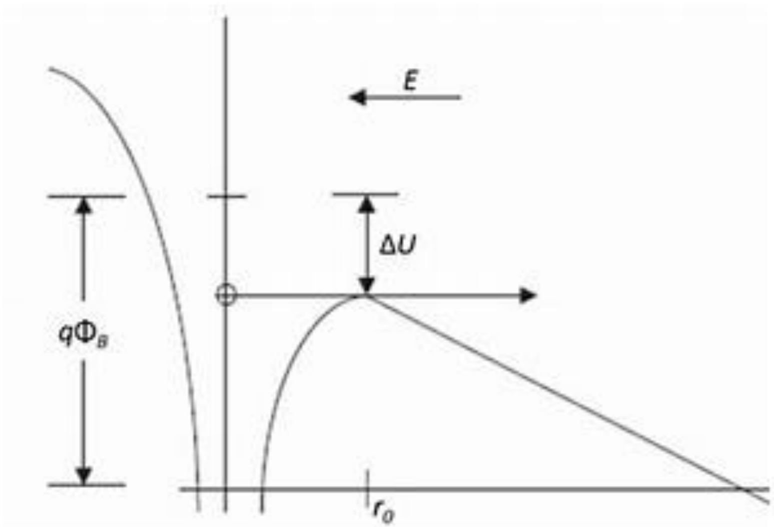
Derating and Technology in Polymer Tantalum Capacitors

Y. Freeman and P. Lessner

Leakage Current and Electric Field

Poole-Frenkel Conduction



$$J \propto E \exp\left(\frac{q\sqrt{qE/(\pi\epsilon)}}{k_B T}\right)$$

$$E = V_a/d$$

V_a – applied voltage
d – dielectric thickness

Capacitor World (Murata 2000)

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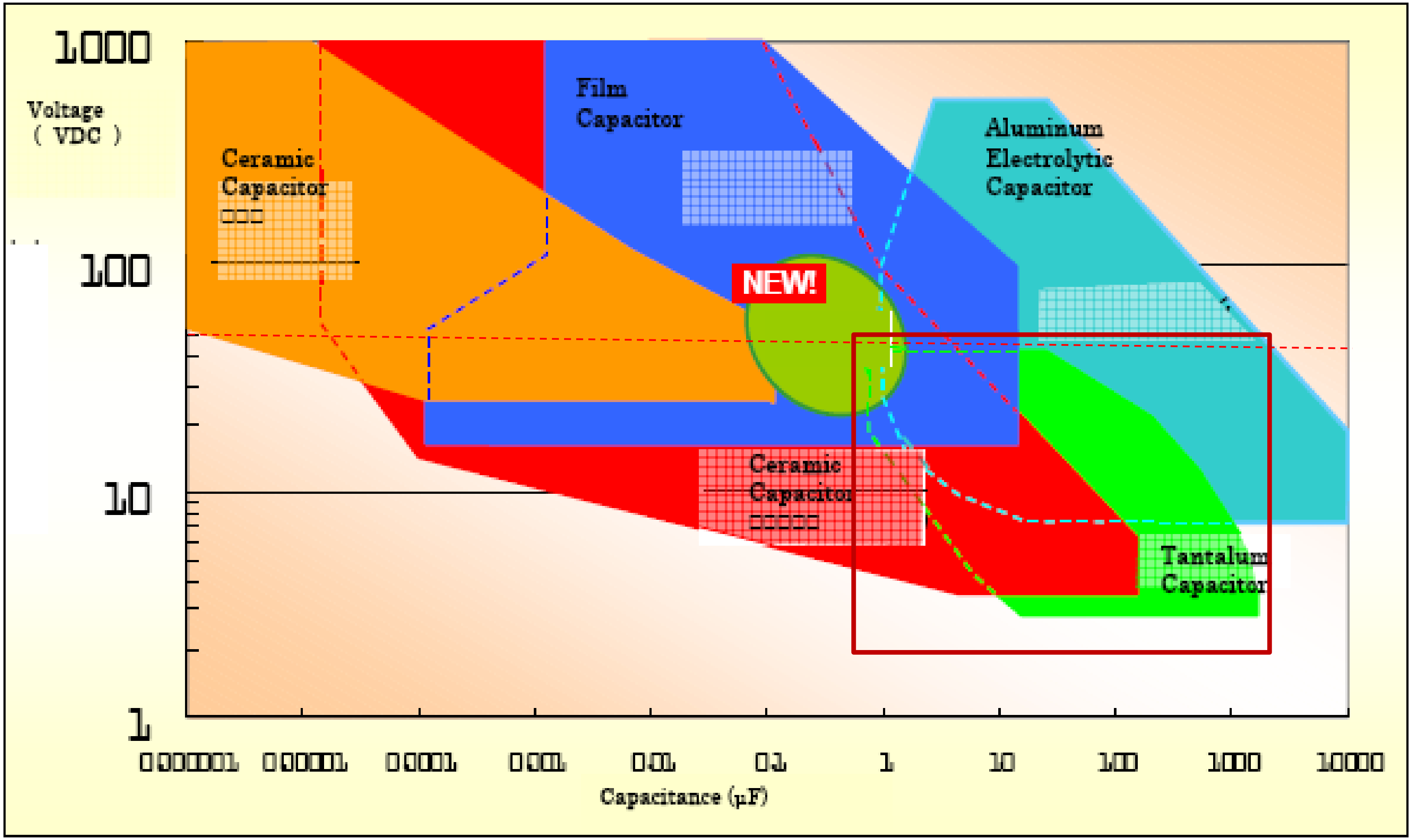
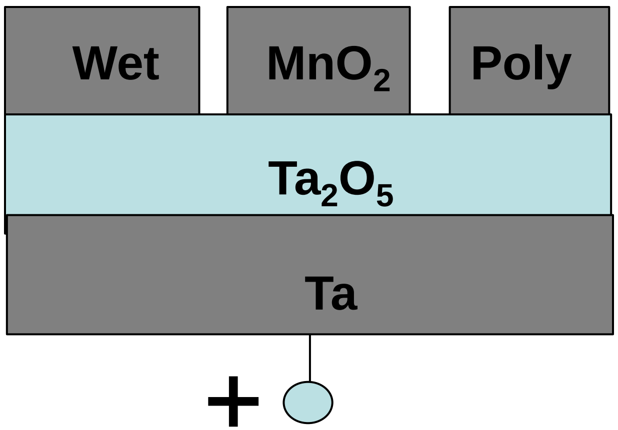
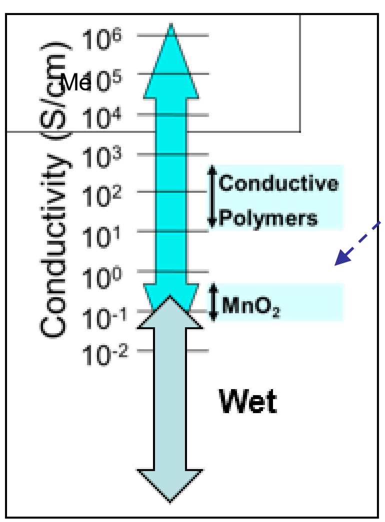


