Electronic Components

KEMET

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2015 DOE Solid-State Lighting R&D Workshop

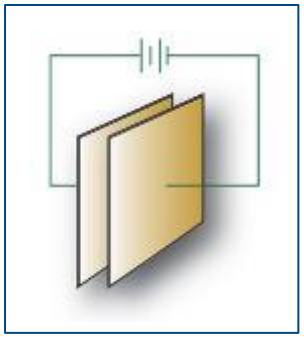
January 29, 2015

San Francisco, CA

Agenda

- KEMET Overview
- Aluminum Electrolytic Technology
- Film Technology
- Ceramic Technology
- Polymer Technology

Company Profile



- 36,000,000,000 Components shipped in FY14

- 9,806 employees worldwide
  - USA 673
  - Asia 2,111
  - Mexico 5,483
  - Europe 1,539

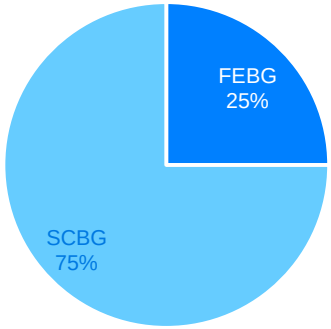
- "Easy-To-Buy-From" philosophy

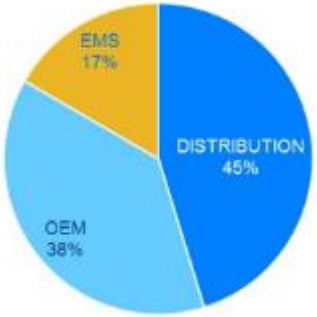
Company Overview

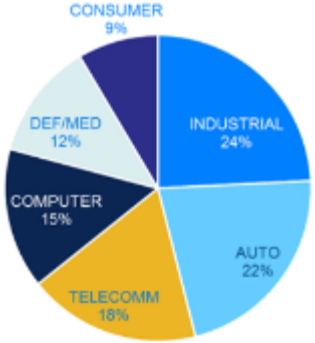
History & Locations

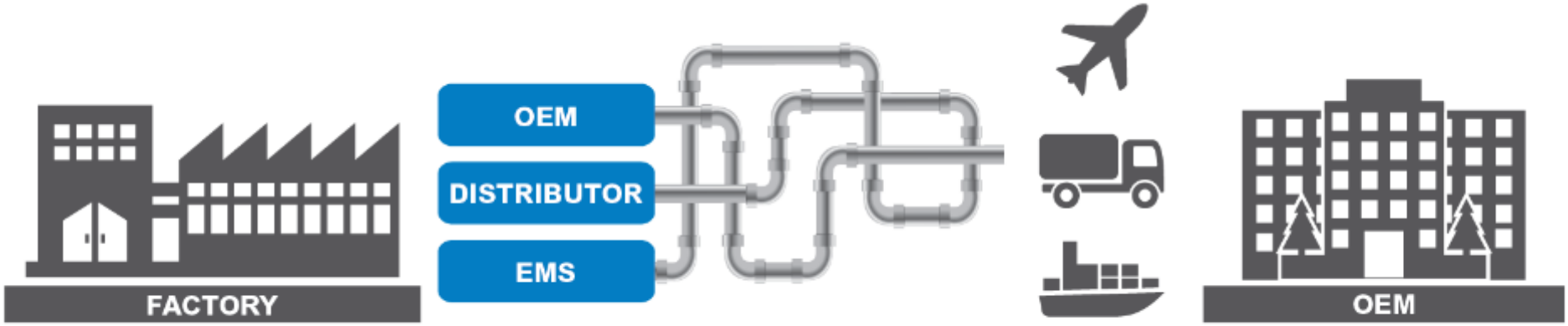
1919	1958	1963	1968	2002	2003	2006	2007	2011	2012	2013	2014
KEMET Laboratories (Union Carbide)	Ta Capacitors	Simpsonville HQ	Mexico	China	FELCO	EPCOS Ta	Arcotronics & Evox Rifa	CDE Al Foil	Niotan & Macedonia	NEC TOKIN	Pontecchio

