(2022.07.28 revised)

Comparison Evaluation of MPP(Metalized Polypropylene) Capacitors

フィルムキャパシタ比較試験結果報告Vol.1

KETI

J_Chip Consulting

Table of Contents

I. Introduction

II. Environmental test (raw data, graphs)

III.X-ray analyses

IV. SEM analyses

V. Summary and conclusions

I. Introduction

Introduction

- **Specimen**: MPP(Metalized PolyPropylene) Capacitors

- **Test**:
  - Environmental test
  - Electrical characteristic evaluation
  - X-ray analyses
  - SEM analyses

- **Test term:** 2022. 05. 11. ~ 2022. 07. 12.

- **Test environment**: (25 ± 5) ℃, Below 75% room humidity

- **Test apparatuses**:
  - Temperature and humidity test chamber (SE-CT-02, SuksanTech, Korea)
  - Temperature and humidity test chamber (SE-CT-04, SuksanTech, Korea)
  - Thermal shock test chamber (DS-890-2, Daewon sci, Korea)
  - Vibration tester (IPA120h/1537m, ETS Solution, China)
  - Precision LCR meter (4284A, Agilent, USA)
  - Withstanding voltage tester (TOS-9201, Kikusui, Japan)
  - X-ray (XT V160, Nikon, Japan)
  - Focused ion beam (Helios 5 UX, ThermoFisher, USA)

- **Etc**: Blind test

- **Contact**: Lee, Ju Ho ☎ +82-31-789-7282 / leejuho@keti.re.kr

Introduction

- **Test apparatuses**:
  - Temperature and humidity test chamber (SE-CT-02, SuksanTech, Korea)

Introduction

- **Test apparatuses**:
  - Temperature and humidity test chamber (SE-CT-04, SuksanTech, Korea)

Introduction

- **Test apparatuses**:
  - Thermal shock test chamber (DS-890-2, Daewon sci, Korea)

Introduction

- **Test apparatuses**:
  - Vibration tester (IPA120h/1537m, ETS Solution, China)

Introduction

- **Test apparatuses**:
  - Precision LCR Meter (4284A, Agilent, USA)

Introduction

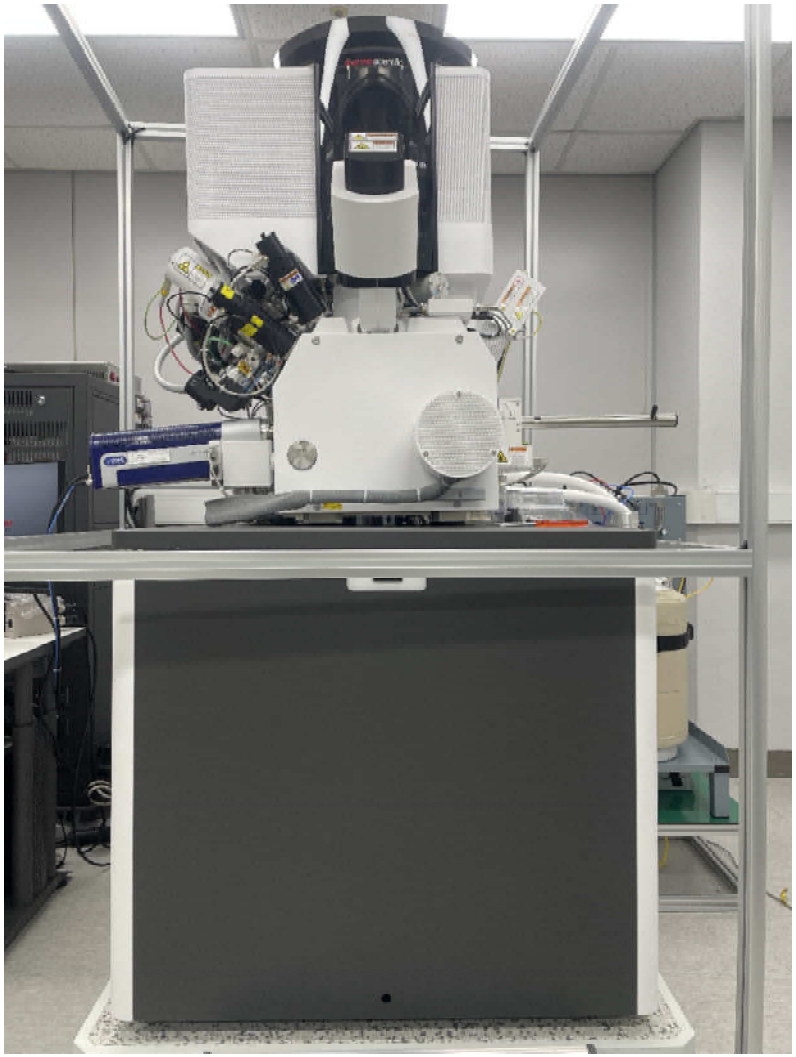
- **Test apparatuses**:
  - Withstanding voltage tester (TOS-9201, Kikusui, Japan)

Introduction

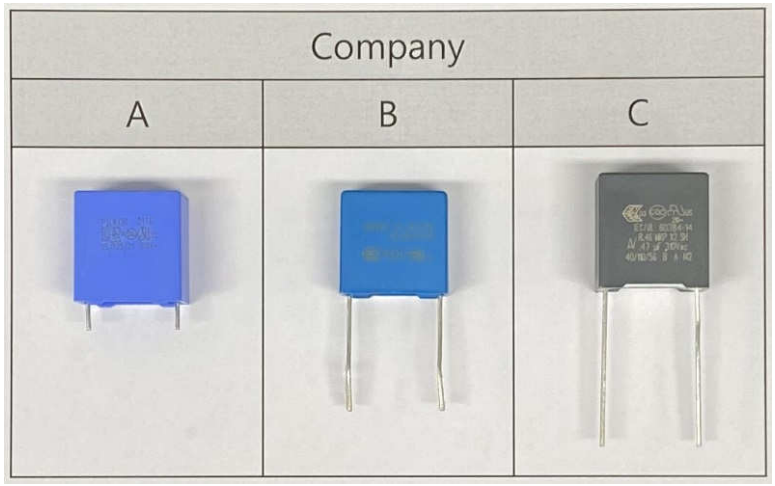
- **Test apparatuses**:
  - X-ray (XT V160, Nikon, Japan)

Introduction

- **Test apparatuses**:
  - Nanolab focused ion beam (Helios 5 UX, ThermoFisher, USA)



Specimens



Sample	Capacitance (μF) (±10%)	Rated voltage (V_{AC})	Capacitance tolerance (%)	Operation Temp. (°C)
A	0.44	305	±10	-55 ~ +105
B	0.47	305	±10	-40 ~ +110
C	0.47	305	±10	-40 ~ +110

· A社：PILKOR (韓国) (PCX2 339J3F31474)
· B社：TDK EPCOS (日本/米国) (B32922C3474K189)
· C社：KEMET (米国) (R463I347050M1K)

II. Environmental test
(raw data, graphs)

Environmental test conditions

- **Test**:
  - High temperature test: 105 °C, 16 hr
  - Low temperature test: -40 °C, 2 hr
  - High humidity test: 40 °C, 93 %R.H., 500 hr
  - Thermal shock test: (-40~105) ℃, each 30 min., 5 cycles
  - Vibration test: (min 10 Hz, max 55 Hz), 0.75 mm, each 2 hr/X,Y,Z
  - Withstanding voltage: 500 V_{DC}, 60 sec, 10 mA
  - Insulation resistance: 500 V_{DC}, 60 sec, 10 MΩ

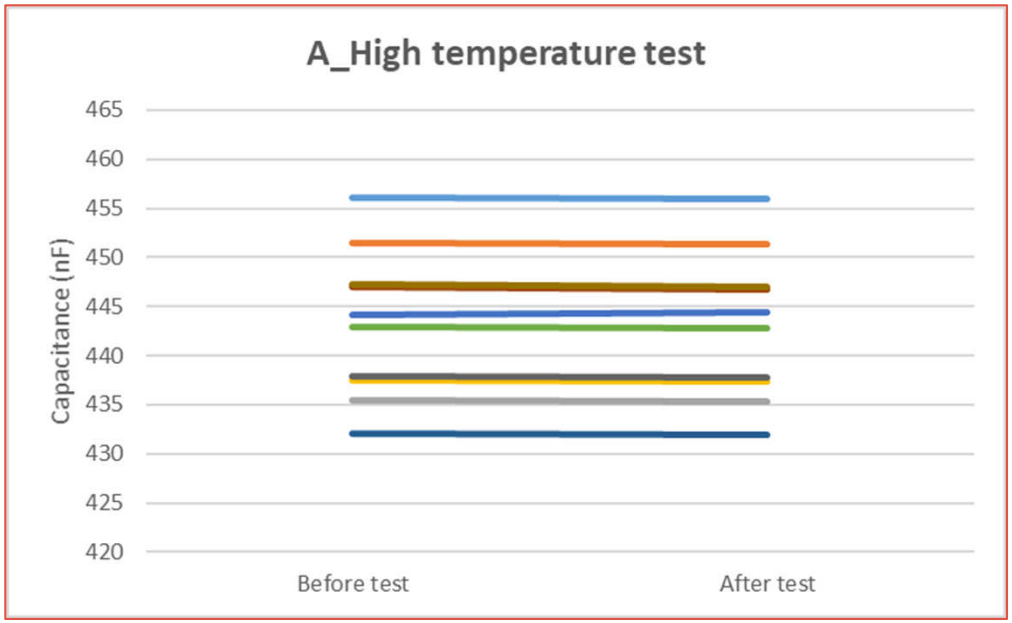
Summary

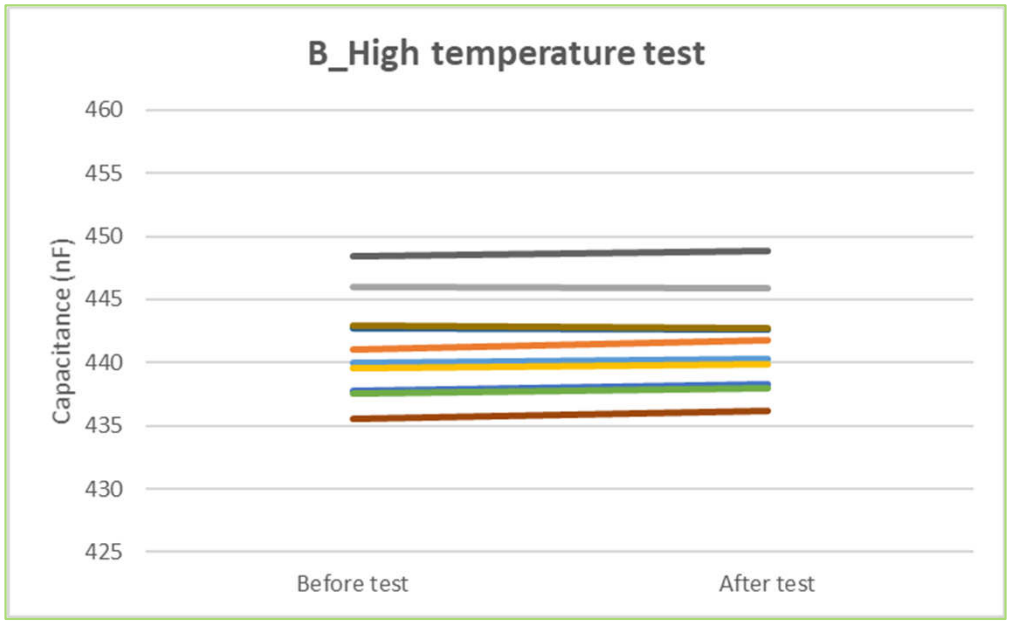
- 環境試験によるキャパシターの静電容量の変化 (@1 kHz)（平均値）

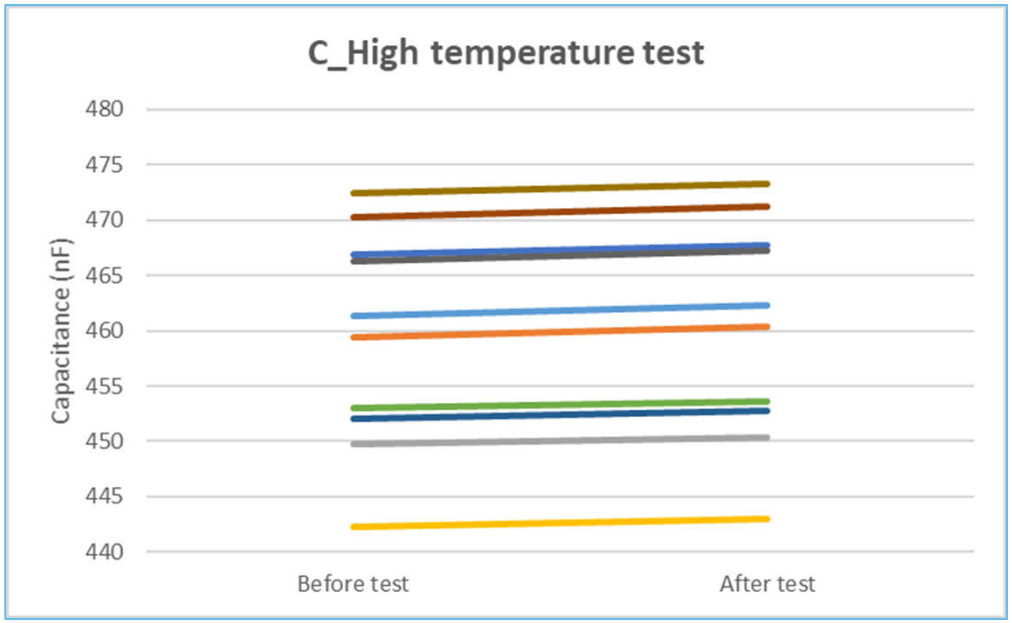
High temp.	Rate of change (%)	Low temp.	Rate of change (%)	High hum.	Rate of change (%)	Thermal shock	Rate of change (%)	Vibration	Rate of change (%)
A1	-0.03%	A1	-0.03%	A1	0.02%	A1	0.04%	A1	0.01%
A2	-0.02%	A2	-0.02%	A2	0.02%	A2	0.02%	A2	0.00%
A3	-0.04%	A3	-0.02%	A3	0.04%	A3	0.07%	A3	0.01%
A4	-0.03%	A4	-0.04%	A4	0.02%	A4	0.08%	A4	0.00%
A5	0.08%	A5	-0.03%	A5	0.01%	A5	0.09%	A5	0.02%
A6	-0.03%	A6	-0.04%	A6	0.05%	A6	0.02%	A6	0.01%
A7	-0.04%	A7	-0.05%	A7	0.01%	A7	0.11%	A7	0.01%
A8	-0.04%	A8	-0.03%	A8	0.03%	A8	-0.01%	A8	0.01%
A9	-0.03%	A9	-0.03%	A9	0.03%	A9	0.01%	A9	0.02%
A10	-0.04%	A10	-0.01%	A10	0.02%	A10	0.11%	A10	0.01%
average	**-0.02%**	average	**-0.03%**	average	**0.02%**	average	**0.06%**	average	**0.01%**
B1	0.06%	B1	-0.02%	B1	0.24%	B1	0.08%	B1	0.01%
B2	0.16%	B2	-0.02%	B2	0.12%	B2	0.03%	B2	-0.02%
B3	-0.01%	B3	-0.03%	B3	0.15%	B3	0.03%	B3	0.01%
B4	0.07%	B4	-0.03%	B4	0.21%	B4	0.07%	B4	0.00%
B5	0.13%	B5	-0.01%	B5	0.16%	B5	0.03%	B5	0.00%
B6	0.10%	B6	-0.04%	B6	0.23%	B6	0.00%	B6	0.00%
B7	0.00%	B7	-0.01%	B7	0.24%	B7	0.08%	B7	0.01%
B8	0.15%	B8	-0.02%	B8	0.13%	B8	0.00%	B8	0.03%
B9	0.11%	B9	-0.03%	B9	0.12%	B9	-0.05%	B9	0.00%
B10	-0.03%	B10	-0.02%	B10	0.21%	B10	0.10%	B10	0.00%
Average	**0.07%**	Average	**-0.02%**	Average	**0.18%**	Average	**0.04%**	Average	**0.00%**
C1	0.22%	C1	-0.02%	C1	0.07%	C1	0.21%	C1	0.01%
C2	0.20%	C2	-0.01%	C2	0.04%	C2	0.12%	C2	-0.01%
C3	0.16%	C3	-0.03%	C3	0.07%	C3	0.16%	C3	0.00%
C4	0.16%	C4	-0.01%	C4	0.03%	C4	0.15%	C4	0.02%
C5	0.19%	C5	-0.01%	C5	0.08%	C5	0.17%	C5	0.02%
C6	0.13%	C6	-0.03%	C6	0.08%	C6	0.15%	C6	0.02%
C7	0.14%	C7	-0.02%	C7	0.09%	C7	0.18%	C7	0.02%
C8	0.18%	C8	-0.01%	C8	0.05%	C8	0.22%	C8	0.01%
C9	0.21%	C9	-0.03%	C9	0.06%	C9	0.13%	C9	0.01%
C10	0.18%	C10	-0.01%	C10	0.06%	C10	0.16%	C10	0.01%
average	**0.18%**	average	**-0.02%**	average	**0.06%**	average	**0.17%**	average	**0.01%**