Evolution of Ta Capacitors

$MnO_2 = MnO + O$





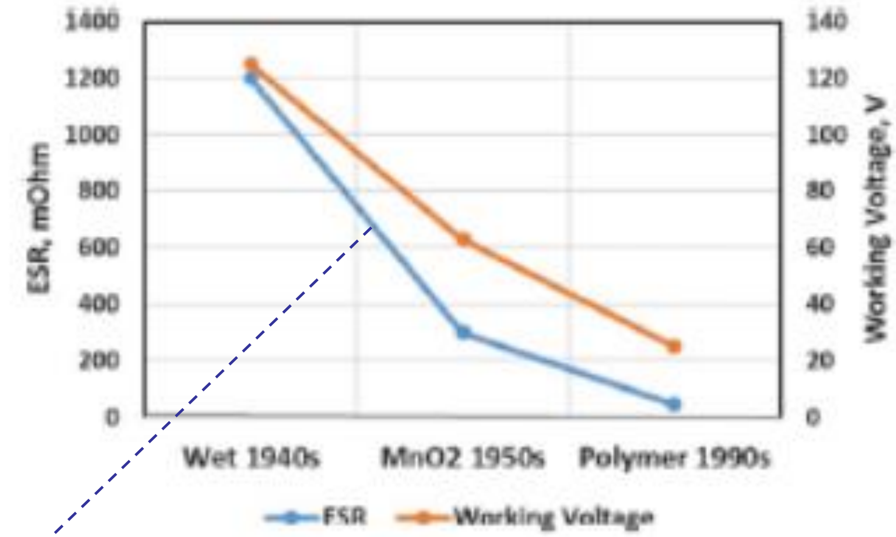


Fig. 4 ESR and maximum working voltage in different types of tantalum capacitors

Ignition Failure Mode

Solid Electrolytic Ta Capacitors

rated voltage reversed

All Solid Ta Capacitors

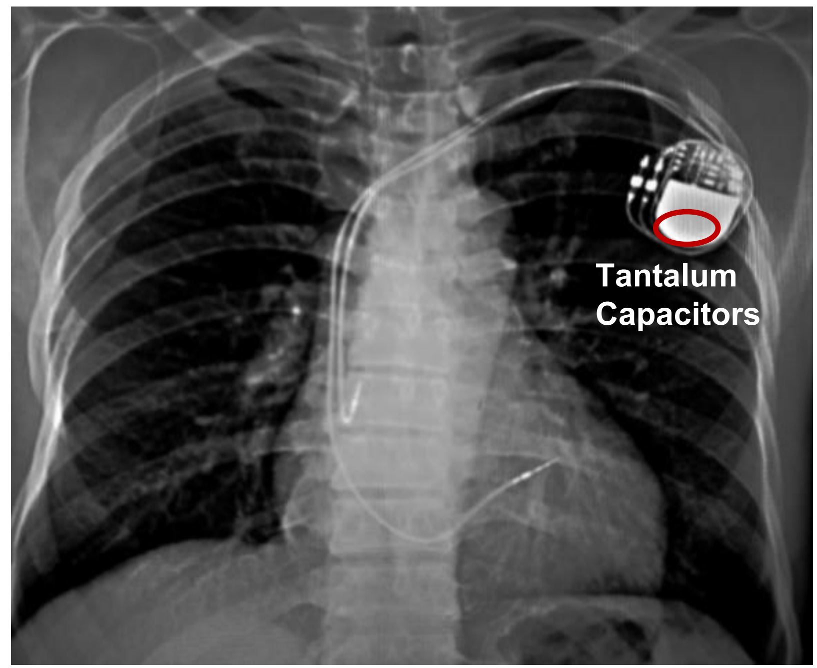
a b c

Fig. 3.27 Tantalum anode ignited with a burner (a), burning (b) and cooled to room temperature (c)

Volumetric Efficiency

Stationary defibrillator

ICD



Wikipedia

Volumetric Efficiency and Derating

C~A/d

50% Derating

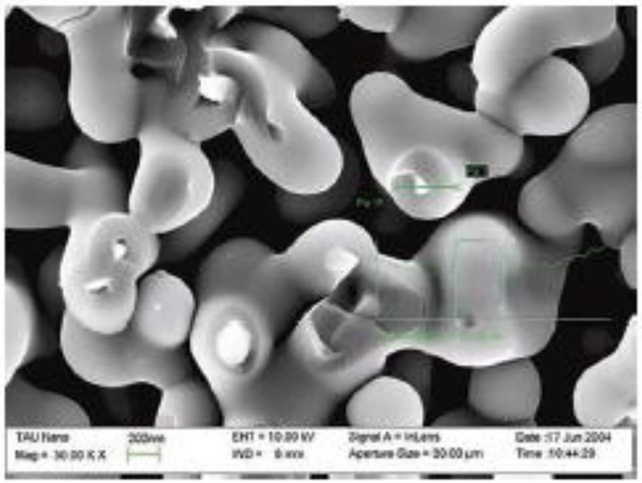


Fig. 3.3 Breakage of the tantalum anode sintered with 50,000 µC/g tantalum powder and formed to 75 V

