A COMPARISON OF MOISTURE RESISTANCE WITH DIFFERENT TYPES OF END-TERMINATIONS IN CERAMIC CAPACITORS*

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SUMMARY

Failures (shorts) were observed in MIL-C-20 like, molded-case, radial-leaded, ceramic capacitors after a low-voltage, 85%-relative-humidity, 85° C test was performed. Case removal revealed silver whisker growth on the chips between the non-coated solder area or the end-terminations where the radial leads extend from the chip. Insulation-resistance failures were observed in MIL-C-123 like, molded-case, radial-leaded, ceramic capacitors after moisture resistance, normal voltage testing (MIL STD 202 Method 106) was performed. In the case of the MIL-C-l23 capacitors, no silver migration was observed.

Three lots of molded-case, radia1-leaded, MIL-C-123 capacitors with experimental end-terminations, were fabricated by KEMET Electronics Corporation, Greenvi1le, South Carolina from a single chip lot. Three control lots with standard silver end-terminations were also fabricated. Each of the control lots was processed with each of the experimental lots through the subsequent processing and testing steps.

This paper describes the different end-terminations, testing and evaluation of these three experimental lots and their counterpart control lots. These included a 4,000-hour, 85%-re1ative humidity, 85° C test and multiple cycles of moisture, normal voltage (MIL STD 202 Method 106) tests.

PURPOSE

Martin Marietta Specialty Components, a DOE Production Agency in Largo, FL experienced failures (low-voltage shorts) at incoming inspection with molded-case, radial-leaded, MIL-C-20-like ceramic capacitors during the 85° C -relative humidity, 85° C, volt test. Case removal revealed silver whisker growth on the chips between the non-coated solder area of the end-terminations where the radial leads extend from the chip. These capacitors chips were usually not dipped deep enough into the solder during lead, attachment to cover the complete end-termination with solder, because sometimes the solder will wick up the lead and cause lead pinching during the case molding operation.

AlliedSignal Aerospace, a DOE Production Agency in Kansas City, MO, experienced insulation resistance failures after moisture-Resistance, normal-voltage test (MIL STD 202 Method 106) during qualification testing of MIL-C-123 like,

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molded, radial-leaded, ceramic capacitors. Case removal did not reveal any indication of silver migration.

Although these failures were not related, they were considered to have a similar root cause because both types of failures occurred in the presence of temperature, humidity, and voltage. Because of the silver migration discovered in the MIL-C-20 like parts, the end-terminations were considered to be suspect.

APPROACH

Several approaches to protect the uncoated silver end-margins were considered. Pre-dipping the chips in solder before lead attachment was not considered, because solder between the lead and chip during placement of the chip in the leads would not allow the accuracy required for the case molding operation. Complete solder dipping of the chip during lead attachment was ruled out because of the previously mentioned problem of solder wicking up the lead. The three methods chosen to investigate for decreasing the possibility of silver migration on the chip between the end-terminations were:

EX #l. Plating a nickel barrier layer on the silver end-terminations.

EX #2. Using palladium/silver end-terminations.

EX #3. Plating a nickel barrier layer on a palladium/silver end-termination.

FABRICATION

KEMET Electronics Corporation, Greenville, South Carolina was contracted to fabricate the three experimental lots and their respective control lots. All lots were fabricated from a single chip lot. The MIL-C-123 capacitors were 1000-pf ±5%, 100-volt, NPO-ceramic, radially-leaded, molded-case (size-CK06). Standard manufacturing MIL-C-123 processing and testing were performed on both the experimental and the control lots. Lot #1 was fabricated with a nickel barrier layer on 100% Ag composition end-terminations. Lot #2 had end-terminations with a composition of 75% Ag/25% Pd weight. Lot #3 was fabricated with a nickel barrier layer on its 75% Ag/25% Pd by weight composition end-terminations. The control lots for each experimental lot were processed concurrently through all the fabrication steps except the nickel barrier plating. All the control lots had a 100% Ag composition end-terminations. The control groups are identified CN corresponding to "EX" group. The lot size, for each of the experimental and control lots, was 400 capacitors.

TESTING

The 400 capacitors from each of the lots were group I tested per MIL-C-123 for capacitance, dissipation factor and insulation resistance.