Summary

High temperature test_Capacitance (nF)

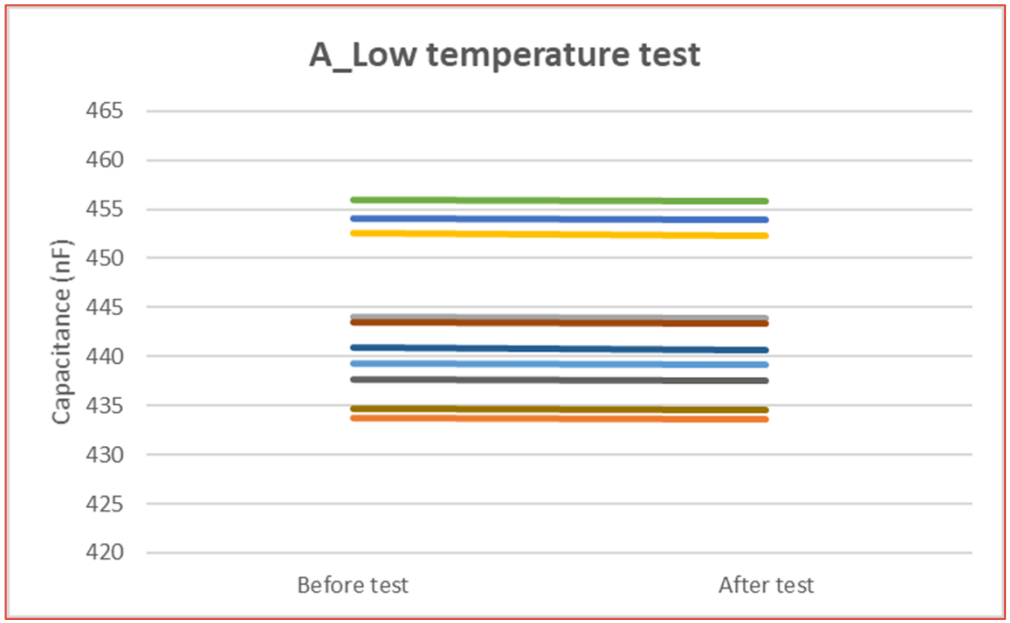


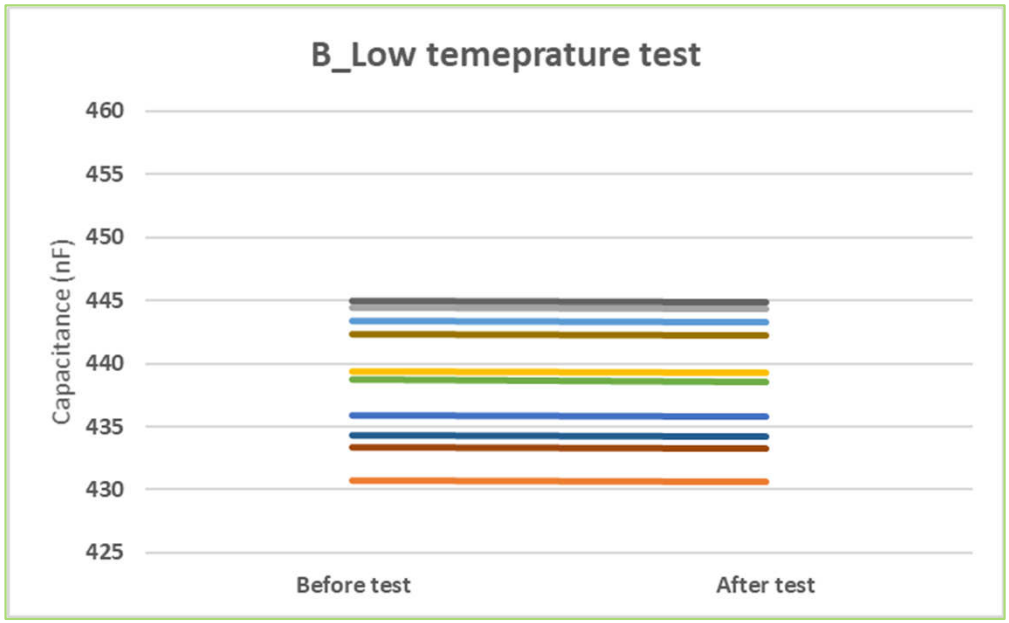


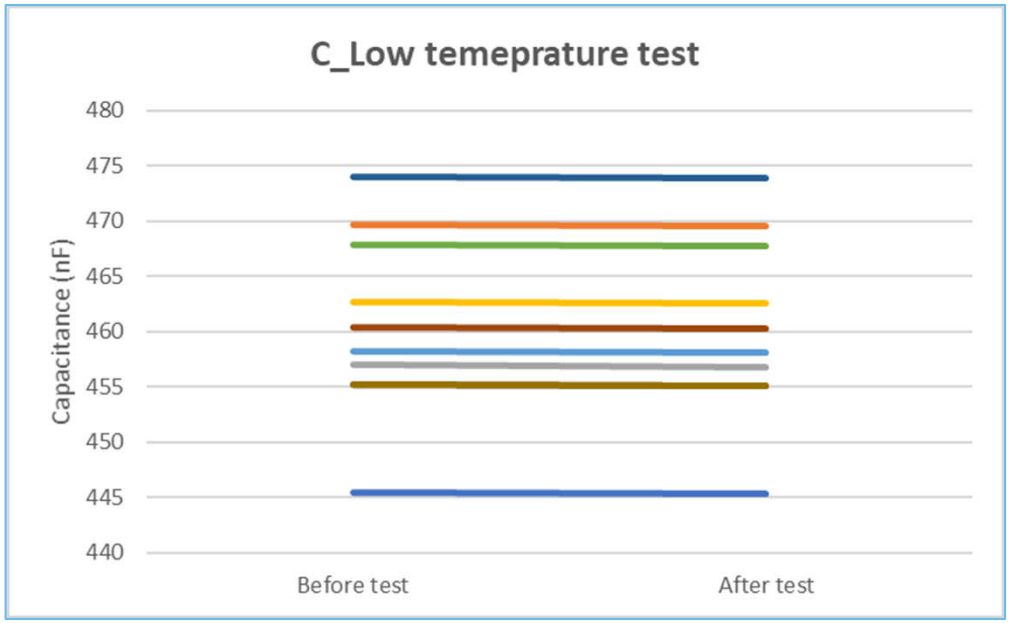


Summary

Low temperature test_Capacitance (nF)

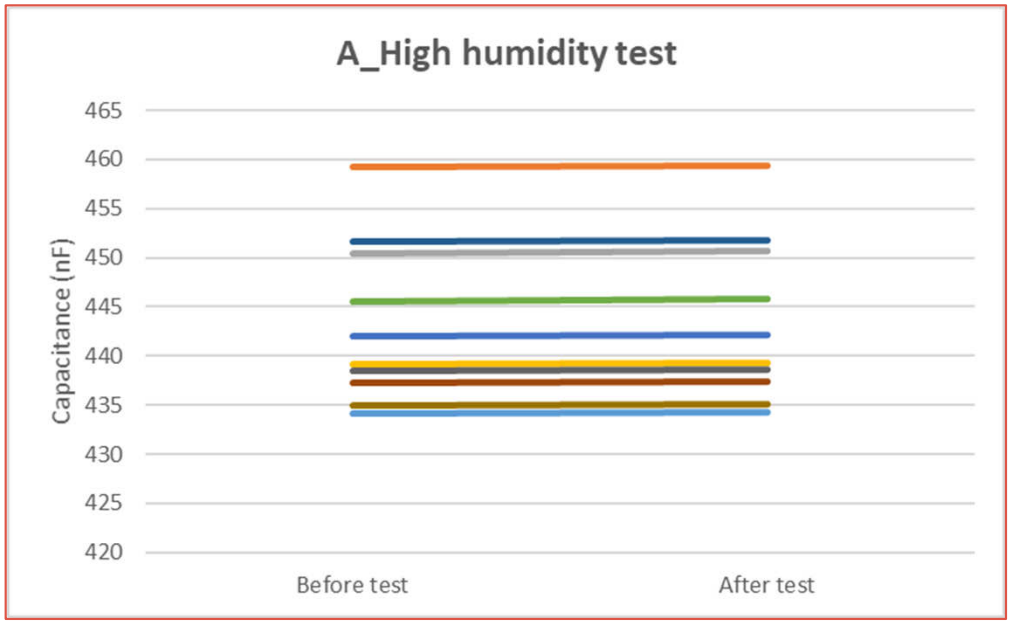


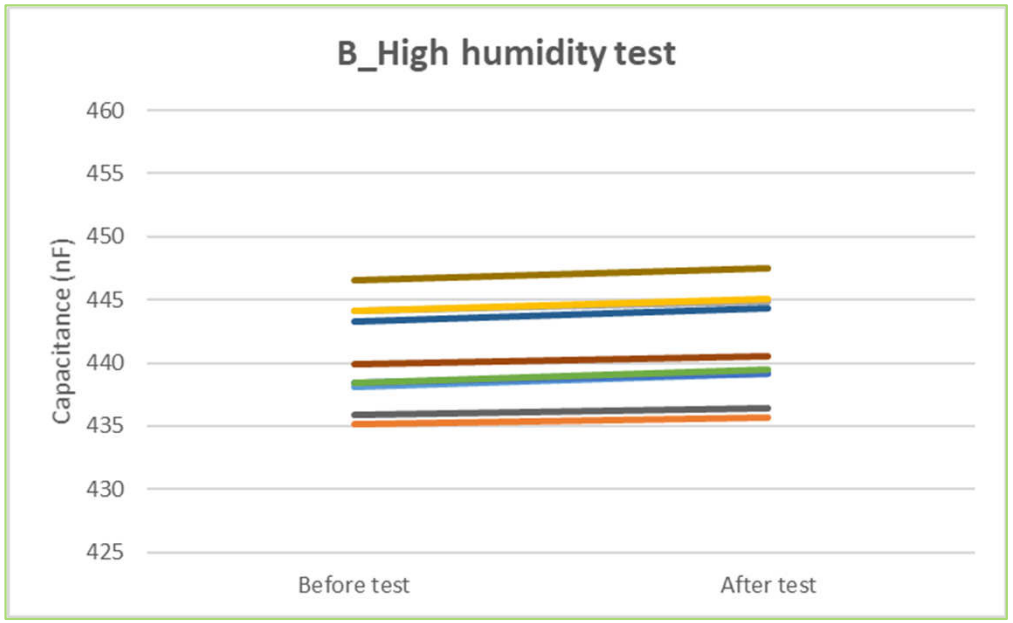


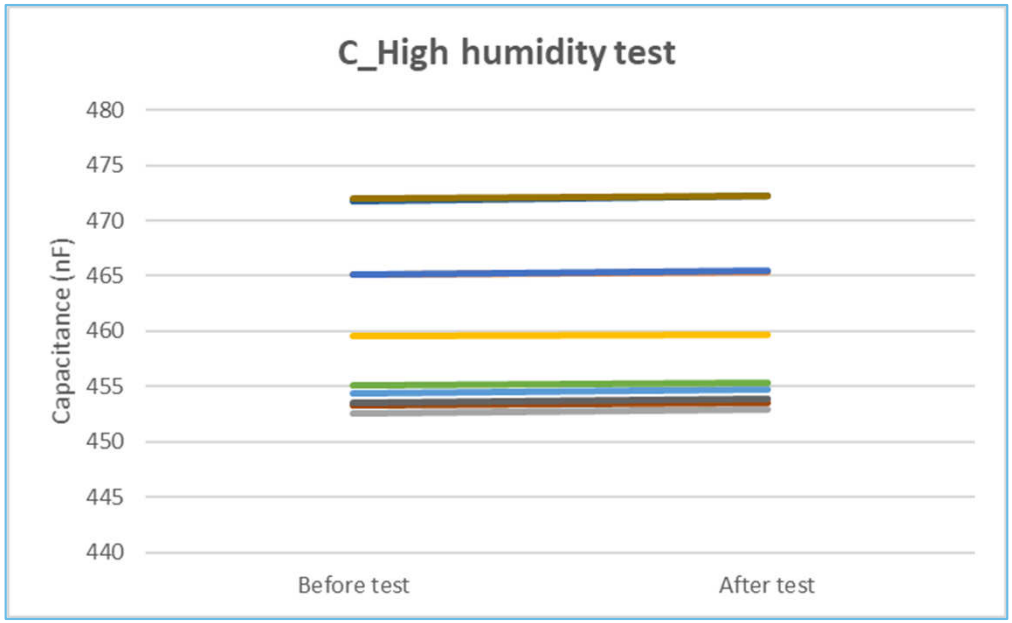


Summary

High humidity test_Capacitance (nF)