Fig. 3.16 Solid Electrolytic Tantalum capacitors: D-case 4.7 µF, 50 V (*left*), and A-case 4.7 µF, 25 V (*right*)

increased
volume,
weight,
cost

Effect of Dielectric Thickness

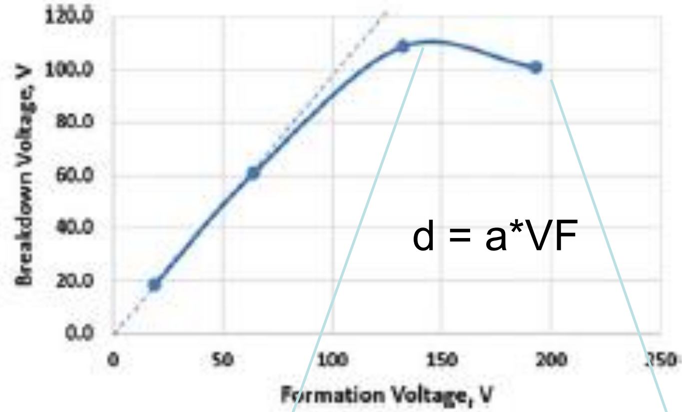


Fig. 3.18 Breakdown voltage dependence on formation voltage in Solid Electrolytic Tantalum capacitors

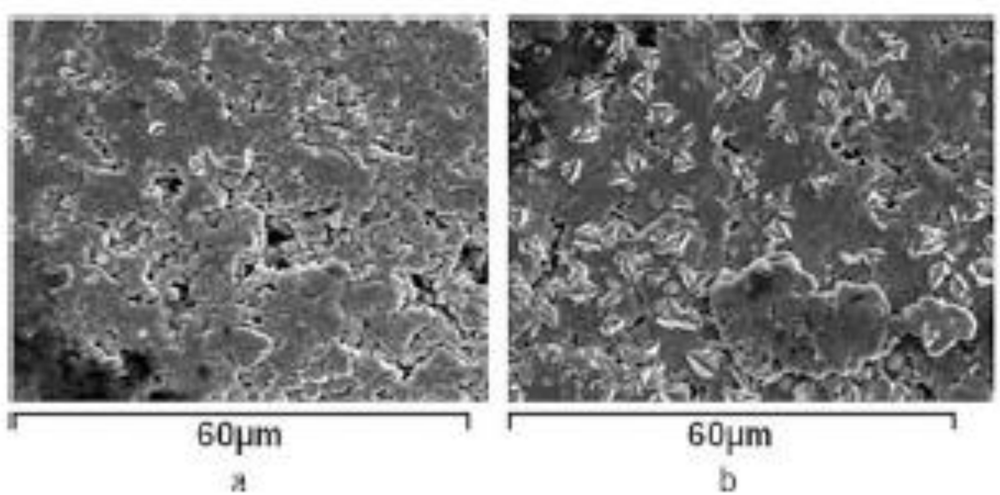
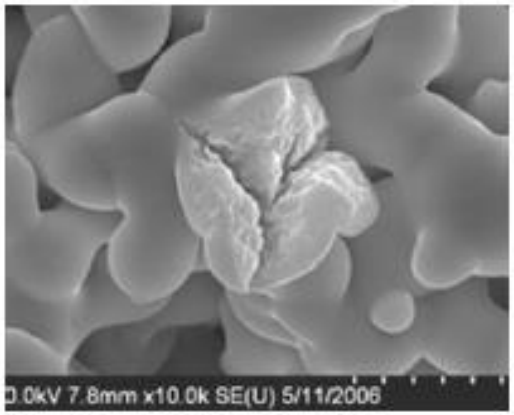


Fig. 3.17 SEM images of tantalum anodes formed at formation voltages 130 V (a) and 190 V (b)

Crystallization and Flawless Dielectric Technology (F-Tech)

Conventional

Fig. 1.8 Cracks from a crystal growing in anodic oxide film on tantalum anode with critical oxygen content



F-Tech

Fig. 2.25 SEM image of flawless Ta_2O_5 dielectric formed on F-Tech tantalum anode

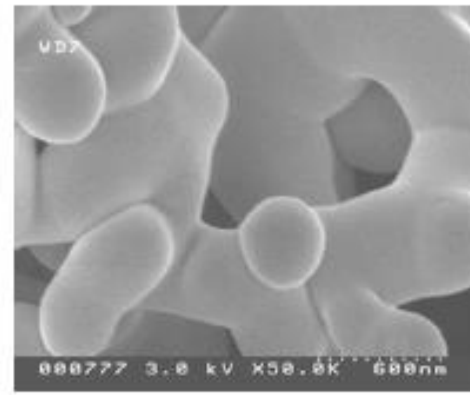
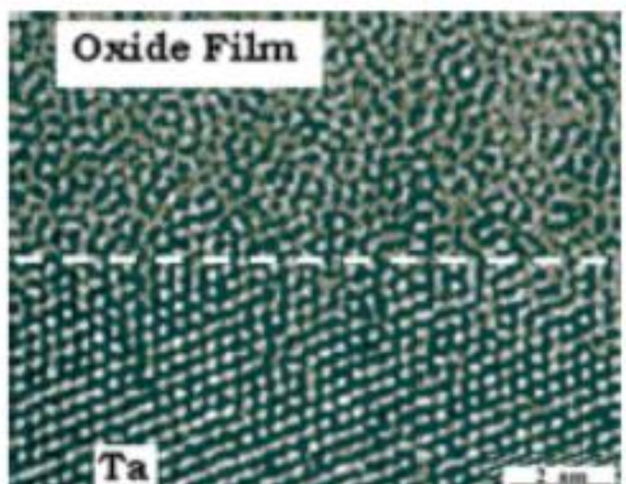


