Hi CV SMD Capacitor Solutions

Capacitor Types - Technologies

- MLCC
- Film
- Thin Film
- MLO
- Mica

▪ Low - Medium Cap / Voltage Small Case

- High CV MLCC

▪ Large Cap / Voltage Small Case

Electrostatic Capacitors

Electrolytic Capacitors

Solid Electrolytics

- Tantalum Chip
- Tantalum Polymer
- Niobium Oxide Chip
- Tantalum Leaded
- Al Solid

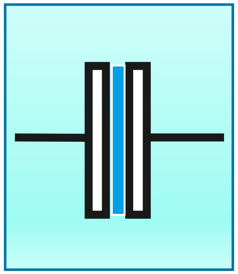
▪ Large Cap / Voltage Small Case

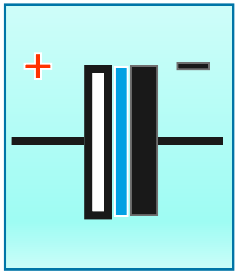
Power Filtering
Digital / Decoupling

Wet Electrolytics

- Tantalum Wet
- Al Wet / Hybrid

▪ High Cap / Voltage large case





Non-Polar components
Electrode, dielectric, Electrode

Polar components
Anode, dielectric, cathode

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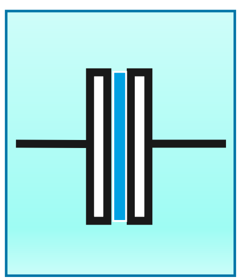
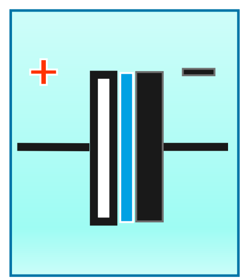




Non-Polar components
Electrode, dielectric, Electrode

Polar components
Anode, dielectric, cathode

Hi CV SMD Capacitor Technologies

Polar Electrolytic

Metal Base

MIS: Metal – Insulator - Semiconductor

Ceramic-like Base

OIS : Oxide – Insulator – Semiconductor

- ***Unique non-metallic discrete capacitor element***

Non-Polar Electrostatic

Ceramic Base

MIM: Metal – Insulator - Metal

Hi CV SMD Capacitor Technologies

Polar Electrolytic

Metal Base		Aluminium		Tantalum		Niobium
	Metal Anode	Al	Al	Ta	Ta	Nb
	Oxide Dielectric	Al_2O_3	Al_2O_3	Ta_2O_5	Ta_2O_5	Nb_2O_5
	Semiconductor	Wet	MnO_2	MnO_2	Polymer	MnO_2
						

Ceramic-like Base		Niobium Oxide
	Ceramic-like Anode	NbO
	Oxide Dielectric	Nb_2O_5
	Semiconductor	MnO_2
		

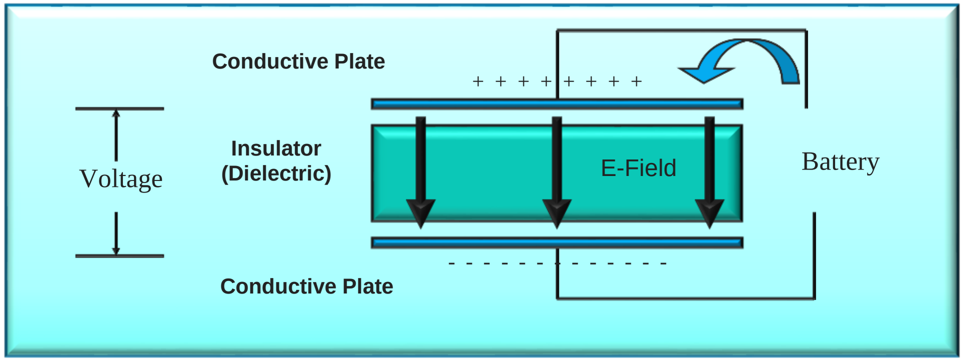
Non-Polar Electrostatic

Ceramic Base		Ceramic
	Metal Electrode	Ni
	Ceramic Dielectric	$BaTiO_3$
	Metal Electrode	Ni
		

Similar Footprints

Common CV Characteristics

Capacitor Basics



Capacitor equation:

$$\textbf{Capacitance} = \frac{KA}{d}$$

K = Dielectric Constant (ε_0 x ε_r)
A = Plate Area
d = Plate separation

To maximize capacitance, we need:

- *High dielectric constant insulator*
- *High plate surface area*
- *Less distance between conductors*

(Bearing in mind some trade-offs:

- *Less temperature stability*
- *Higher leakage current*
- *Lower breakdown voltage / voltage rating)*

Dielectric Constants:

$\varepsilon_0 = 8.85 \times 10^{-12}$

ε_r (Relative Permittivity):