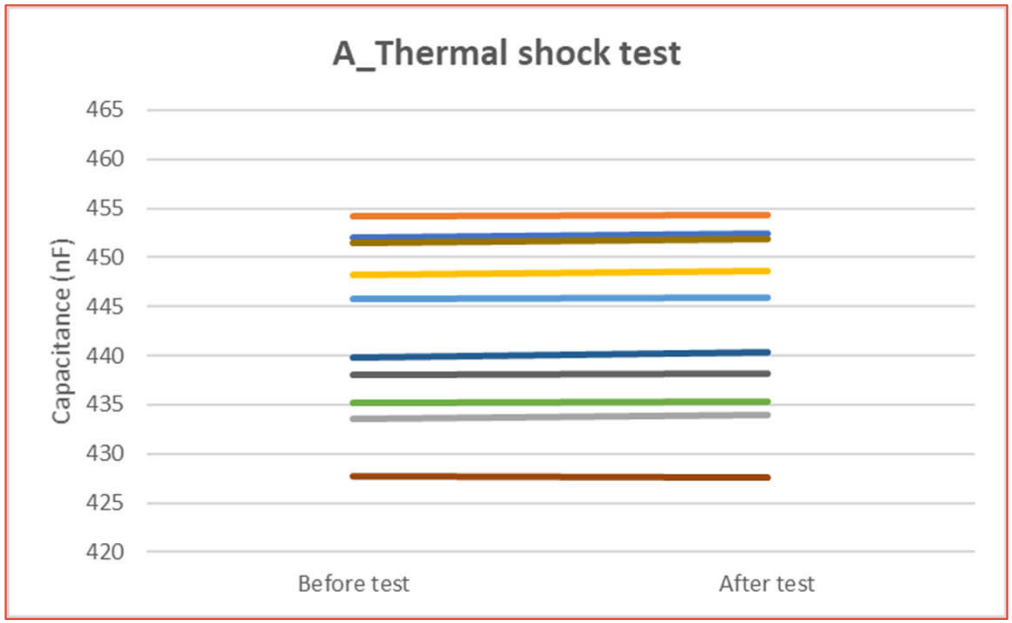


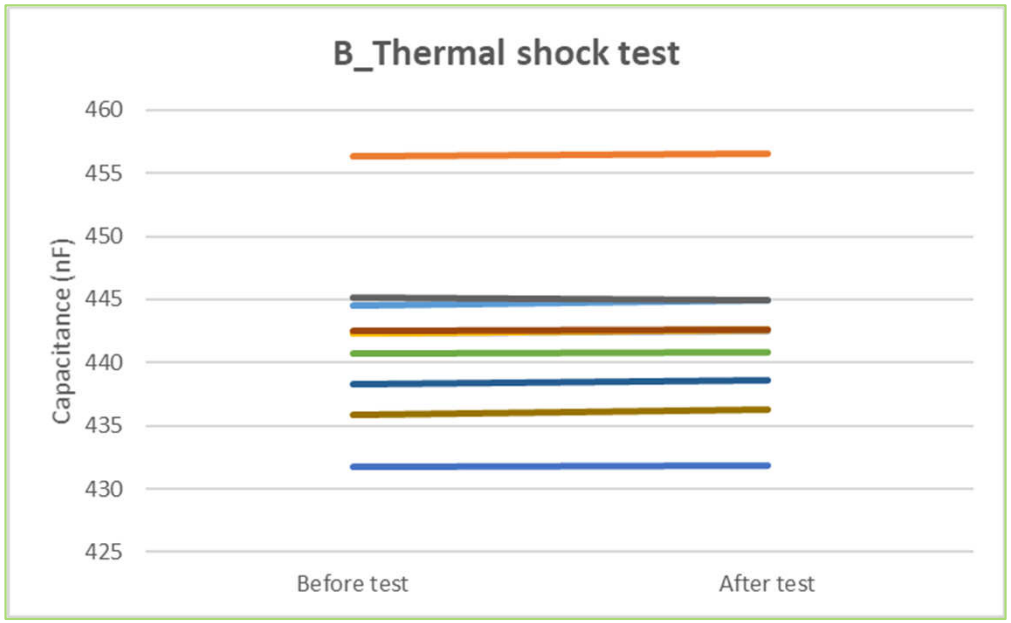


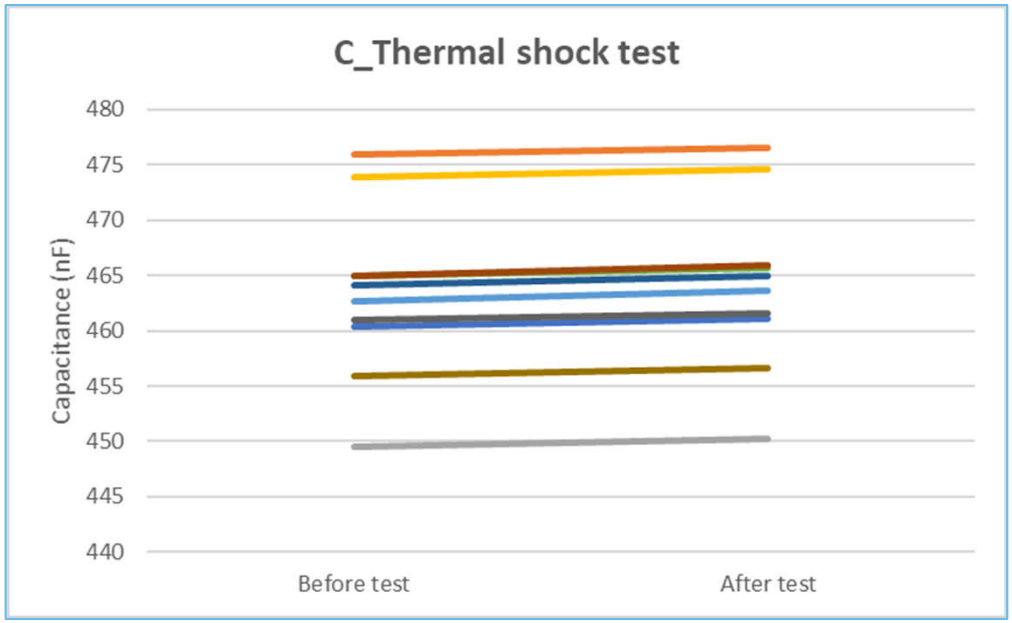


Summary

Thermal shock test_Capacitance (nF)

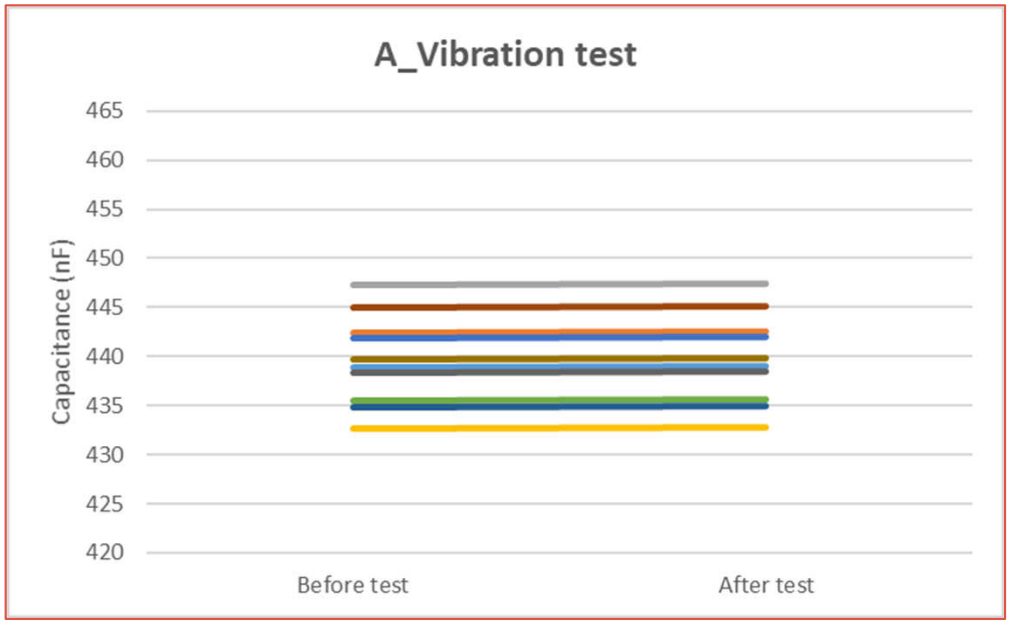


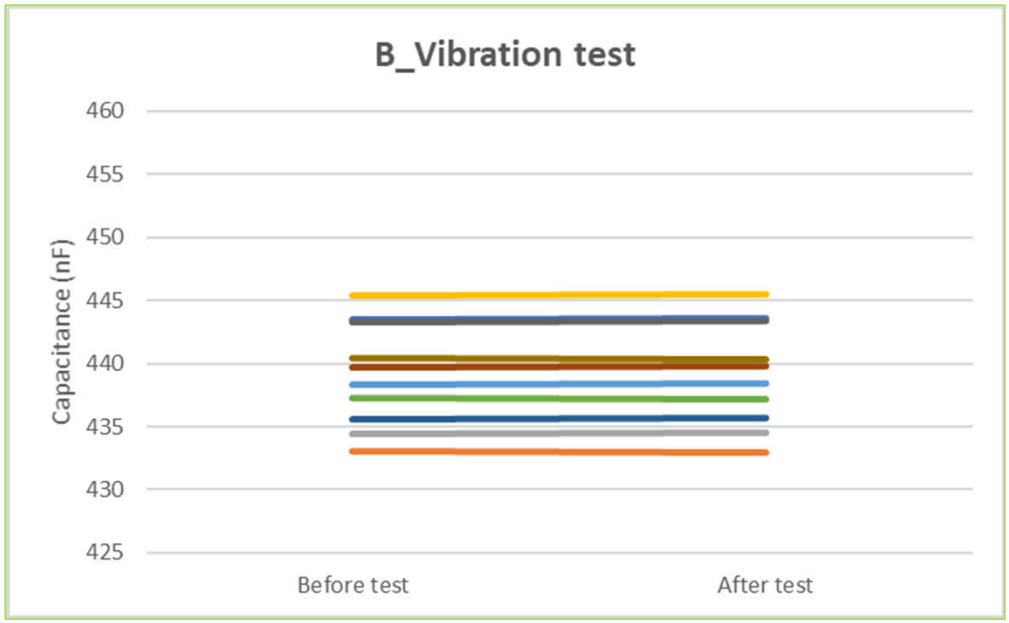


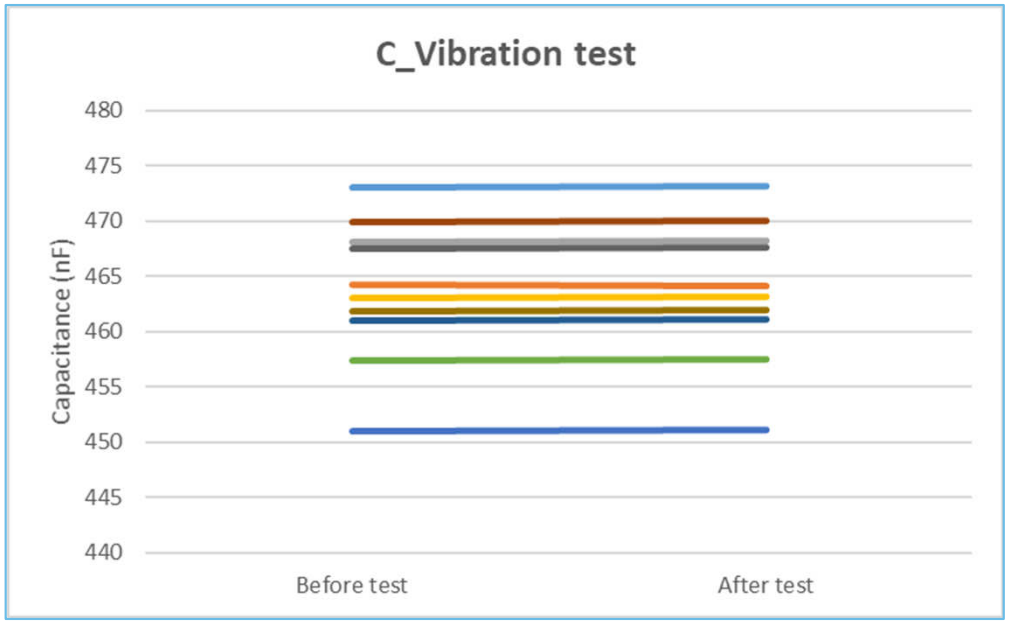


Summary

Vibration test_Capacitance (nF)

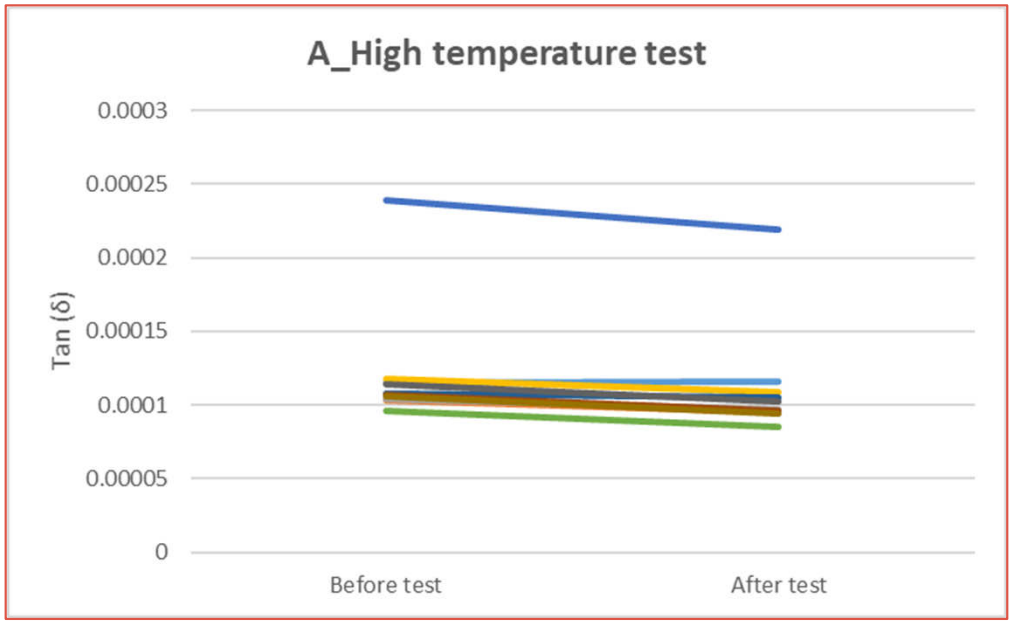


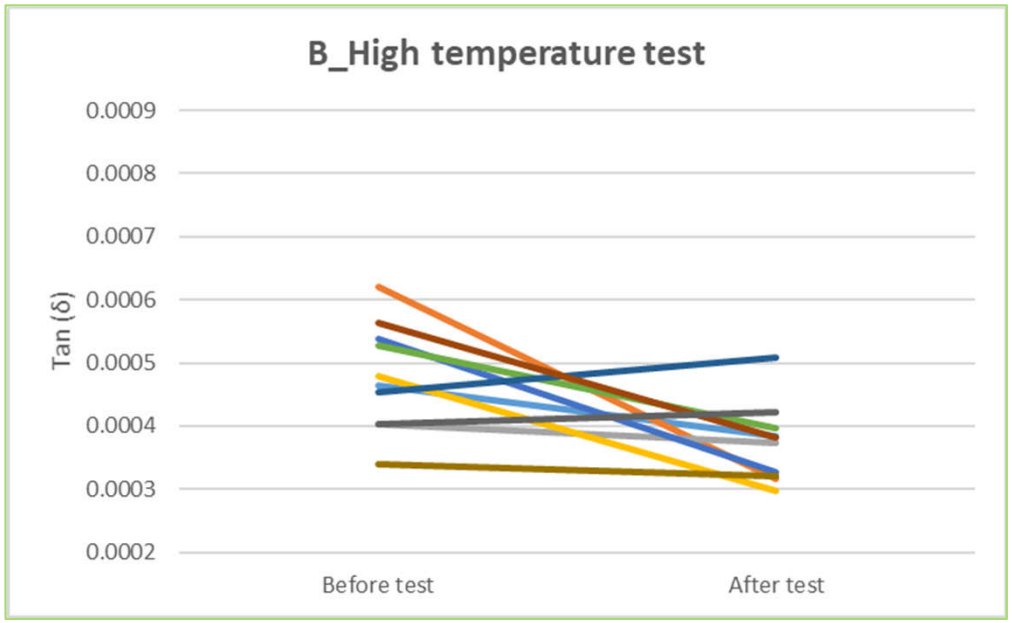


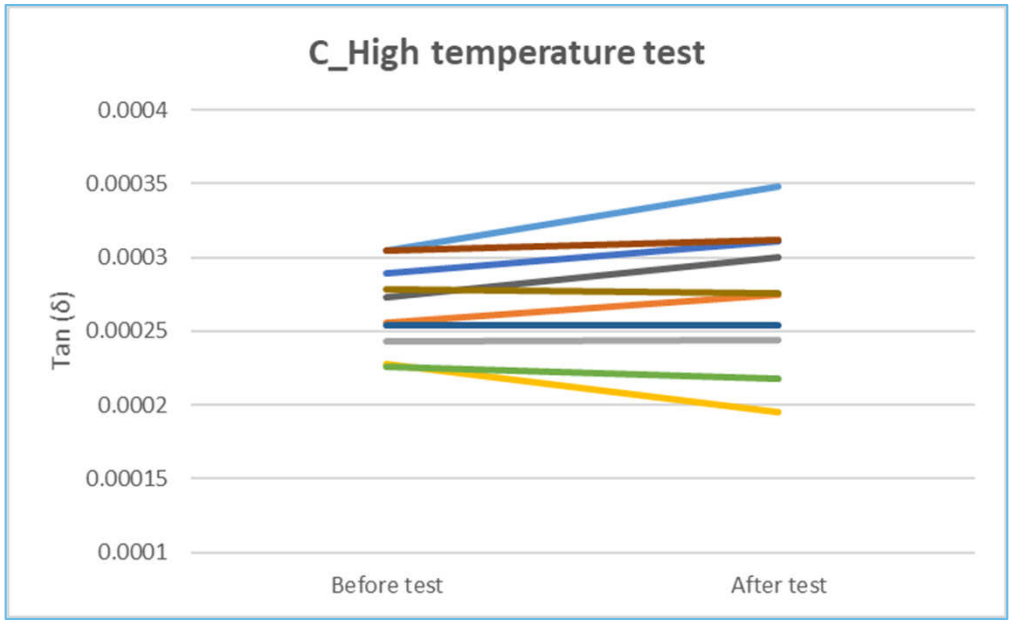


Summary

High temperature test_Tan (δ)

