pad 11 and pad 12, and pad 36 and pad 37.

The diagram of board and package. It shows all pin locations.



## OTHER OBSERVATIONS:

External visual inspections on the pins which were suspected to be opened showed cracks at the contact between the pins and the pads of the packages (See Figures A – L).

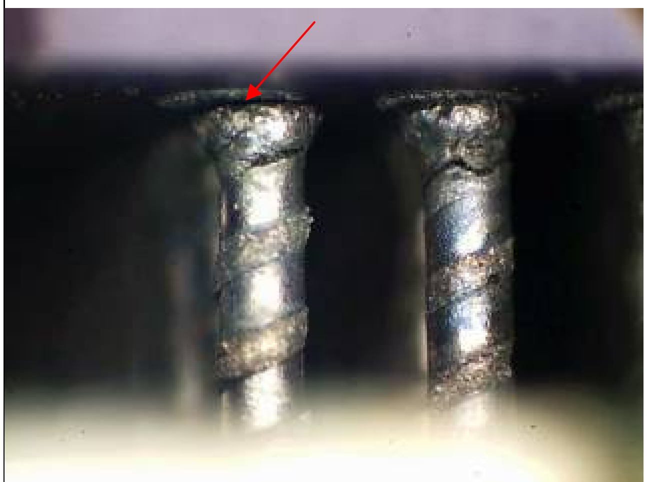
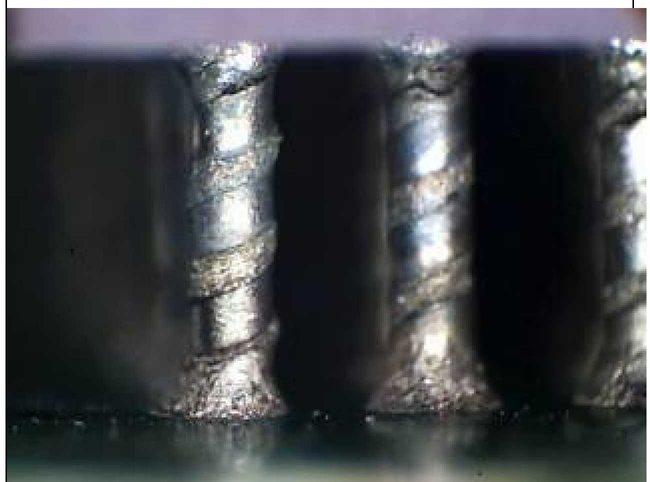
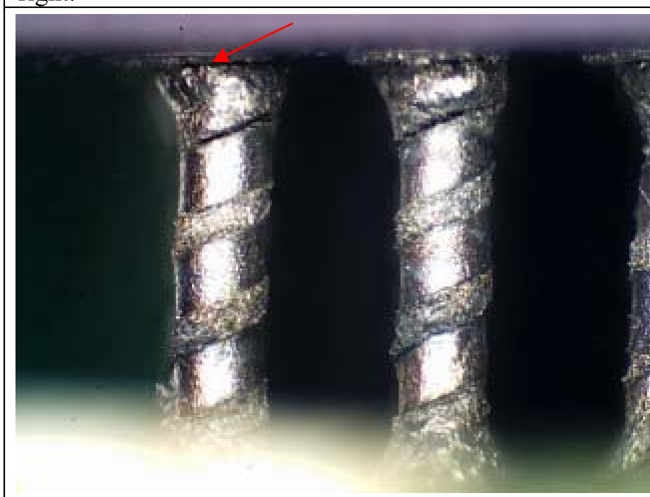
| | |
|---|---|
| Figure A. The image of the contacts between the column and the package showed cracks on SN3. Its location is at the first row from the bottom and the first two pins from the left. | Figure B. The image of the contacts between the column and the PCB board showed no anomalies on SN3. |
|  |  |
| Figure D. The image of the contacts between the column and the package showed cracks on SN15. Its location is at the first row from the top and the first two pins from the right. | Figure C. The image of the contacts between the column and PCB board showed no anomalies on SN15. |
|  |  |

Figure E. The image of the contacts between the column and the package showed cracks on SN21. Its location is at the first column from the left and the second and the third pins from the bottom.

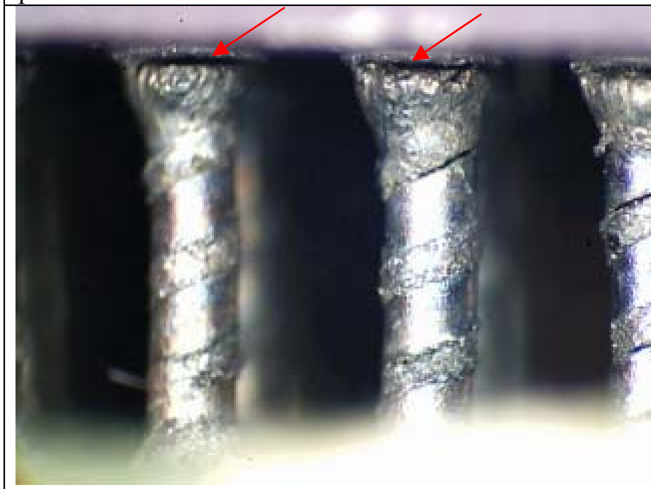


Figure F. The image of the contacts between the column and the PCB board showed no anomalies on SN21.