Fig. 1.2 TEM image of the amorphous anodic oxide film formed on crystalline tantalum (the white spots represent individual atoms)



Simulated Breakdown Screening (SBDS)

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BDV Before/After SBDS

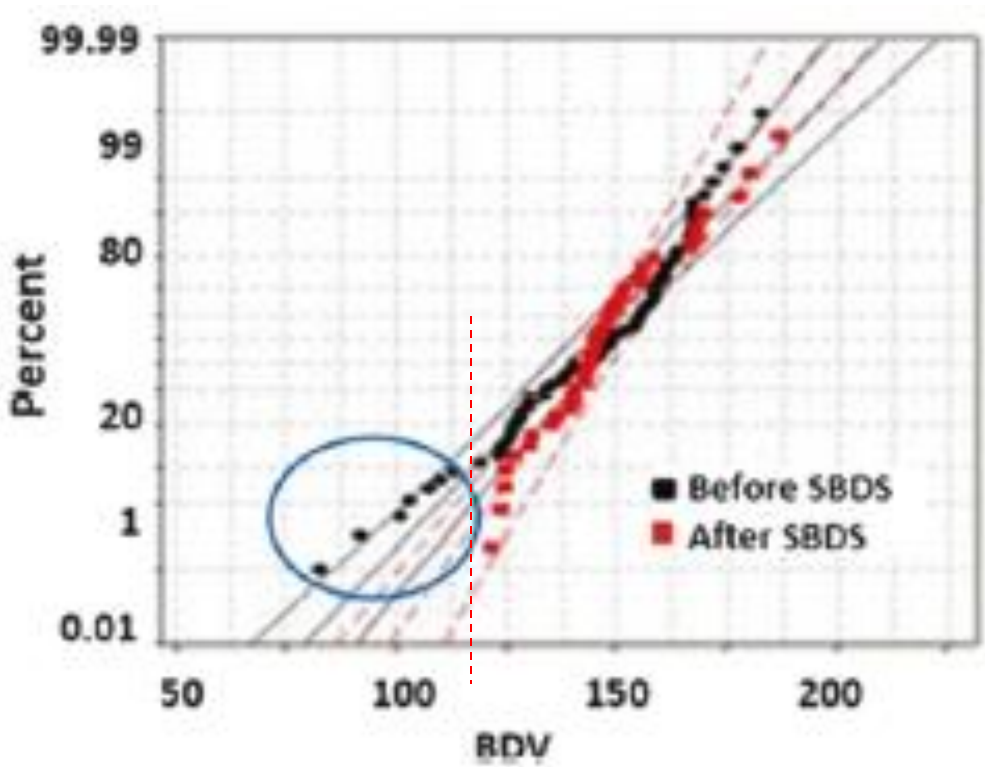

Fig. 2.33 BDV distributions in D-case 4.7 µF–50 V Solid Electrolytic Tantalum capacitors before and after SBDS

Customers on F-Tech/SBDS and Advantages of Lo/No De-rating

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Northrop Grumman in Proceedings CARTS USA 2014

The F-TECH Process Demonstrated Improved Capacitor Failure Rate Versus "Standard" Processing

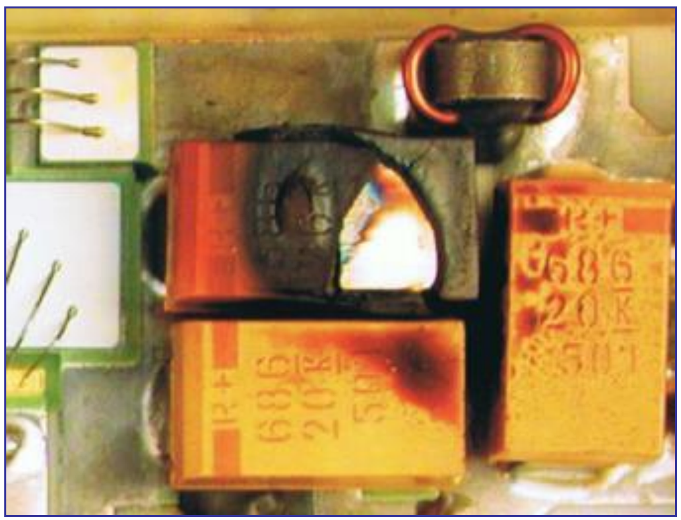
Industry average 0.1% lots	Industry average 1% lots	KEMET F-Tech/SBDS
1.65E-03	2.60E-03	3.64E-11

Time-to-failure for 1M parts:	***8 months***	***12 months***	***~ 5,000 years***

Efficient, Reliable, and Cost Effective with Low/No Derating

No Ignition Failure Mode in Ta/MnO2 Capacitors

"Burning Tantalum"



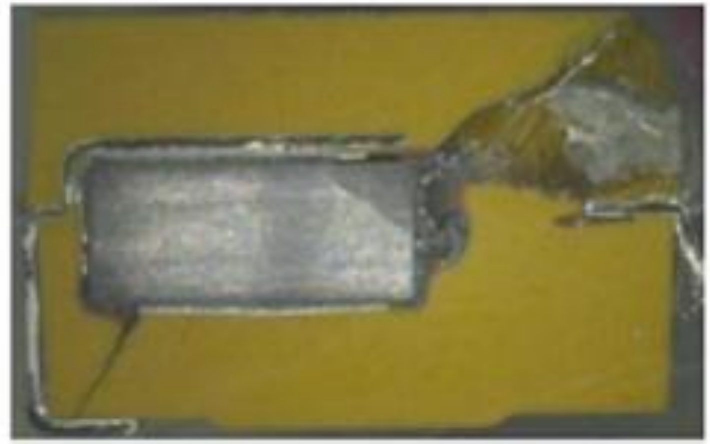


Fig. 3.28 Cross section of the failed short X-case 6.8 µF, 50 V Solid Electrolytic Tantalum capacitor

