Comparison Evaluation of MLCC

Strength test & bending test

KETI

J_Chip Consulting

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Table of Contents

I. Introduction

Introduction

- **Specimen**: Multi-Layer Ceramic Capacitor (1005, 1608 size)

- **Test**:
  - Strength test
  - Bending test with PCB
  - Cross-sectional observation

- **Test term**: 2013. 12. 01 ~ 2104. 2. 03

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

- **Test apparatuses**:
  - Precision impedance analyzer (4294A, Agilent, USA)
  - Material testing system (MTS858, MTS, USA)
  - Scanning electron microscopy (Quanta 3D DualBeam, FEI, Netherland)

- **Etc**: Blind test

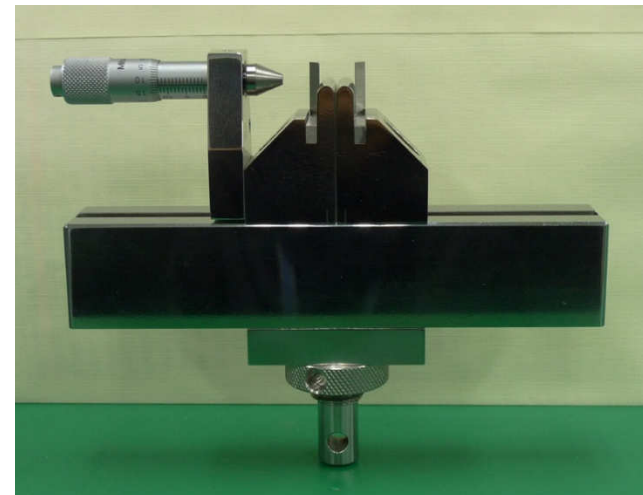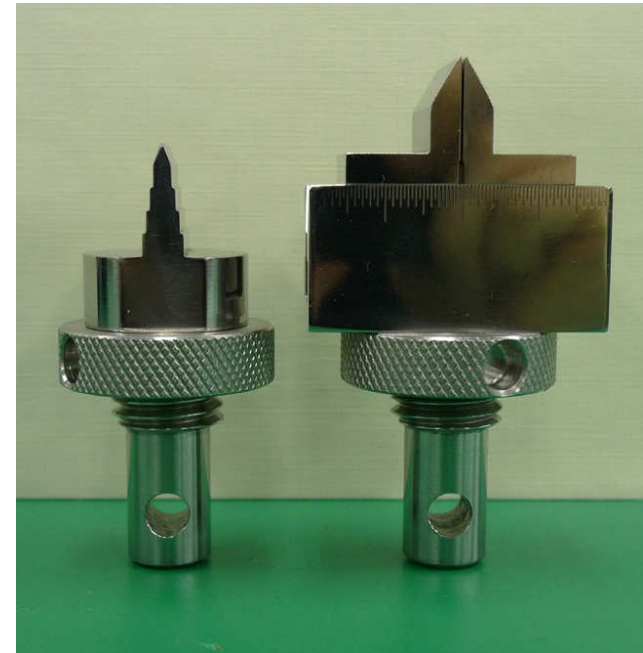- **Contact**: Lee, Ju Ho ☎ +82-31-789-7282 / leejuho@keti.re.kr

- **Test apparatuses**:
  - Precision impedance analyzer (4294A, Agilent, USA)

Introduction

- **Test apparatuses**:
  - Material testing system (MTS858, MTS, USA)

- **Test apparatuses**:
    - Scanning electron microscopy (Quanta 3D DualBeam, FEI, Netherland)

Strength test method/Regulation

- **Test standard**: EIAJ ET-7403
  - According to "EIAJ ET-7403", the strength test was performed using MTS858 material testing system.

- **Regulation**
  - 10N was applied to the sample during 10 second. After testing, capacitance change value should be small(within individual specification).
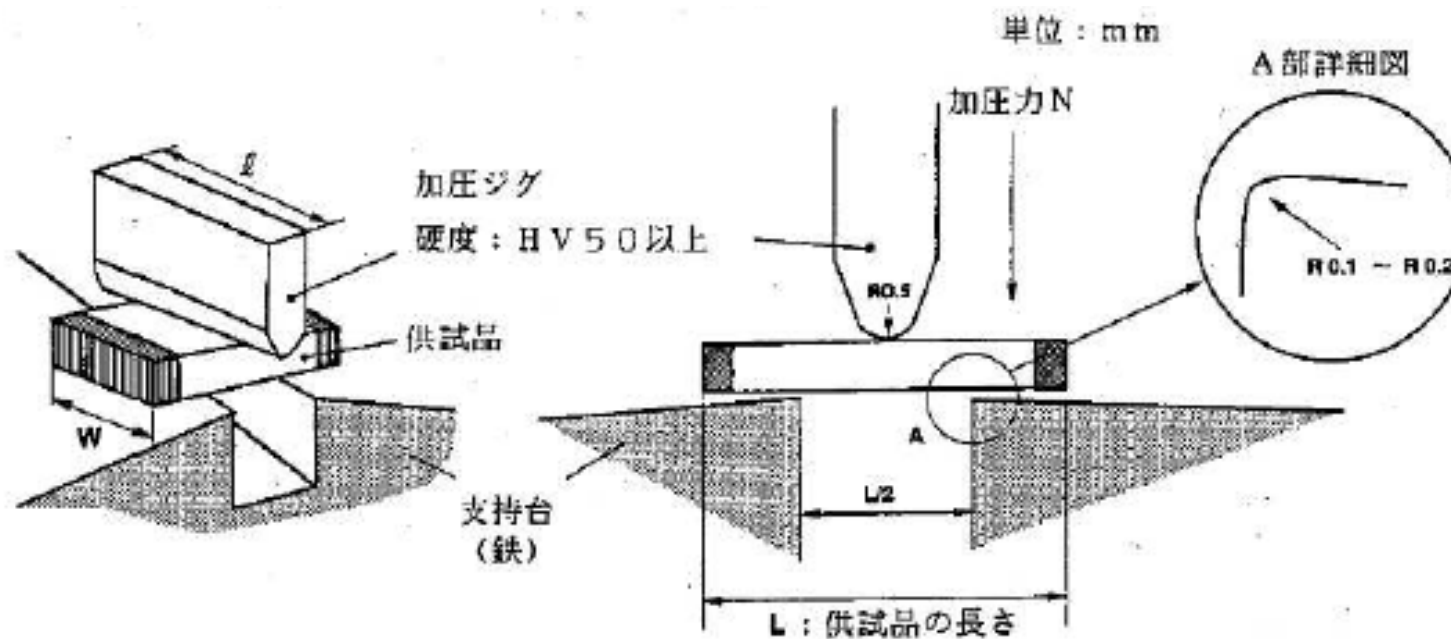
(Schematic diagram of strength test)