Figure G. The image of the contacts between the column and the package showed cracks on SN21. Its location is at the first column from the left and the second and the third pins from the top.

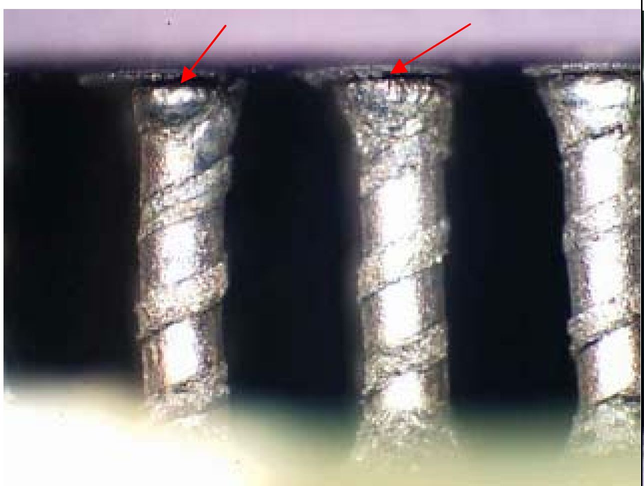
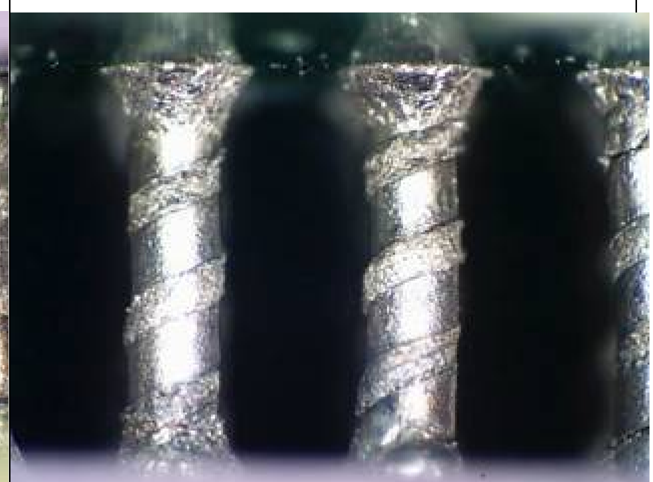
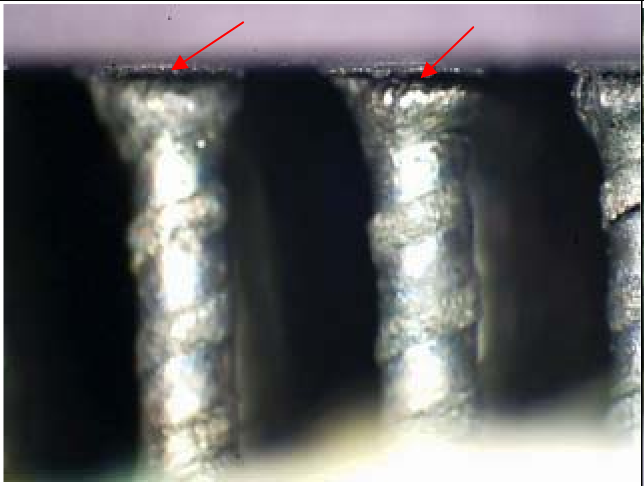
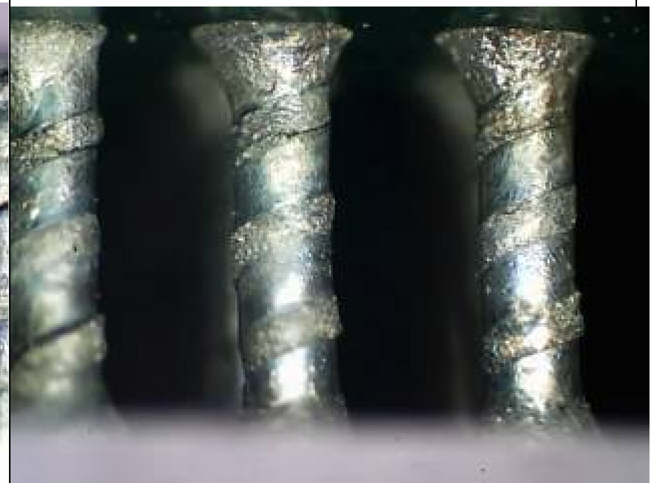
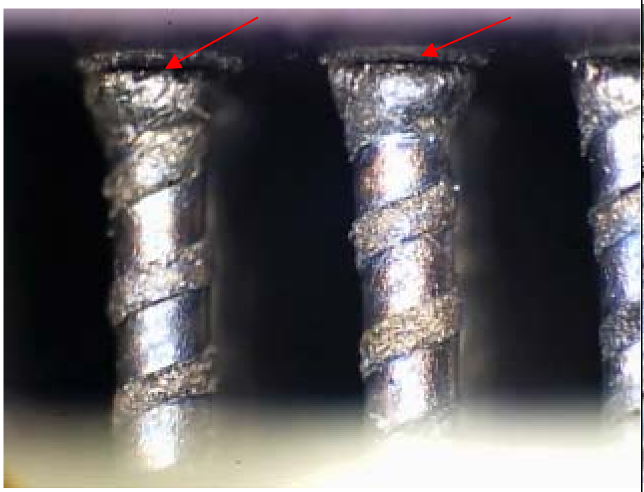
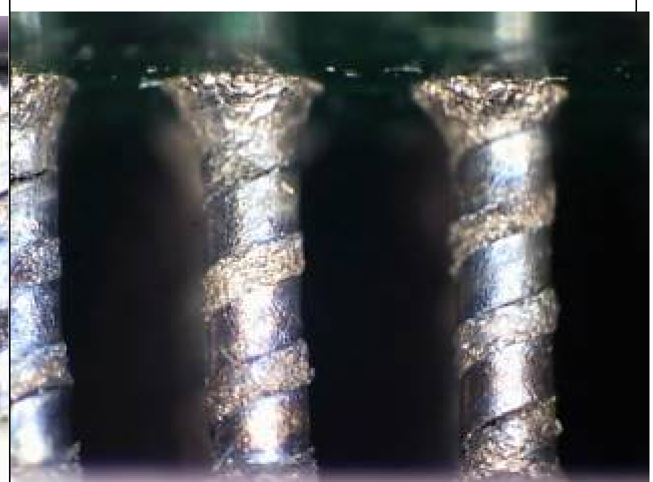