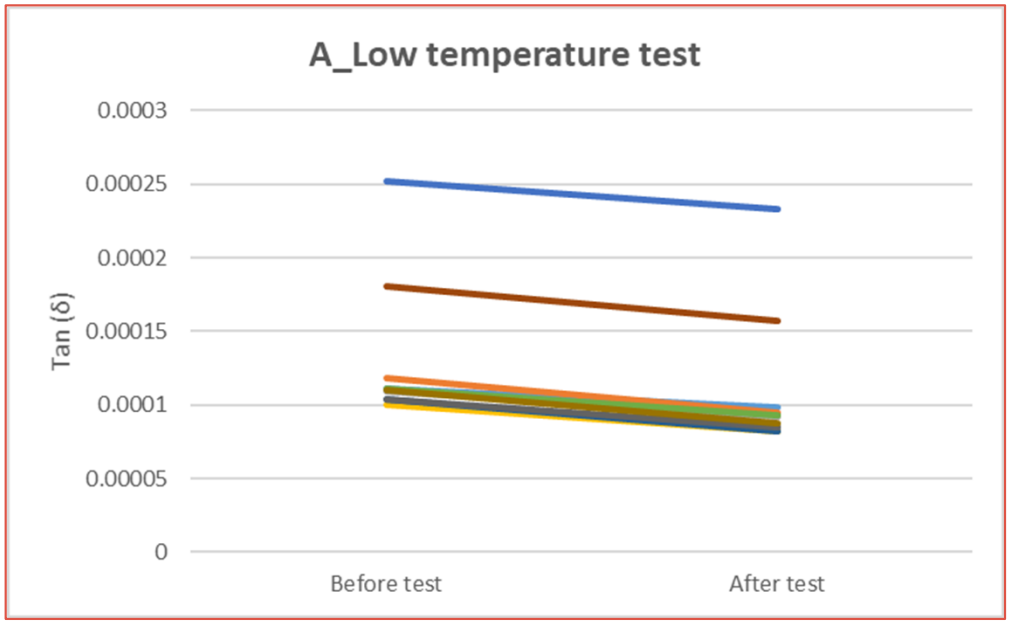


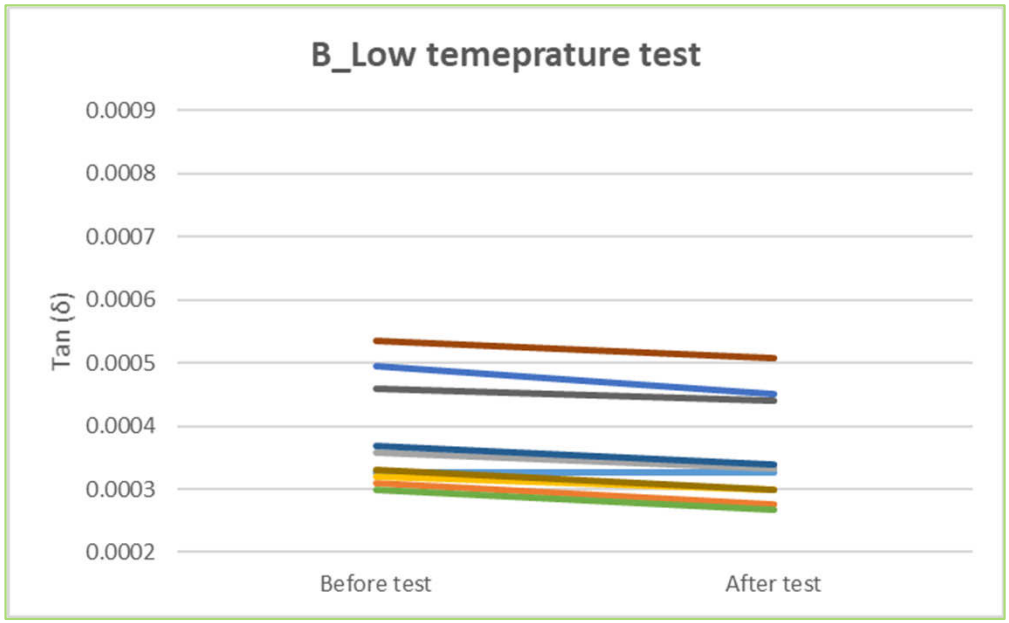


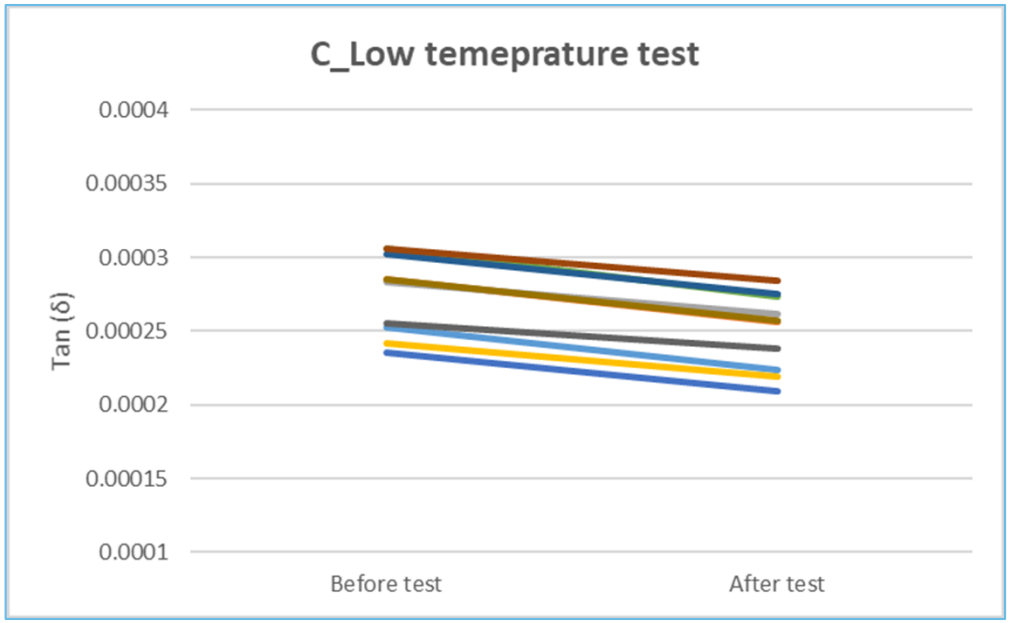


Summary

Low temperature test_Tan (δ)

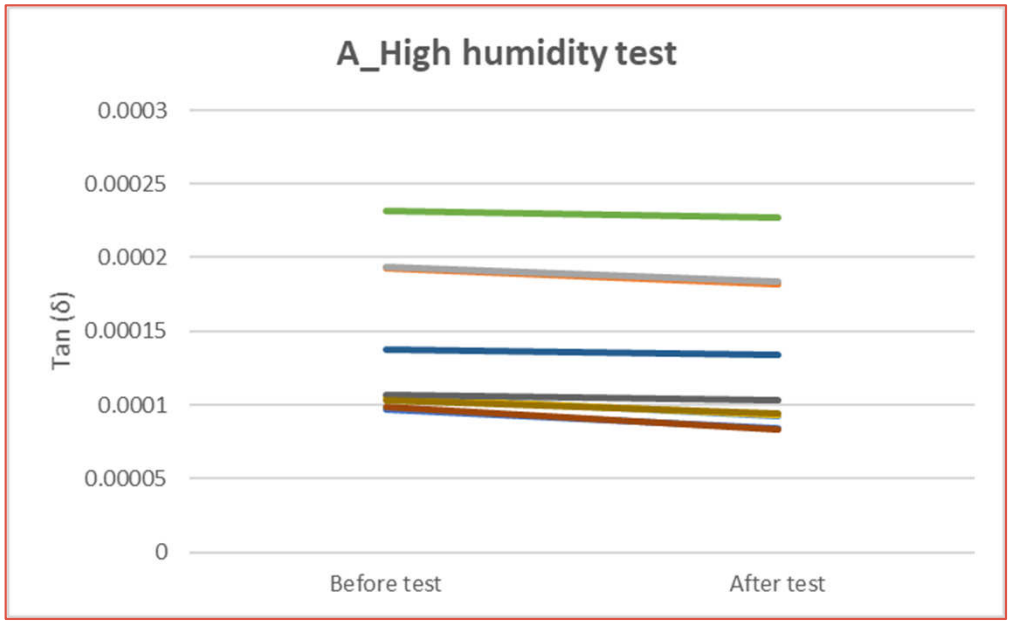


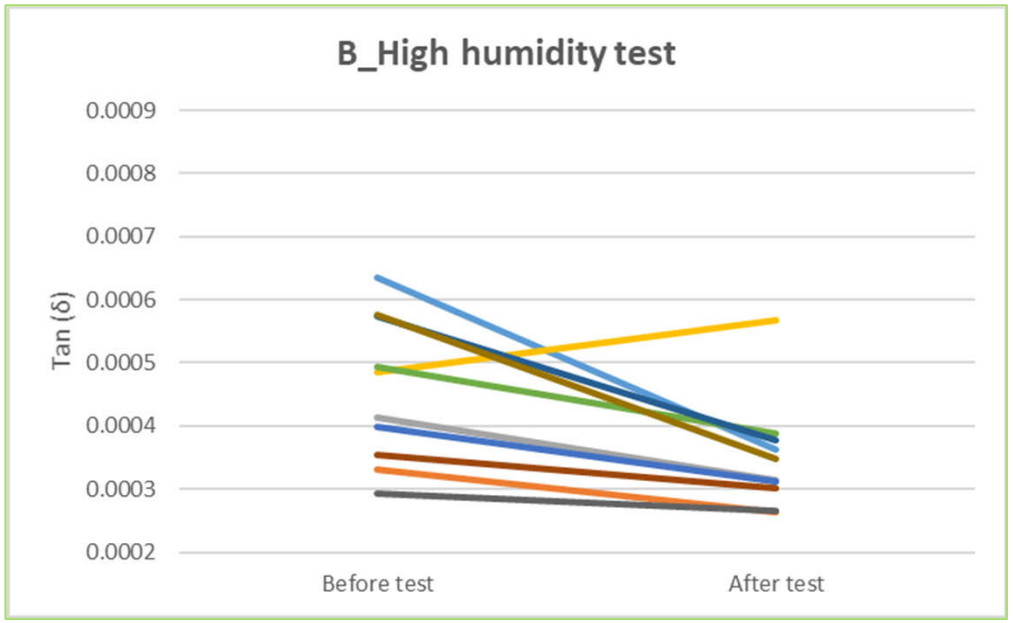


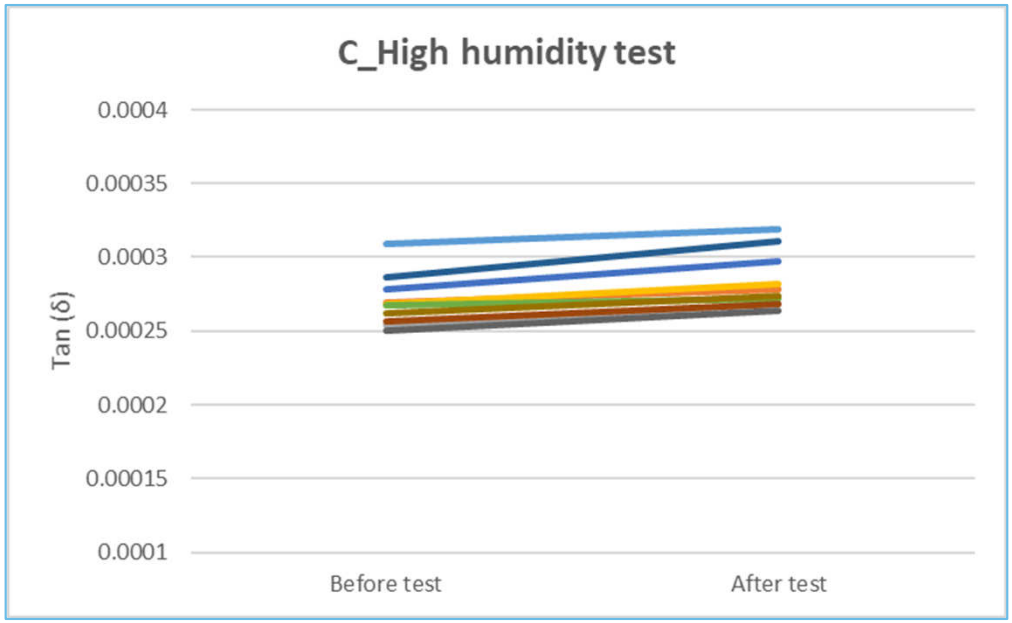


Summary

High humidity test_Tan (δ)

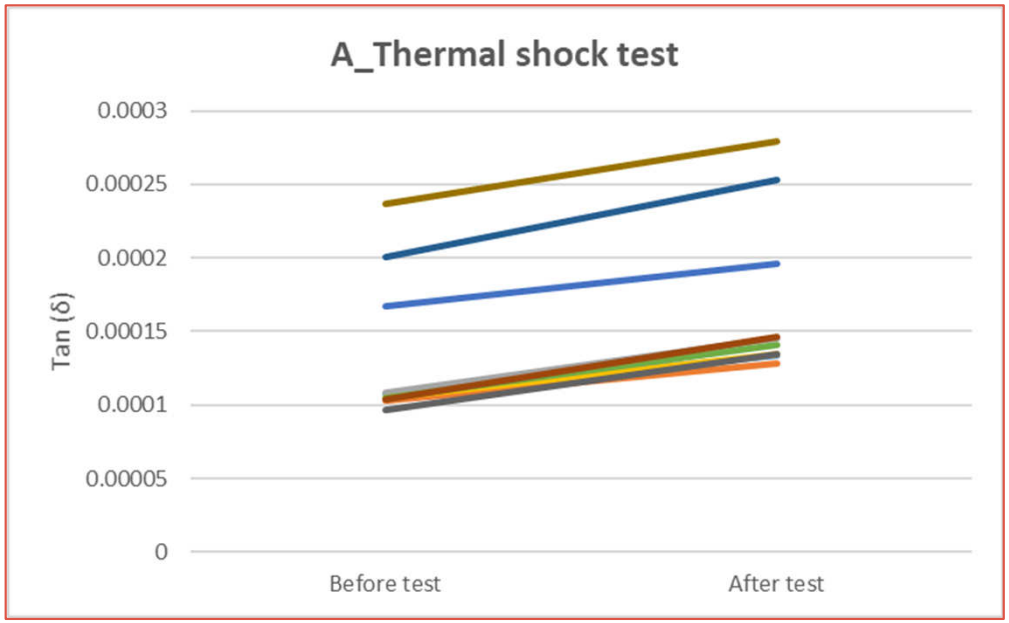


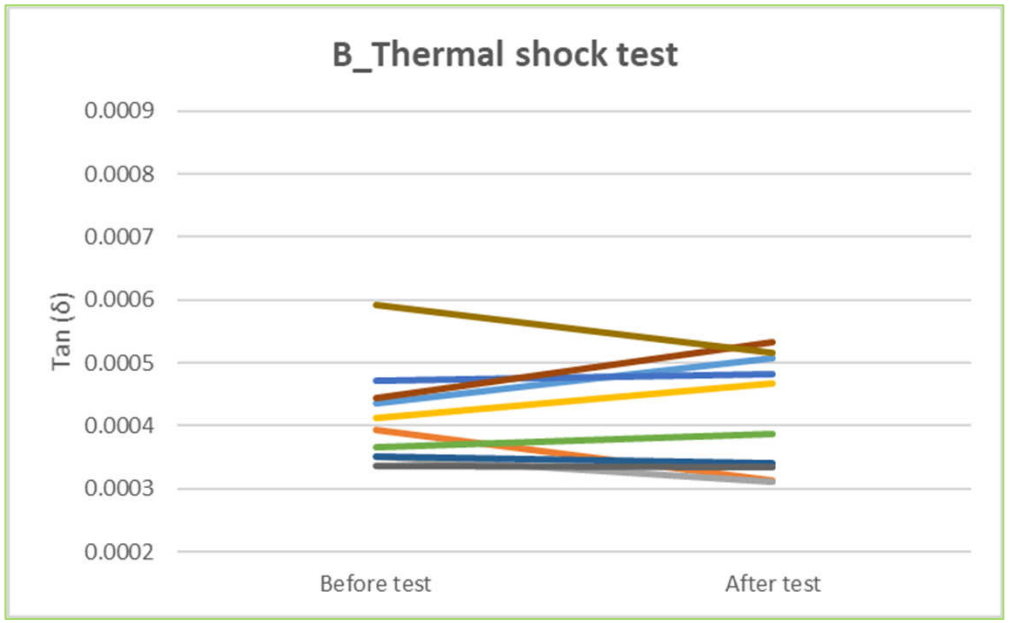


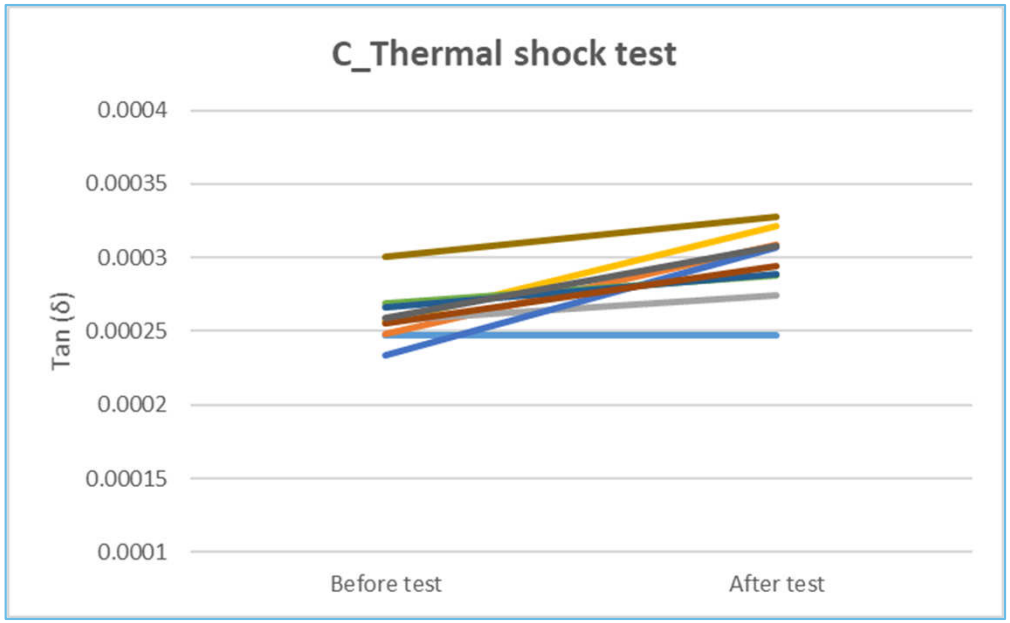


Summary

Thermal shock test_Tan (δ)