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Bending test method/Regulation

- **Test standard**: JEITA ET-7409-104A
  - Basically, according to "JEITA ET-7409-104A", the bending test was performed using MTS858 material testing system.
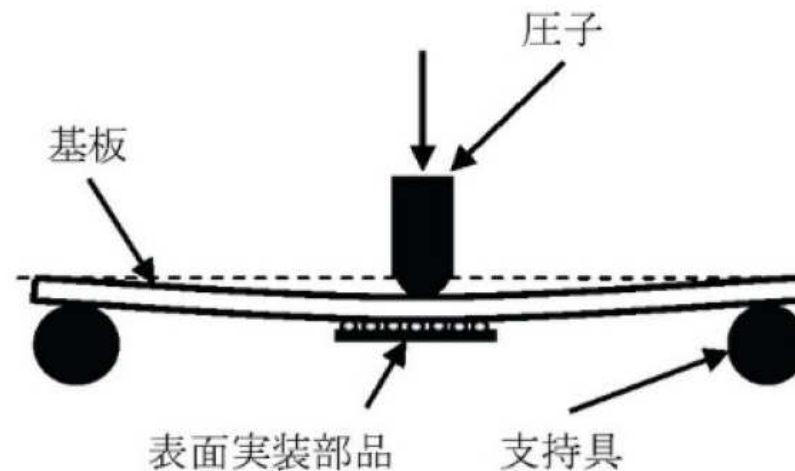
- **Etc**:
  - Due to the limitation of apparatus, we measured force (kN) to bend the PCB and displacement (mm) when capacitance was changed to ± 10%.

  - Capacitance of some MLCCs were not changed up to ± 10% even the PCB bended up to 20 mm. In this case, we only measured displacement of PCB and capacitance after bending test.
  - Moving speed of indenter: 10mm/min (up to 20 mm)

圧子

基板

表面実装部品　　支持具

(Schematic diagram of bending test)

Layout of PCB

15　45 mm　45 mm　15

60 mm

Electrode for impedance analyzer

Line indication for jig
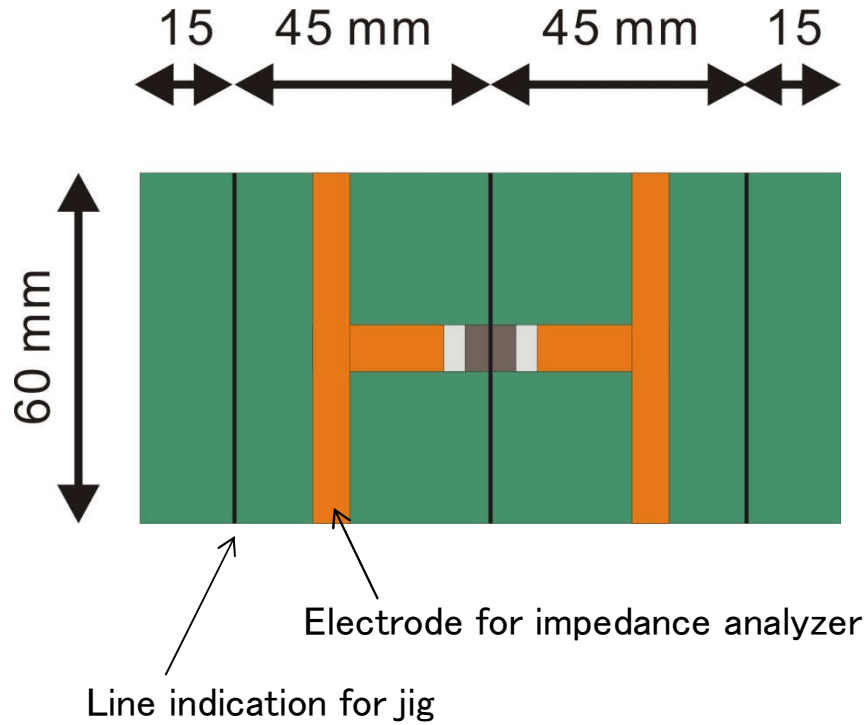
(Schematic diagram of PCB)