$Al_2O_3 = 9.1$

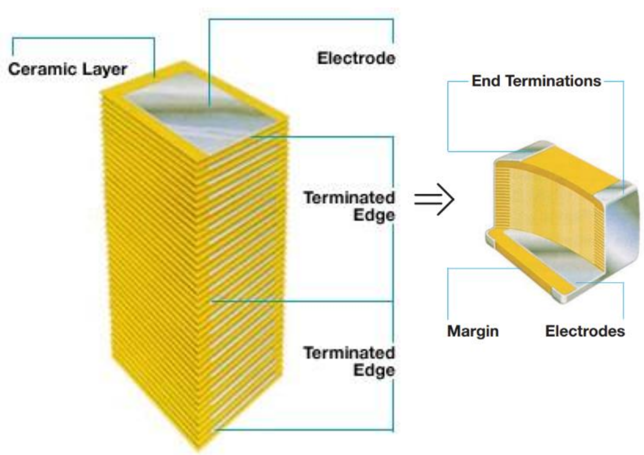
$Ta_2O_5 = 27$

$Nb_2O_5 = 41$

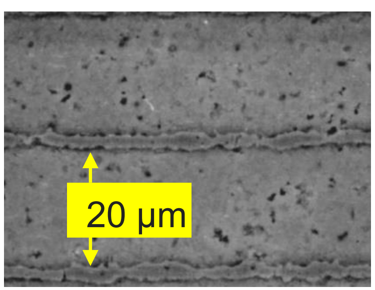
$BaTiO_3 = 2,000$

Capacitor Construction

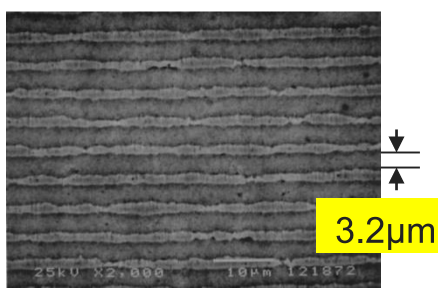
MLCC



Typical surface area (100uF High CV): **20cm²**

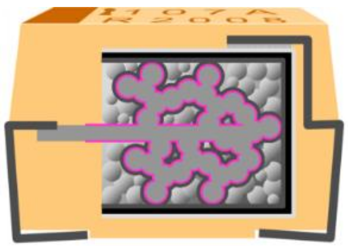


1206 X7R 0.1uF / 50V



1210 X5R 100uF / 6.3V

Tantalum / Niobium Oxide

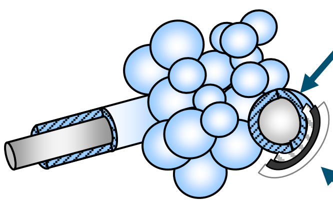


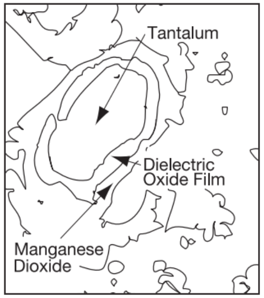
Typical surface area (100uF High CV): **600cm²**

(0.03 – 0.5)m

Dielectric Layer

Ta_2O_5 or Nb_2O_5





Cathode System Outside

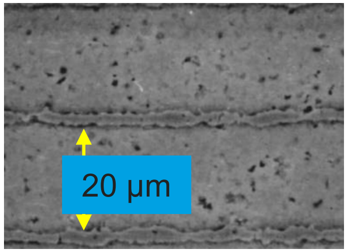
-MnO2 or Polymer

-Carbon Coated

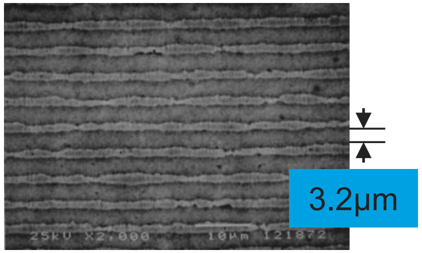
-Silver Dipped

MLCC & Tantalum / Oxicap CV Evolution

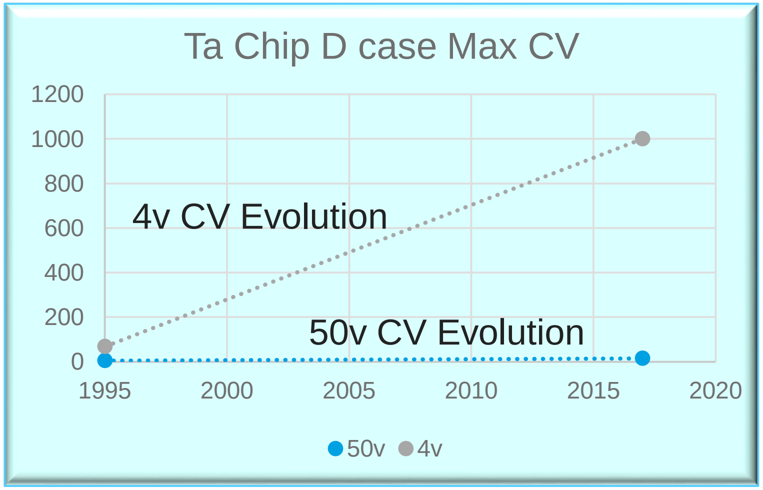
MLCC



1206 X7R 0.1uF / 50V
(1990s)

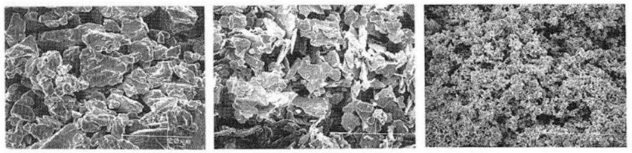


1210 X5R 100uF / 6.3V
(2008)

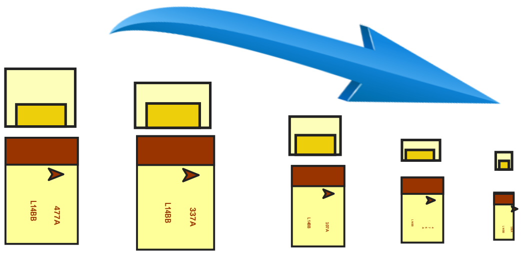


Tantalum / Niobium Oxide

Low CV (8000 CV/g) | Medium CV (18000 CV/g) | High CV (27000 CV/g)



