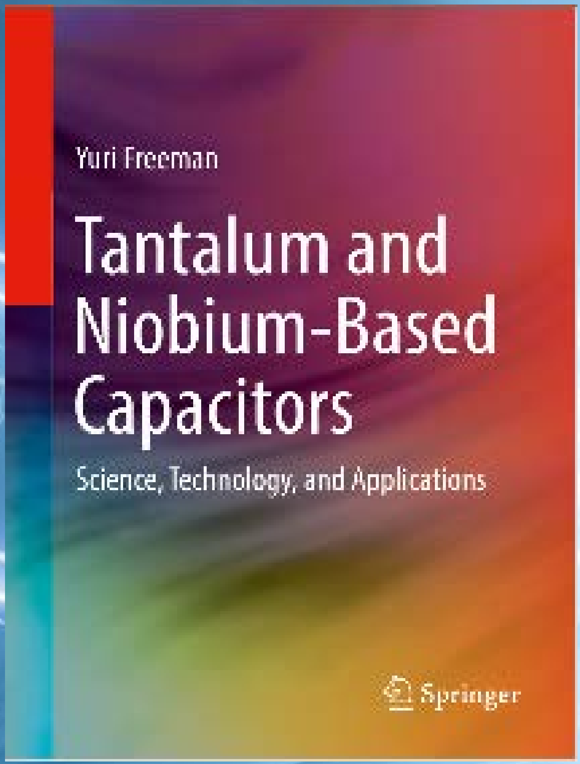

Electronic Components
KEMET
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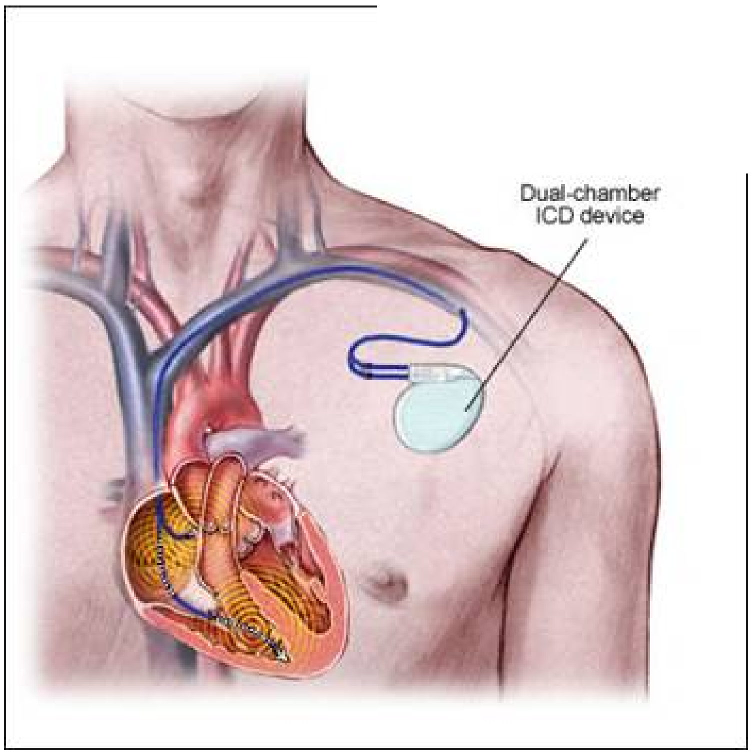
Tantalum Capacitors in Space Applications