（Image of fabricated PCB）

260 DEG.C － A C E
270 DEG.C － B D
1005

260 DEG.C － A C E
270 DEG.C － B D
1608-1
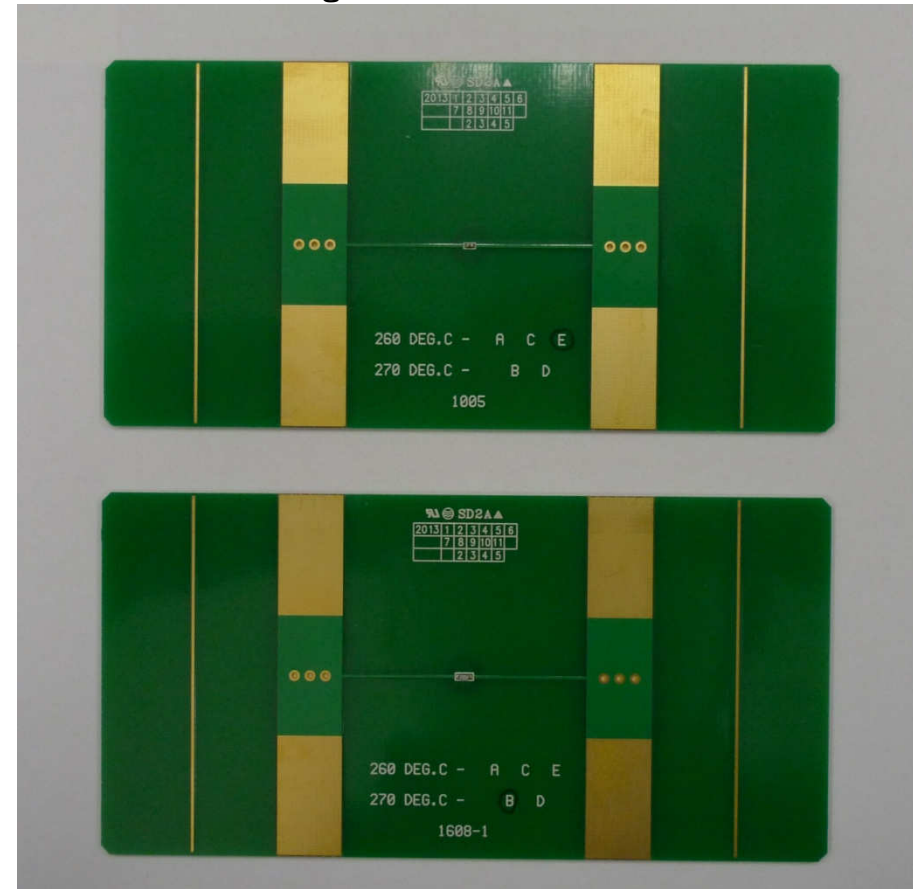
Information on Solder

Manufacturer: Senju Metal Industry Co.
Name of goods: M705-GRN360-K2-V
Composition: Sn-3.0Ag-0.5Cu

260 DEG.C － A C E
270 DEG.C － B D

Specimens (Test items)

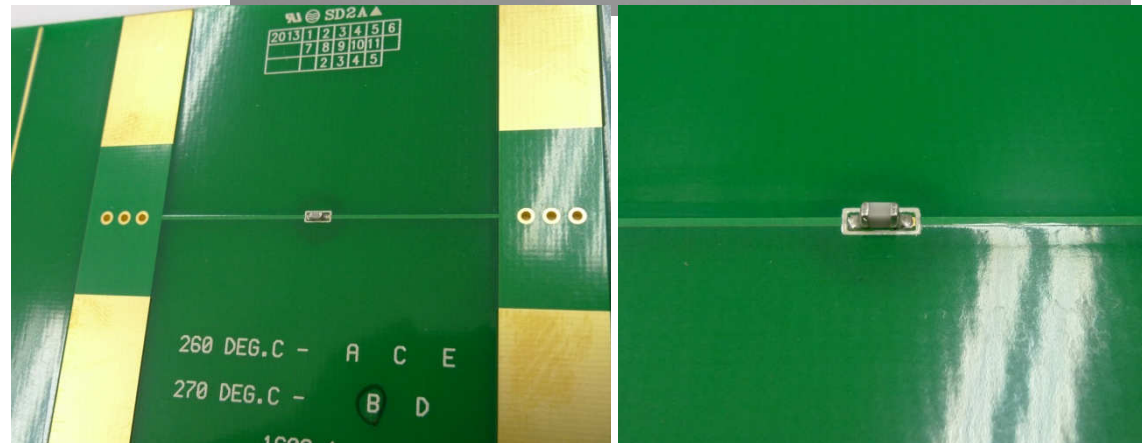| Chip size(mm)	A	B	C	D
1005				
1608-1				
1608-2				

	Spec.	A	B	C	D
1005	SIZE(mm)	1.0X0.5X0.5	1.0X0.5X0.5	1.0X0.5X0.5	1.0X0.5X0.5
	Capacitance	0.1uF±10%	0.1uF±10%	0.1uF±10%	0.1uF±10%
	Voltage	10VDC	10VDC	10VDC	10VDC
	Temp. chara	X7R	B	X7R	X7R
	Top.range	−55～125℃	−25～85℃	−55～125℃	−55～125℃
	Soldering tem.	260±5℃/10sec	270±5℃/10sec	260±5℃/10sec	270±5℃/10sec
1608-1	SIZE(mm)	1.6X0.8X0.8	1.6X0.8X0.8	1.6X0.8X0.8	1.6X0.8X0.8
	Capacitance	100pF±5%	100pF±5%	100pF±5%	100pF±5%
	Voltage	50VDC	50VDC	50VDC	50VDC
	Temp. chara	NPO	CH	NPO	COG
	Top.range	−55～125℃	−20～125℃	−55～125℃	−55～125℃
	Soldering tem.	260±5℃/10sec	270±5℃/10sec	260±5℃/10sec	270±5℃/10sec
1608-2	SIZE(mm)	1.6X0.8X0.4	1.6X0.8X0.4	1.6X0.8X0.5	1.6X0.8X0.8
	Capacitance	0.1uF+80%/−20%	0.1uF+80%/−20%	0.1uF+80%/−20%	0.1uF+80%/−20%
	Voltage	25VDC	25VDC	25VDC	25VDC
	Temp. chara	Y5V	F	Y5V	Y5V
	Top.range	−25～85℃	−25～85℃	−30～85℃	−30～85℃
	Soldering tem.	260±5℃/10sec	270±5℃/10sec	260±5℃/10sec	270±5℃/10sec