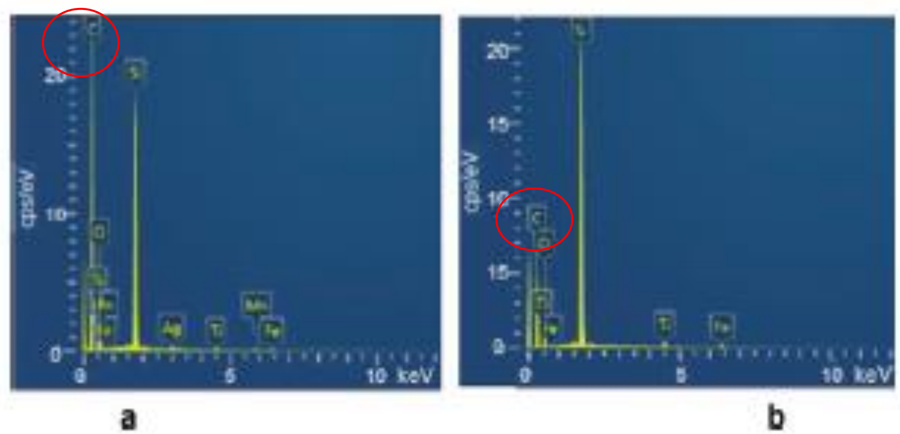


Fig. 3.29 EDX spectrums of the epoxy compound inside (a) and outside (b) the black mark on the surface of the epoxy compound in failed short X-case 6.8 µF, 50 V Solid Electrolytic Tantalum capacitor

Progress in Polymer Tantalum Capacitors (PTC)

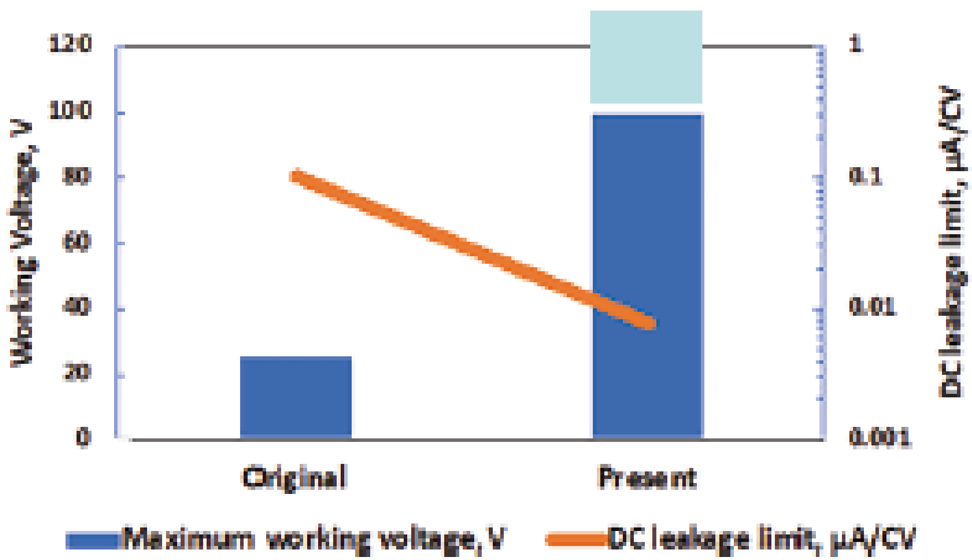
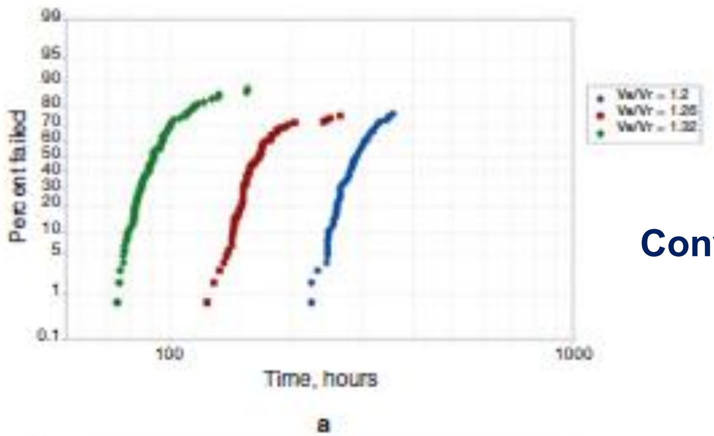
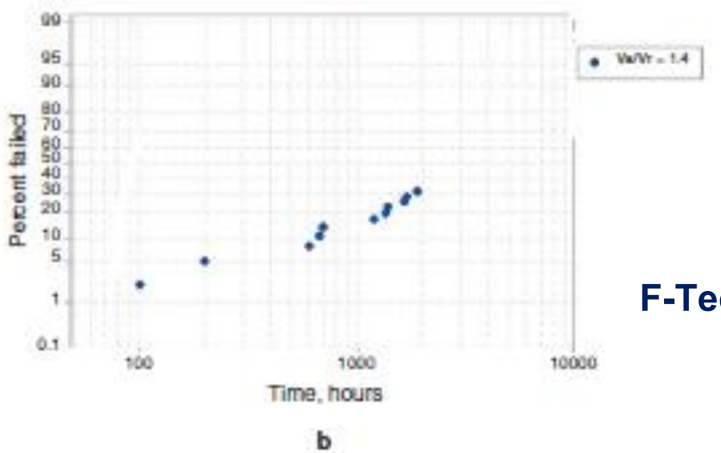