DC LIFE TEST

Ninety capacitors from each of the six lots were chosen at random for a 4,000-hour. DC

Life test. A Summary of the electrical testing before the DC Life test is shown in Table 1. The DC Life test conditions were 125 °C and 250 volts. The DC life test was interrupted 250 hours. 1,000 hours, and 2,000 hours elapsed time for capacitance, dissipation factor, and insulation resistance measurements. Since this data was essentially the same as the data from the before and after electrical data, it was not included. A summary of the electrical testing data after 4,000 hours is shown in Table 2.

85% REL. HUM./85°C TEST

Sixteen capacitors from each or the six lots were chosen at random for a 4,000-hour

85% relative humidity/85°C, low voltage (1.5- volts) test. This test circuit consisted of a 1.5-volt battery providing a bias to a large parallel network of 100-kΩ resistors in series with the capacitors under test and 10-kΩ resistors to ground. At 5-hour intervals, an A/T IBM personal computer/Hewlett Packard 3497 A Acquisition Control Unit, connected to a Keithley 619 Electrometer/Multimeter across each of the 10-kΩ resistors, recorded any leakage current that was present. The very low input impedance of the Keithley prevented the 10-kΩ shunt across its input from having an appreciable effect on the reading. This provided a simple means of ensuring that the capacitors under test had a bias

Initial Electrical Test Summary

Lot #		IR amb. Ω	IR 128 °C Ω	Cap amb. pF	Cap 125°C %	DF amb. %	DF 125°C %
EX #1	AVG.	5.11E-11	5.70E-10	980.46	981.21	0.03	0.02
	STD. D	5.93E-11	1.85E-10	8.21	8.36	0.008	0.002
CN #1	AVG.	4.62E-11	1.54E-10	980.72	980.85	0.02	0.02
	STD. D	4.71E-11	5.00E-11	8.32	8.665	0.003	0.05
EX #2	AVG.	1.93E-10	1.24E-10	1000.63	1001.214	0.02	0.05
	STD. D	1.82E-10	5.39E-11	16.759	16.69	0.001	0.01
CN #2	AVG.	2.02E-10	1.60E-10	1005.7	987.4	0.02	0.05
	STD. D	4.20E-10	3.50E-11	9.61	9.58	0.001	0.004
EX #3	AVG.	1E-10	6.50E-11	977.31	979.27	0.02	0.02
	STD. D			8.86	8.94	0.006	0.004
CN #3	AVG.	6.00E-11	6.00E-11	995.68	993.69	0.019	0.023
	STD. D			21.73	21.69	0.001	0.006

Table 1

Electrical Test Summary After 4,000 hr. DC Life

Lot #		IR amb. Ω	IR 128 °C Ω	Cap amb. pF	Cap 125°C %	DF amb. %	DF 125°C %
EX #1	AVG.	5.11E-11	5.70E-10	980.46	981.21	0.03	0.02
	STD. D	5.93E-11	1.85E-10	8.21	8.36	0.008	0.002
CN #1	AVG.	4.62E-11	1.54E-10	980.72	980.85	0.02	0.02
	STD. D	4.71E-11	5.00E-11	8.32	8.665	0.003	0.05
EX #2	AVG.	1.93E-10	1.24E-10	1000.63	1001.214	0.02	0.05
	STD. D	1.82E-10	5.39E-11	16.759	16.69	0.001	0.01
CN #2	AVG.	2.02E-10	1.60E-10	1005.7	987.4	0.02	0.05
	STD. D	4.20E-10	3.50E-11	9.61	9.58	0.001	0.004
EX #3	AVG.	1E-10	6.50E-11	977.31	979.27	0.02	0.02
	STD. D			8.86	8.94	0.006	0.004
CN #3	AVG.	6.00E-11	6.00E-11	995.68	993.69	0.019	0.023
	STD. D			21.73	21.69	0.001	0.006

Table 2

applied at all times. Some of the test positions were occupied by resistors so that a known reading could be obtained to confirm proper functioning of the system. After completion of the 4000-hour, 85%

relative humidity/85°C test, the samples were group I tested per MIL-C-123 for capacitance and dissipation factor. The insulation resistance test was per MIL-C-123, except the applied voltage was 1.5 Vdc instead of rated voltage. This low voltage was used during this test because there would be less chance in clearing a short or a silver whisker, if one had grown during the 85/85 test. A summary of the initial and post electrical data is shown in table 3.

