



iNEMI Medical TIG Forum
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Reliability of Flexible Termination Ceramic Capacitors in Temperature-Humidity-Bias Conditions

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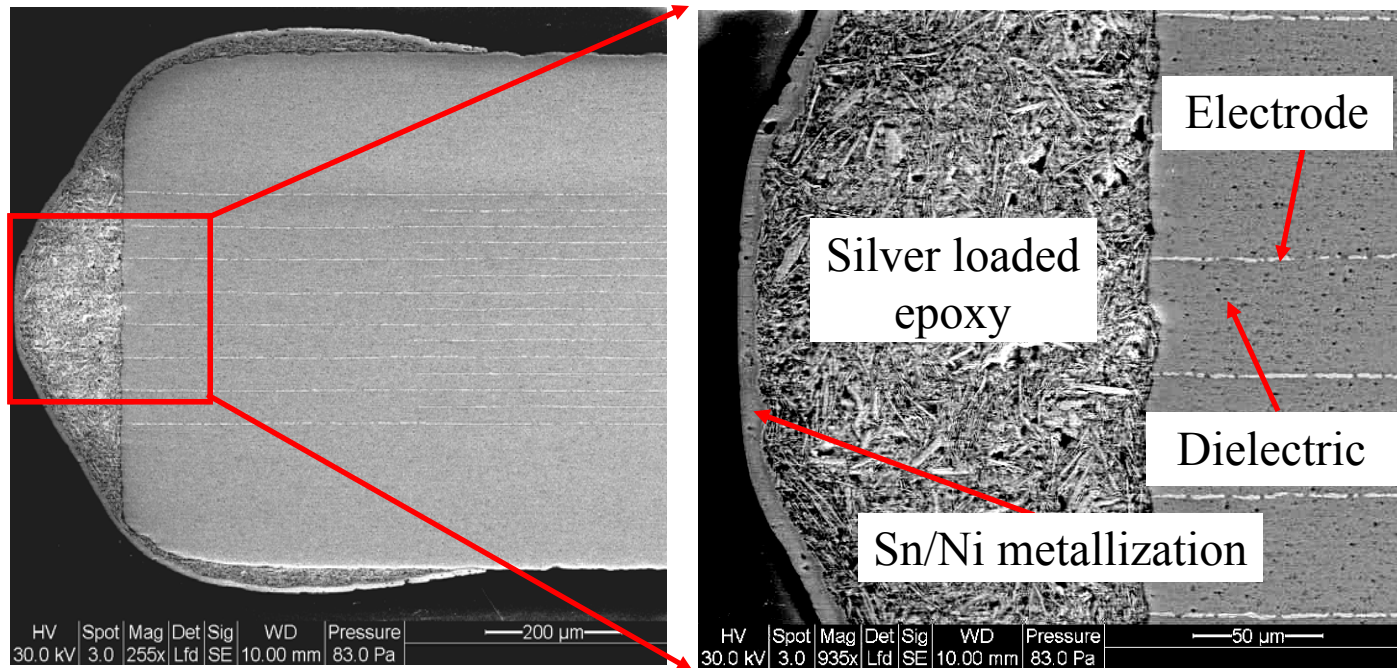
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MLCCs with Flexible Terminations



- Flexible-termination MLCCs were developed in order to reduce flex cracking susceptibility, by reducing stresses transmitted to the brittle ceramic body of MLCCs through their end terminations.
- CALCE has been conducting flex tests, as well as temperature-humidity storage and bias tests to evaluate their susceptibility to electrical degradation due to moisture ingress or silver migration.