Fig. 3.31 Maximum working voltage and DC leakage per CV limit in Polymer Tantalum capacitors

No Wear-Out in PTC with F-Tech



Conventional



F-Tech/SBDS

Fig. 3.20 Cumulative percent of failed parts versus time at accelerated test of H-case 220 µF, 25 V Polymer Tantalum capacitors manufactured with conventional technology (a) and F-Tech (b) at different V_a/V_r and 105 °C

$$A = A_V * A_T$$

Av – Weibull equation
A_T – Arrhenius equation

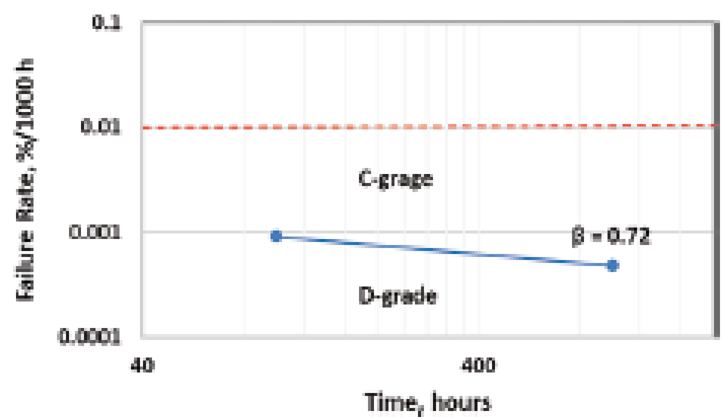


Fig. 3.21 Failure rate vs. time in H-case 220 µF, 25 V Polymer Tantalum capacitors manufactured with F-Tech and tested at V_a/V_r = 1.4 and 105 °C

Long-term Stability vs. Rated Voltage

75V **60V**

Humid

Dry

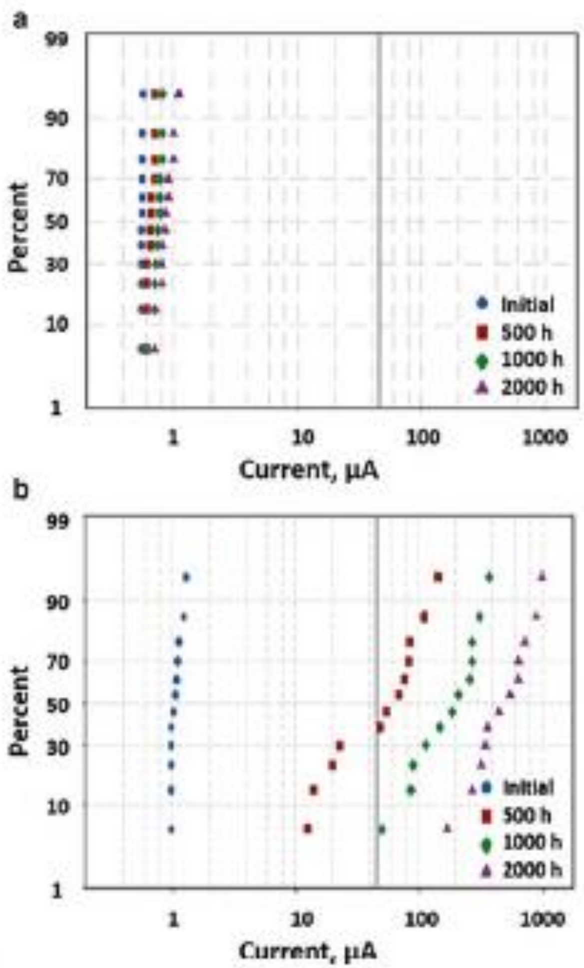


Fig. 3.40 DCL during life test at rated voltage and 85 °C in B-case 75 µF–75 V humid (a) and dry (b) PHS Tantalum capacitors

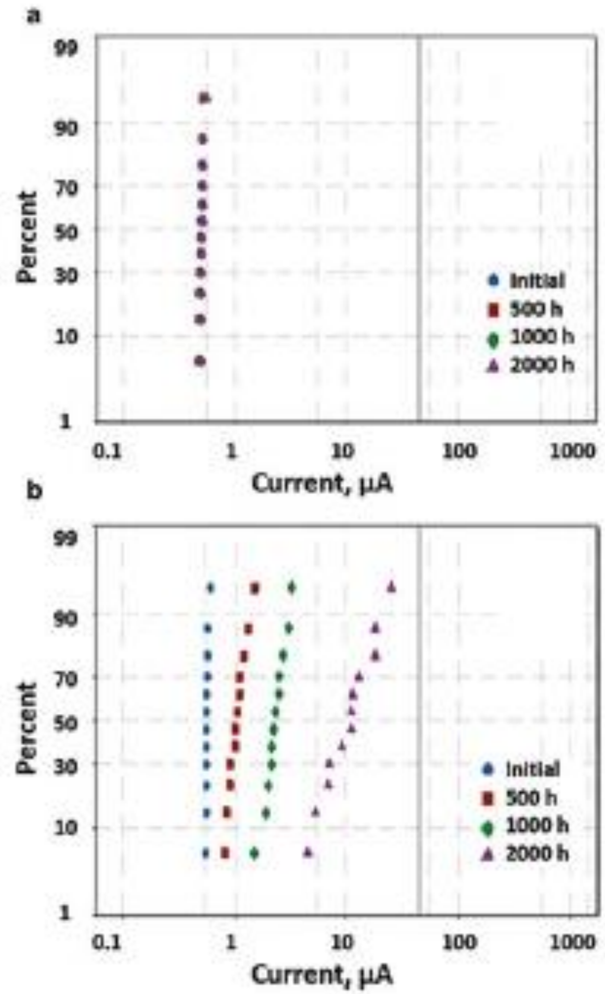


Fig. 3.42 DCL during life test at rated voltage and 85 °C in humid (a) and dry (b) B-case 100 µF–60 V PHS Tantalum capacitors