4000 hr., 85% Rel. Humidity/85°C Test

Lot #		Initial Cap. pF	Post Cap. pF	Percent Change pF	Initial DF %	Post DF %	Initial IR Ω	Post IR Ω
EX #1	AVG.	978.67	978.66	-0.001	0.0263	0.015	1.91E+12	1.20E+13
	STD. D	8.40	8.41		0.006	0.003	8.98E+11	4.26E+12
CN #1	AVG.	979.95	979.42	-0.05	0.0244	0.01	2.06E+12	2.32E+13
	STD. D	6.47	6.42		0.008	0.008	8.90E+11	8.07E+12
EX #2	AVG.	1005.08	1005.05	-0.003	0.0288	0.0118	2.31E+12	2.50E+13
	STD. D	16.71	16.75		0.0063	0.003	7.04E.+11	1.89E+13
CN #2	AVG.	1004.71	1004.63	-0.007	0.0244	0.0104	1.73E+12	2.27E+13
	STD. D	9.62	9.64		0.008	0.001	7.18E+11	1.21E+13
EX #3	AVG.	980.2563	980.3788	0.01	0.0238	0.0148	2.25E+12	1.72E+13
	STD. D	7.60	7.68		0.008	0.007	1.06E+12	6.09E+12
CN #3	AVG.	1001.71	1000.88	-0.08	0.0219	0.0106	1.39E+12	2.84E+13
	STD. D	17.73	18.58		0.0111	0.001	6.13E+11	1.45E+13

Table 3

MOISTURE RESISTANCE TEST

Twenty capacitors from each lot were chosen at random for moisture resistance testing and shipped to AlliedSigna1, Kansas City for testing. Group I electrical tests were taken on each capacitor when received. Insulation resistance was performed at 100 Vdc, and dielectric withstanding was performed at 250 Vdc. The capacitors were then electrica1ly tested per the requirements of MIL-C-123B. Paragraph 4.6.16.2 in accordance with Method 106 of MIL-STD-202. This testing sequence subjected the capacitors to twenty continuous cycles. The capacitors had 50 Vdc applied only during the first ten cycles. The hot and cold cycles were performed, but the vibration cycle was deleted. The system computer continuously scanned each capacitor during the test, checking for shorts. Once the twenty cycles were complete, the Group I electrical measurements were repeated. Two of the Capacitors from Control Lot #1 were out of tolerance for insulation resistance. After being held at room environment for two weeks the capacitors were retested, and found to be acceptable. These capacitors were not subjected to the second moisture resistance test. Upon completion of the second moisture-resistance test, Group I electrical testing was repeated. All the capacitors were in the acceptable tolerance range. The moisture resistance was then repeated for the third time. Upon completion of this third test, Group I electrical measurements were again rechecked. During these tests the two capacitors from Control Lot # 1 were again out of tolerance for the insulation resistance test. After being allowed to sit in a room environment for two weeks, the capacitors were retested and again they were acceptable. These two capacitors were included in the sample of capacitors which had their cases removed for visual inspection. Both of the capacitors, which exhibited moisture-resistance problems, had stains between the terminations on the lead end of the chip. These stains appeared to be flux residue. No visual contamination was observed on the rest or the ceramic chip sample.

CONLUSIONS

This effort was originally intended to explore the possibility or developing a molded-case, radial-leaded capacitor with increased moisture resistance. The 85% relative humidity/85°C test was intended to be continued until failure of some or the capacitors occurred, but after 4000 hours (166 days) the test was terminated without any failures. A1so, the moisture resistance test was intended to continue until some or the capacitors had failed. After 4000 hours of 85% relative humidity/85°C testing and three 20 day cycles or moisture resistance testing, it was concluded that the MIL-C-123 capacitors with the standard-composition silver end-terminations are indeed robust enough for our applications and that the three experimental end-termination modifications provided no noticeable performance improvements.

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