II. Strength test

A社 1005

〈Test result〉

Sample		1 KHz			1 MHz		
		Before (nF)	After (nF)	Rate of change (%)	Before (nF)	After (nF)	Rate of change (%)
Company **A** 1005 (@ 1 Vrms)	No.1	100.95	97.97	-2.95	89.07	86.56	-2.82
	No.2	97.42	95.43	-2.04	86.27	84.36	-2.21
	No.3	98.33	97.12	-1.23	86.82	85.93	-1.03
	No.4	97.69	96.65	-1.06	86.57	85.08	-1.72
	No.5	98.07	97.86	-0.21	86.85	86.58	-0.31
	No.6	95.74	95.16	-0.61	84.82	84.10	-0.85
	No.7	98.61	95.17	-3.49	87.07	84.25	-3.24
	No.8	97.69	97.17	-0.53	86.62	86.05	-0.66
	No.9	98.82	96.66	-2.19	87.27	85.40	-2.14
	No.10	98.07	96.72	-1.38	86.85	85.41	-1.66
Avg. rate of change (%)=			-1.57				-1.66

〈Judgement〉

The test results is satisfied with regulation.

B社 1005

〈Test result〉

Sample		1 KHz			1 MHz		
		Before (nF)	After (nF)	Rate of change (%)	Before (nF)	After (nF)	Rate of change (%)
Company **B** 1005 (@ 1 Vrms)	No.1	99.24	96.35	-2.91	87.44	86.05	-1.59
	No.2	97.28	96.26	-1.05	86.75	86.60	-0.17
	No.3	96.43	95.96	-0.49	85.75	85.42	-0.38
	No.4	97.38	93.97	-3.50	86.94	84.07	-3.30
	No.5	95.79	94.03	-1.84	85.59	84.03	-1.82
	No.6	96.65	96.32	-0.34	86.77	86.52	-0.29
	No.7	96.67	95.84	-0.86	86.45	85.38	-1.24
	No.8	98.26	93.90	-4.44	87.77	84.01	-4.28
	No.9	97.34	96.39	-0.98	87.12	85.97	-1.32
	No.10	98.63	96.27	-2.39	87.93	86.62	-1.49
Avg. rate of change (%)=				-1.88			-1.59

〈Judgement〉

The test results is satisfied with regulation.

C社 1005

⟨Test result⟩

Sample		1 KHz			1 MHz		
		Before (nF)	After (nF)	Rate of change (%)	Before (nF)	After (nF)	Rate of change (%)
Company **C** **1005** (@ 1 Vrms)	No.1	94.02	92.46	-1.66	81.74	80.35	-1.70
	No.2	93.95	93.39	-0.60	81.74	81.36	-0.46
	No.3	96.26	95.43	-0.86	83.73	83.14	-0.70
	No.4	95.24	94.53	-0.75	82.71	82.16	-0.66
	No.5	94.12	93.76	-0.38	81.98	81.56	-0.51
	No.6	99.63	92.41	-7.25	86.77	80.29	-7.47
	No.7	95.27	98.95	3.86	84.32	86.45	2.53
	No.8	95.29	95.56	0.28	82.16	83.34	1.44
	No.9	96.57	96.17	-0.41	84.11	83.76	-0.42
	No.10	98.09	97.36	-0.74	85.02	84.45	-0.67
Avg. rate of change (%)=				-0.85			-0.86

⟨Judgement⟩

The test results is satisfied with regulation.
However, No.6 result is close to a limit value(±10%).

D社 1005

〈Test result〉

Sample		1 KHz			1 MHz		
		Before (nF)	After (nF)	Rate of change (%)	Before (nF)	After (nF)	Rate of change (%)
Company **D** **1005** (@ 1 Vrms)	No.1	110.03	108.67	-1.24	91.53	90.67	-0.94
	No.2	106.29	105.08	-1.14	88.67	88.12	-0.62
	No.3	104.41	91.02	-12.82	87.16	80.69	-7.42
	No.4	105.23	105.22	-0.01	88.01	88.12	0.12
	No.5	103.74	96.27	-7.20	87.34	86.33	-1.16
	No.6	105.36	104.91	-0.43	88.07	87.84	-0.26
	No.7	112.01	96.37	-13.96	93.53	86.36	-7.67
	No.8	106.72	105.29	-1.34	89.42	88.00	-1.59
	No.9	106.91	105.13	-1.66	89.43	88.12	-1.46
	No.10	109.42	108.61	-0.74	91.37	90.67	-0.77
Avg. rate of change (%)=				-4.05			-2.18

〈Judgement〉

The test results is not satisfied with regulation.   : NG
No.3&No.7 result is over the limit value(±10%).

A社 1608-1

\<Test result\>

Sample		1 KHz			1 MHz		
		Before (pF)	After (pF)	Rate of change (%)	Before (pF)	After (pF)	Rate of change (%)
Company **A** **1608-1** (@ 1 Vrms)	No.1	99.95	99.15	-0.80	98.43	98.42	-0.01
	No.2	102.22	98.29	-3.85	102.31	99.15	-3.09
	No.3	100.11	99.64	-0.47	100.31	100.08	-0.23
	No.4	99.78	99.08	-0.70	100.15	100.15	0.00
	No.5	100.42	99.10	-1.31	99.51	99.52	0.01
	No.6	102.56	100.51	-2.00	101.67	101.67	0.00
	No.7	100.22	98.08	-2.14	99.17	99.15	-0.02
	No.8	101.57	99.39	-2.15	99.86	99.88	0.02
	No.9	100.71	99.47	-1.24	100.08	100.07	-0.01
	No.10	101.34	101.85	0.51	99.78	99.79	0.01
Avg. rate of change (%)=				-1.41			-0.33

\<Judgement\>

The test results is satisfied with regulation.