Y. Freeman

October 2018

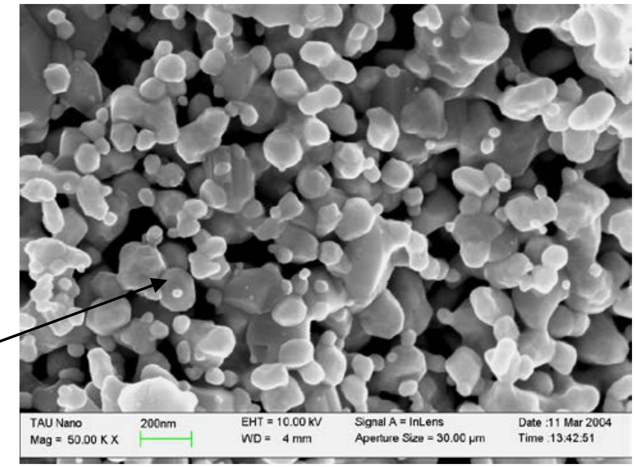
Efficiency

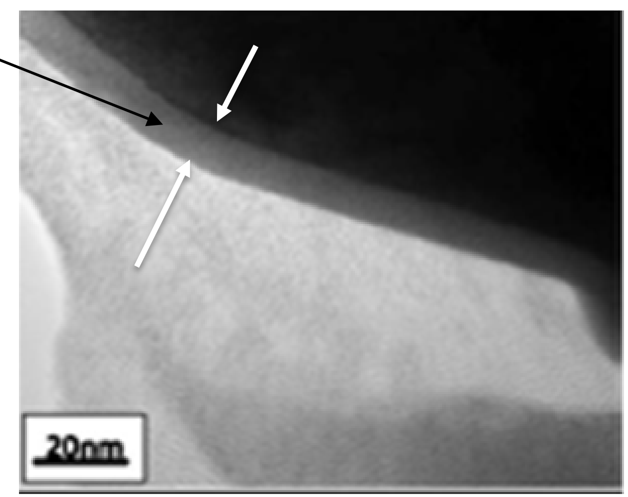
Fig. 1 Medtronic cardio implant with tantalum capacitors



With permission from Medtronic Corporation

$$C \sim \frac{A}{d}$$

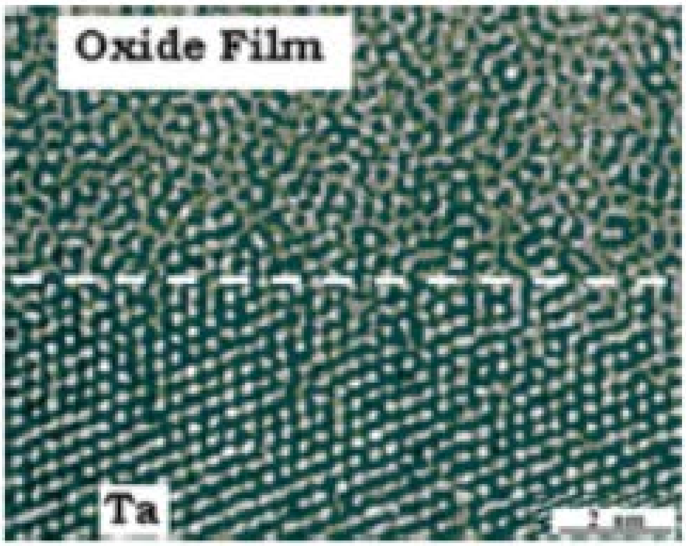




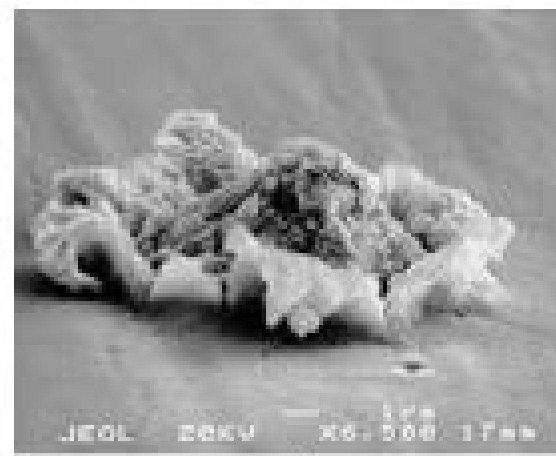
Charge time ≤ 8s

Entropy

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



Entropy



a

Fig. 1.14 SEM image of the anodic oxide film

Entropy (instability) increases with dielectric thickness (voltage)