Magnification x 4k



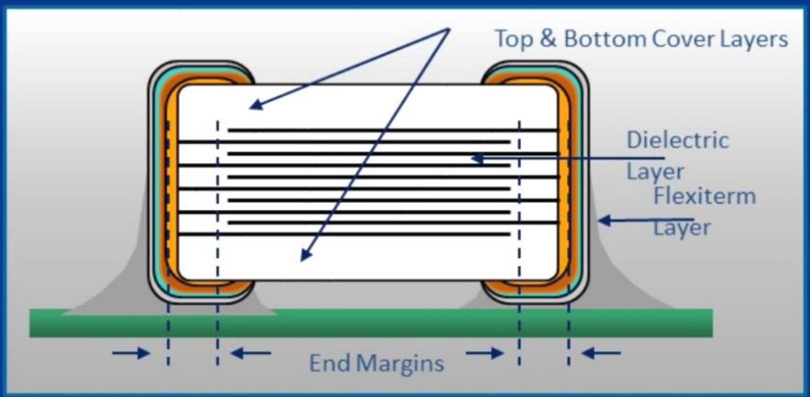
High voltage ratings (35v – 63v) require larger particle size to support thicker dielectric.

Low Voltage ratings (≤ 16v) have thinner dielectric and can use finer powder.

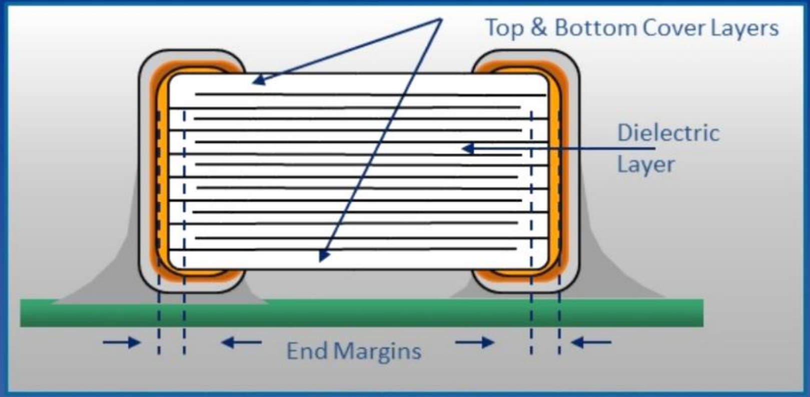
New fine particle powders enable higher capacitance yield in ≤ 16v ratings