B社 1608-1

〈Test result〉

Sample		1 KHz			1 MHz		
		Before (pF)	After (pF)	Rate of change (%)	Before (pF)	After (pF)	Rate of change (%)
Company **B** **1608-1** (@ 1 Vrms)	No.1	104.32	97.92	-6.13	99.24	99.23	-0.01
	No.2	105.49	97.02	-8.03	100.51	100.50	-0.01
	No.3	102.48	94.98	-7.32	96.88	96.87	-0.01
	No.4	102.31	97.06	-5.13	98.14	98.12	-0.02
	No.5	108.07	98.99	-8.40	101.99	101.97	-0.02
	No.6	104.16	96.12	-7.72	98.93	98.92	-0.01
	No.7	103.59	94.36	-8.91	97.57	97.56	-0.02
	No.8	106.12	97.53	-8.09	101.02	101.03	0.01
	No.9	106.51	98.42	-7.60	105.51	100.50	-4.75
	No.10	104.61	96.28	-7.97	99.32	99.31	-0.02
Avg. rate of change (%)=				-7.53			-0.48

〈Judgement〉

The test results is satisfied with regulation.
However, all data except No.1 & No.4 result is close to a limit value(±10%).

C社 1608-1

⟨Test result⟩

Sample		1 KHz			1 MHz		
		Before (pF)	After (pF)	Rate of change (%)	Before (pF)	After (pF)	Rate of change (%)
Company **C** **1608-1** (@ 1 Vrms)	No.1	102.03	93.95	-7.92	96.47	96.46	-0.01
	No.2	104.74	98.96	-5.52	100.57	100.56	-0.01
	No.3	102.83	95.14	-7.48	97.35	97.34	-0.02
	No.4	104.38	97.32	-6.76	99.15	99.15	0.00
	No.5	104.96	97.12	-7.47	99.34	99.33	-0.01
	No.6	102.44	94.40	-7.85	96.61	96.60	-0.01
	No.7	104.81	98.62	-5.90	97.91	100.66	2.80
	No.8	104.45	94.47	-9.56	98.17	97.03	-1.16
	No.9	104.77	95.78	-8.58	100.65	97.89	-2.74
	No.10	103.03	95.10	-7.70	97.03	98.18	1.19
Avg. rate of change (%)=				-7.47			1.50

⟨Judgement⟩

The test results is satisfied with regulation.
However, all data except No.2 & No.4 &No.7 result is close to a limit value(±10%).

D社 1608-1

〈Test result〉

Sample		1 KHz			1 MHz		
		Before (pF)	After (pF)	Rate of change (%)	Before (pF)	After (pF)	Rate of change (%)
Company **D** 1608-1 (@ 1 Vrms)	No.1	107.94	101.24	-6.21	100.24	100.24	0.00
	No.2	109.16	102.51	-6.10	101.64	101.63	-0.01
	No.3	108.51	102.00	-6.00	100.68	100.68	0.00
	No.4	108.76	102.79	-5.49	101.52	101.50	-0.02
	No.5	107.34	102.29	-4.71	101.18	101.17	-0.01
	No.6	108.63	102.54	-5.61	101.17	101.16	-0.01
	No.7	108.92	102.69	-5.72	101.31	101.29	-0.02
	No.8	107.19	101.26	-5.53	100.25	100.24	-0.01
	No.9	106.92	101.56	-5.01	99.38	100.67	1.30
	No.10	109.54	102.65	-6.29	101.77	101.75	-0.02
Avg. rate of change (%)=				-5.67			0.12

〈Judgement〉

The test results is satisfied with regulation.
However, No.1&No.2 &No.3 &No.10 result is close to a limit value(±10%).

A社 1608-2

⟨Test result⟩

Sample		1 KHz			1 MHz		
		Before (nF)	After (nF)	Rate of change (%)	Before (nF)	After (nF)	Rate of change (%)
Company A 1608-2 (@ 1 Vrms)	No.1	129.08	123.80	-4.09	98.22	96.01	-2.26
	No.2	130.85	119.39	-8.76	95.25	93.42	-1.92
	No.3	127.94	117.47	-8.18	94.17	90.67	-3.72
	No.4	123.75	119.85	-3.15	96.94	93.46	-3.59
	No.5	120.55	122.12	1.30	93.24	95.88	2.84
	No.6	118.14	117.47	-0.57	91.97	90.71	-1.37
	No.7	117.23	118.91	1.43	89.56	93.47	4.37
	No.8	117.08	123.72	5.67	94.16	96.39	2.37
	No.9	124.24	117.89	-5.12	94.84	90.53	-4.54
	No.10	118.83	119.13	0.25	90.15	93.47	3.68
Avg. rate of change (%)=				-2.12			-0.41

⟨Judgement⟩

The test results is satisfied with regulation.
However, No.2 &No.3 &No.8 result is close to a limit value(±10%).

⟨Test result⟩

Sample		1 KHz			1 MHz		
		Before (nF)	After (nF)	Rate of change (%)	Before (nF)	After (nF)	Rate of change (%)
Company **B** 1608-2 (@ 1 Vrms)	No.1	106.44	104.72	-1.62	85.15	84.10	-1.23
	No.2	120.88	116.49	-3.64	88.93	86.67	-2.54
	No.3	102.72	100.86	-1.81	81.32	80.53	-0.97
	No.4	102.77	102.10	-0.66	81.32	82.01	0.85
	No.5	105.77	104.21	-1.48	83.76	83.20	-0.67
	No.6	104.94	103.37	-1.50	83.06	82.49	-0.68
	No.7	102.15	100.45	-1.67	81.52	80.70	-1.00
	No.8	104.11	102.07	-1.96	83.09	82.04	-1.26
	No.9	97.41	95.37	-2.09	78.45	77.19	-1.60
	No.10	102.04	100.64	-1.38	80.94	80.04	-1.12
Avg. rate of change (%)=				-1.78			-1.02

⟨Judgement⟩

The test results is satisfied with regulation.