Revenue Stream



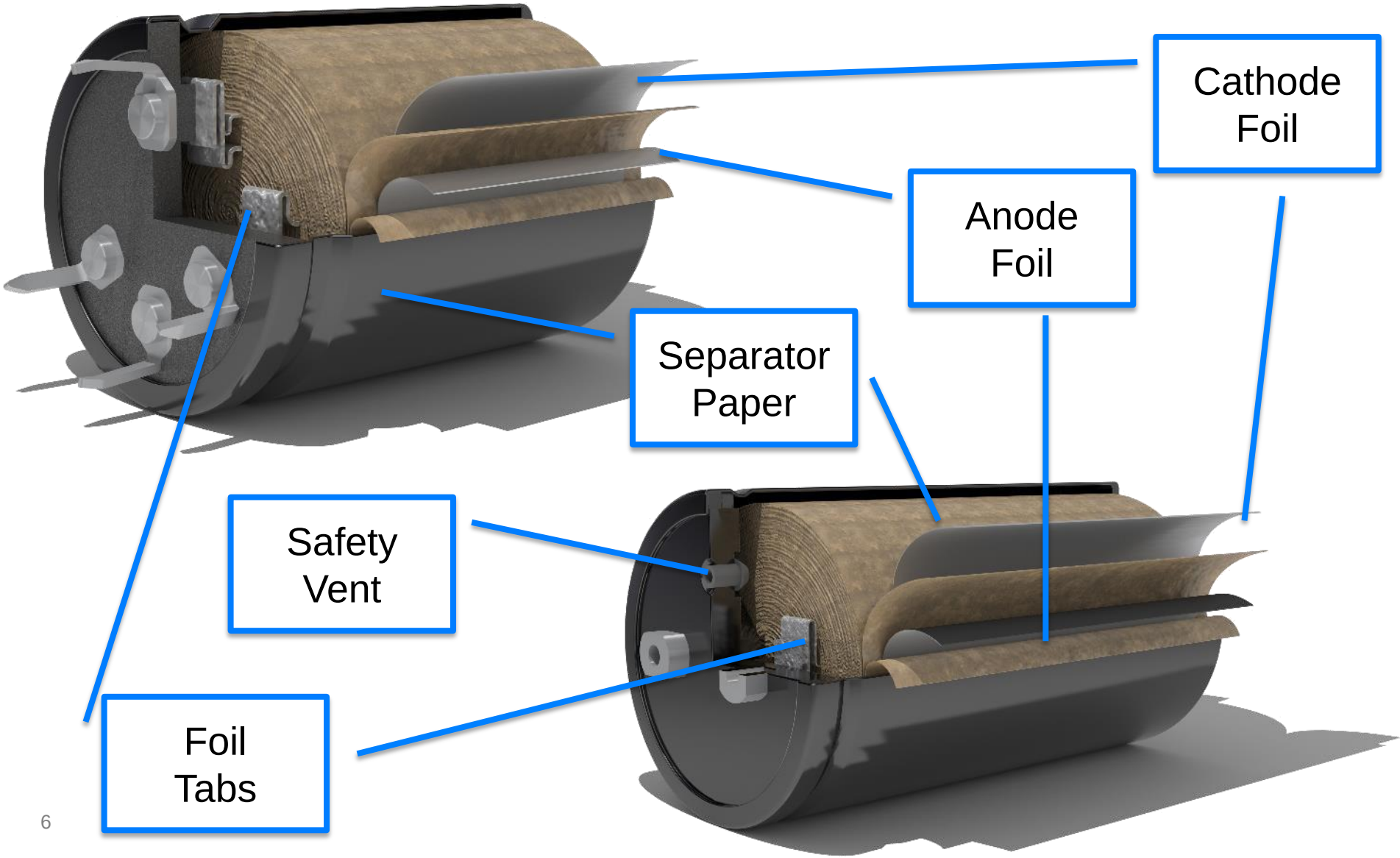




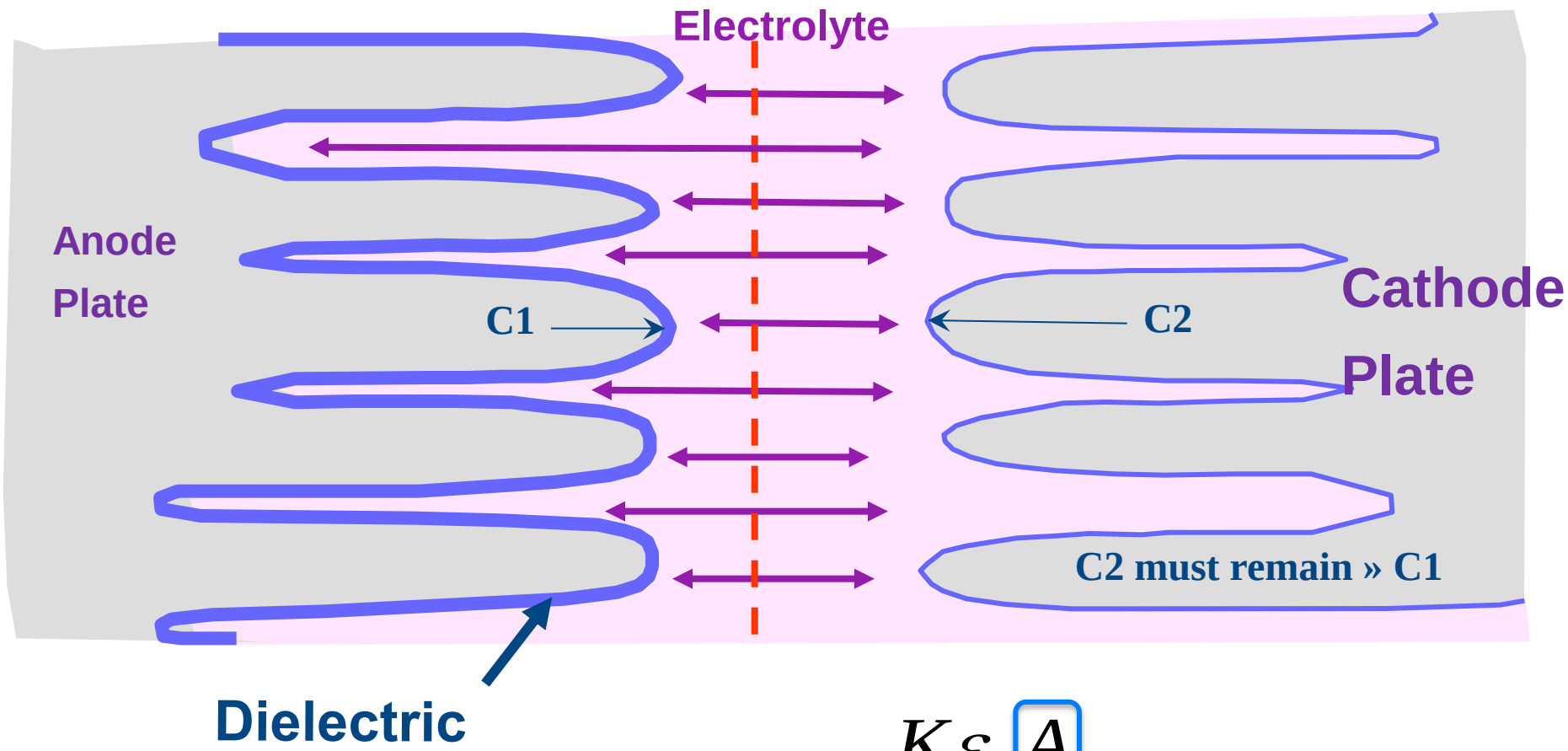


Aluminum Electrolytic Can

Construction

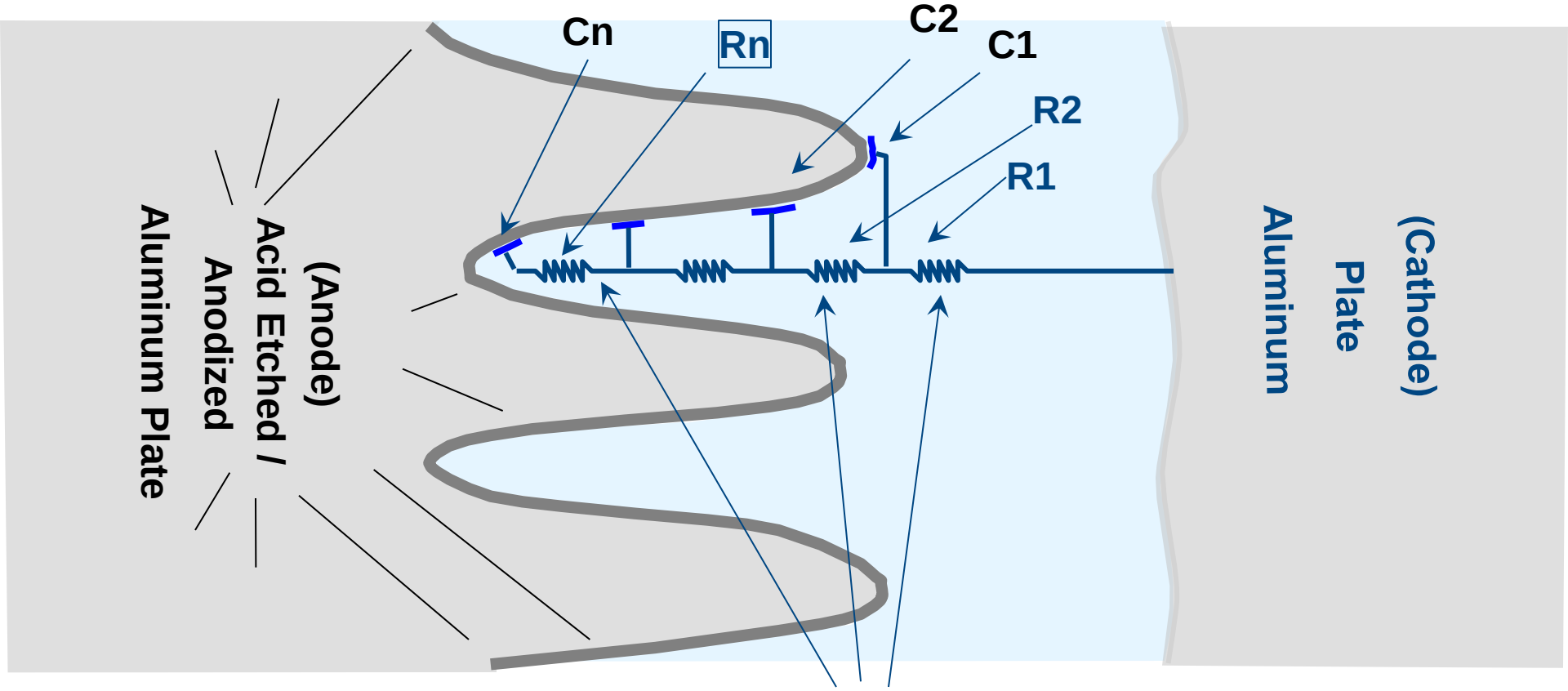


Aluminum Acid-Etched Surface Area



$$C = \frac{K\varepsilon_0 A}{d}$$

RC-Ladder in Aluminum Electrolytic



Electrolyte Resistivity

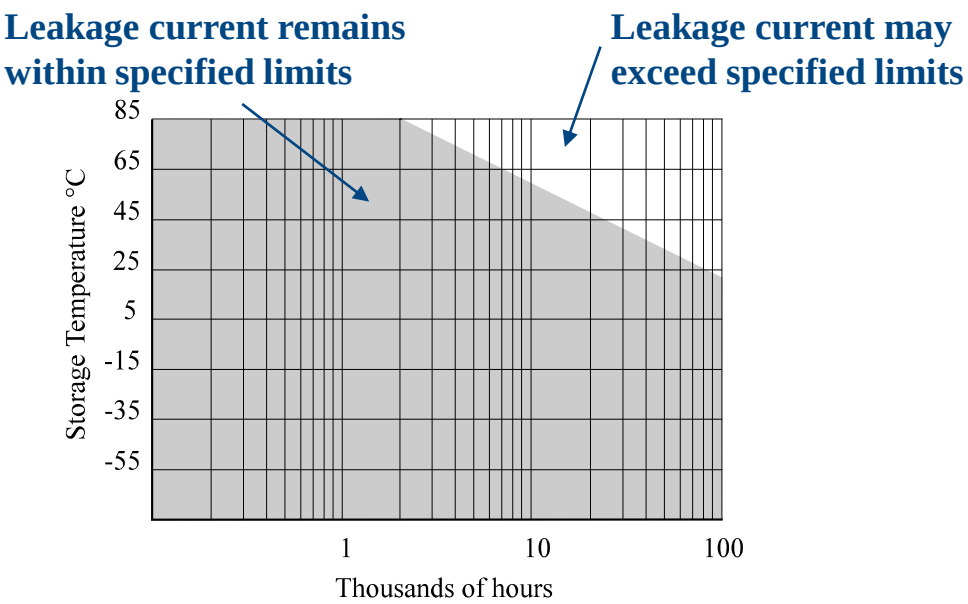
Aging and Shelf Life

- Application of voltage to the capacitor under controlled conditions (temperature, current limit etc…) to repair the oxide and reduce the leakage current.
- Repairs oxide layer :
  - on anode surface (roller damage)
  - on slit edges & cut ends of anode foil and tabs
  - at weld sites (tab-to-foil & tab-to deck)
  - on deck terminals & rivet heads
- Shelf Life