Figure H. The image of the contacts between the column and PCB board showed no anomalies on SN21.



| | |
|---|---|
| Figure I. The image of the contacts between the column and the package showed cracks on SN27. Its location is at the first column from the left and the second and the third pins from the bottom. | Figure J. The image of the contacts between the column and the PCB board showed no anomalies on SN27. |
|  |  |
| Figure K. The image of the contacts between the column and the package showed cracks on SN29. Its location is at the first column from the left and the second and the third pins from the bottom. | Figure L. The image of the contacts between the column and the PCB board showed no anomalies on SN29. |
|  |  |

The package including the PCB board was potted using epoxy to enable the failing columns to be cross sectioned. Visual inspection was performed on the open pins of SN 3, SN 15, SN 21, SN 27 and 29 at the contacts between the columns and the packages (See Figures M – NN).

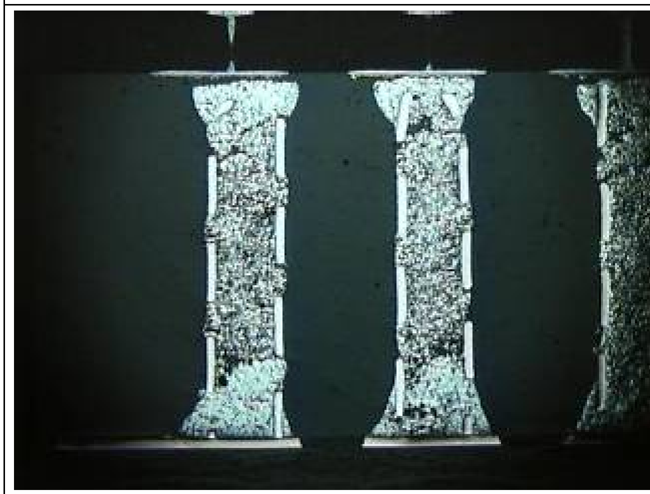
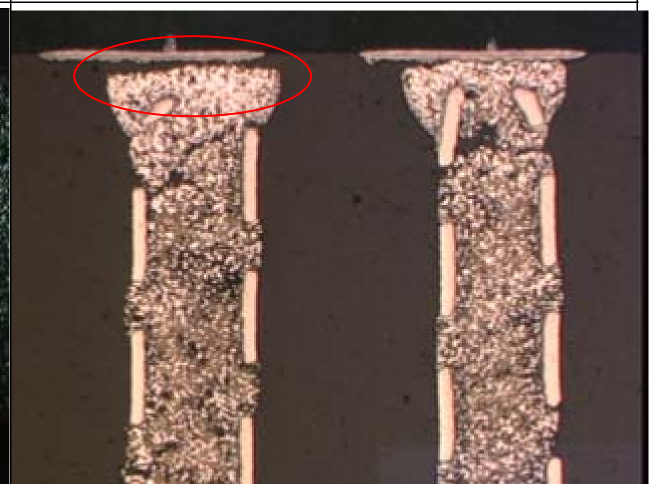
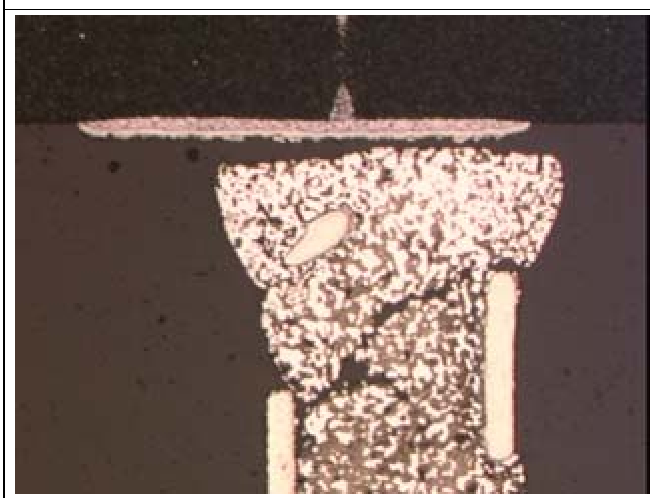
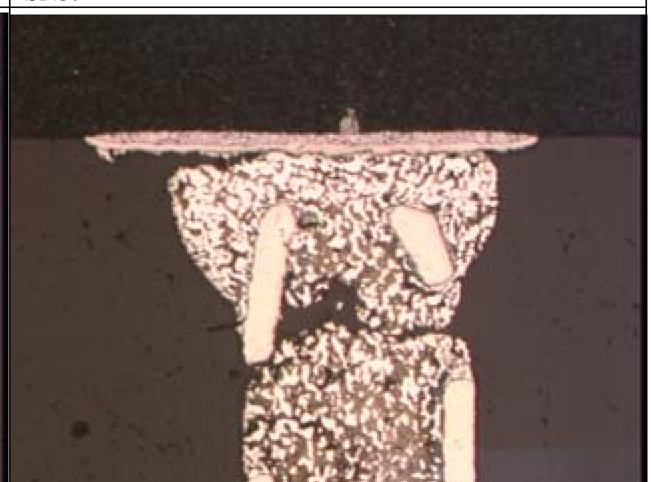
| | |
|---|---|
| Figure M The cross section image of the open column shows the gap at the contact between the column and the pad of the package on SN3. The location of the column is the first row from the bottom and the first two pins from the left. | Figure N. The circle indicates the gap at the contact between the column and the pad of the package on SN3. |
|  |  |
| Figure O. High magnification photo of the first contact between the column and pad of the package on SN3. | Figure P. High magnification photo of the second contact between the column and pad of the package on SN3. |
|  |  |