C社 1608-2

〈Test result〉

Sample		1 KHz			1 MHz		
		Before (nF)	After (nF)	Rate of change (%)	Before (nF)	After (nF)	Rate of change (%)
Company **C** **1608-2** (@ 1 Vrms)	No.1	103.42	102.48	-0.91	86.37	85.27	-1.28
	No.2	100.34	99.51	-0.83	83.45	82.53	-1.10
	No.3	100.95	99.41	-1.53	84.07	82.63	-1.72
	No.4	95.95	95.71	-0.25	78.96	78.25	-0.90
	No.5	100.08	100.13	0.05	83.07	82.50	-0.68
	No.6	102.49	102.39	-0.10	85.64	84.98	-0.77
	No.7	101.49	99.07	-2.38	85.37	81.84	-4.14
	No.8	95.72	101.08	5.60	79.51	84.17	5.85
	No.9	99.26	101.35	2.11	82.78	84.46	2.03
	No.10	101.24	95.22	-5.95	84.92	78.76	-7.26
Avg. rate of change (%)=				-0.42			-1.00

〈Judgement〉

The test results is satisfied with regulation.

D社 1608-2

<Test result>

Sample		1 KHz			1 MHz		
		Before (nF)	After (nF)	Rate of change (%)	Before (nF)	After (nF)	Rate of change (%)
Company **D** **1608-2** (@ 1 Vrms)	No.1	89.21	88.28	-1.04	81.37	80.43	-1.15
	No.2	90.04	89.04	-1.11	82.12	81.17	-1.16
	No.3	91.12	90.25	-0.95	82.94	82.27	-0.80
	No.4	90.25	88.52	-1.91	82.12	80.47	-2.01
	No.5	89.81	88.99	-0.92	82.06	81.04	-1.24
	No.6	92.14	91.02	-1.21	83.75	82.67	-1.29
	No.7	92.12	90.97	-1.25	83.66	82.64	-1.22
	No.8	90.12	89.09	-1.14	82.21	81.02	-1.44
	No.9	91.07	90.58	-0.54	83.27	82.67	-0.72
	No.10	89.04	88.25	-0.88	81.35	80.44	-1.12
Avg. rate of change (%)=				-1.10			-1.22

<Judgement>

The test results is satisfied with regulation.

Sample (1005)	Test result:1KHz			Test result:1KHz		
	Min. value	Max. Value	Avg.value	Min. value	Max. Value	Avg.value
A	−0.21	−3.49	−1.57	−0.31	−3.24	−1.66
	Judg:○	Judg:○	Judg:○	Judg:○	Judg:○	Judg:○
B	−0.34	−3.5	−1.88	−0.17	−4.28	−1.59
	Judg:○	Judg:○	Judg:○	Judg:○	Judg:○	Judg:○
C	0.28	−7.25	−0.85	−0.42	7.47	−0.86
	Judg:○	Judg:△	Judg:○	Judg:○	Judg△	Judg:○
D	−0.01	−13.96	−4.05	−0.26	−7.67	−2.18
	Judg:○	Judg:×	Judg△	Judg:○	Judg△	Judg:○

Sample (1608-1)	Test result:1KHz			Test result:1KHz		
	Min. value	Max. Value	Avg.value	Min. value	Max. Value	Avg.value
A	−0.47	−3.85	−1.41	−0.01	−3.09	−0.33
	Judg:○	Judg:○	Judg:○	Judg:○	Judg:○	Judg:○
B	−5.13	−8.91	−7.53	−0.01	−4.75	−0.48
	Judg:○	Judg:△	Judg:△	Judg:○	Judg:○	Judg:○
C	−5.52	−9.56	−7.47	−0.01	2.8	1.59
	Judg:○	Judg:△	Judg:△	Judg:○	Judg:○	Judg:○
D	−4.71	−6.29	−5.67	0	1.3	−0.12
	Judg:○	Judg:△	Judg:△	Judg:○	Judg:○	Judg:○

Sample (1608-2)	Test result:1KHz			Test result:1KHz		
	Min. value	Max. Value	Avg.value	Min. value	Max. Value	Avg.value
A	0.25	−8.76	−2.12	−1.37	−4.54	−0.41
	Judg:○	Judg:○	Judg:○	Judg:○	Judg:○	Judg:○
B	−0.66	−3.64	−1.79	−0.67	−2.54	−0.12
	Judg:○	Judg:○	Judg:○	Judg:○	Judg:○	Judg:○
C	0.08	−5.95	−0.42	−0.68	−7.26	−1.0
	Judg:○	Judg:△	Judg:○	Judg:○	Judg△	Judg:○
D	−0.54	−1.25	−1.1	−0.72	−2.01	−1.22
	Judg:○	Judg:○	Judg:○	Judg:○	Judg:○	Judg:○

<J-chip comment>

Company D strength capability level is no good, if compare to another company level.

Company B/C/D strength capability is a little bit low.

Company C strength capability is a little bit low.

II. Bending test

1. In the case of bending test using PCB, due to limitations of apparatus, we measured force (kN) to bend the PCB and displacement (mm) when capacitance was changed ± 10%.

2. Capacitances of some MLCCs were not changed ± 10% even the PCB bended up to 20 mm. In this case, we only measured displacement of PCB and capacitance after bending test.