MLCC – Tantalum Chip Construction

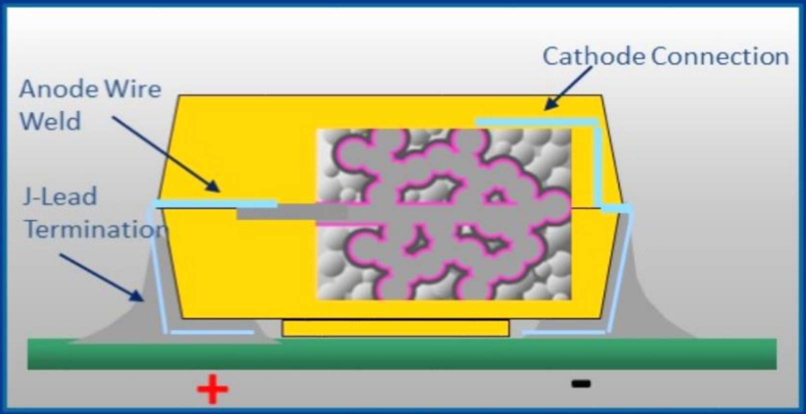
MLCC	Tantalum / Niobium



AEC-Q200 – High Shock / Vibration



Standard Hi CV Low ESR



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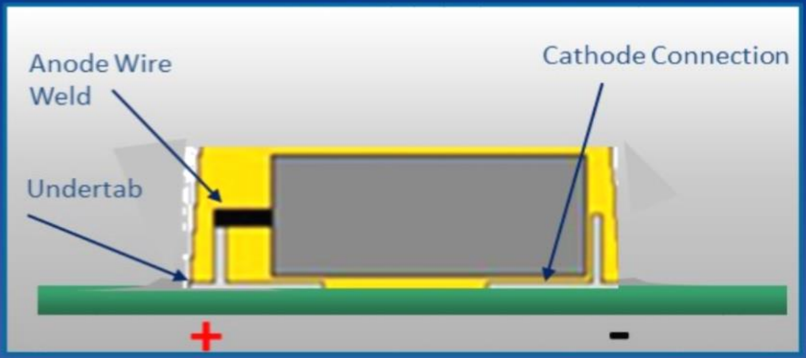
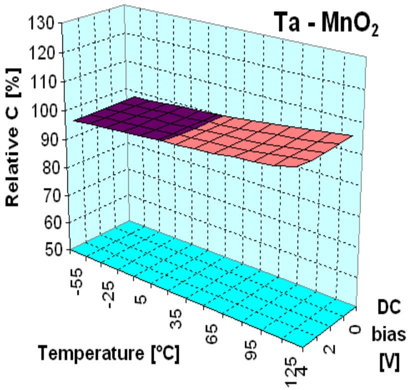
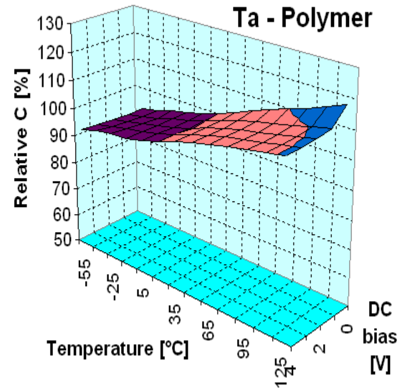
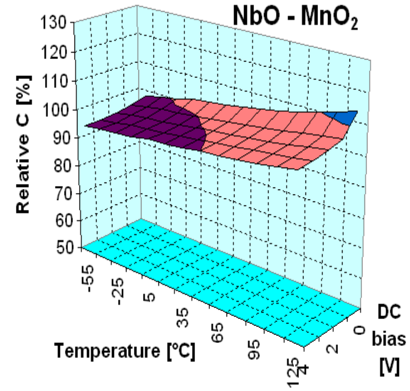


Standard Hi CV Low ESR

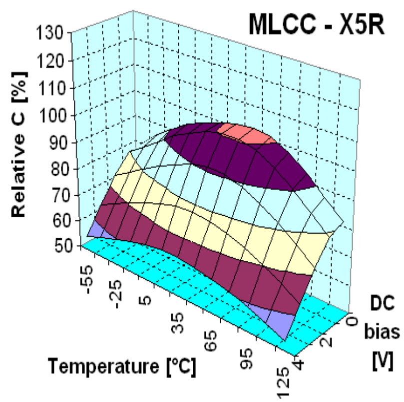
Capacitance Stability - Technology Comparison

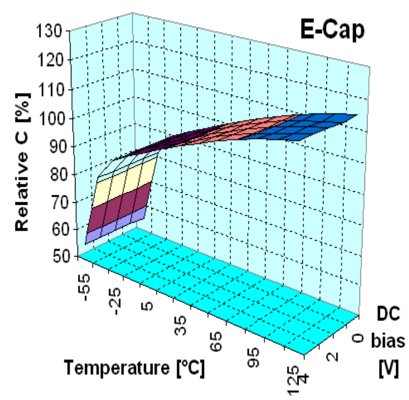






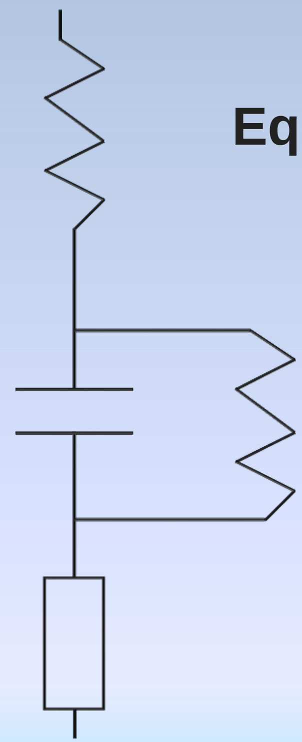
Ta MnO_2, Ta Polymer & NbO Solid Electrolytic Capacitors demonstrate cap stability wrt temperature and DC BIAS vs MLCC & Al.





Capacitor Characteristics

Capacitor Equivalent Circuit



Capacitor

Equivalent Series Resistance
ESR

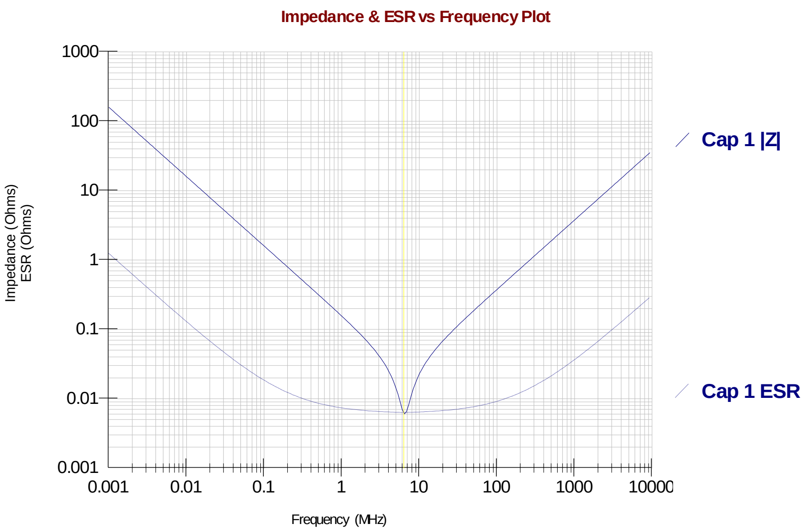
Insulation Resistance
(Leakage Current)
IR or DCL