Figure Q. The cross section image of the open column shows the gap at the contact between the column and the pad of the package on SN15. The location of the column is the first row from the top and the first two pins from the right.

Figure R. The circle indicates the gap at the contact between the column and the pad of the package on SN15.

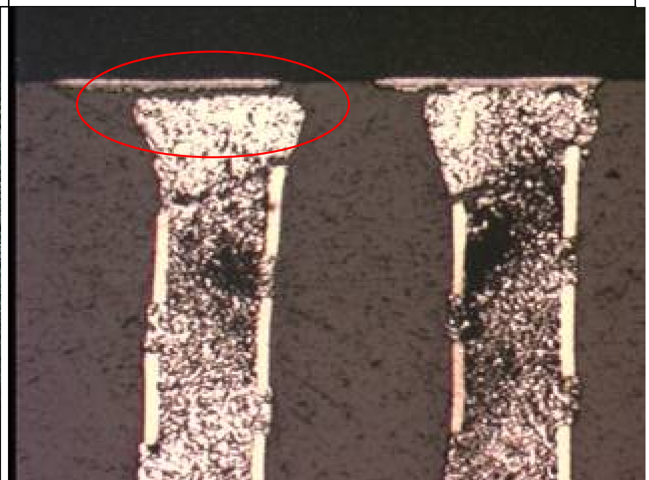


Figure S. High magnification photo of the first contact between the column and pad of the package on SN15.

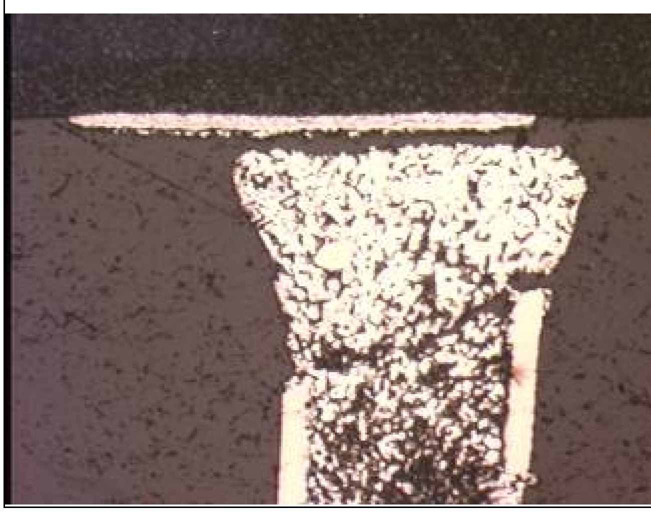
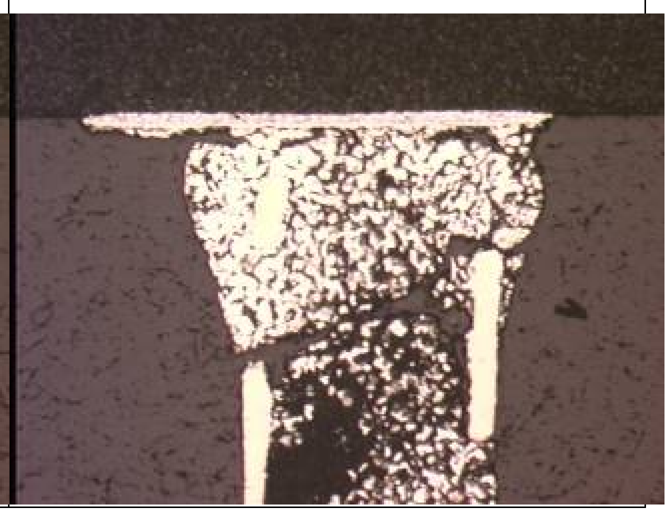