Anomalous Charge Current (ACC) in Dry PTC

Effect of Polymer Cathode

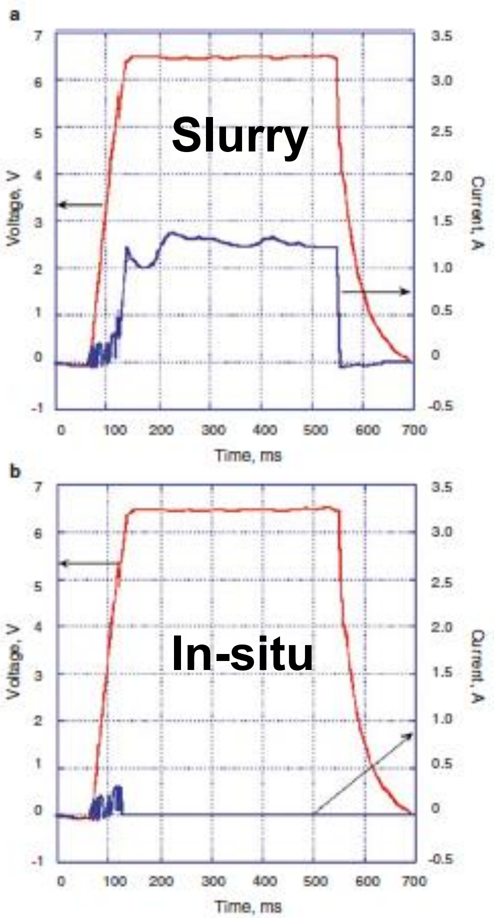


Fig. 3.61 *I*(*t*) response to one pulse, *V*(*t*), applied at –200 °C to a W-case 470 μF–6.3 V hybrid (a) and pure in situ (b) Polymer Tantalum capacitors

Conventional vs. F-Tech

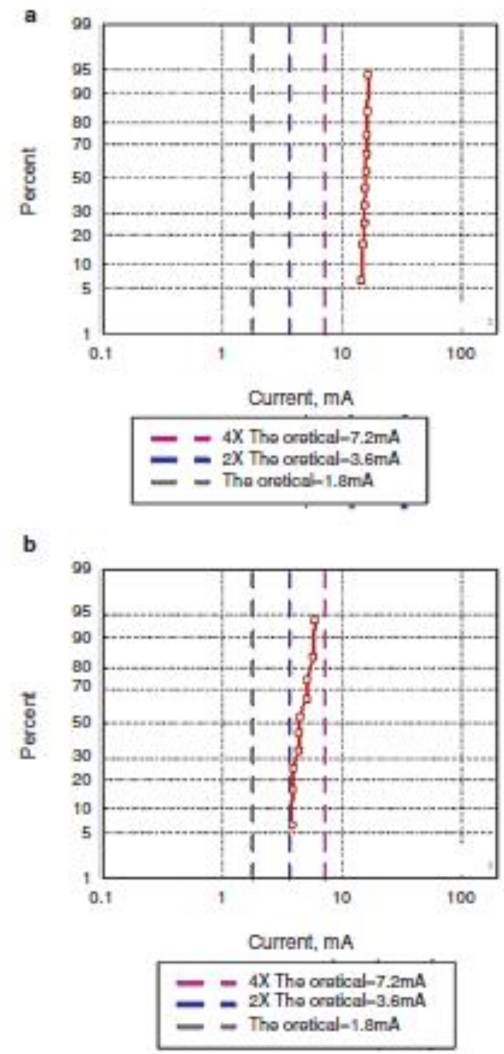


Fig. 3.64 Probability plots for the current distributions in D-case 15 μF–35 V Polymer Tantalum capacitors with slurry PEDOT cathodes and either conventional dielectric technology (a) or F-Tech (b) charged to 28 V with a ramp of 120 V/s

Polymer Hermetic Seal (PHS) Ta Capacitors

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(12) **United States Patent**
Chen et al.

(10) **Patent No.:** **US 8,379,371 B2**
(45) **Date of Patent:** **Feb. 19, 2013**

(54) **UTILIZATION OF MOISTURE IN HERMETICALLY SEALED SOLID ELECTROLYTIC CAPACITOR AND CAPACITORS MADE THEREOF**

(75) Inventors: **Qingping Chen**, Simpsonville, SC (US); **Yuri Freeman**, Greer, SC (US); **Steven C. Hussey**, Simpsonville, SC (US)

(73) Assignee: **Kemet Electronics Corporation**, Simpsonville, SC (US)

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C(f,T) in Wet and PHS B:82-75

Wets

PHS

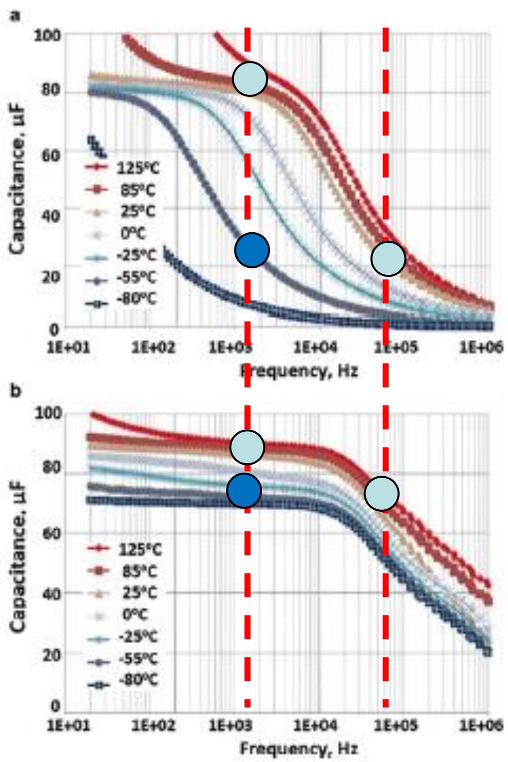

Fig. 3.37 Capacitance vs. frequency and temperature in B-case 82 µF–75 V Wet (a) and PHS (b) Tantalum capacitors