F-Tech and SBDS

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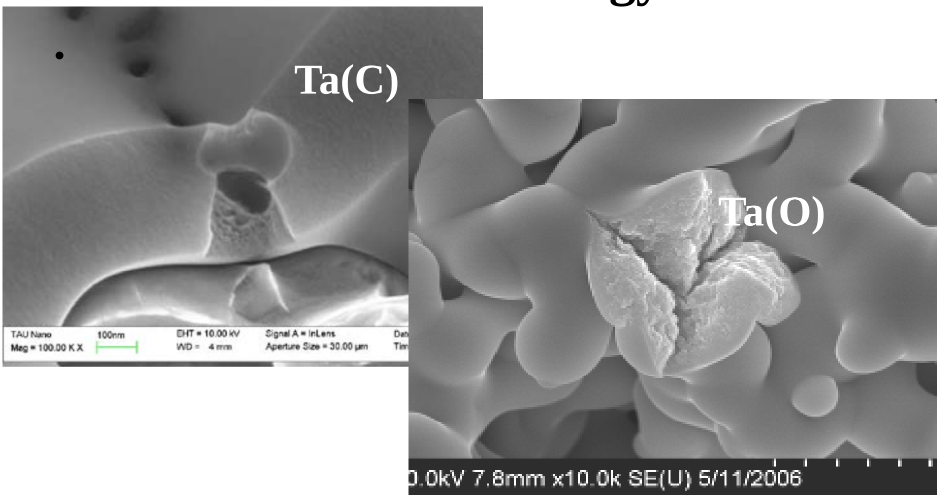
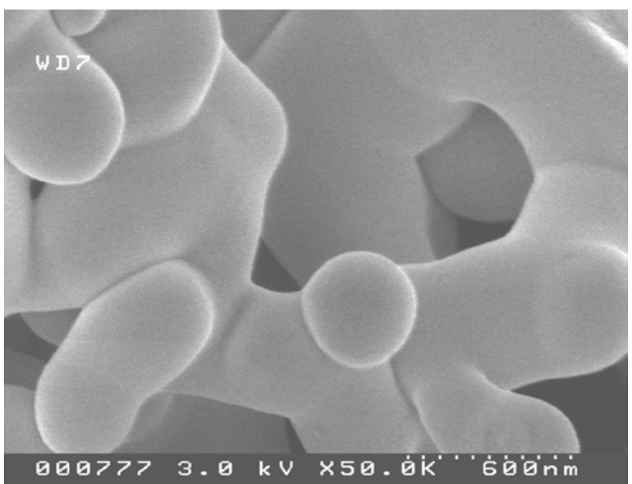
Conventional Technology

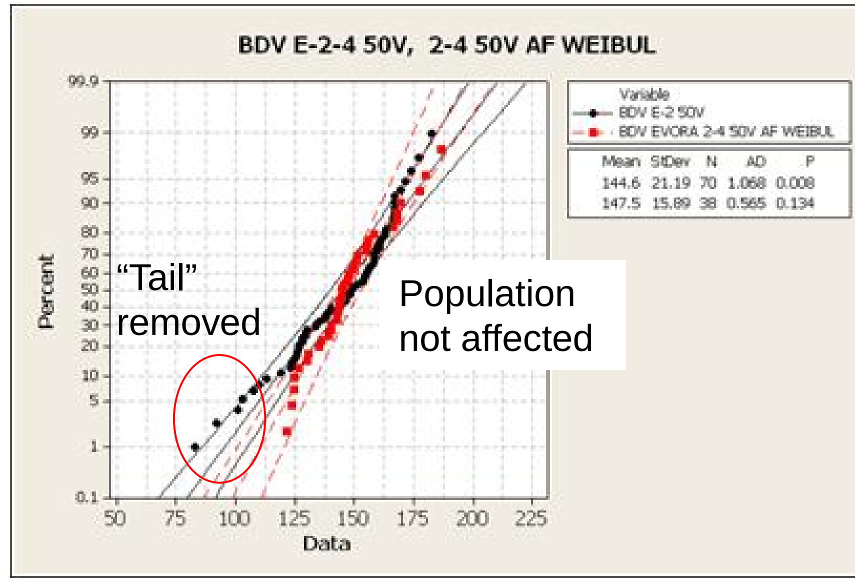


F-Tech



(verified on every production lot)