$$AL_2O_3 + 3H_2O \rightleftharpoons 2AL(OH)_3$$

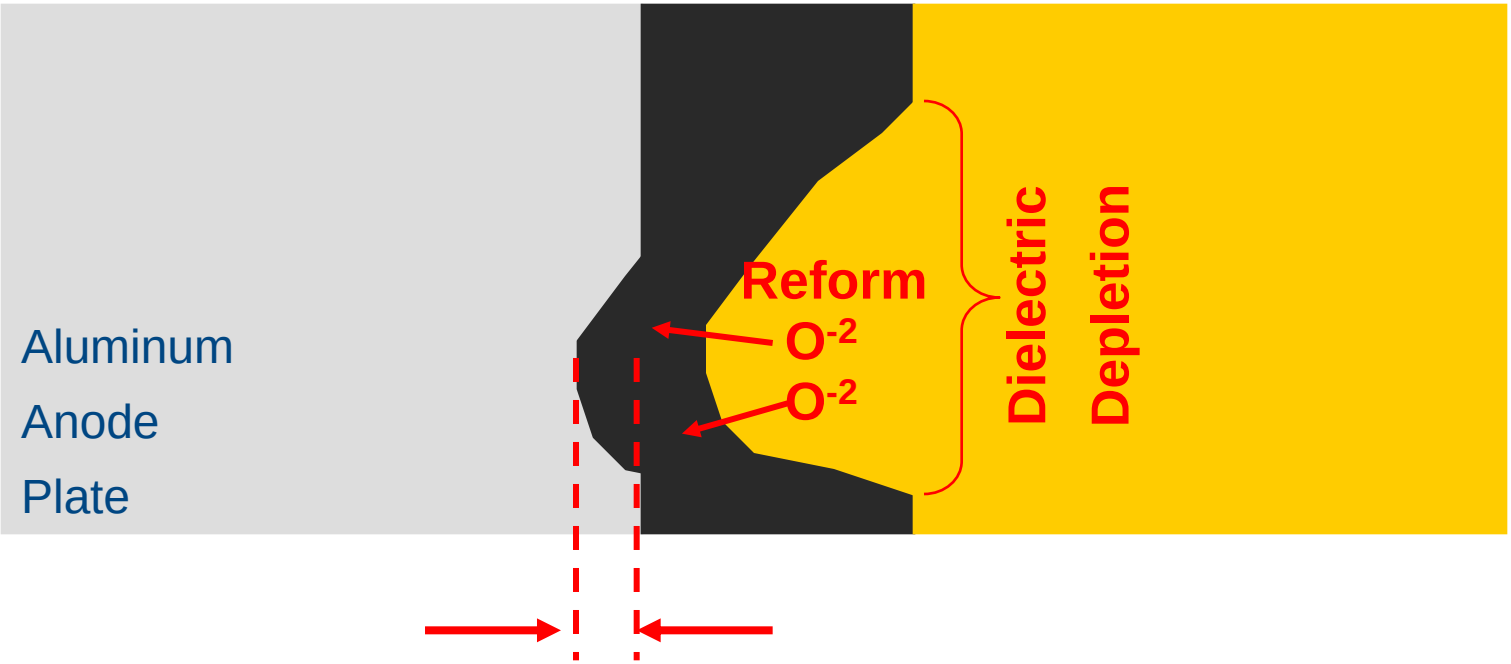
Re-age (Reforming) Procedure

Apply the rated voltage to the capacitor at room temperature for a period of one hour, or until the leakage current has fallen to a steady value below the specified limit. During re-ageing a maximum charging current of twice the specified leakage current or 5mA (whichever is greater) is suggested.



“Reform” / Self-Healing Wet Aluminum

Forward bias is same as formation bias. If dielectric gets thin enough, the forward bias voltage will form new dielectric (thinner than original because $V_{Formation} > V_{Rating} > V_{application}$)

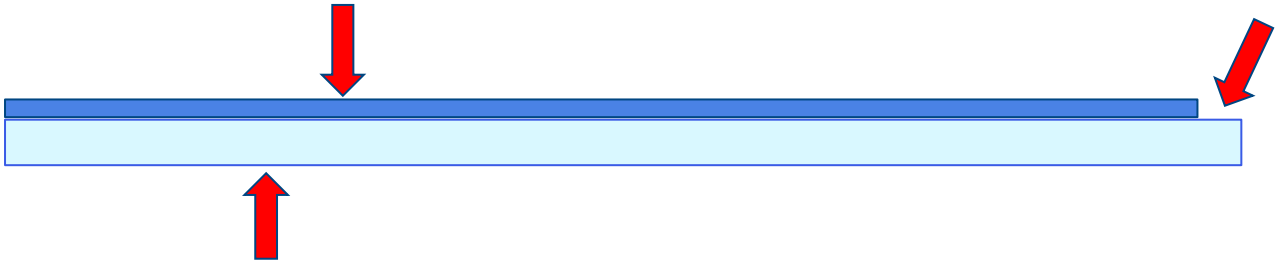


Reformed dielectric region

Metalized Film

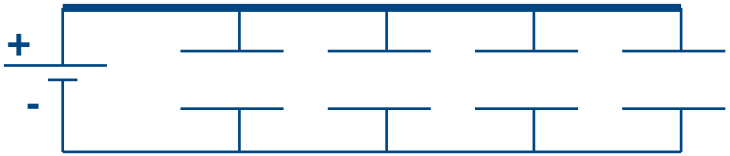
Metallization (few ångström - measured as Ω^2 the higher this value the thinner the metal)