Equivalent Series Inductance
ESL

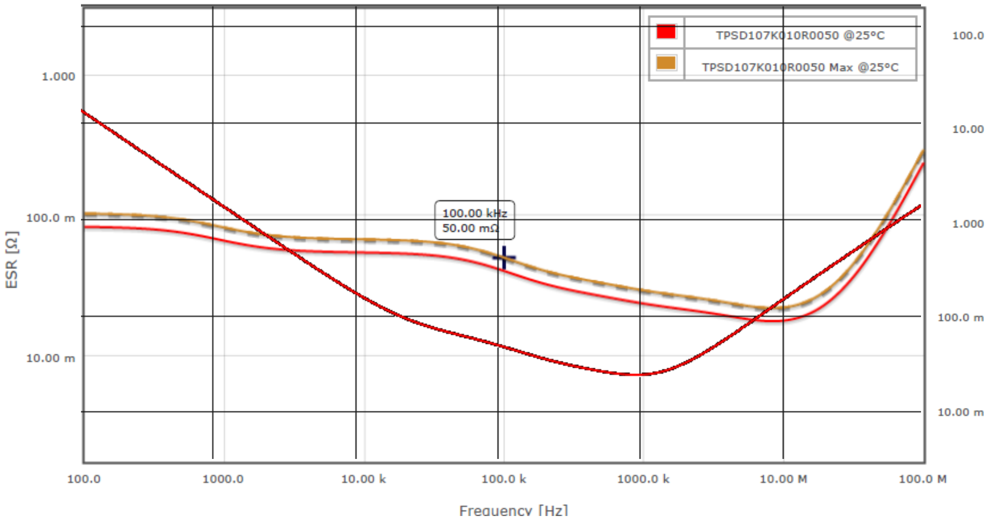
LCR Circuit – has Self Resonant Frequency

ESR vs Frequency Comparison

MLCC



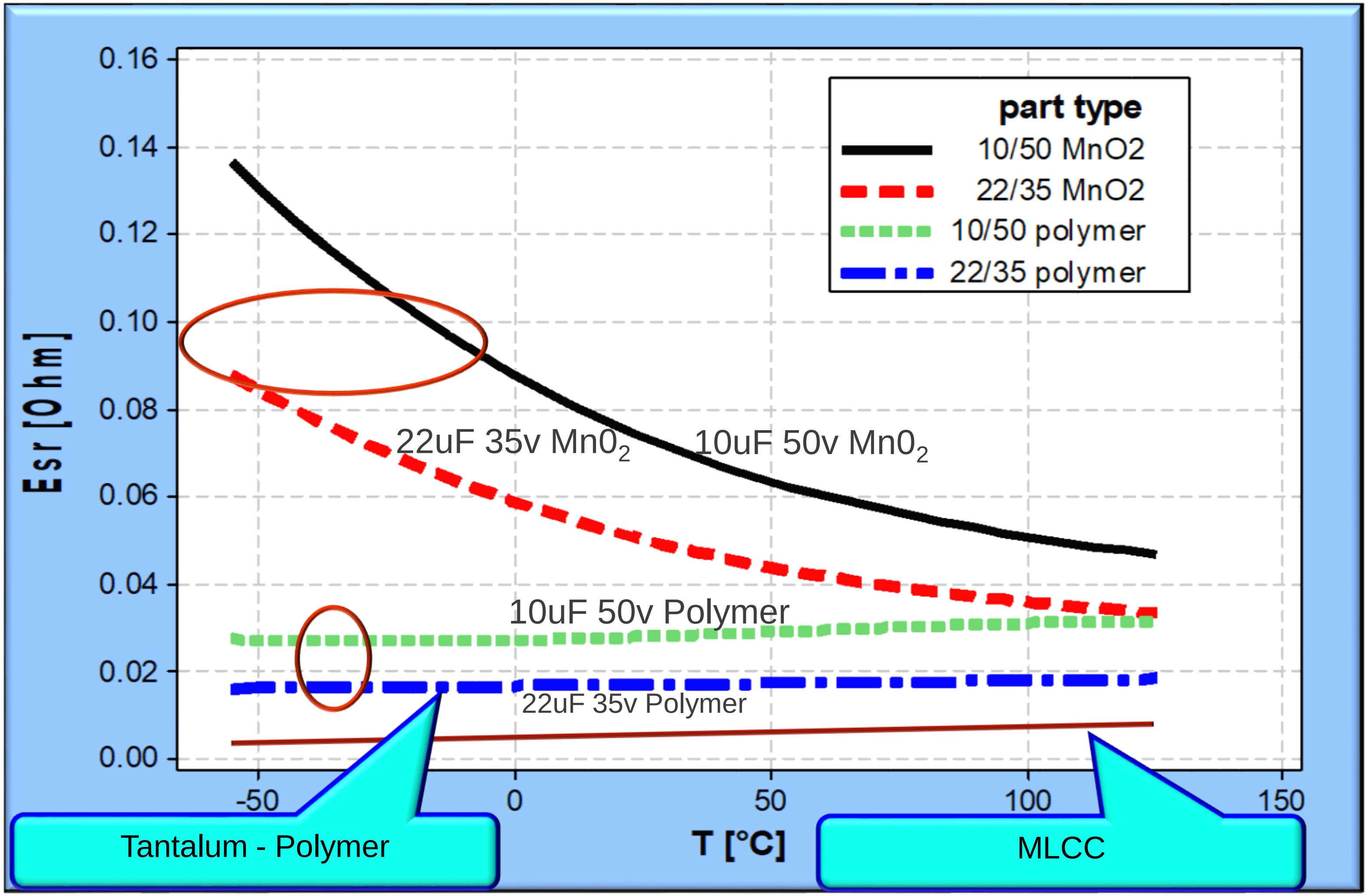
Tantalum / Niobium



MLCC – regular geometry gives “tuned” device: distinct SRF ~ 1MHz – 10MHz and high Q (notch filter).