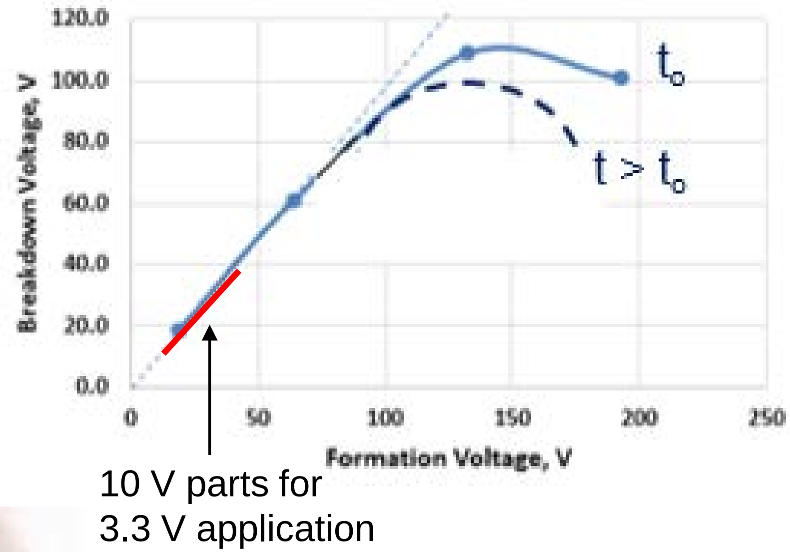
100% Simulated Breakdown Screening (SBDS)



Crystallization will happen, but this can occur in 100 hours or 100 years

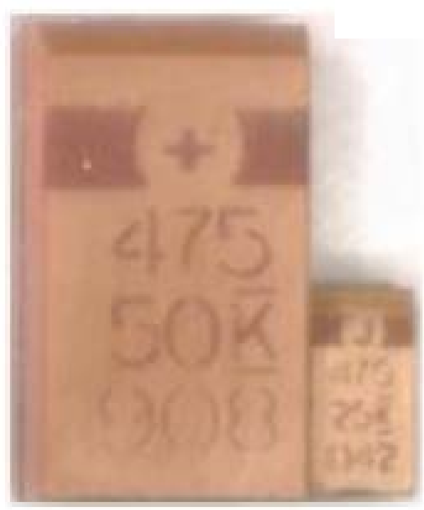
De-rating

$$\frac{t_1}{t_2} = \left(\frac{V_2}{V_1}\right)^n exp\left[\frac{E_a}{kT}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)\right]$$



$V_{50}/V \approx 10$

Fig. 3.19 MnO_2 tantalum capacitors: D-case 4.7 µF, 50 V (*left*), and A-case 4.7 µF, 25 V (*right*)



Hi-Rel and COTS vs. Commercial (Automotive)

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	MIL-PRF-55365 T-Level	MIL-PRF-55365	COTS	Commercial
KEMET Series	409/419/429/492	409/419/429/492	497*	490/491
DPA	X			
100% X-ray	X			
Group C Testing	X			
+3 Std Dev Screening	X			
Established Relaibility	B, C, D	B, C, D	B, C	
Surge Current	X	X	X	
Mil Maintenance	X	X		
F-TECH			optional	
SBDS			optional	

Made in USA

Automotive: moisture resistance

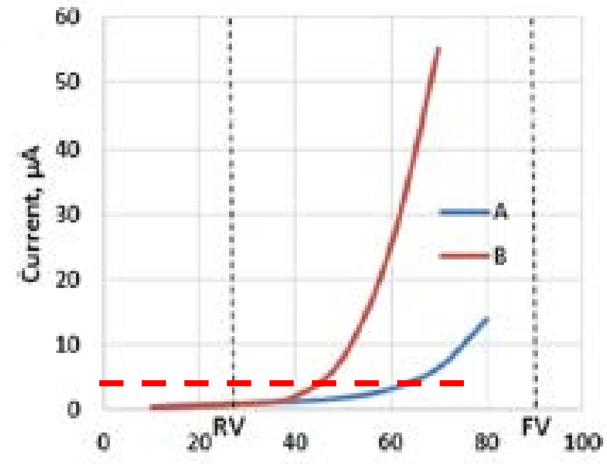
Make "New Space" with reliable parts

Cost Reduction

Powder cost = price * weight P

$$P = const*CV*\frac{V_f/V}{CV_f/g}$$

Fig. 3.25 I(V) characteristics of the D-case 16 μF – 25 V MnO_2 tantalum capacitors