A社 1005

<Test result>

Sample		1 KHz			
		Before (nF)	Force to bending (kN)	Displacement (mm)	Capacitance after bending (nF)
Company A 1005 (@ 1 Vrms)	No.1	95.64	0.6842	5.27	N/A
	No.2	99.06	0.14361	12.53	N/A
	No.3	97.94	-	20	99.47
	No.4	101.26	-	20	103.27
	No.5	98.71	0.07787	6.35	14.09
	No.6	97.43	0.08423	6.67	99.04
	No.7	99.87	0.08739	6.64	83.00
	No.8	101.58	0.07949	6.16	86.08
	No.9	100.70	0.07376	5.71	50.05
	No.10	96.05	0.06457	5.04	77.55

- Note: N/A = Not Available to measure the capacitance of sample
- It may be that inner electrodes of MLCC opened.

<Judgement>

Total 2items are satisfied with regulation.

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B社 1005

〈Test result〉

Sample		1 KHz			
		Before (nF)	Force to bending (kN)	Displacement (mm)	Capacitance after bending (nF)
Company **B** 1005 (@ 1 Vrms)	No.1	96.11	0.05933	4.83	91.16
	No.2	95.67	0.05234	3.98	47.75
	No.3	99.00	0.06389	5.05	99.90
	No.4	97.67	0.04598	3.58	28.26
	No.5	98.66	0.04795	3.81	169.05 mF
	No.6	97.29	0.04724	3.66	15.94
	No.7	97.20	0.08014	6.3	97.98
	No.8	96.68	0.05443	4.35	48.18
	No.9	97.01	0.05728	4.43	64.37
	No.10	96.93	0.04647	3.59	98.23

- Note: The capacitance value of sample No.5 is 169.05 mF.
  It may be that the some inner electrodes were damaged during the
  bending test. This low capacitance does not mean 'open' or 'short'.
- $C = Q/V = \varepsilon (A/t)$

Here, C, Q, V, ε, A, and t are capacitance, electric charge, voltage, dielectric constant, area of electrode, and distance between electrodes, respectively.

〈Judgement〉

All of items are not satisfied with regulation. : NG

C社 1005

〈Test result〉

Sample		1 KHz			
		Before (nF)	Force to bending (kN)	Displacement (mm)	Capacitance after bending (nF)
Company **C** 1005 (@ 1 Vrms)	No.1	100.16	0.14169	12.27	102.09
	No.2	101.69	-	20	103.70
	No.3	101.31	-	20	103.05
	No.4	106.16	0.07338	5.79	71.94
	No.5	99.74	-	20	101.09
	No.6	99.18	-	20	100.69
	No.7	102.33	0.1529	14.38	104.72
	No.8	103.98	0.07827	6.02	33.17
	No.9	101.05	0.15917	15.98	102.81
	No.10	98.60	0.15689	18.85	99.33

〈Judgement〉

Total 4items are satisfied with regulation.

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D社 1005

<Test result>

Sample		1 KHz			
		Before (nF)	Force to bending (kN)	Displacement (mm)	Capacitance after bending (nF)
Company D 1005 (@ 1 Vrms)	No.1	105.32	0.04805	3.7	45.39
	No.2	113.64	0.08866	6.87	73.97
	No.3	115.19	0.04827	3.88	32.79
	No.4	111.12	0.05693	4.35	35.55
	No.5	113.91	0.07235	5.64	36.84
	No.6	111.82	0.05135	4.01	63.40
	No.7	113.07	0.05631	4.64	11.47
	No.8	110.48	0.03961	3.17	97.22
	No.9	109.55	0.04453	3.54	111.43
	No.10	106.63	0.03941	3.19	47.50

<Judgement>

All of items are not satisfied with regulation. : NG

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A社 1608-1

〈Test result〉

Sample		1 KHz			
		Before (nF)	Force to bending (kN)	Displacement (mm)	Capacitance after bending (nF)
Company **A** 1608-1 (@ 1 Vrms)	No.1	101.20	-	20	101.23
	No.2	100.66	0.15874	16.05	100.69
	No.3	101.56	-	20	101.59
	No.4	100.72	-	20	100.77
	No.5	100.10	-	20	100.12
	No.6	101.56	-	20	101.62
	No.7	101.23	-	20	101.24
	No.8	101.16	-	20	101.19
	No.9	101.03	-	20	101.07
	No.10	99.83	-	20	99.86

〈Judgement〉

Total 9items are satisfied with regulation.

B社 1608-1

〈Test result〉

Sample		1 KHz			
		Before (nF)	Force to bending (kN)	Displacement (mm)	Capacitance after bending (nF)
Company **B** 1608-1 (@ 1 Vrms)	No.1	101.56	-	20	101.61
	No.2	100.94	-	20	100.99
	No.3	100.64	-	20	100.70
	No.4	98.55	-	20	98.60
	No.5	101.02	-	20	101.05
	No.6	99.65	-	20	99.68
	No.7	98.81	0.9096	7.02	90.27
	No.8	101.24	-	20	101.29
	No.9	100.51	-	20	100.54
	No.10	100.61	-	20	100.67

〈Judgement〉

Total 9items are satisfied with regulation.

C社 1608-1

〈Test result〉

Sample		1 KHz			
		Before (nF)	Force to bending (kN)	Displacement (mm)	Capacitance after bending (nF)
Company **C** 1608-1 (@ 1 Vrms)	No.1	100.49	0.1419	11.78	100.52
	No.2	97.73	-	20	97.78
	No.3	97.73	-	20	97.77
	No.4	100.04	0.16011	18.06	100.08
	No.5	99.21	-	20	99.25
	No.6	102.70	-	20	102.76
	No.7	99.59	-	20	99.64
	No.8	99.86	-	20	99.91
	No.9	99.87	-	20	99.92
	No.10	98.74	-	20	98.77

〈Judgement〉

Total 8items are satisfied with regulation.