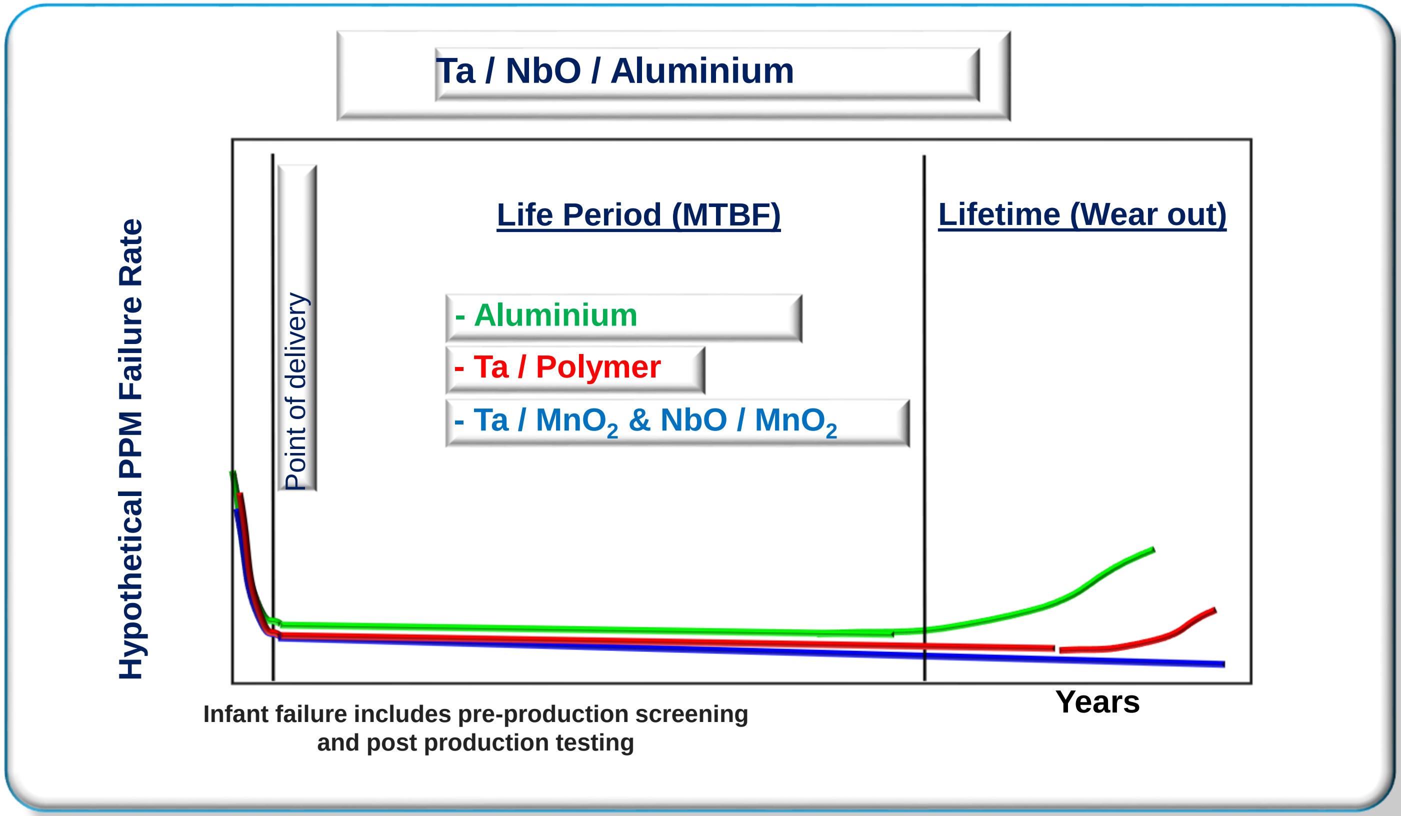
Ta / NbO Electrolytic – convoluted surfaces give range of signal paths: broadband SRF ~ 100kHz – 5MHz.

ESR vs Temperature Comparison



ESR @ 100 kHz - Temperature Dependency

Long Term Reliability - Ta / Polymer / NbO



Standard Tantalum Capacitors have excellent long term reliability (MTBF), with no dielectric wear out mechanism and dielectric – cathode self-healing.

Tantalum Polymer Capacitors MTBF is similar, but with a additional wear out mechanism associated with the polymer electrolyte that can result in parametric capacitance & ESR shift under harsh conditions.