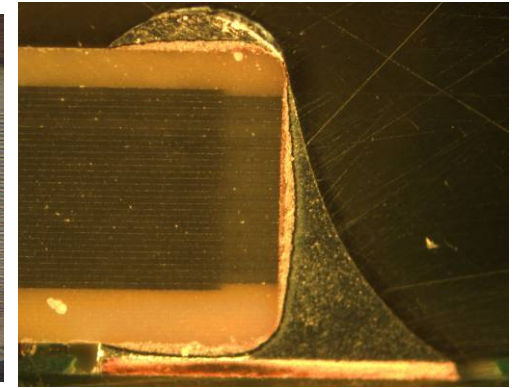
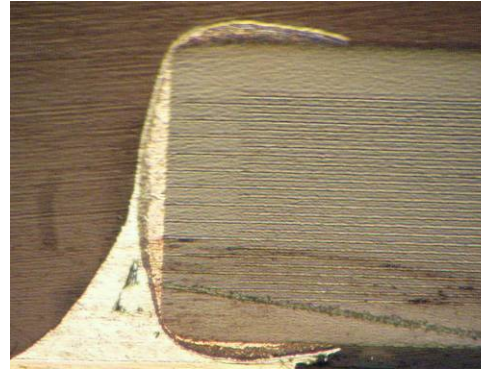
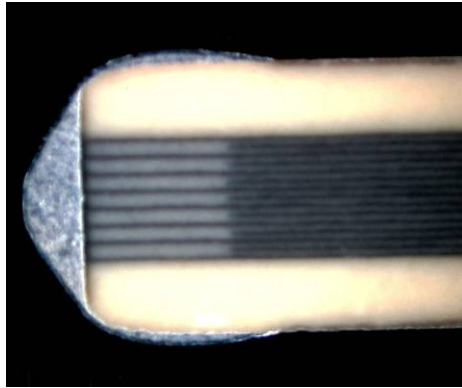
Comparison of Flex and Standard Terminations for Three Capacitors

SYFER 1812

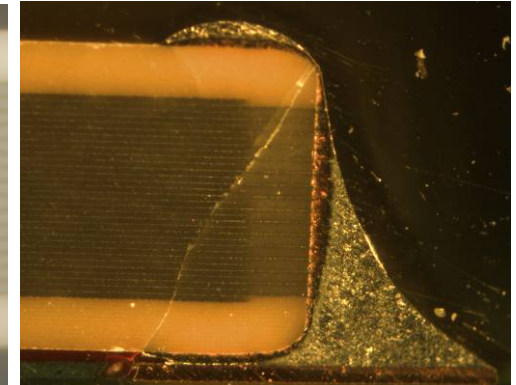
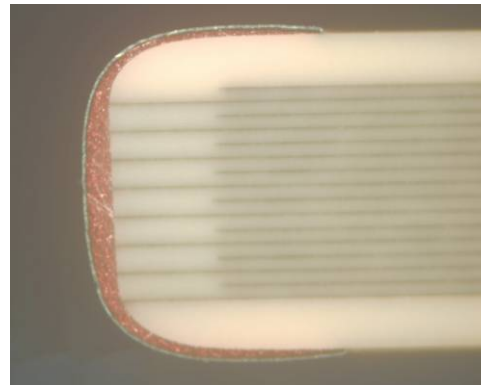
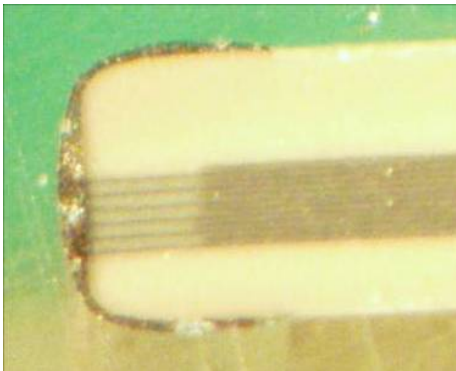
AVX 1812

AVX 0805

Flex
Termination



Standard
Termination



Same rounded body.
Termination geometry
is very different.

Different thickness and
corners. Termination
geometry is different.

Same thickness and
body. Termination
geometry is similar.