10,000h Life at 85C and RV

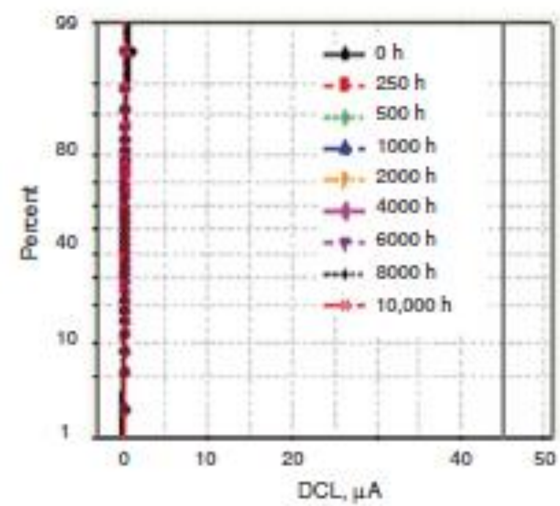

Fig. 3.35 DCL distributions in B-case 100 µF–60 V PHS Tantalum capacitors during life test at rated voltage and 85 °C

Effect of Radiation

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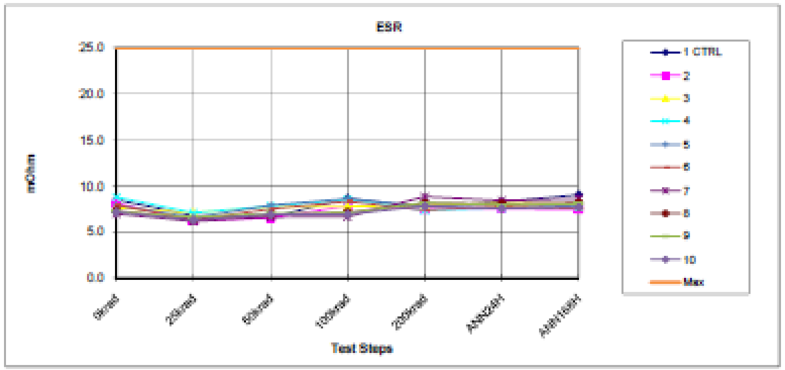
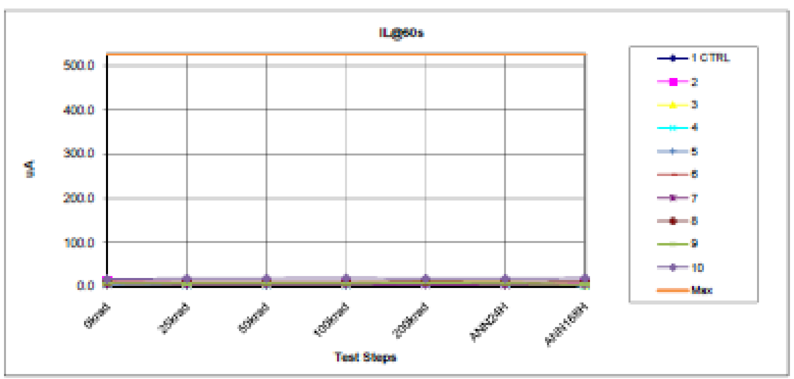
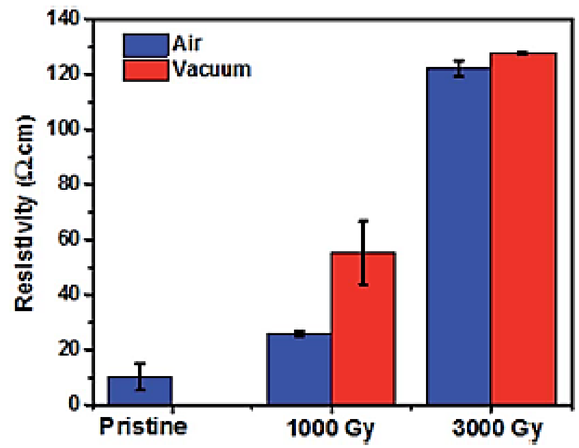
Solid Electrolytic Ta Capacitors





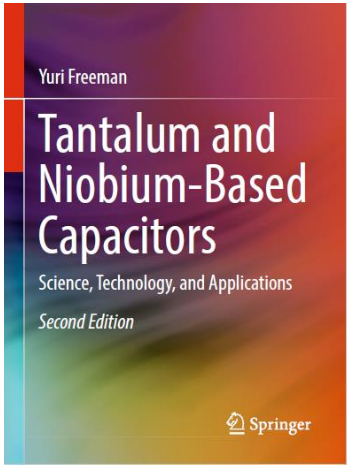
ALTER TECHNOLOGY	TOTAL DOSE RADIATION TEST REPORT No. ATN-RR-317	Issue/Rev: 1	Page: 3/12
		Date: 2014/12/18	
		R.L: 2014900938	

Cathode in Polymer Ta Capacitors



Resistivity as a function of dose for the PEDOT-PSS samples irradiated in air and vacuum [5]

[5] Anbalagan, A. K.; Gupta, S.; Chaudhary, M.; Kumar, R. R.; Chueh, Y.-L.; Tai, N.-H.; Lee, C.-H., Consequences of gamma-ray irradiation on structural and electronic properties of PEDOT:PSS polymer in air and vacuum environments. RSC Advances 2021, 11 (34), 20752-20759.



Questions?

Consulting:
Science, Technology, and Applications of Tantalum Capacitors

Purpose:
Efficient, reliable and cost effective Ta solutions for your applications

Dr. Yuri Freeman
Ekeberg Prize and Tantalum Hall of Fame
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