Lifetime - Ta Polymer / Al

Industry std. lifetime model for solid Polymer capacitors:

$$Lx = Lo \times 10^{\frac{To-Tx}{20}}$$

Lx : Expected Life
Lo : Endurance Load Life
To : Rated Operating Temperature
Tx : Application Temperature

Al electrolytic offers only 2x increase in lifetime per 10°C reduction

$$Lx = Lo \times 2^{\frac{To-Tx}{10}}$$

Ta polymer offers
> 3x increase in lifetime per 10°C reduction in operating temperature

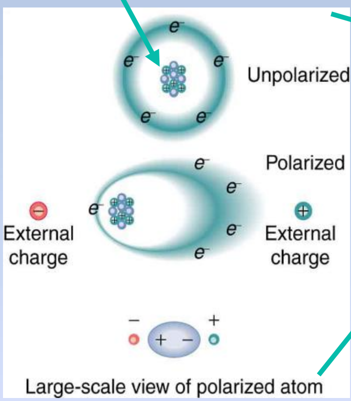
Operating Temp./Time	Solid Polymer		Wet Hybrid	
	Hrs	Yrs	Hrs	Yrs
65°C	2,000,000	228.00	128,000	14.60
85°C	200,000	22.80	32,000	3.65
105°C	20,000	2.28	8,000	0.91
125°C	2,000	0.23	2,000	0.23

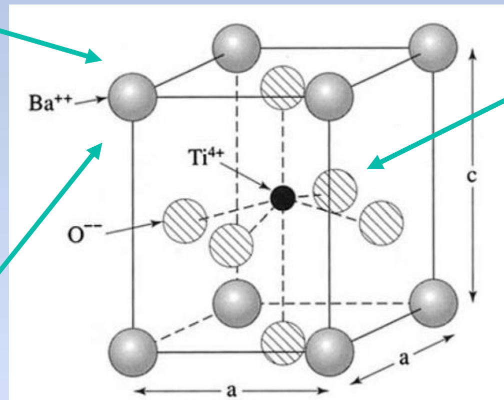
The wear out effect can be partially reduced by protective layers applied to capacitor or pcb.

Capacitors – Dielectric Effects

Dielectric Polarization Models:

Ta_2O_5 & Nb_2O_5 — **Class II MLCC**





Dielectric effects can be reduced by using lower K materials, more conservative design and application voltage derating.

Major contribution to charge polarization from BCC (Ti) displacement within lattice

Displacement of BCC Ti^{4+} increases field / dielectric constant, but also gives rise to:

- Limited temperature range for max CV (85ºC max. for X5R)
- Microphonics
- Voltage Coefficient
- Aging
- Reverse bias ripple heating

AL & Hi CV MLCC Replacement

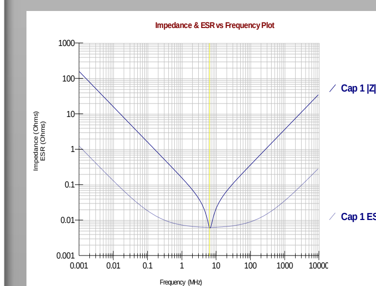
AL Electrolytic
- Limited Life Time
- Limited Lead-Free Assembly
- Limited Operation Temperature
- Large Case Sizes

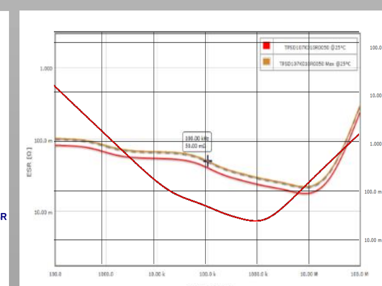
=> Replacement by high CV SMD polymer capacitors

X5R MLCC
- Noise / Voltage Coeff. Limitation
- Limited Operation Temperature
- Very Low ESR

=> Replacement by high CV SMD Ta or Conductive polymer capacitors or X7R / Polymer combination

Opportunity for replacement





Achieve: target bulk capacitance + Broadband + Low notch ESR

http://www.avx.com

Standard Tantalum – Hostile Environment

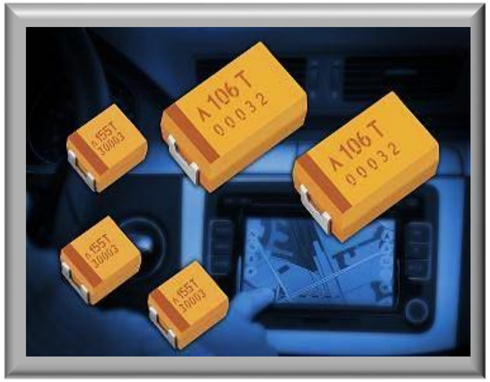
Professional Series:
AEC-Q200
Continuous 125°C operating temperature
0.5% / 1000hrs Improved Reliability
0.005 CV DCL
85/85/Ur / 1000hrs Humidity
Capacitance Range: 0.10-220µF,
6.3 - 50V Ratings, 50% Voltage Derating Typical

High Temperature Series:
AEC-Q200
Continuous 175°C / 200°C operating temperature
0.5% / 1000hrs Improved Reliability
0.01 CV DCL
85/85/Ur / 1000hrs Humidity
Capacitance Range: 0.10-220µF,
6.3 - 50V Ratings, 50% Voltage Derating Typical

Conductive Polymer – High Voltage

Commercial Series:
Continuous (105 – 125)°C operating temperature
1% / 1000hrs Reliability
0.1 CV DCL
60/90 / 1000hrs Humidity
CV: 0.47-470µF,
2.5 - 125V Ratings, 20% Derating Typical