Figure T. High magnification photo of the second contact between the column and pad of the package on SN15.



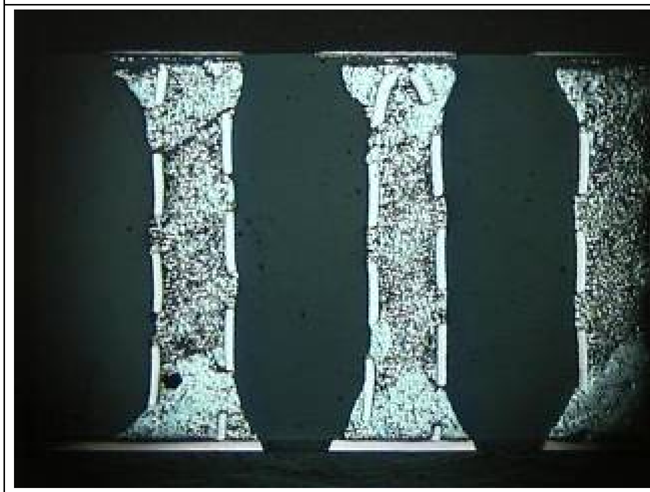
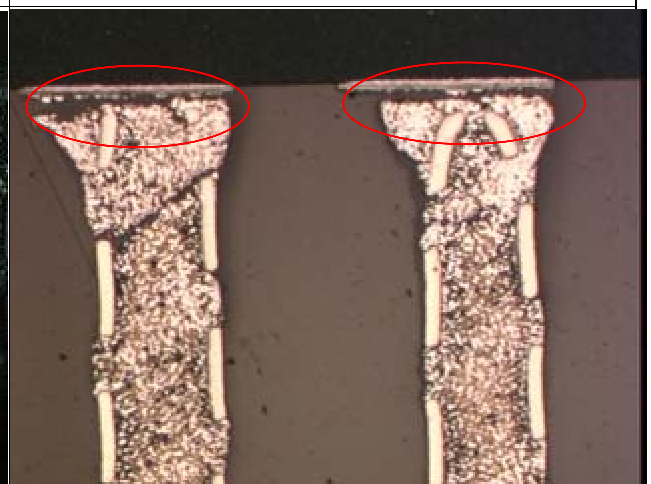
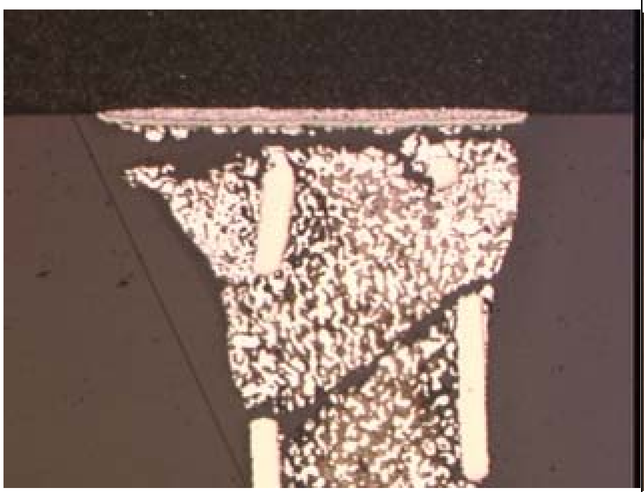
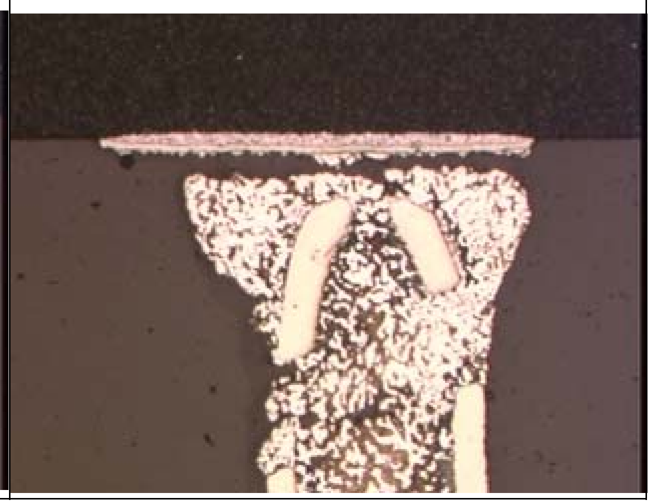
| Figure U. The cross section image of the open column shows the gap at the contact between the pcolumn and the pad of the package on SN21. The location of the column is the second row from the bottom and the first and second column from the left. | Figure V. The circle indicates the gap at the contact between the column and the pad of the package on SN21. |
|---|---|
|  |  |
| Figure W. High magnification photo of the first contact between the column and pad of the package on SN21. | Figure X. High magnification photo of the second contact between the column and pad of the package on SN21. |
|  |  |

Figure Y. The cross section image of the open column shows the gap at the contact between the column and the pad of the package on SN21. The location of the column is the second row from the bottom and the first and the second pins from the right.