Free Border



PP Film – measured in µm

$$C = \frac{\epsilon_0 K A (n-1)}{d}$$



$C_T = C_1 + C_2 + C_3 + \ldots C_n$

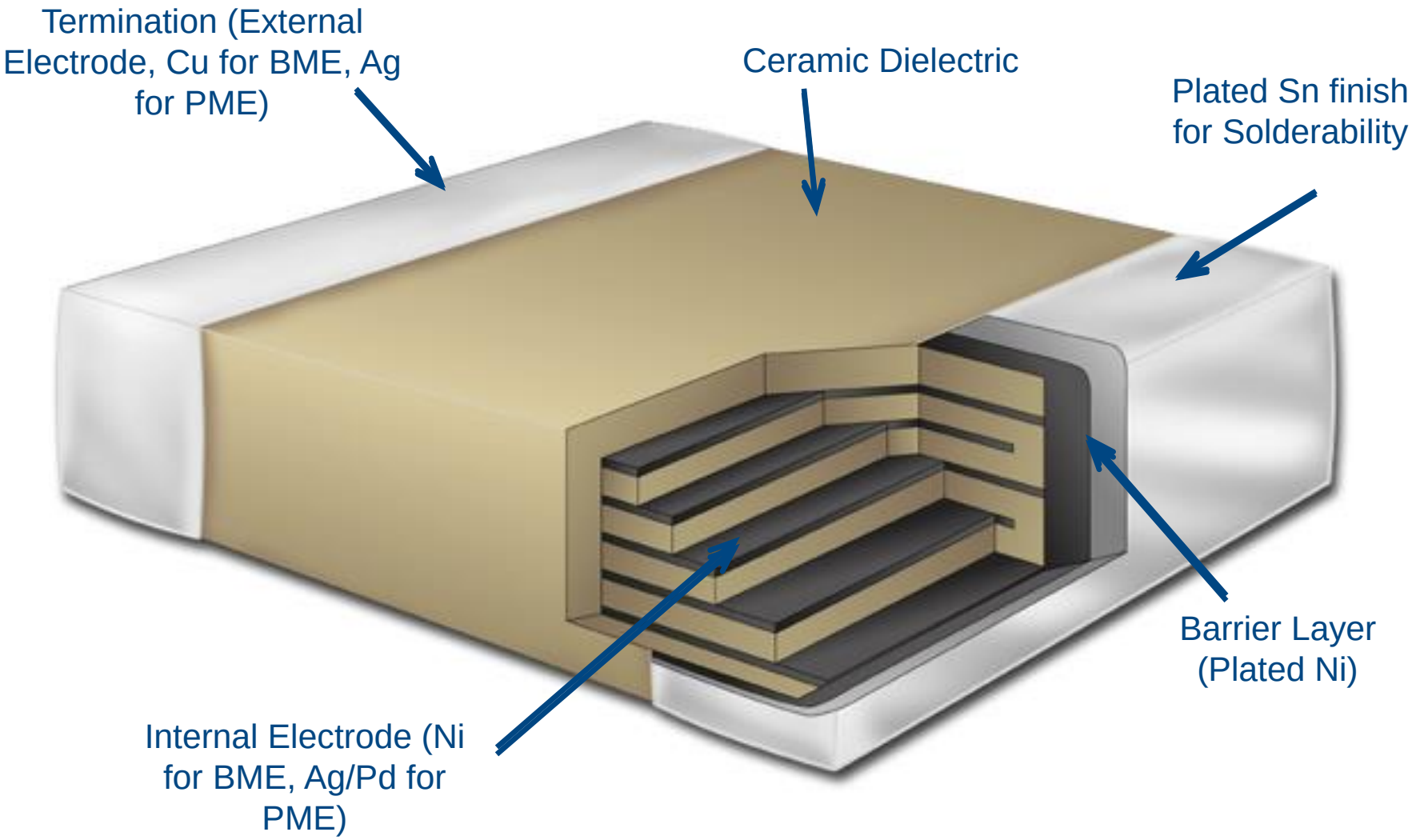
Film Material Comparison

Property	PP	PET	PEN	PPS	MP
Dielectric Constant (@1 KHz)	2.2	3,3	3	3	3.5-5.5
Min Commercial Thickness (µm)	2.4	0,9	1,4	1,2	5-10
DF (% @ 1 KHz)	0.02	0.5	0.4	0.05	1.3
TCC (ΔC/C), -55°C to +125°C	±2.5%	± 5 %	± 5 %	± 1.5 %	± 10 %
Max Temperature Typical (°C)	105	125	125	125	85
Max Temperature Extended (°C)	125	150	170	170	100
Dielectric Breakdown (V/µm)	400	280	300	220	60
Reflow & Multiple Reflows for SMD Tmax (°C)	NO	225-235*	245-255*	260*	250
Self Healing	Good	Medium	Medium-Low	Low	Good