Automotive Series:
AEC-Q200
Continuous 125°C operating temperature
1% / 1000hrs Improved Reliability
0.1 CV DCL
85/85/Ur / 1000hrs Humidity
CV: 10-470µF,
4 - 50V Ratings, 20% Derating Typical



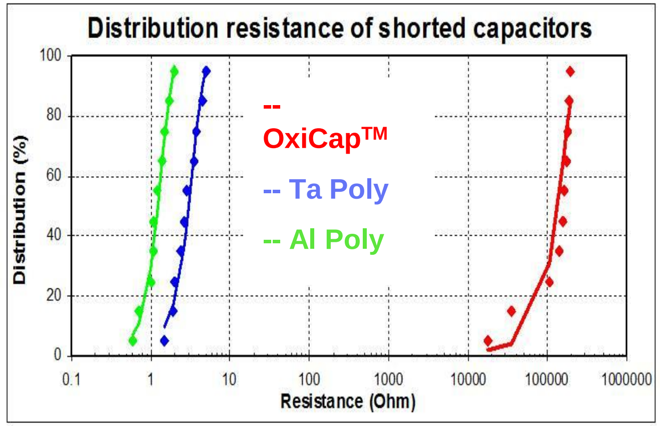
Oxicap™ Niobium Oxide – Digital

Commercial Series:
Continuous (105 – 125)°C operating temperature
0.5% / 1000hrs Reliability
0.1 CV DCL
85/85/Ur / 1000hrs Humidity
CV: 10-1000µF,
1.8 - 10V Ratings, 20% Derating Typical

Low ESR Series:
AEC-Q200
Continuous 125°C operating temperature
0.2% / 1000hrs Improved Reliability
85/85/Ur / 1000hrs Humidity
CV: 10-1000µF,
1.8 - 8V Ratings, 20% Derating Typical

Oxicap® Fail Safe - Niobium Oxide

At category voltage : The current does not flow and the Oxicap will not burn.



NbO – lower density than Ta, so dielectric grows thicker per formation volt.

Consequences:

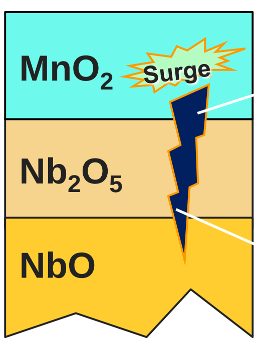
- Lower electric field stress

- **Higher base reliability (0.2% / 1000 hrs)**

- Increased "d" (offset by higher K)

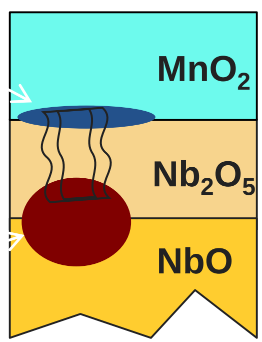
- Lower Voltage Ratings (Parity to Ta up to 10v)

Oxicap, after forced dielectric breakdown occurs: The failure mode is high resistance path through the breakdown site.



Mn_2O_3 formed on break down "self healing"

NbO_2 formed on break down "self arresting"



This mechanism is useful in PAAT applications (Powered At All Times).

e.g. regulator output, filtering from a regulated line etc.

Specification Comparison – 1210 Equivalent

	MLCC		Standard Ta Chip		Polymer Ta Chip		NbO Chip OxiCap®	
Attributes	Commercial	AEC-Q200	Commercial	AEC-Q200	Commercial	AEC-Q200	Commercial	AEC-Q200
Max Capacitance 1210	100uF	10uF	150uF	100uF	220uF	47uF	47uF	47uF
Voltage Range 1210	4v - 50v	16v - 100v	4v - 50v	4v - 50v	4v - 50v	4v - 50v	4v - 10v	4v - 10v
Typical ESR 1210	7 - 15mOhms	10 - 40mOhms	300 - 800mOhms	300 - 800mOhms	30 - 200mOhms	70 - 250mOhms	300 - 600mOhms	300 - 600mOhms
Temperature Range	-55°C - +85°C	-55°C - +125 / +150°C	-55°C - +125°C	-55°C - +125 / +200°C	-55°C - +105 / +125°C	-55°C - +125°C	-55°C - +105°C	-55°C - +125°C
Base Reliability	1% / 1000hrs	1% / 1000hrs	1% / 1000hrs	(0.05 - 1%) / 1000hrs	1% / 1000hrs	1% / 1000hrs	0.02 - 0.05% / 1000hrs	0.02 - 0.05% / 1000hrs
Primary Failure Mode	Short	Short	Short	Short	Short	Short	Resistive	Resistive
Lifetime (10% Cap loss @ Tmax / Vmax)	Indefinite	Indefinite	Indefinite	Indefinite	10,000hrs	10,000hrs	Indefinite	Indefinite
Recommended Voltage Derating	20%	20%	50%	50%	20%	20%	20%	20%
Disadvantages	**Commercial**	**AEC-Q200**	**Commercial**	**AEC-Q200**	**Commercial**	**AEC-Q200**	**Commercial**	**AEC-Q200**
Voltage Coefficient	Cap Loss vs V	Cap Loss vs V						
Piezo Noise	@ Audio Frequencies	@ Audio Frequencies						
Reverse Voltage			Not Allowed	Not Allowed	Not Allowed	Not Allowed	Not Allowed	Not Allowed

THANK YOU