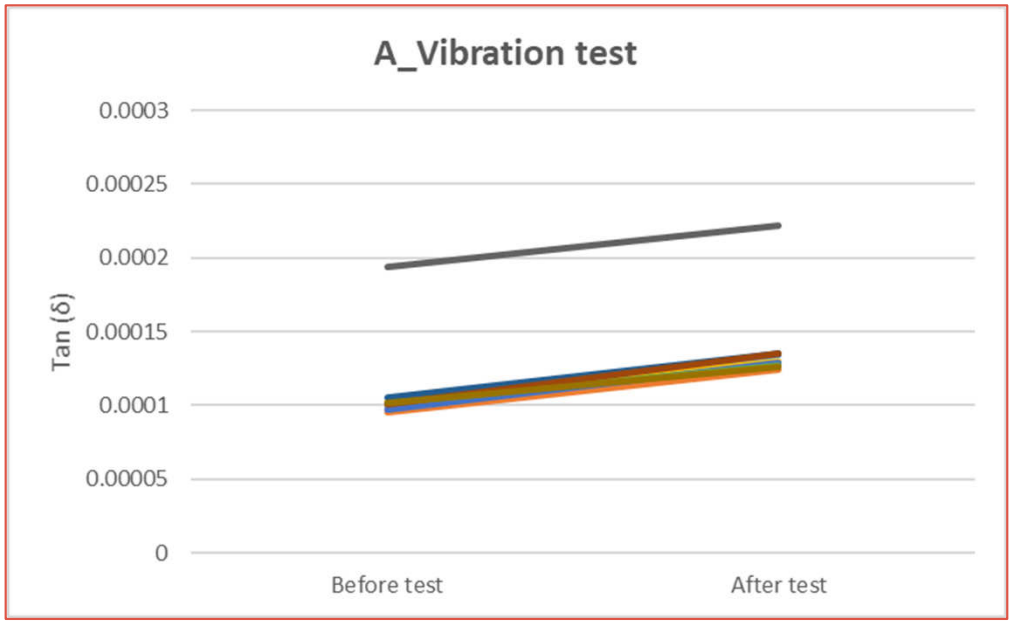


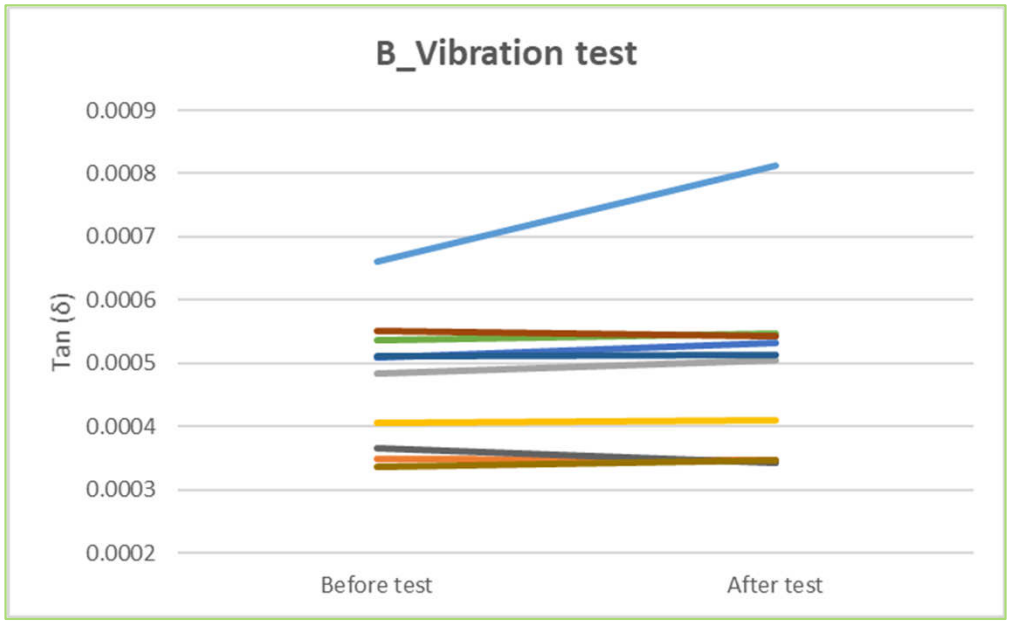


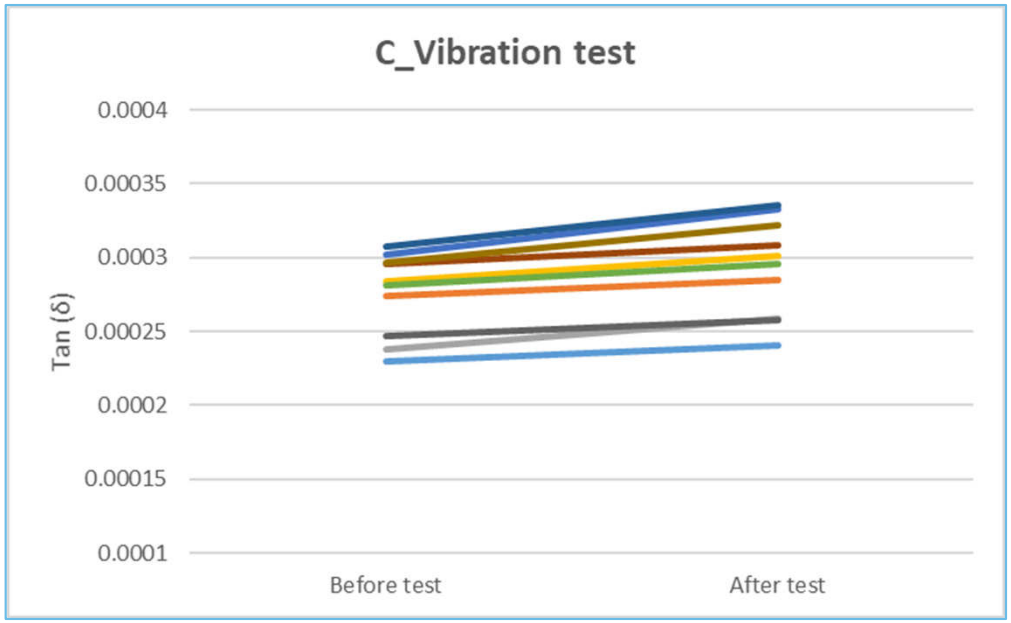


Summary

Vibration test_Tan (δ)

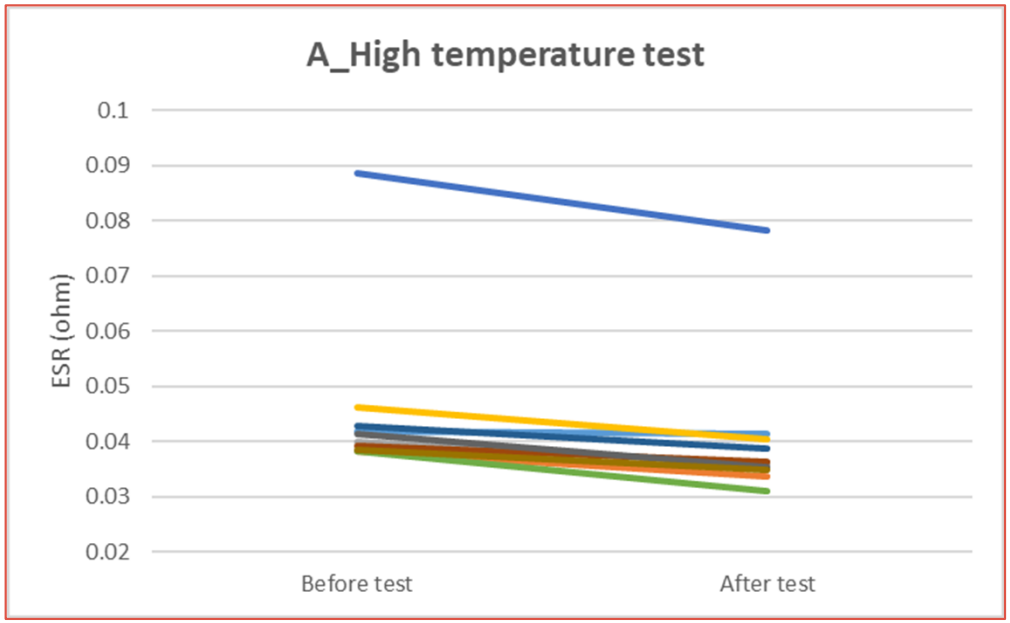


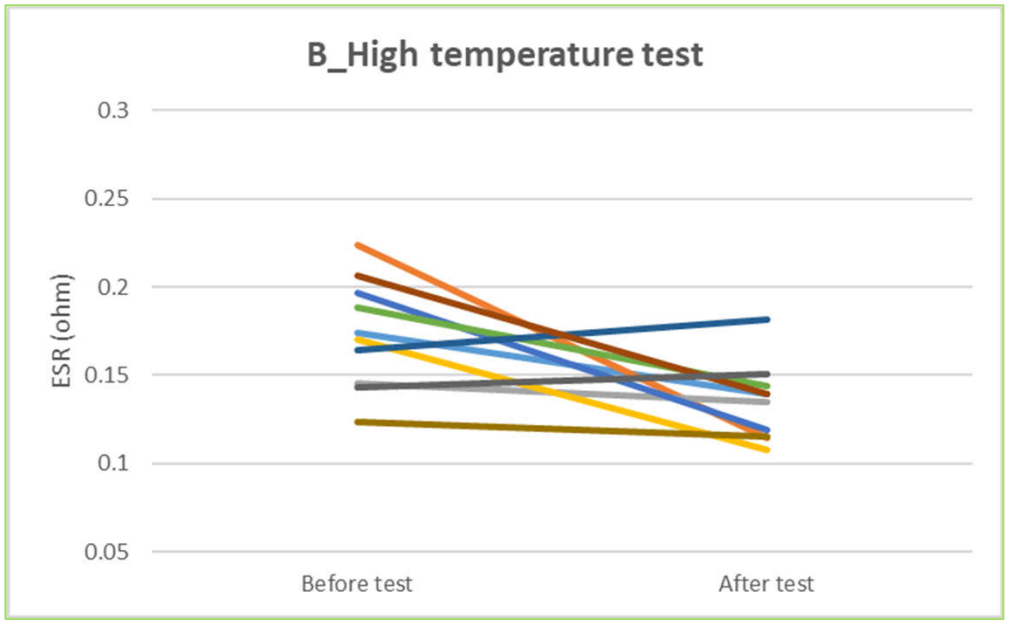


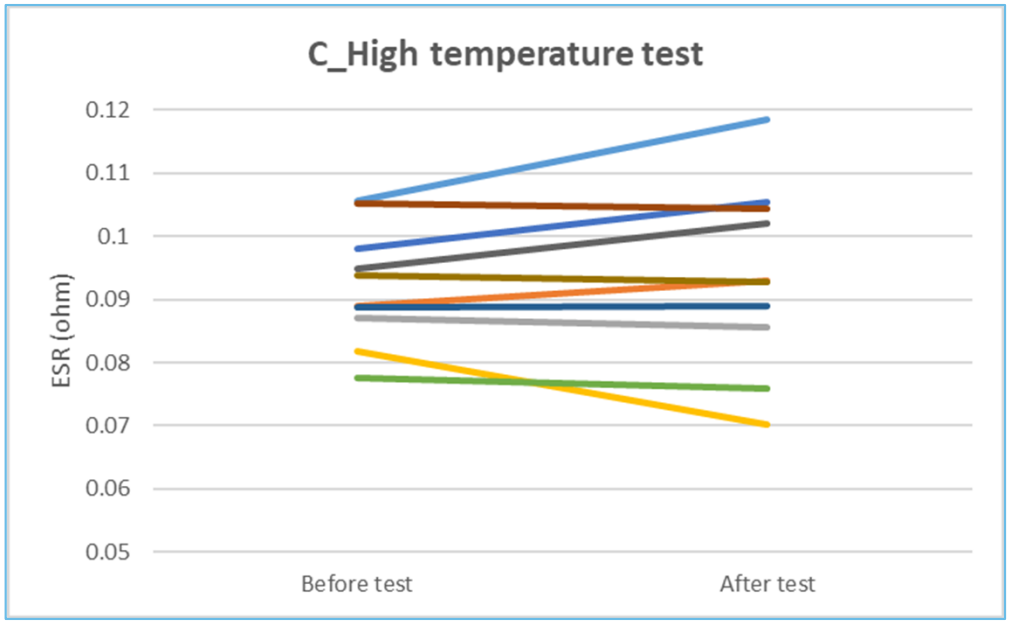


Summary

High temperature test_ESR (ohm)