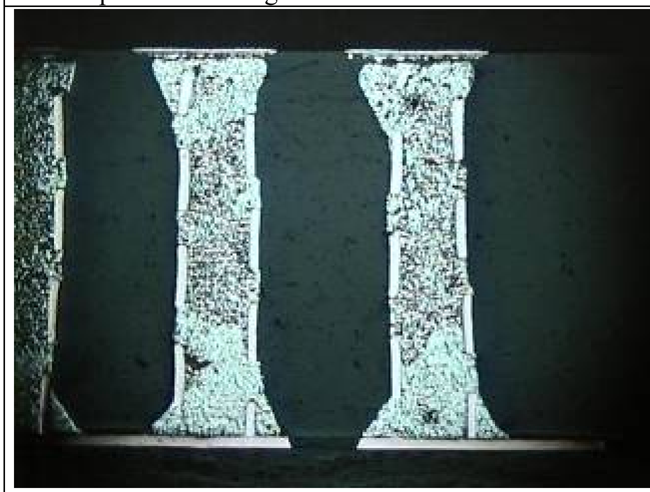


Figure Z. The circle indicates the gap at the contact between the columns and the pad of the package on SN21.

Figure AA. High magnification photo of the first contact between the column and pad of the package on SN21.

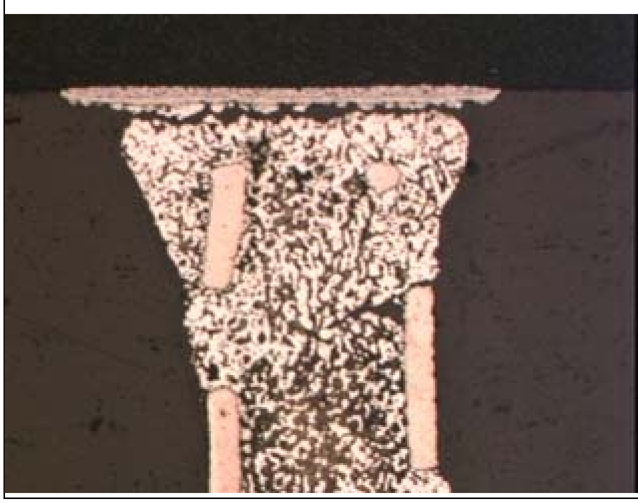


Figure BB. High magnification photo of the second contact between the column and pad of the package on SN21.

Figure CC. The cross section image of the open columns shows the gap at the contact between the columns and the pad of the package on SN27. The location of the columns is the second row from the bottom and the first and the second columns from the left.

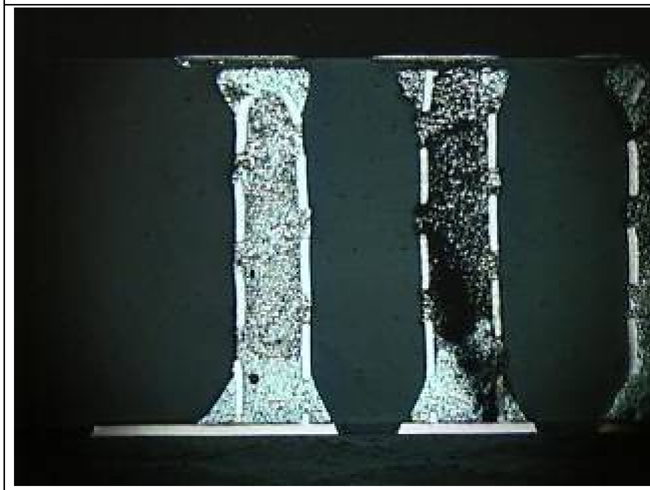


Figure DD. The circle indicates the gap at the contact between the columns and the pad of the package on SN27.

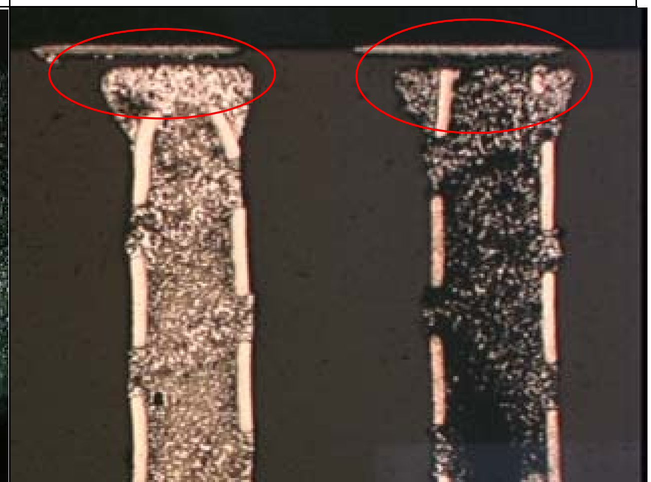


Figure EE. High magnification photo of the first contact between the column and pad of the package on SN27.