D社 1608-1

〈Test result〉

Sample		1 KHz			
		Before (nF)	Force to bending (kN)	Displacement (mm)	Capacitance after bending (nF)
Company **D** **1608-1** (@ 1 Vrms)	No.1	101.61	-	20	101.66
	No.2	101.25	-	20	101.28
	No.3	101.59	-	20	101.65
	No.4	99.71	-	20	99.78
	No.5	101.87	-	20	101.91
	No.6	102.07	-	20	102.13
	No.7	101.83	-	20	101.88
	No.8	102.37	0.07622	6.04	15.107 pF
	No.9	100.68	-	20	100.73
	No.10	99.61	-	20	99.66

• Note: The capacitance value of sample No.8 is 15.107 pF.
 It may be that the some inner electrodes were damaged during the
 bending test. This low capacitance does not mean 'open' or 'short'.
•$C = Q/V = \varepsilon (A/t)$
Here, C, Q, V, ε, A, and t are capacitance, electric charge, voltage, dielectric constant, area of electrode, and distance between electrodes, respectively.

〈Judgement〉

   Total 8items are satisfied with regulation.

A社 1608-2

〈Test result〉

Sample		1 KHz			
		Before (nF)	Force to bending (kN)	Displacement (mm)	Capacitance after bending (nF)
Company A 1608-2 (@ 1 Vrms)	No.1	123.87	0.08521	6.81	129.20
	No.2	121.93	-	20	127.47
	No.3	135.23	-	20	144.43
	No.4	129.40	0.08442	6.41	69.83
	No.5	126.87	-	20	129.33
	No.6	130.30	0.09632	7.4	98.97
	No.7	124.83	-	20	128.69
	No.8	133.65	0.08579	6.51	136.44
	No.9	126.88	0.21138	19.35	132.82
	No.10	126.13	-	20	130.92

〈Judgement〉

Total 5items are satisfied with regulation.

B社 1608-2

＜Test result＞

Sample		1 KHz			
		Before (nF)	Force to bending (kN)	Displacement (mm)	Capacitance after bending (nF)
Company **B** 1608-2 (@ 1 Vrms)	No.1	118.95	-	20	122.68
	No.2	109.18	-	20	113.06
	No.3	112.81	0.09813	7.99	85.43
	No.4	111.21	0.10951	9.6	111.93
	No.5	110.97	0.15288	14.36	94.26
	No.6	106.36	0.07091	5.52	84.72
	No.7	114.10	-	20	115.56
	No.8	111.03	0.06542	5.27	50.52
	No.9	107.60	0.05736	4.68	87.69
	No.10	105.94	0.09163	7.71	109.23

＜Judgement＞

Total 3items are satisfied with regulation.

C社 1608-2

〈Test result〉

Sample		1 KHz			
		Before (nF)	Force to bending (kN)	Displacement (mm)	Capacitance after bending (nF)
Company **C** **1608-2** (@ 1 Vrms)	No.1	124.54	-	20	127.44
	No.2	127.42	-	20	130.88
	No.3	127.63	-	20	130.91
	No.4	128.11	-	20	132.56
	No.5	126.87	0.15311	14.33	128.95
	No.6	125.05	-	20	128.83
	No.7	125.79	-	20	129.06
	No.8	123.26	-	20	127.69
	No.9	125.59	0.16044	16.43	129.87
	No.10	125.36	0.15834	14.51	129.83

〈Judgement〉

Total 7items are satisfied with regulation.

D社 1608-2

<Test result>

Sample		1 KHz			
		Before (nF)	Force to bending (kN)	Displacement (mm)	Capacitance after bending (nF)
Company **D** **1608-2** (@ 1 Vrms)	No.1	90.71	0.07413	6.47	86.70
	No.2	90.18	0.07682	7.21	81.77
	No.3	91.51	0.0744	6.85	70.95
	No.4	88.95	0.05113	5.24	11.08
	No.5	89.16	0.05588	5.17	69.64
	No.6	91.26	0.05769	5.54	420.931 mF
	No.7	89.50	0.05931	5.77	7.30
	No.8	90.49	0.07755	7.43	93.18
	No.9	89.71	0.04391	3.54	47.23
	No.10	91.49	0.05798	5.76	188.571 mF

• Note: The capacitance values of sample No.6 and No.10 are 420.931 and 188.571 mF, respectively.
  It may be that the some inner electrodes were damaged during the
  bending test. This low capacitance does not mean 'open' or 'short'.
•$C = Q/V = \varepsilon (A/t)$
Here, C, Q, V, ε, A, and t are capacitance, electric charge, voltage, dielectric constant, area of electrode, and distance between electrodes, respectively.

<Judgement>

All of items are not satisfied with regulation. : NG

Summary

Sample (1005)	OK (20mm bend)	NG (Over limit)	N/A (Damaged)	No result (Stop test)
A	2pcs	6pcs	2pcs	
B		5pcs	1pc	4pcs
C	4pcs	2pcs		4pcs
D		7pcs		3pcs

Sample (1608-1)	OK (20mm bend)	NG (Over limit)	N/A (Damaged)	No result (Stop test)
A	9pcs			1pc
B	9pcs			1pc
C	8pcs			2pcs
D	9pcs		1pc	

Sample (1608-2)	OK (20mm bend)	NG (Over limit)	N/A (Damaged)	No result (Stop test)
A	5pcs			5pcs
B	3pcs	1pc		6pcs
C	7pcs			3pcs
D		3pcs	2pcs	5pcs

<J-chip comment>

Due to all of samples are NG, it is difficult to judge.

All of company items are satisfied with regulation(except a few pcs).

Company D's PCB bending capability level is no good, if compare to another company level.