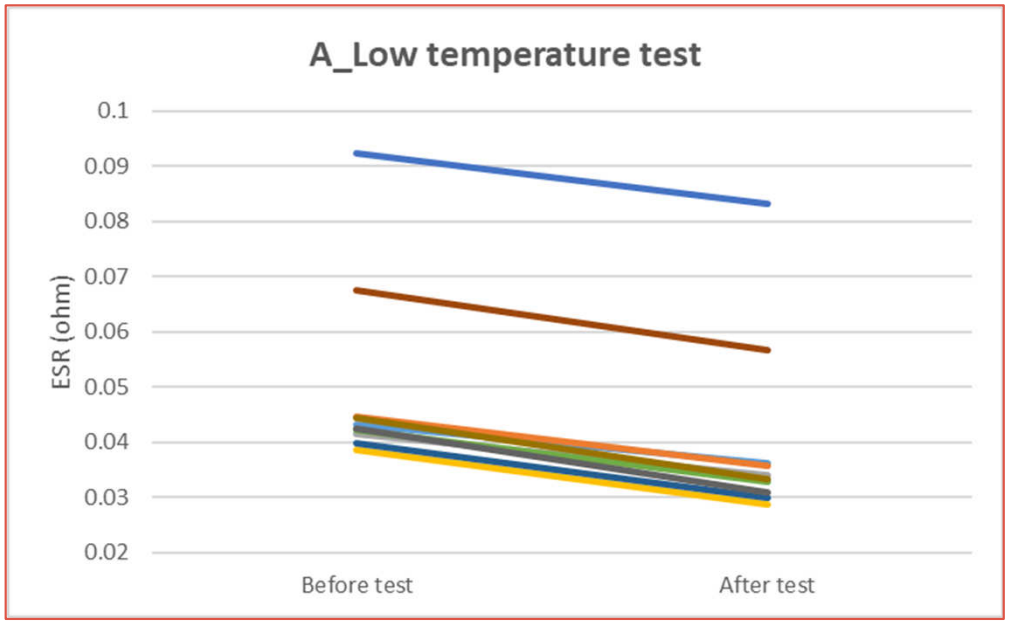


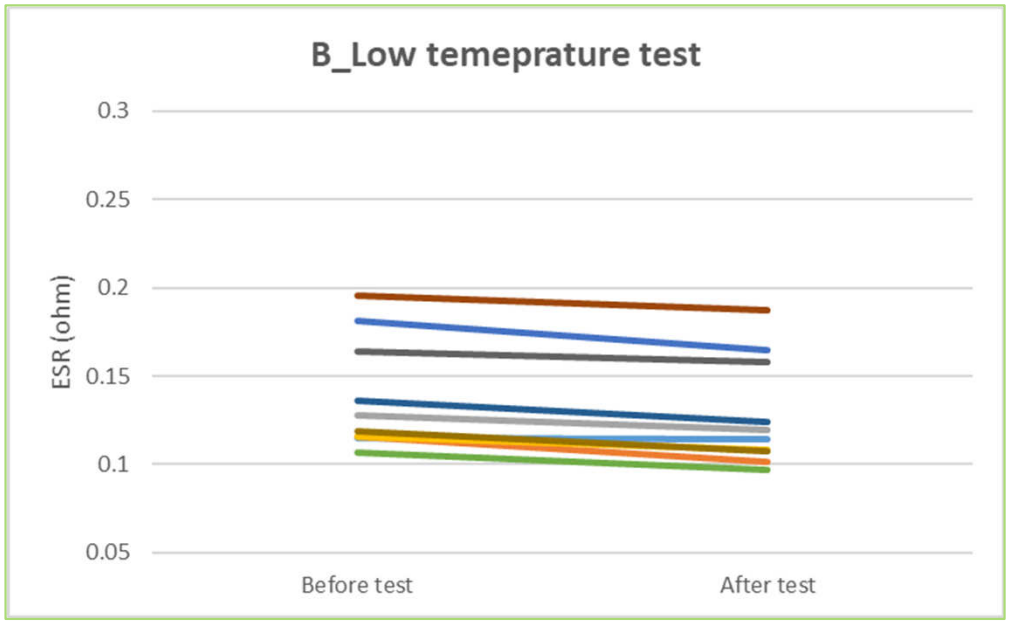


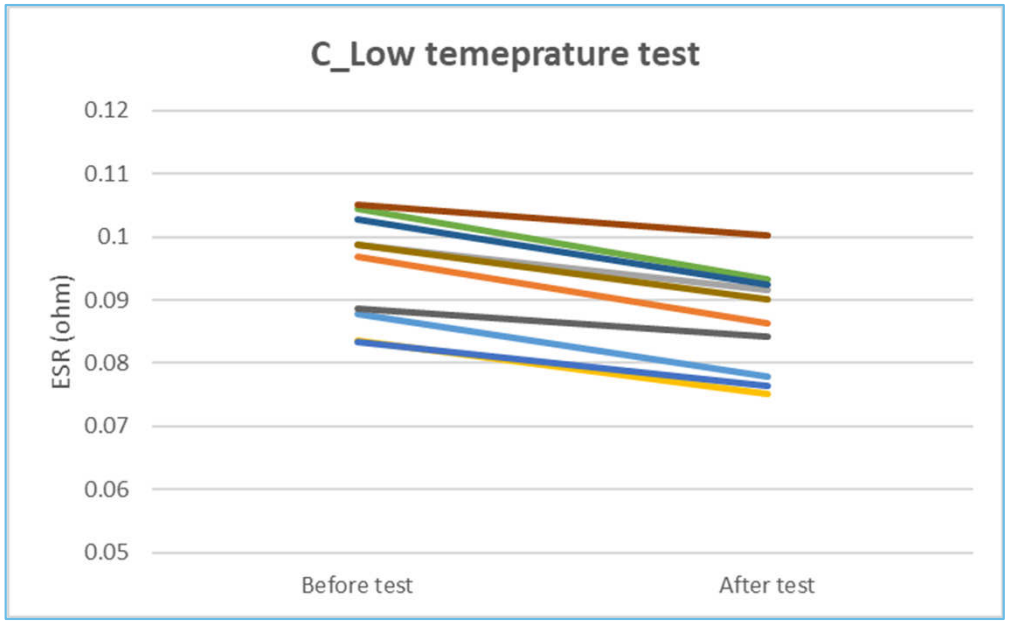


Summary

Low temperature test_ESR (ohm)

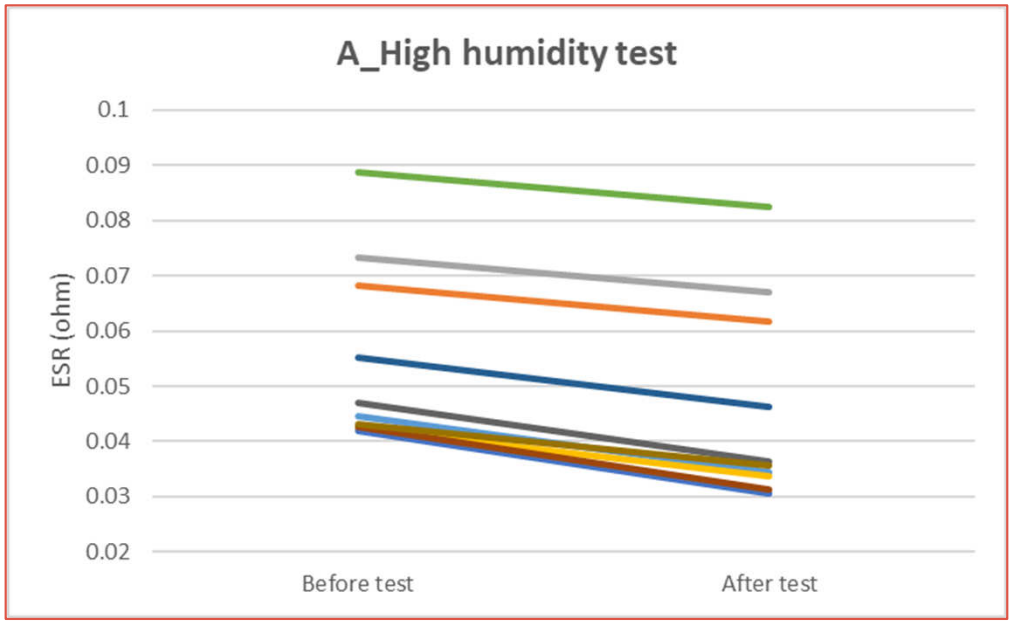


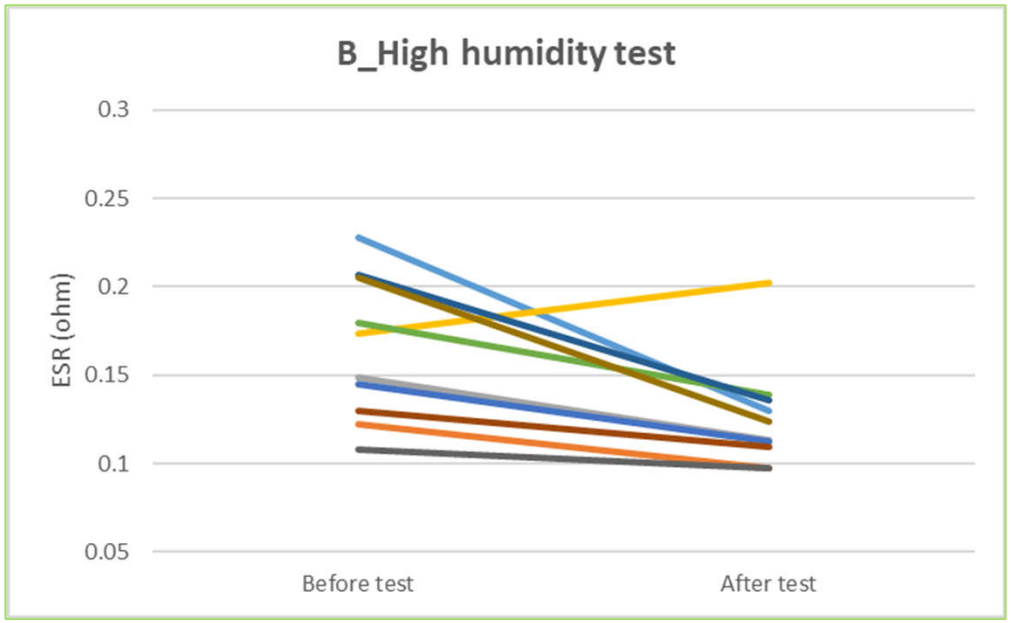


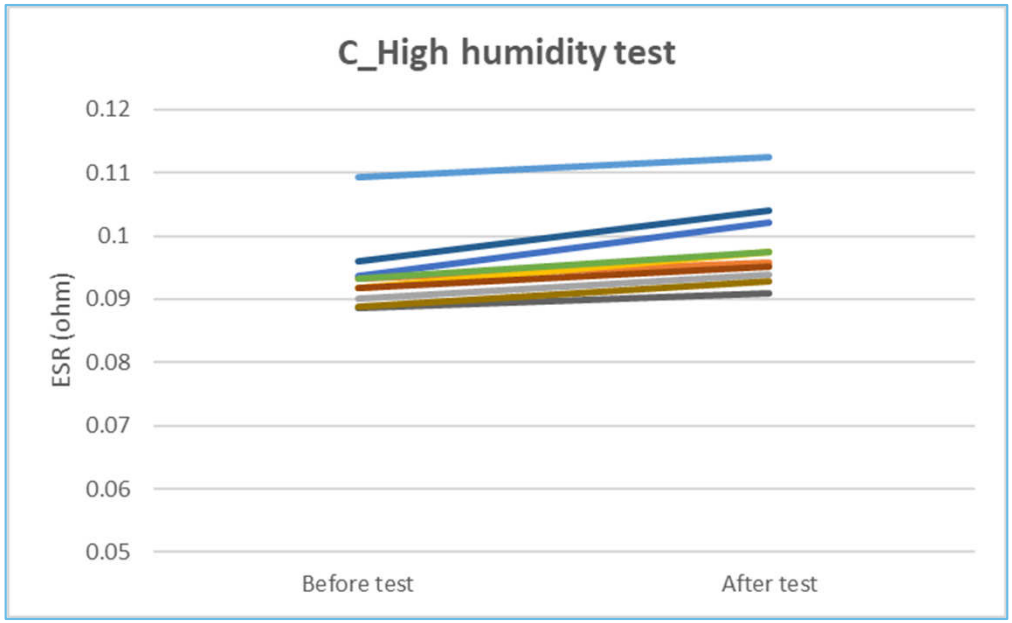


Summary

High humidity test_ESR (ohm)

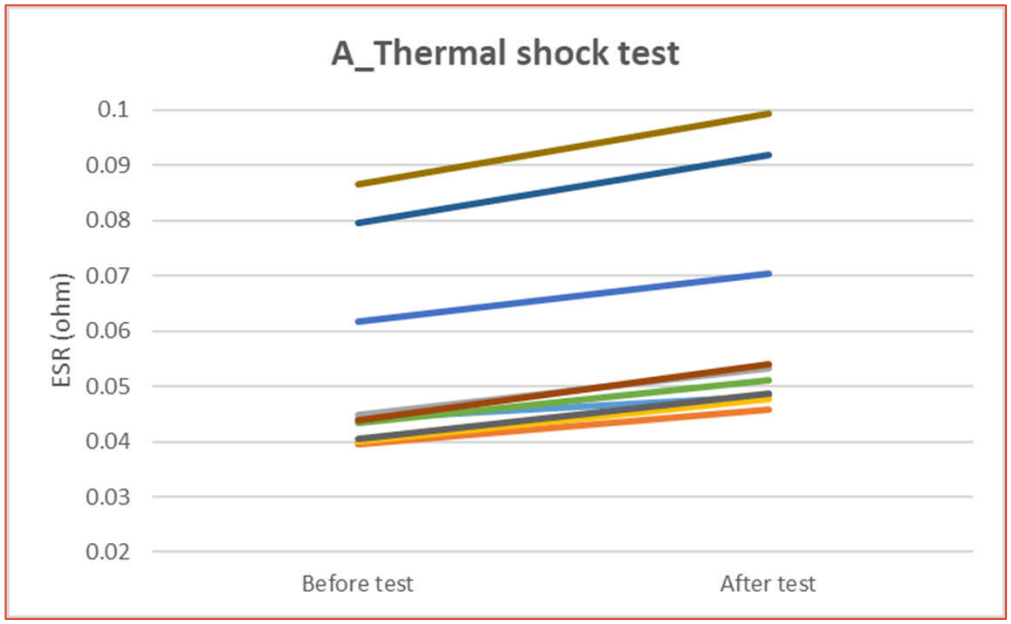


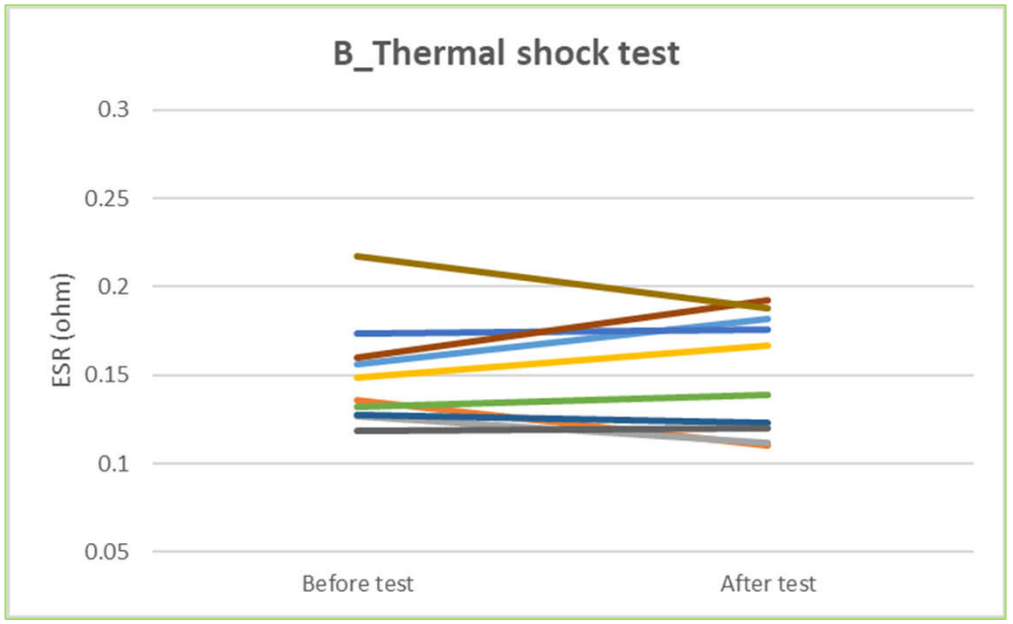


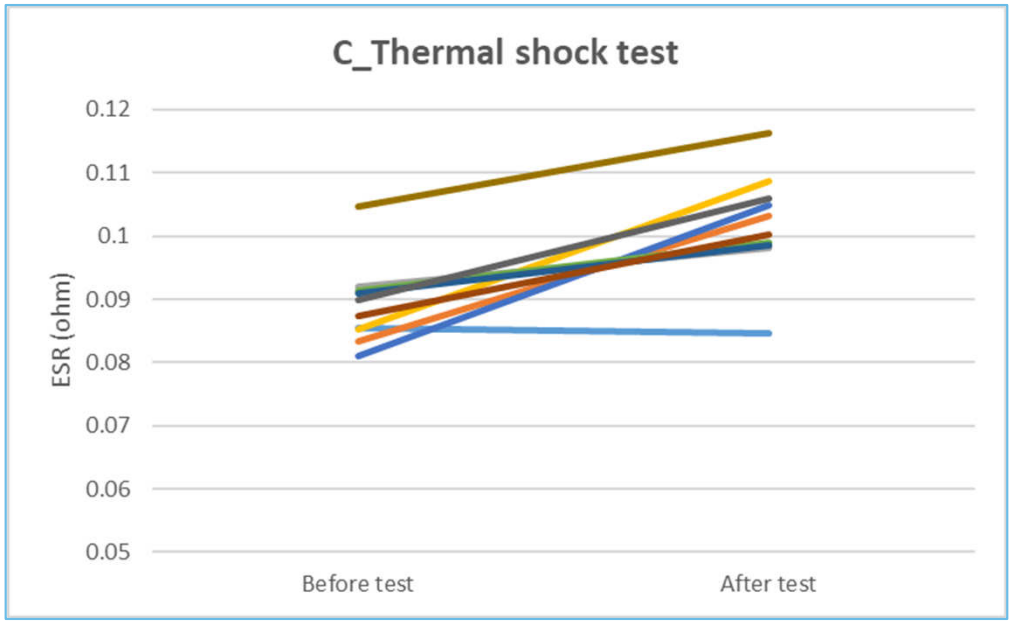


Summary

Thermal shock test_ESR (ohm)