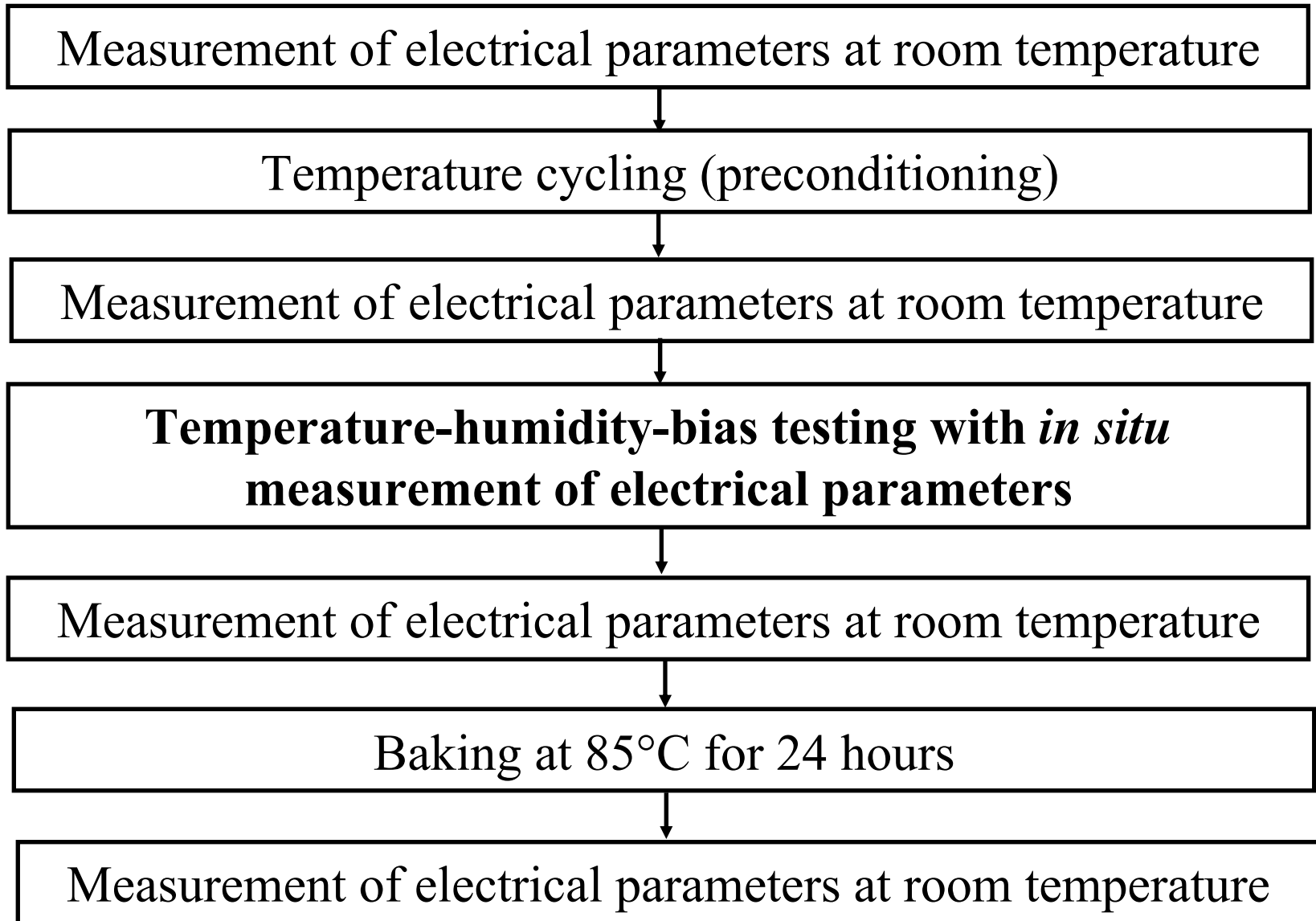
Concerns Regarding Reliability of MLCCs Exposed to THB Conditions

- There is little published data available on reliability of flexible-termination MLCCs in temperature-humidity-bias (THB) conditions.
 - In most published reports, THB testing of MLCCs is not performed to failure, and usually does not involve *in situ* monitoring.
- The presence of the polymer termination may provide a diffusion path for moisture, which could potentially cause electrical degradation.
 - The flexible termination includes silver-loaded polymer, and some MLCCs contain precious metal electrodes (Ag-Pd). Either of these may lead to silver migration.

Experimental Details of THB Tests

- CALCE tested 4 boards assembled with eutectic tin-lead (Sn37Pb) solder, each containing 24 capacitors, at 85 °C and 85% humidity.
- Experimental factors evaluated:
 - **Conformal coating**
 - Acrylic coating (48 out of 96 total capacitors)
 - Uncoated (48 out of 96 total capacitors)
 - **Termination Type**
 - Flexible (48 out of 96 total capacitors)
 - Standard (48 out of 96 total capacitors)
 - **Voltage**
 - 50 V (10 out of 24 capacitors on each board)
 - 1.5 V (10 out of 24 capacitors on each board)
 - No applied bias (4 out of 24 capacitors on each board)
- Parts were monitored in-situ, with capacitance, dissipation factor and insulation resistance measured approximately every three and a half hours.
- Total test duration was 1766 hrs.