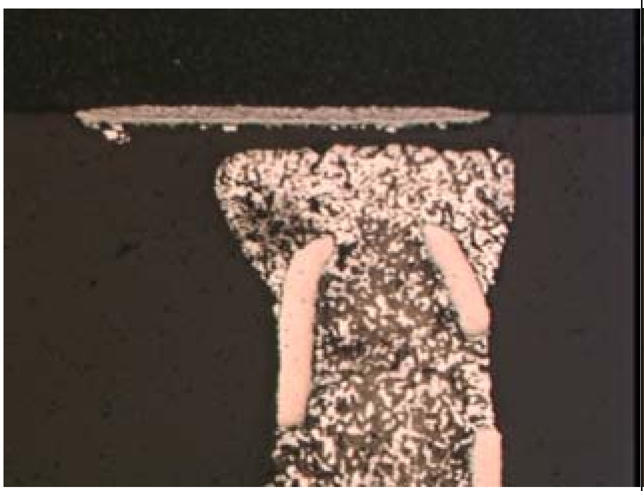


Figure FF. High magnification photo of the second contact between the column and pad of the package on SN27.

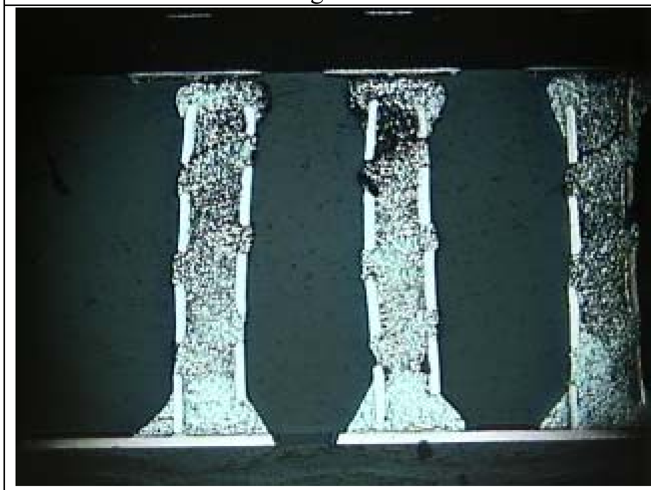
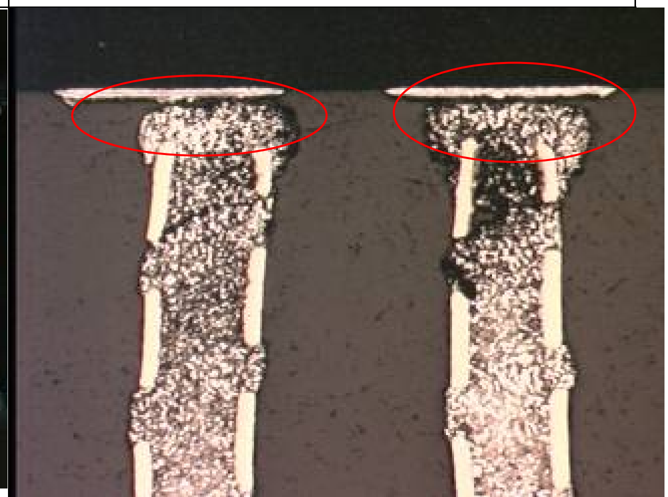
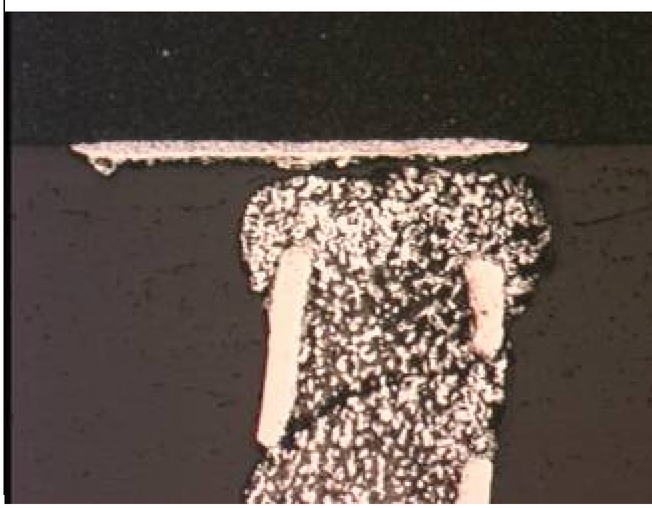
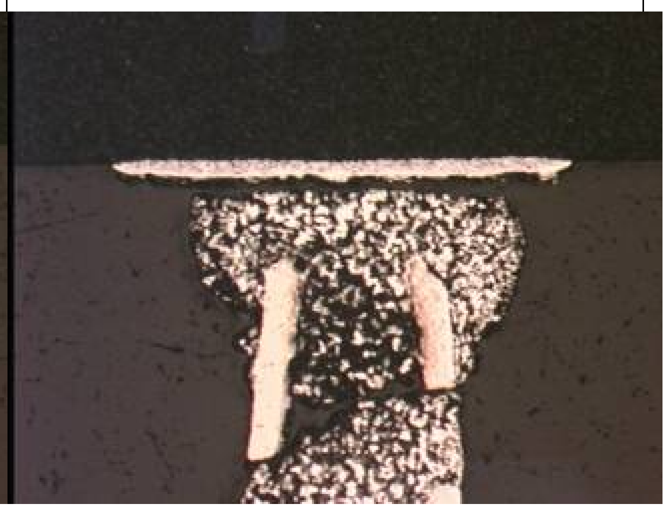
| Figure GG. The cross section image of the open columns shows the gap at the contact between the columns and the pad of the package on SN29. The location of the columns is the second row from the top and the first and the second columns from the right. | Figure HH. The circle indicates the gap at the contact between the columns and the pad of the package on SN29. |
|---|---|
|  |  |
| Figure II. High magnification photo of the first contact between the column and pad of the package on SN29. | Figure JJ. High magnification photo of the second contact between the column and pad of the package on SN29. |
|  |  |