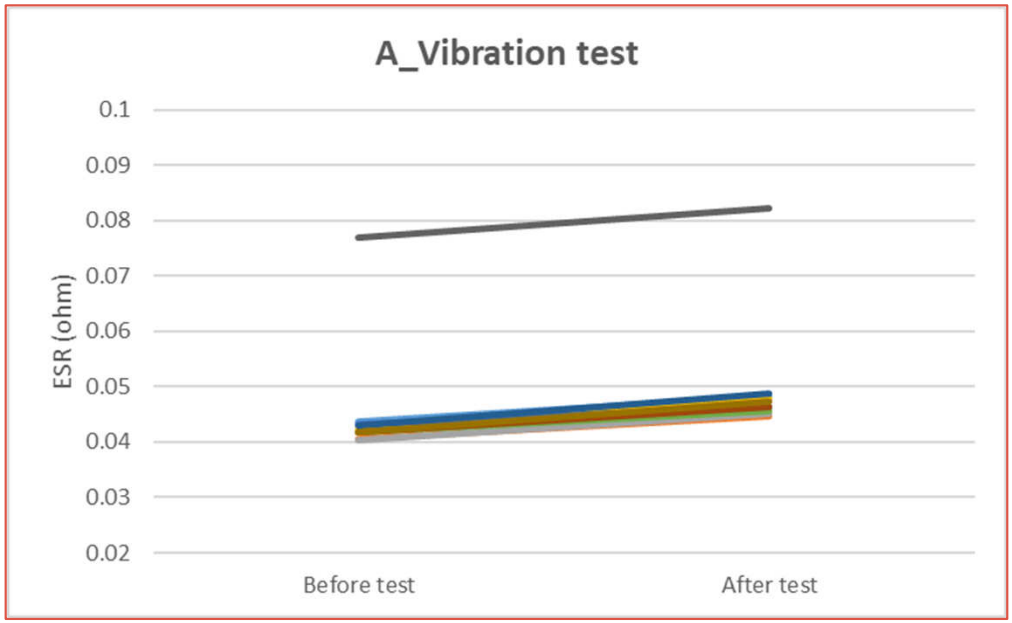


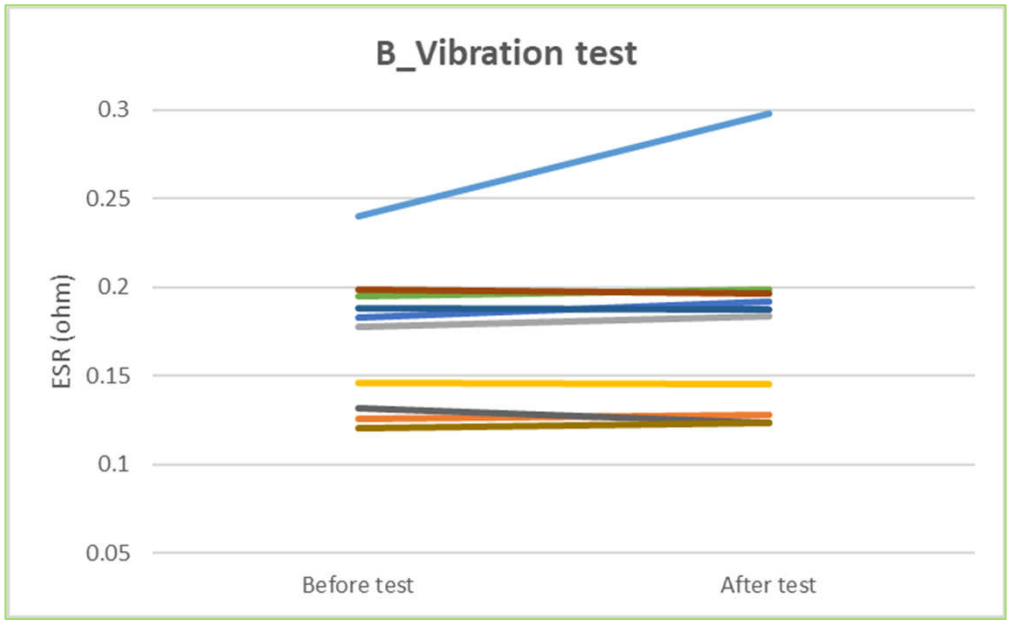


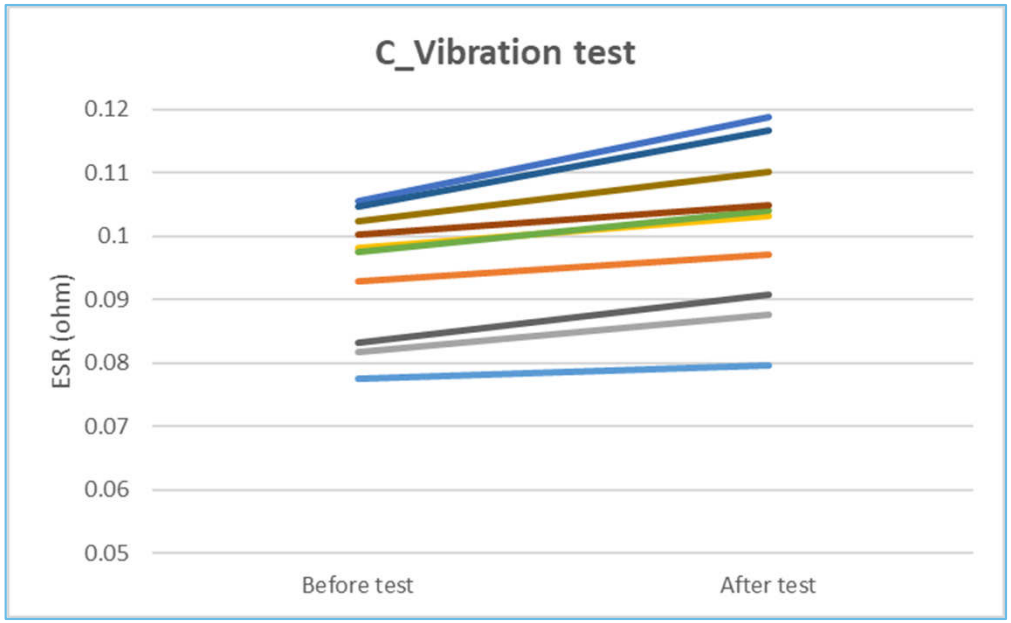


Summary

Vibration test_ESR (ohm)







A社

High temperature test

＊1 kHzで測定

No.	Capacitance (uF)			Tan (δ)			ESR (ohm)		
	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)
1	456.094	455.977	-0.025653	0.000115	0.000116	0.869565	0.04195	0.04127	-1.620977
2	451.451	451.383	-0.015063	0.000103	0.000095	-7.766990	0.03818	0.03375	-11.60293
3	435.447	435.263	-0.042255	0.000104	0.000097	-6.730769	0.03984	0.03577	-10.21586
4	437.543	437.428	-0.026283	0.000118	0.000109	-7.627119	0.04629	0.04037	-12.78894
5	444.081	444.415	0.075212	0.000239	0.000219	-8.368201	0.08865	0.07823	-11.75409
6	442.928	442.791	-0.030931	0.000096	0.000085	-11.45833	0.03836	0.03115	-18.79562
7	432.058	431.904	-0.035643	0.000108	0.000105	-2.777778	0.04277	0.03879	-9.305588
8	446.961	446.775	-0.041614	0.000107	0.000096	-10.28037	0.03923	0.03638	-7.264848
9	437.841	437.708	-0.030376	0.000114	0.000102	-10.52632	0.04133	0.03542	-14.29954
10	447.207	447.033	-0.038908	0.000106	0.000094	-11.32075	0.03842	0.03477	-9.500260
Min	432.058	431.904	-0.042255	0.000096	0.000085	-11.45833	0.03818	0.03115	-18.79562
Max	456.094	455.977	0.075212	0.000239	0.000219	0.869565	0.08865	0.07823	-1.620977
Avg	443.161	443.068	-0.021151	0.000121	0.000112	-7.598707	0.04550	0.04059	-10.71487

A社

Low temperature test

＊1 kHzで測定

No.	Capacitance (uF)			Tan (δ)			ESR (ohm)		
	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)
1	439.240	439.114	-0.028686	0.000111	0.000098	-11.71171	0.04319	0.03625	-16.06853
2	433.720	433.636	-0.019367	0.000118	0.000095	-19.49153	0.04466	0.03581	-19.81639
3	443.987	443.877	-0.024776	0.000109	0.000092	-15.59633	0.04162	0.03416	-17.92407
4	452.500	452.325	-0.038674	0.000100	0.000082	-18.00000	0.03867	0.02876	-25.62710
5	454.028	453.873	-0.034139	0.000252	0.000233	-7.539683	0.09237	0.08327	-9.851683
6	455.995	455.818	-0.038816	0.000111	0.000093	-16.21622	0.04229	0.03290	-22.20383
7	440.911	440.695	-0.048989	0.000104	0.000082	-21.15385	0.03976	0.02991	-24.77364
8	443.523	443.400	-0.027732	0.000181	0.000157	-13.25967	0.06753	0.05661	-16.17059
9	437.671	437.533	-0.031531	0.000104	0.000085	-18.26923	0.04252	0.03088	-27.37535
10	434.628	434.585	-0.009894	0.000110	0.000088	-20.00000	0.04448	0.03331	-25.11241
Min	433.720	433.636	-0.048989	0.000100	0.000082	-21.15385	0.03867	0.02876	-27.37535
Max	455.995	455.818	-0.009894	0.000252	0.000233	-7.539683	0.09237	0.08327	-9.851683
Avg	443.620	443.486	-0.030260	0.00013	0.000111	-16.12382	0.04971	0.04019	-20.49236

A社

High humidity test

＊1 kHzで測定

No.	Capacitance (uF)			Tan (δ)			ESR (ohm)		
	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)
1	434.167	434.254	0.020038	0.000106	0.000092	-13.20755	0.04459	0.03445	-22.74052
2	459.268	459.353	0.018508	0.000193	0.000182	-5.699482	0.06832	0.06179	-9.557963
3	450.456	450.624	0.037296	0.000194	0.000184	-5.154639	0.07328	0.06694	-8.651747
4	439.142	439.235	0.021178	0.000105	0.000093	-11.42857	0.04248	0.03363	-20.83333
5	442.090	442.154	0.014477	0.000097	0.000084	-13.40206	0.04182	0.03065	-26.70971
6	445.525	445.749	0.050278	0.000232	0.000227	-2.155172	0.08876	0.08245	-7.109058
7	451.725	451.789	0.014168	0.000138	0.000134	-2.898551	0.05527	0.04630	-16.22942
8	437.268	437.382	0.026071	0.000099	0.000083	-16.16162	0.04272	0.03126	-26.82584
9	438.499	438.610	0.025314	0.000107	0.000103	-3.738318	0.04704	0.03630	-22.83163
10	435.027	435.125	0.022527	0.000103	0.000094	-8.737864	0.04316	0.03572	-17.23818
Min	434.167	434.254	0.014168	0.000097	0.000083	-16.16162	0.04182	0.03065	-26.82584
Max	459.268	459.353	0.050278	0.000232	0.000227	-2.155172	0.08876	0.08245	-7.109058
Avg	443.317	443.428	0.024985	0.000137	0.000128	-8.258382	0.05474	0.04595	-17.87274

A社

Thermal shock test

＊1 kHzで測定

No.	Capacitance (uF)			Tan (δ)			ESR (ohm)		
	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)
1	445.725	445.892	0.037467	0.000107	0.000134	25.23364	0.04406	0.04821	9.418974
2	454.146	454.257	0.024441	0.000103	0.000128	24.27184	0.03952	0.04583	15.96660
3	433.609	433.922	0.072185	0.000108	0.000145	34.25926	0.04494	0.05337	18.75834
4	448.187	448.561	0.083447	0.000105	0.000135	28.57143	0.04004	0.04781	19.40559
5	452.041	452.442	0.088709	0.000167	0.000196	17.36527	0.06168	0.07033	14.02399
6	435.233	435.336	0.023665	0.000105	0.000141	34.28571	0.04329	0.05116	18.17972
7	439.807	440.279	0.107320	0.000201	0.000253	25.87065	0.07969	0.09181	15.20893
8	427.699	427.667	-0.007482	0.000104	0.000146	40.38462	0.04394	0.05391	22.69003
9	438.122	438.183	0.013923	0.000097	0.000135	39.17526	0.04053	0.04865	20.03454
10	451.450	451.934	0.107210	0.000237	0.000279	17.72152	0.08663	0.09946	14.81011
Min	427.699	427.667	-0.007482	0.000097	0.000128	17.36527	0.03952	0.04583	9.418974
Max	454.146	454.257	0.107320	0.000237	0.000279	40.38462	0.08663	0.09946	22.69003
Avg	442.602	442.847	0.055089	0.000133	0.000169	28.71392	0.05243	0.06105	16.84968

A社

Vibration test

＊1 kHzで測定

No.	Capacitance (uF)			Tan (δ)			ESR (ohm)		
	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)
1	439.001	439.066	0.014806	0.000101	0.000134	32.67327	0.04364	0.04828	10.63245
2	442.488	442.504	0.003616	0.000095	0.000124	30.52632	0.04068	0.04459	9.611603
3	447.317	447.359	0.009389	0.000099	0.000129	30.30303	0.04027	0.04504	11.84505
4	432.717	432.729	0.002773	0.000103	0.000130	26.21359	0.04238	0.04785	12.90703
5	441.967	442.035	0.015386	0.000097	0.000129	32.98969	0.04331	0.04641	7.157700
6	435.521	435.575	0.012399	0.000102	0.000127	24.50980	0.04180	0.04564	9.186603
7	434.861	434.907	0.010578	0.000105	0.000135	28.57143	0.04305	0.04876	13.26365
8	445.139	445.168	0.006515	0.000101	0.000135	33.66337	0.04176	0.04628	10.82375
9	438.416	438.486	0.015967	0.000194	0.000222	14.43299	0.07698	0.08216	6.729021
10	439.802	439.867	0.014779	0.000102	0.000126	23.52941	0.04175	0.04731	13.31737
Min	432.717	432.729	0.002773	0.000095	0.000124	14.43299	0.04027	0.04459	6.729021
Max	447.317	447.359	0.015967	0.000194	0.000222	33.66337	0.07698	0.08216	13.31737
Avg	439.723	439.770	0.010621	0.000110	0.000139	27.74129	0.04556	0.05023	10.54742

A社

Withstanding voltage & Insulation resistance

	Original sample		After the high temperature test sample		
No.	Withstanding voltage(uA)	Insulation resistance(GΩ)	No.	Withstanding voltage(uA)	Insulation resistance(GΩ)
1	1	99.9	11	1	33.3
2	1	71.4	12	1	45.5
3	1	99.9	13	1	99.9
4	1	71.4	14	1	71.4
5	1	45.5	15	1	35.7
6	1	99.9			
7	1	99.9			
8	1	71.4			
9	1	45.5			
10	1	99.9			