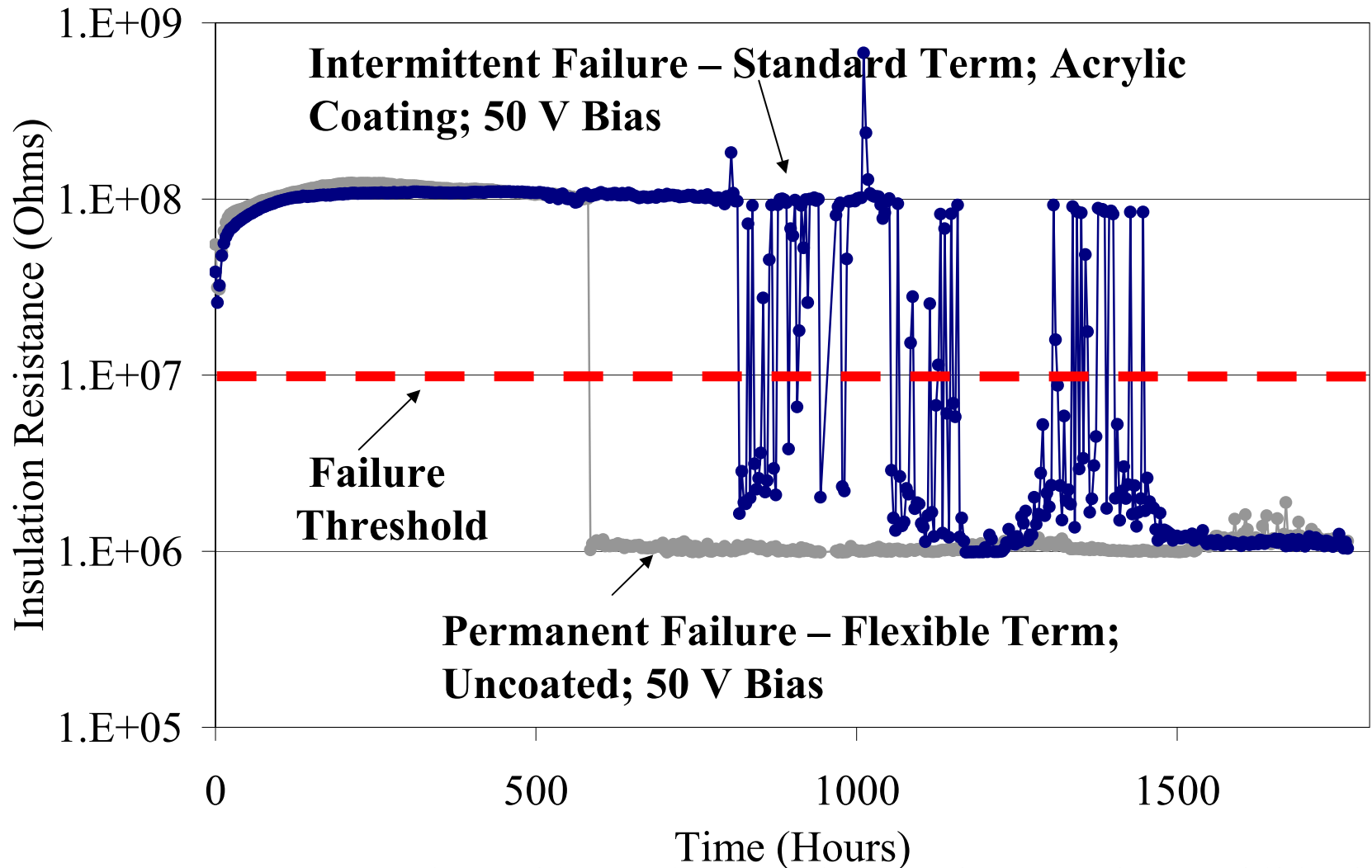
Experimental Procedure for THB Testing of MLCCs