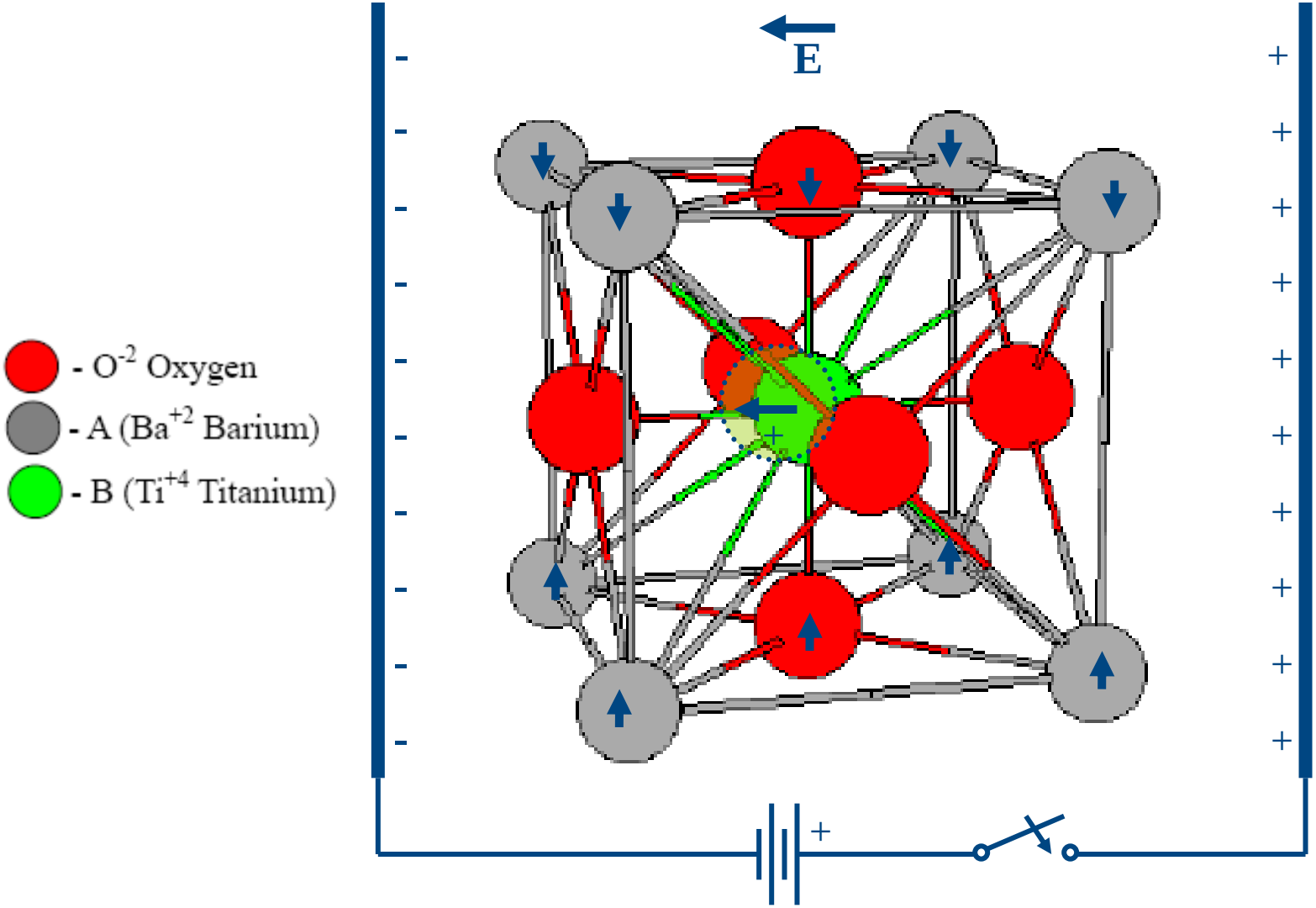
Key Advantage	High Pulse/Voltage/ Freq Application	High Temperature	High Temperature	Very Stable Tight tolerance High Temp	Stable and high dv/dt
Key Limitation	Not suitable for High Temp	Not suitable for High Freq	Not suitable for High Freq	Cost	Not suitable for High Temp

Typical Use	Pulse X/Y DC-Link	Decoupling Filtering	Decoupling Filtering	Coupling Filtering Resonant	Y2 class Applications

Multilayer Ceramic Capacitor (MLCC)