B社

High temperature test

＊1 kHzで測定

No.	Capacitance (uF)			Tan (δ)			ESR (ohm)		
	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)
1	439.977	440.242	0.060230	0.000465	0.000383	-17.63441	0.17382	0.13931	-19.85387
2	441.024	441.747	0.163937	0.000620	0.000317	-48.87097	0.22362	0.11456	-48.77024
3	445.989	445.941	-0.010763	0.000404	0.000373	-7.673267	0.14513	0.13491	-7.041962
4	439.572	439.869	0.067566	0.000479	0.000298	-37.78706	0.17043	0.10785	-36.71889
5	437.745	438.295	0.125644	0.000538	0.000327	-39.21933	0.19681	0.11891	-39.58132
6	437.519	437.943	0.096910	0.000528	0.000396	-25.00000	0.18802	0.14381	-23.51346
7	442.674	442.652	-0.004970	0.000454	0.000508	11.89427	0.16450	0.18192	10.58967
8	435.530	436.186	0.150621	0.000563	0.000382	-32.14920	0.20616	0.13930	-32.43112
9	448.402	448.889	0.108608	0.000404	0.000422	4.455446	0.14309	0.15085	5.423160
10	442.896	442.768	-0.028901	0.000340	0.000321	-5.588235	0.12377	0.11567	-6.544397
Min	435.530	436.186	-0.028901	0.000340	0.000298	-48.87097	0.12377	0.10785	-48.77024
Max	448.402	448.889	0.163937	0.000620	0.000508	11.89427	0.22362	0.18192	10.58967
Avg	441.133	441.453	0.072888	0.000480	0.000373	-19.75727	0.17354	0.13471	-19.84424

B社

Low temperature test

＊1 kHzで測定

No.	Capacitance (uF)			Tan (δ)			ESR (ohm)		
	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)
1	443.325	443.246	-0.017820	0.000326	0.000326	0.000000	0.11533	0.11499	-0.294806
2	430.731	430.652	-0.018341	0.000310	0.000276	-10.96774	0.11549	0.10165	-11.98372
3	444.481	444.343	-0.031047	0.000358	0.000332	-7.262570	0.12788	0.11923	-6.764154
4	439.397	439.258	-0.031634	0.000321	0.000299	-6.853583	0.11587	0.10804	-6.757573
5	435.899	435.869	-0.006882	0.000494	0.000451	-8.704453	0.18093	0.16434	-9.169292
6	438.765	438.578	-0.042620	0.000298	0.000267	-10.40268	0.10689	0.09657	-9.654785
7	434.351	434.323	-0.006446	0.000368	0.000339	-7.880435	0.13577	0.12432	-8.433380
8	433.349	433.274	-0.017307	0.000535	0.000507	-5.233645	0.19522	0.18733	-4.041594
9	444.954	444.833	-0.027194	0.000459	0.000441	-3.921569	0.16404	0.15812	-3.608876
10	442.279	442.191	-0.019897	0.000330	0.000299	-9.393939	0.11859	0.10716	-9.638249
Min	430.731	430.652	-0.042620	0.000298	0.000267	-10.96774	0.10689	0.09657	-11.98372
Max	444.954	444.833	-0.006446	0.000535	0.000507	0.000000	0.19522	0.18733	-0.294806
Avg	438.753	438.657	-0.021919	0.000380	0.000354	-7.062062	0.13760	0.12818	-7.034643

B社

High humidity test

＊1 kHzで測定

No.	Capacitance (uF)			Tan (δ)			ESR (ohm)		
	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)
1	438.119	439.160	0.237607	0.000634	0.000362	-42.90221	0.22815	0.13011	-42.97173
2	435.112	435.628	0.118590	0.000332	0.000263	-20.78313	0.12211	0.09707	-20.50610
3	444.149	444.808	0.148374	0.000413	0.000315	-23.72881	0.14862	0.11328	-23.77876
4	444.163	445.114	0.214111	0.000486	0.000567	16.66667	0.17381	0.20211	16.28215
5	438.447	439.143	0.158742	0.000398	0.000313	-21.35678	0.14521	0.11211	-22.79457
6	438.452	439.482	0.234917	0.000494	0.000387	-21.65992	0.17991	0.13885	-22.82252
7	443.258	444.301	0.235303	0.000573	0.000377	-34.20593	0.20689	0.13564	-34.43859
8	439.930	440.516	0.133203	0.000355	0.000302	-14.92958	0.12955	0.10974	-15.29139
9	435.897	436.417	0.119294	0.000293	0.000265	-9.556314	0.10772	0.09704	-9.914593
10	446.560	447.482	0.206467	0.000576	0.000348	-39.58333	0.20558	0.12376	-39.79959
Min	435.112	435.628	0.118590	0.000293	0.000263	-42.90221	0.10772	0.09704	-42.97173
Max	446.560	447.482	0.237607	0.000634	0.000567	16.66667	0.22815	0.20211	16.28215
Avg	440.409	441.205	0.180661	0.000455	0.000350	-21.20393	0.16476	0.12597	-21.60357

B社

Thermal shock test

＊1 kHzで測定

No.	Capacitance (uF)			Tan (δ)			ESR (ohm)		
	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)
1	444.556	444.900	0.077381	0.000435	0.000507	16.55172	0.15662	0.18176	16.05159
2	456.384	456.517	0.029142	0.000393	0.000314	-20.10178	0.13584	0.11043	-18.70583
3	442.331	442.459	0.028938	0.000352	0.000311	-11.64773	0.12677	0.11196	-11.68257
4	442.298	442.606	0.069636	0.000412	0.000467	13.34951	0.14837	0.16695	12.52275
5	431.725	431.857	0.030575	0.000472	0.000482	2.118644	0.17355	0.17572	1.250360
6	440.779	440.791	0.002722	0.000366	0.000388	6.010929	0.13233	0.13857	4.715484
7	438.286	438.655	0.084192	0.000351	0.000341	-2.849003	0.12748	0.12283	-3.647631
8	442.581	442.586	0.001130	0.000444	0.000532	19.81982	0.15974	0.19218	20.30800
9	445.098	444.893	-0.046057	0.000337	0.000335	-0.593472	0.11890	0.11978	0.740118
10	435.852	436.289	0.100263	0.000593	0.000516	-12.98482	0.21708	0.18786	-13.46048
Min	431.725	431.857	-0.046057	0.000337	0.000311	-20.10178	0.11890	0.11043	-18.70583
Max	456.384	456.517	0.100263	0.000593	0.000532	19.81982	0.21708	0.19218	20.30800
Avg	441.989	442.155	0.037792	0.000416	0.000419	0.967383	0.14967	0.15080	0.809179

B社

Vibration test

＊1 kHzで測定

No.	Capacitance (uF)			Tan (δ)			ESR (ohm)		
	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)
1	438.431	438.453	0.005018	0.00066	0.000812	23.03030	0.23971	0.29778	24.22511
2	433.097	433.021	-0.017548	0.000349	0.000348	-0.286533	0.12531	0.12775	1.947171
3	434.462	434.519	0.013120	0.000483	0.000504	4.347826	0.17789	0.18389	3.372871
4	445.499	445.518	0.004265	0.000405	0.000410	1.234568	0.14590	0.14483	-0.733379
5	443.619	443.622	0.000676	0.000509	0.000533	4.715128	0.18282	0.19195	4.993983
6	437.268	437.267	-0.000229	0.000536	0.000546	1.865672	0.19462	0.19850	1.993629
7	435.614	435.642	0.006428	0.000511	0.000514	0.587084	0.18779	0.18744	-0.186378
8	439.726	439.841	0.026153	0.000552	0.000543	-1.630435	0.19861	0.19655	-1.037209
9	443.332	443.334	0.000451	0.000365	0.000342	-6.301370	0.13164	0.12354	-6.153145
10	440.401	440.395	-0.001362	0.000336	0.000346	2.976190	0.12070	0.12311	1.996686
Min	433.097	433.021	-0.017548	0.000336	0.000342	-6.301370	0.12070	0.12311	-6.153145
Max	445.499	445.518	0.026153	0.00066	0.000812	23.03030	0.23971	0.29778	24.22511
Avg	439.145	439.161	0.003697	0.000471	0.000490	3.053843	0.17050	0.17753	3.041933

B社

Withstanding voltage & Insulation resistance

	Original sample		After the high temperature test sample		
No.	Withstanding voltage(uA)	Insulation resistance(GΩ)	No.	Withstanding voltage(uA)	Insulation resistance(GΩ)
1	1	99.9	11	1	62.5
2	1	71.4	12	1	41.7
3	1	99.9	13	1	99.9
4	1	71.4	14	1	99.9
5	1	99.9	15	1	50.1
6	1	99.9			
7	1	45.5			
8	1	71.4			
9	1	99.9			
10	1	71.4			

C社

High temperature test

＊1 kHzで測定

No.	Capacitance (uF)			Tan (δ)			ESR (ohm)		
	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)
1	461.327	462.364	0.224786	0.000305	0.000348	14.09836	0.10570	0.11852	12.12867
2	459.429	460.338	0.197854	0.000256	0.000275	7.421875	0.08896	0.09296	4.496403
3	449.700	450.421	0.160329	0.000243	0.000244	0.411523	0.08715	0.08562	-1.755594
4	442.311	443.026	0.161651	0.000228	0.000195	-14.47368	0.08183	0.07028	-14.11463
5	466.878	467.747	0.186130	0.000289	0.000311	7.612457	0.09791	0.10545	7.700950
6	453.036	453.617	0.128246	0.000226	0.000218	-3.539823	0.07758	0.07596	-2.088167
7	452.075	452.721	0.142897	0.000254	0.000254	0.000000	0.08885	0.08893	0.090039
8	470.322	471.191	0.184767	0.000305	0.000312	2.295082	0.10509	0.10429	-0.761252
9	466.234	467.194	0.205905	0.000273	0.000300	9.890110	0.09485	0.10197	7.506589
10	472.422	473.289	0.183522	0.000278	0.000276	-0.719424	0.09376	0.09271	-1.119881
Min	442.311	443.026	0.128246	0.000226	0.000195	-14.47368	0.07758	0.07028	-14.11463
Max	472.422	473.289	0.224786	0.000305	0.000348	14.09836	0.10570	0.11852	12.12867
Avg	459.373	460.191	0.177609	0.000266	0.000273	2.299648	0.09217	0.09367	1.208313

C社

Low temperature test

＊1 kHzで測定

No.	Capacitance (uF)			Tan (δ)			ESR (ohm)		
	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)
1	458.234	458.148	-0.018768	0.000253	0.000224	-11.46245	0.08785	0.07799	-11.22368
2	469.671	469.629	-0.008942	0.000285	0.000256	-10.17544	0.09683	0.08633	-10.84375
3	456.966	456.834	-0.028886	0.000283	0.000262	-7.420495	0.09877	0.09159	-7.269414
4	462.680	462.615	-0.014049	0.000242	0.000219	-9.504132	0.08355	0.07512	-10.08977
5	445.473	445.408	-0.014591	0.000235	0.000209	-11.06383	0.08328	0.07638	-8.285303
6	467.917	467.754	-0.034835	0.000306	0.000273	-10.78431	0.10444	0.09331	-10.65684
7	474.046	473.955	-0.019196	0.000302	0.000275	-8.940397	0.10271	0.09245	-9.989290
8	460.451	460.398	-0.01151	0.000306	0.000284	-7.189542	0.10516	0.10031	-4.612020
9	455.247	455.131	-0.025481	0.000255	0.000238	-6.666667	0.08869	0.08420	-5.062578
10	455.188	455.160	-0.006151	0.000285	0.000257	-9.824561	0.09885	0.09006	-8.892261
Min	445.473	445.408	-0.034835	0.000235	0.000209	-11.46245	0.08328	0.07512	-11.22368
Max	474.046	473.955	-0.006151	0.000306	0.000284	-6.666667	0.10516	0.10031	-4.612020
Avg	460.587	460.503	-0.018241	0.000275	0.000250	-9.303183	0.09501	0.08677	-8.692489

C社

High humidity test

＊1 kHzで測定

No.	Capacitance (uF)			Tan (δ)			ESR (ohm)		
	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)
1	454.407	454.730	0.071082	0.000309	0.000319	3.236246	0.10927	0.11252	2.974284
2	465.106	465.311	0.044076	0.000269	0.000278	3.345725	0.09327	0.09576	2.669669
3	452.618	452.933	0.069595	0.000254	0.000268	5.511811	0.09004	0.09396	4.353621
4	459.570	459.726	0.033945	0.000268	0.000282	5.223881	0.09169	0.09749	6.325663
5	465.154	465.524	0.079544	0.000278	0.000297	6.834532	0.09365	0.10221	9.140416
6	455.044	455.388	0.075597	0.000267	0.000272	1.872659	0.09334	0.09741	4.360403
7	471.747	472.171	0.089879	0.000286	0.000311	8.741259	0.09591	0.10406	8.497550
8	453.228	453.476	0.054719	0.000257	0.000268	4.280156	0.09167	0.09521	3.861678
9	453.581	453.832	0.055337	0.000250	0.000264	5.600000	0.08858	0.09095	2.675548
10	472.006	472.273	0.056567	0.000262	0.000274	4.580153	0.08876	0.09285	4.607932
Min	452.618	452.933	0.033945	0.000250	0.000264	1.872659	0.08858	0.09095	2.669669
Max	472.006	472.273	0.089879	0.000309	0.000319	8.741259	0.10927	0.11252	9.140416
Avg	460.246	460.536	0.063034	0.00027	0.000283	4.922642	0.09362	0.09824	4.946676

C社

Thermal shock test

＊1 kHzで測定

No.	Capacitance (uF)			Tan (δ)			ESR (ohm)		
	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)
1	462.688	463.681	0.214615	0.000247	0.000247	0.000000	0.08548	0.08452	-1.123070
2	475.961	476.518	0.117026	0.000248	0.000309	24.59677	0.08324	0.10322	24.00288
3	449.472	450.183	0.158186	0.000257	0.000274	6.614786	0.09209	0.09813	6.558801
4	473.923	474.654	0.154244	0.000256	0.000321	25.39063	0.08525	0.10858	27.36657
5	460.342	461.142	0.173784	0.000234	0.000307	31.19658	0.08093	0.10494	29.66761
6	464.946	465.656	0.152706	0.000269	0.000288	7.063197	0.09146	0.09896	8.200306
7	464.139	464.967	0.178395	0.000266	0.000289	8.646617	0.09098	0.09856	8.331501
8	464.909	465.946	0.223054	0.000255	0.000294	15.29412	0.08743	0.10032	14.74322
9	460.962	461.542	0.125824	0.000259	0.000308	18.91892	0.08982	0.10593	17.93587
10	455.892	456.633	0.162538	0.000301	0.000328	8.970100	0.10460	0.11622	11.10899
Min	449.472	450.183	0.117026	0.000234	0.000247	0.000000	0.08093	0.08452	-1.123070
Max	475.961	476.518	0.223054	0.000301	0.000328	31.19658	0.10460	0.11622	29.66761
Avg	463.323	464.092	0.166037	0.000259	0.000297	14.66917	0.08913	0.10194	14.67927

C社

Vibration test

＊1 kHzで測定

No.	Capacitance (uF)			Tan (δ)			ESR (ohm)		
	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)	Before Test	After test	Change rate (%)
1	473.098	473.148	0.010569	0.000230	0.000241	4.782609	0.07759	0.07957	2.551875
2	464.233	464.208	-0.005385	0.000274	0.000285	4.014599	0.09290	0.09701	4.424112
3	468.181	468.189	0.001709	0.000238	0.000259	8.823529	0.08179	0.08771	7.238049
4	463.047	463.125	0.016845	0.000284	0.000301	5.985915	0.09825	0.10320	5.038168
5	451.052	451.129	0.017071	0.000302	0.000333	10.26490	0.10561	0.11889	12.57457
6	457.477	457.555	0.017050	0.000281	0.000296	5.338078	0.09762	0.10396	6.494571
7	461.097	461.173	0.016482	0.000307	0.000335	9.120521	0.10477	0.11680	11.48229
8	470.012	470.076	0.013617	0.000296	0.000308	4.054054	0.10030	0.10483	4.516451
9	467.554	467.613	0.012619	0.000247	0.000258	4.453441	0.08326	0.09077	9.019938
10	461.940	461.988	0.010391	0.000297	0.000322	8.417508	0.10246	0.11014	7.495608
Min	451.052	451.129	-0.005385	0.000230	0.000241	4.014599	0.07759	0.07957	2.551875
Max	473.098	473.148	0.017071	0.000307	0.000335	10.26490	0.10561	0.11889	12.57457
Avg	463.769	463.820	0.011097	0.000276	0.000294	6.525516	0.09446	0.10129	7.083563

C社

Withstanding voltage & Insulation resistance

	Original sample		After the high temperature test sample		
No.	Withstanding voltage(uA)	Insulation resistance(GΩ)	No.	Withstanding voltage(uA)	Insulation resistance(GΩ)
1	1	99.9	11	1	38.3
2	1	99.9	12	1	55.6
3	1	71.4	13	1	99.9
4	1	99.9	14	1	71.4
5	1	99.9	15	1	99.9
6	1	99.9			
7	1	50.1			
8	1	99.9			
9	1	45.5			
10	1	99.9			