Failure Criteria Used for THB Tests

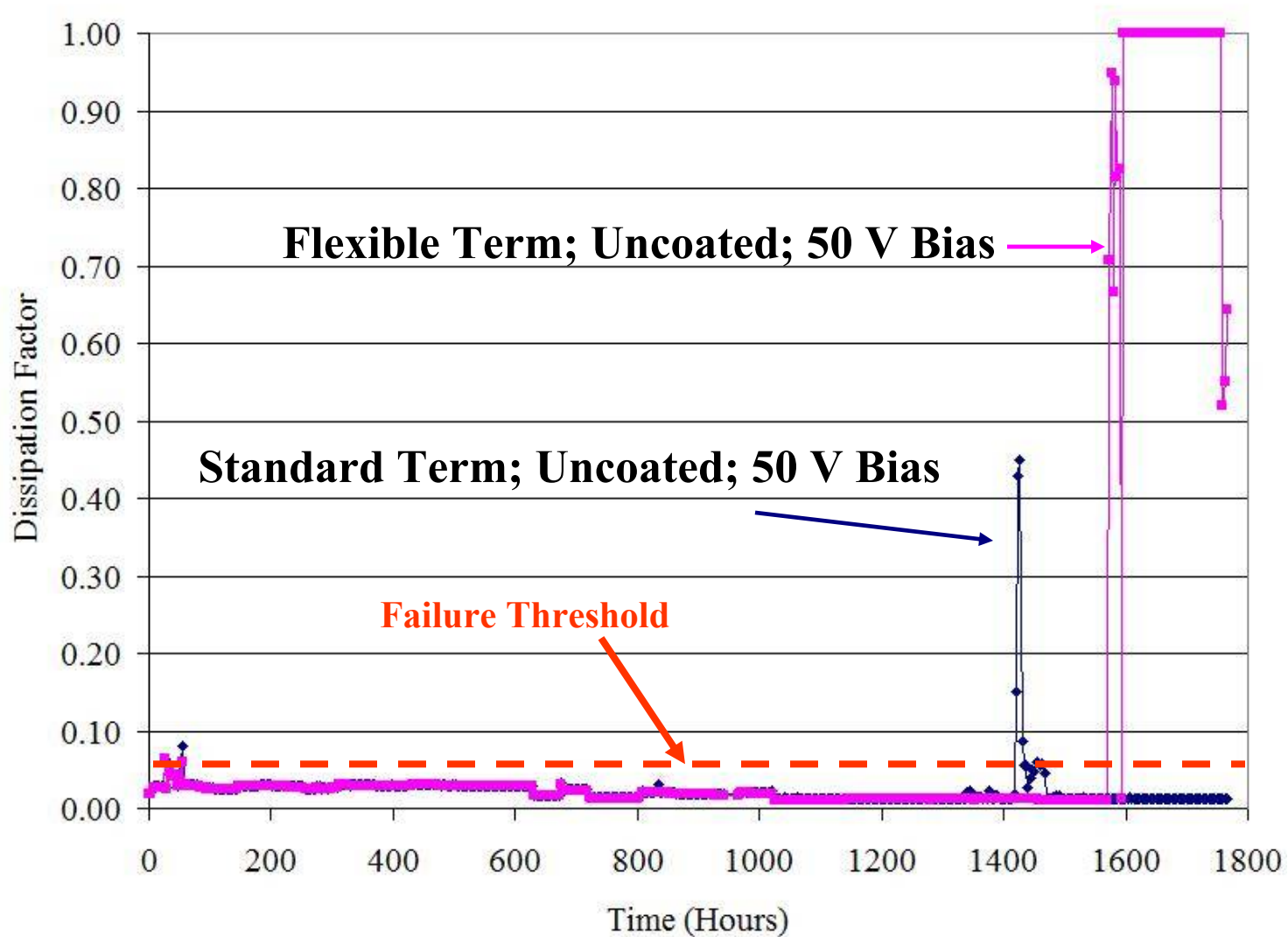
- For *in situ* monitoring in THB conditions:
 - Capacitance: A change of 10% compared to capacitance measured after stabilization in THB conditions.
 - Dissipation Factor: An increase of 100% over DF measured after stabilization in THB conditions.
 - Insulation Resistance: A factor of 10 drop compared to IR measured after stabilization in THB conditions, or a value below 10^7 Ohms.
- For laboratory conditions (based on IEC 60384-22):
 - Capacitance: A change of 20% compared to capacitance measured prior to THB test.
 - Dissipation Factor: A rise above 0.07
 - Insulation Resistance: $IR \times C_{\text{nominal}} < 25 \text{ s}$ (IR below 0.25 G Ω).

Comparison of Permanent and Intermittent Failures in THB Test



Some MLCCs experienced intermittent failures, whereas others exhibited permanent failures. Most failures were for insulation resistance.

Dissipation Failure Examples in THB Test



Most dissipation factor failures were accompanied by failures for insulation resistance.