Figure KK. The cross section image of the open columns shows the gap at the contact between the pins and the pad of the package on SN29. The location of the pins is the second row from the top and the seventh and the eighth pins from the left.

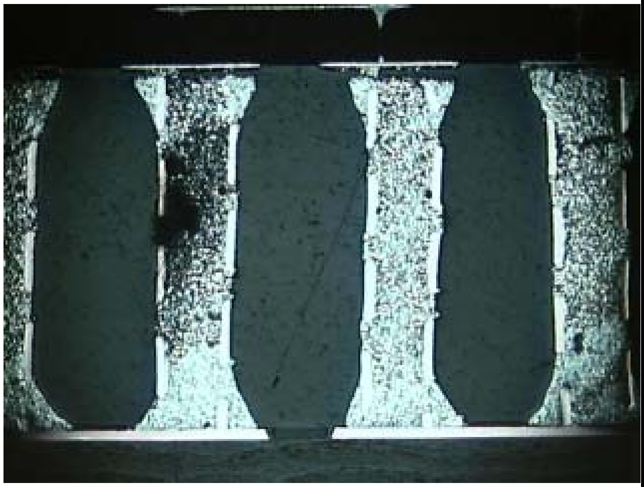


Figure LL. The circle indicates the gap at the contact between the columns and the pad of the package on SN29.

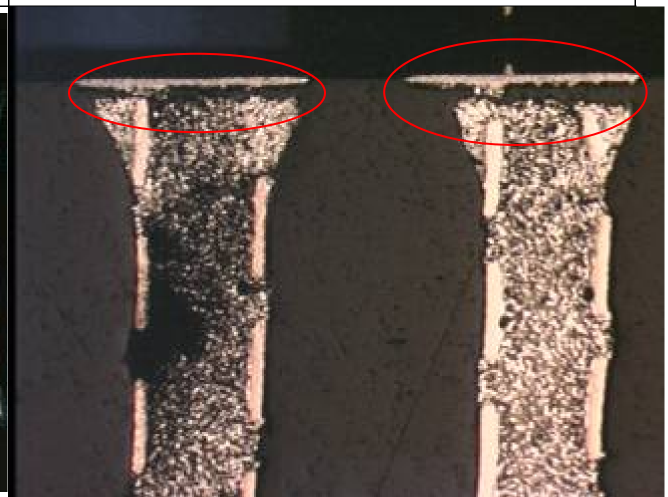


Figure MM. High magnification photo of the seventh contact between the column and pad of the package on SN29.

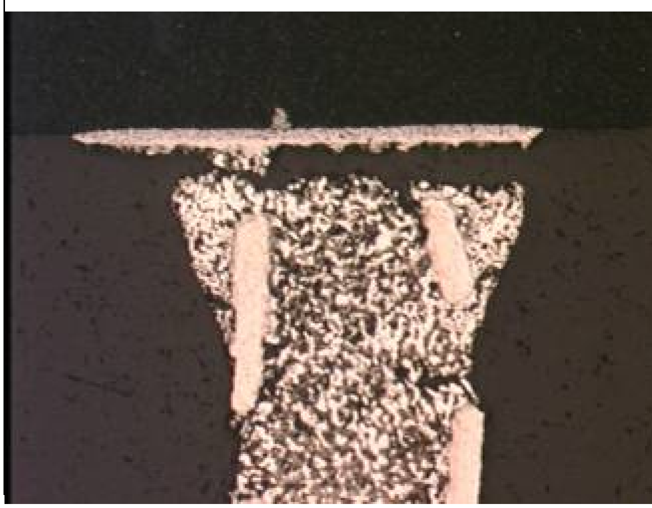


Figure NN. High magnification photo of the eighth contact between the column and pad of the package on SN29.