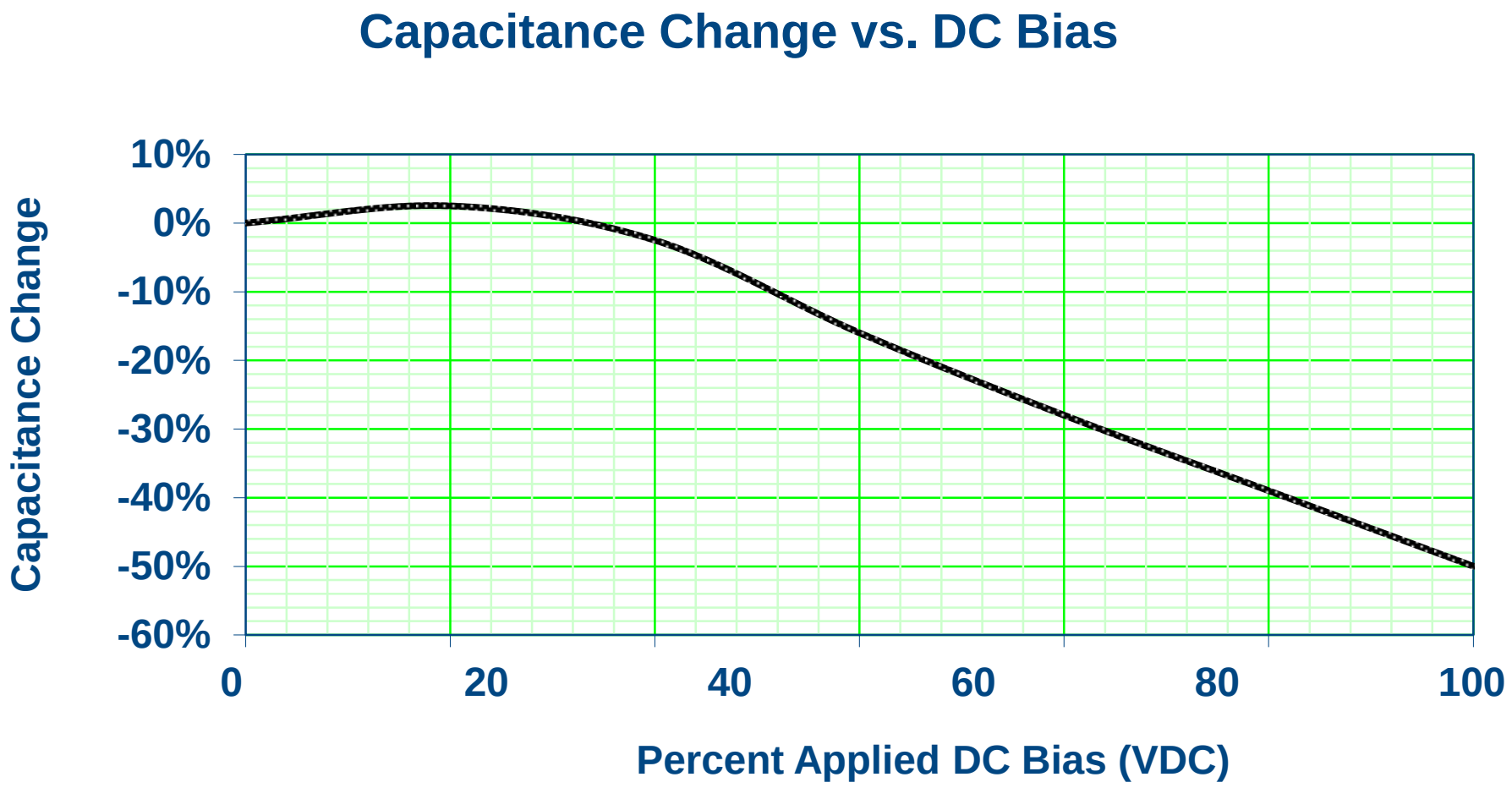


Electrostrictive Behavior in Barium Titanate

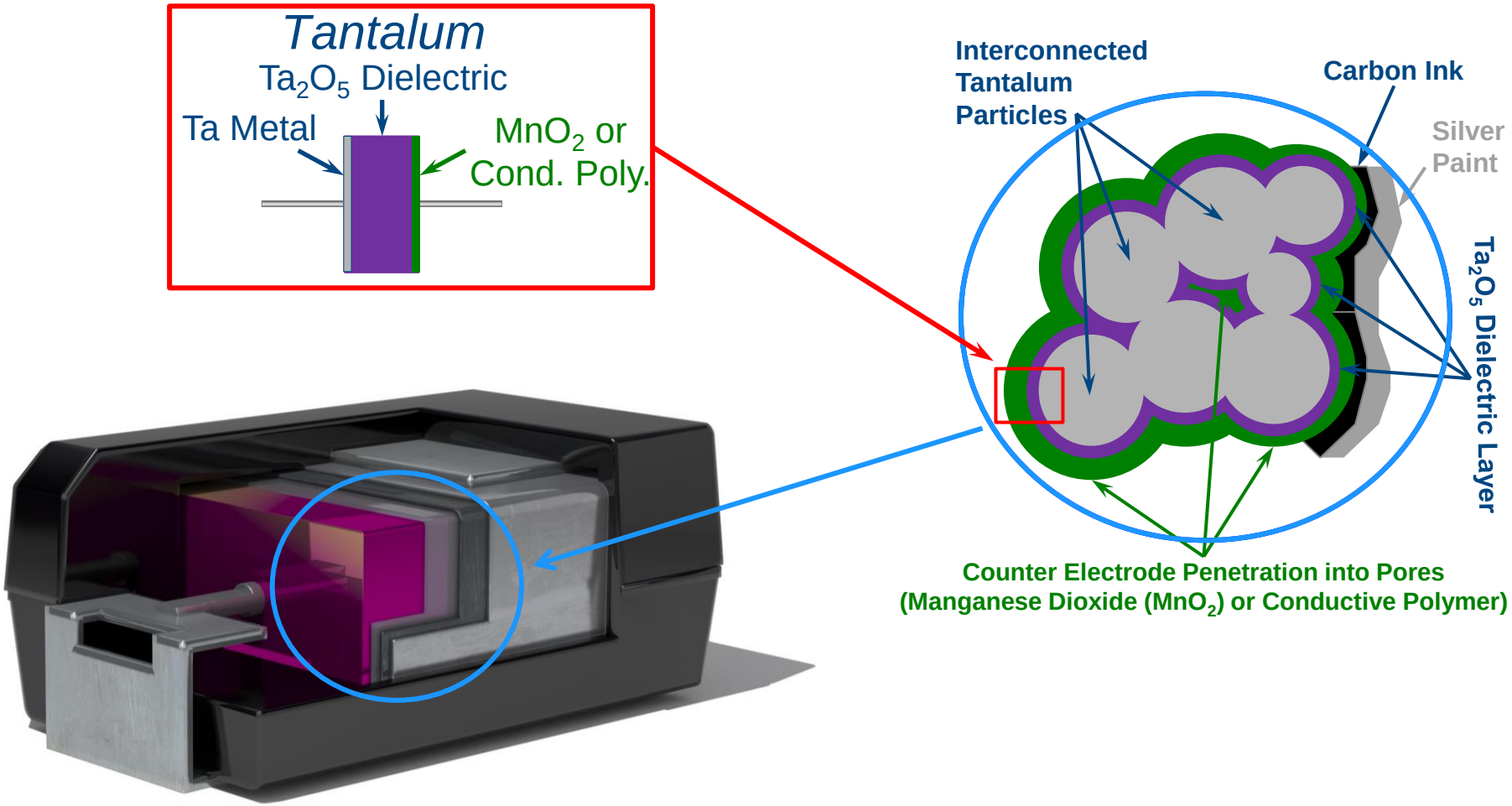


Voltage Coefficient (Class II and III)