In Situ Monitoring Failures

			Time to Failure [h]			
Termination Type	Conformal Coating	Voltage Bias	Total Failures	Insulation Resistance (Ohms)	Capacitance (nF)	Dissipation Factor
Standard	No	None	0	N/A	N/A	N/A
	No	1.5	0	N/A	N/A	N/A
	No	50	2	1017	N/A	1416
				1028	N/A	N/A
	Yes	None	1	N/A	N/A	964
	Yes	1.5	1	N/A	N/A	814
	Yes	50	1	1064	N/A	N/A
Flexible	No	None	1	1656	N/A	N/A
	No	1.5	0	N/A	N/A	N/A
	No	50	2	581	N/A	774
				1569	N/A	1569
	Yes	None	1	1686	N/A	N/A
	Yes	1.5	1	964	1316	1316
	Yes	50	1	1154	N/A	1193

This table shows only failures involving 5 consecutive readings satisfying a failure criterion.

Total Failures After Conclusion of Test

Termination Type	Conformal Coating	Voltage Bias	Cumulative Failures			
			<i>In-Situ</i>	After Removal from Environmental Chamber ¹	After Baking (in Desiccant)	After Removal from Desiccant
Standard	No	None	0	0	0	0
	No	1.5	0	0	0	0
	No	50	2	0	0	0
	Yes	None	1	0	0	0
	Yes	1.5	1	0	0	0
	Yes	50	1	1	1	1
Flexible	No	None	1	1	1	1
	No	1.5	0	0	0	0
	No	50	2	2	2	2
	Yes	None	1	0	0	0
	Yes	1.5	1	1	1	1
	Yes	50	1	4	4	4

¹ Boards equilibrated in laboratory environment prior to measurement

Summary of THB Results

- 11 out of 93 parts failed during a THB test lasting 1766 hours. Most failures (all permanent failures) involved a reduction in IR.
- As of 500 hours there were no failures and as of 1000 hours there were 4 failures.
 - Of the 4 failures prior to 1000 hours, 2 were non-permanent failures solely for dissipation factor; of the 2 IR failures, 1 occurred at 581 hours (50V) and the other at 964 hours (1.5V), both of which had flexible terminations.
- There was little difference in the number of failures for the flexible and standard termination capacitors when measured *in-situ* (5 standard and 6 flexible termination capacitors failed).
- Flexible termination capacitors were more likely to experience permanent failure, while standard termination capacitors were more likely to fail intermittently.
- Conformal coating did not make a significant difference in the failure statistics.

Temperature-Humidity Storage Test

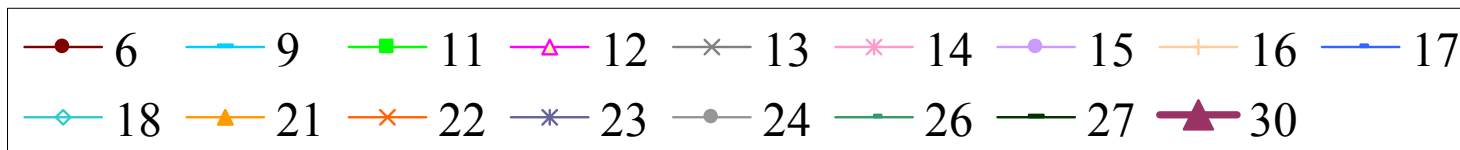
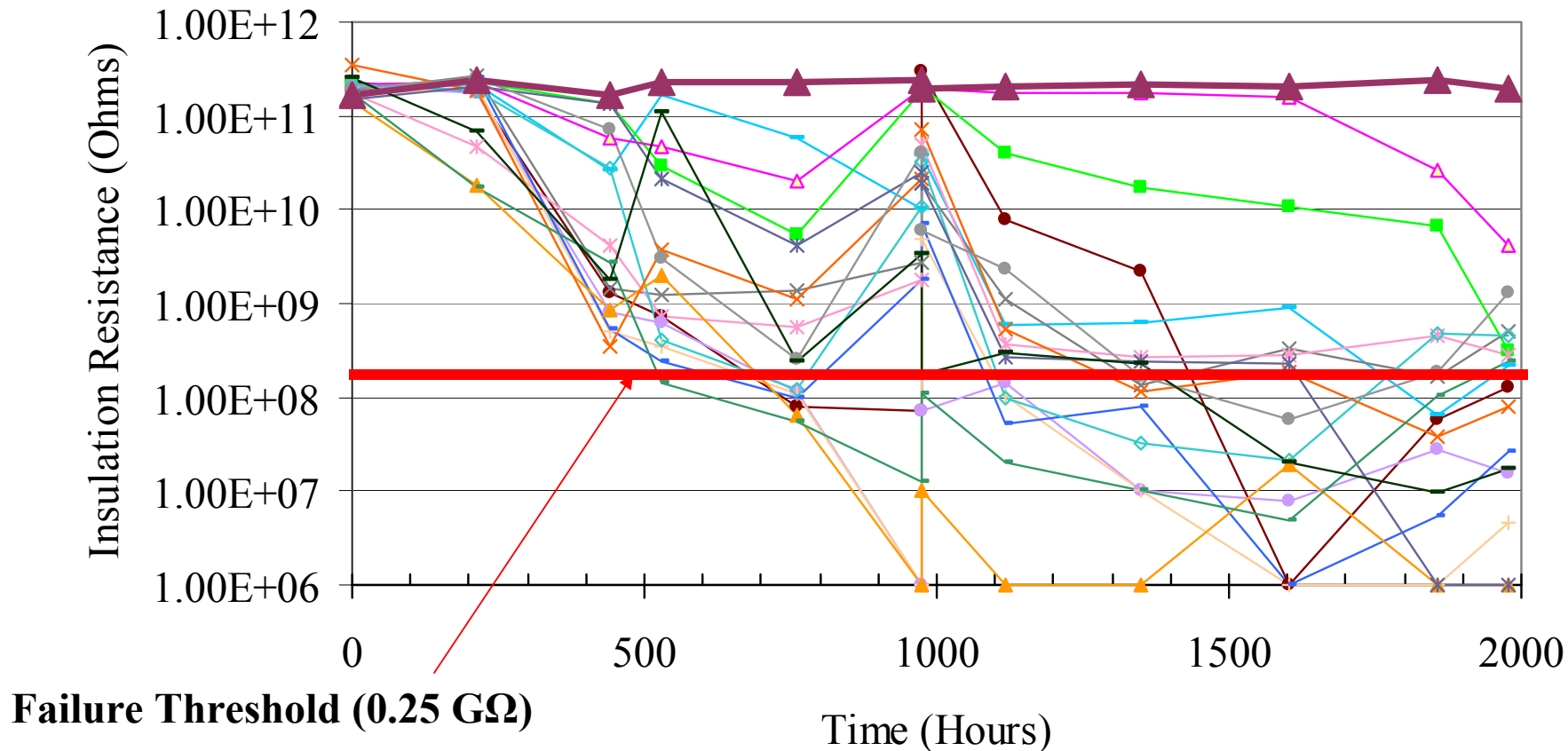
- 28 capacitors of each termination type, standard and flexible, were placed in 85°C, 85% RH conditions for 1976 hours.
- Parts were taken directly from the reel and placed individually into a tray.
- Two controls of each termination type, which were kept at room temperature, were measured with the parts from the chamber.
- Capacitance, dissipation factor and insulation resistance were measured approximately every 10 days.

Cumulative Failures in Storage Test

		Cumulative Failures at Various Time Intervals (Hours)											
		0	212	442	529	761	975	975	1118	1349	1603	1858	1978
Standard Termination	Capacitance	0	0	0	0	0	0	0	0	0	0	0	0
	Dissipation Factor	0	0	0	0	0	0	0	0	0	0	2	3
	Insulation Resistance	0	0	0	2	8	8	8	9	15	16	17	18
Flexible Termination	Capacitance	0	0	0	0	0	0	0	0	0	0	0	0
	Dissipation Factor	0	0	0	0	0	0	0	0	0	0	1	1
	Insulation Resistance	0	0	0	0	0	0	0	0	0	0	0	0

- **This table shows the cumulative number of capacitors which have failed at some point during the test.**
- **New capacitors continue to fail as the parts are exposed to greater amounts of time in the temperature and humidity environment.**

Insulation Resistance Over Time for a Sample Population of the Standard Termination Storage Parts



Storage Test Observations

- Standard termination parts experienced far more failures than the flexible termination parts.
 - There were 18 failures among the standard termination parts for at least one parameter, while there was only 1 failure among the flexible termination parts.
- All standard termination failures occurred first for insulation resistance.
- The only flexible termination failure occurred solely for dissipation factor and no other parameter.