Example

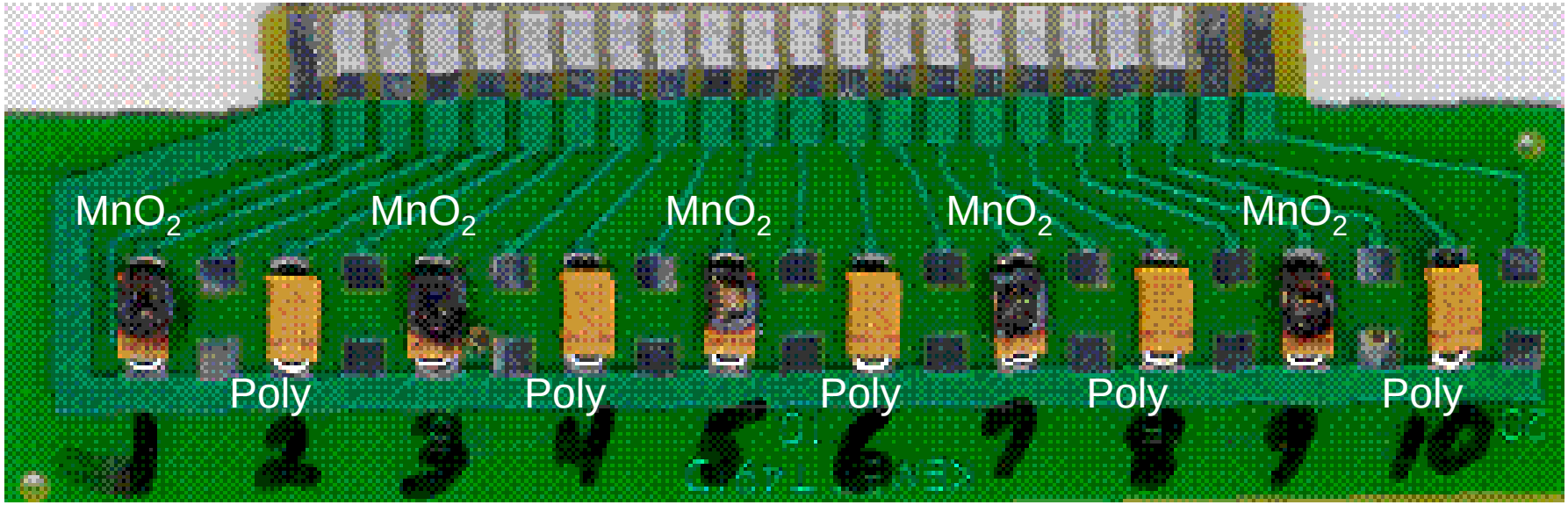


Tantalum Construction



Not All Tantalum Capacitors Burn

- All of the Caps on this board have failed.
  - They are measured as shorts



Test card with capacitors subjected to **2x Rated Voltage**, applied with reverse polarity and > 20 amperes current capability.

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Voltage Derating Guidelines

	Ta-MnO_2	Ta-Poly KO V_R>10VDC	Ta-Poly KO V_R≤10VDC	Alum-Poly AO
100 PPM FR % V_{Rated}	68%	126%	197%	235%
@50% V_{Rated} FR(PPM)	9	0	0	0
@80% V_{Rated} FR(PPM)	458	4	1	0
@90% V_{Rated} FR(PPM)	1,700	12	2	0
@100% V_{Rated} FR(PPM)	6,310	35	8	0

- Typical derating guidelines:
  - Tantalum MnO_2: 50%
  - Tantalum Polymer: 20%(>10V), 10% (≤10V)
  - Aluminum Polymer: 0%!

Quick Compare

	Al-Elect	Ta	Ceramic	Al-Poly	Film
SMT	Limited	Yes	Yes	Yes	Limited
Polar?	Yes	Yes	No	Yes	No
C>300uF	Yes	Yes	No	Yes	Large
+125° C	No	DR	By Diel.	Yes	By Diel.
Pb-Free 260° C	No	Yes	Yes	Yes	Limited
Lo-Freq	Excellent	Good	Poor	Good	Excellent
Hi-Freq	Poor	Fair	Excellent	Good	Excellent
TCC (%Lo/%Hi)	-xx/+15	-10/+15	By Diel. (X_R) -12/-13	-10/+13	By Diel
VCC	Stable	Stable	By Diel. (-0% to -90%)	Stable	Stable
SMT Cracks	No	No	Yes	No	No
Aging	No	No	1% to 10% Per Decade-Hour	No	No
Optimum Piezo	NA	NA	By Diel. (DC-30 kHz)	NA	NA

DR Derating Required

Quick Compare - Ranking

	Al-Elect	Ta	Ceram	Al-Poly	Film
ESR	5	4	1	3	2
ESL	5	3	1	3	3
DCL	5	3	1	4	2
Self-Healing	Yes (Reform)	Yes	No	Yes	Yes
Wear-Out	Yes	No	Aging	No	No
Shelf Decay	Yes	No	No	No	No
Volumetric Eff.	4	1	3	2	5
Over-Volt Capability	3	5	1	2	4
Cost	2	3	1	3	5
Pb-Free	No	Yes	Yes	Yes	Yes
Failure Mode	Open/Short	Short	Short	Short	Open/Short
Piezoelectric	No	No	Yes	No	No

Ranking 1 = Best, 5 = Worst

Thank You!

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