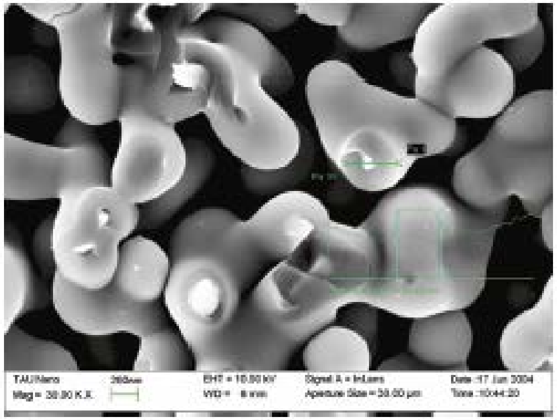


Fig. 3.3 Breakage of the tantalum anode sintered with 50,000 μC/g tantalum powder and formed to 75 V

Bake out 125 C for 24 h plus two Pb-free reflow

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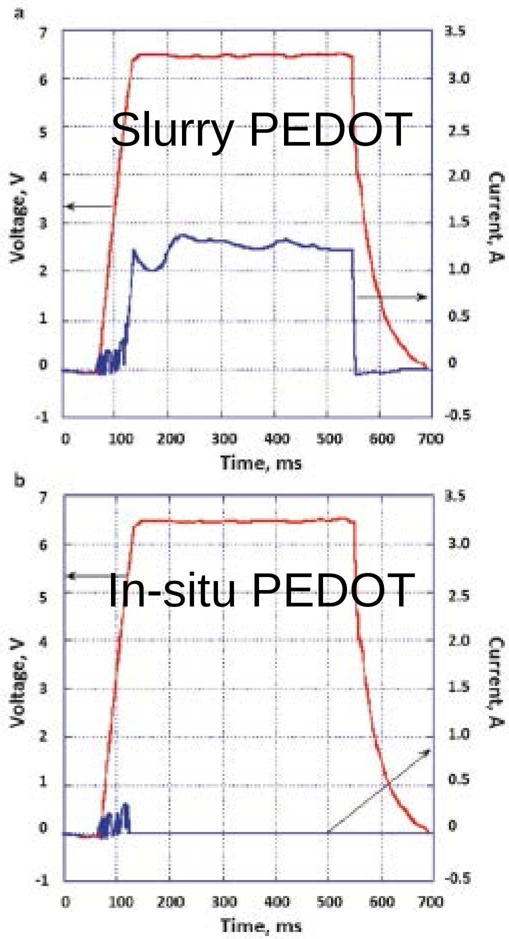
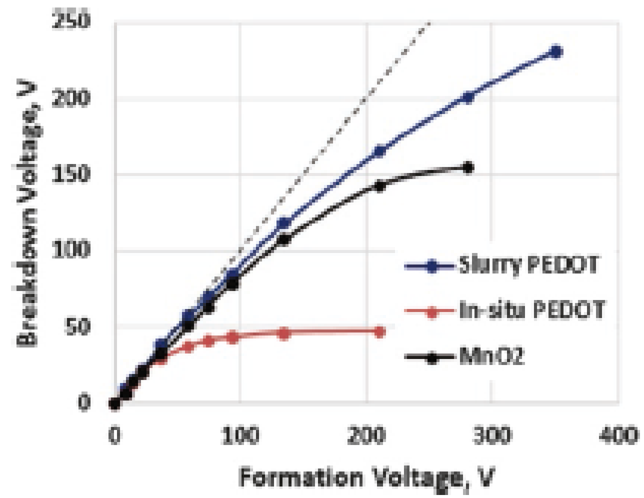


Fig. 3.54 I(t) response to one pulse, V(t), applied at ~200 °C to a W-case 470 µF – 6.3 V hybrid (a) and pure in situ (b) polymer tantalum capacitors

Fig. 3.34 BDV vs. formation voltage in tantalum capacitors with F-Tech anode and either slurry PEDOT, in situ PEDOT, or MnO_2 cathode



JES 2014 - record number of citations

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Negative

Positive

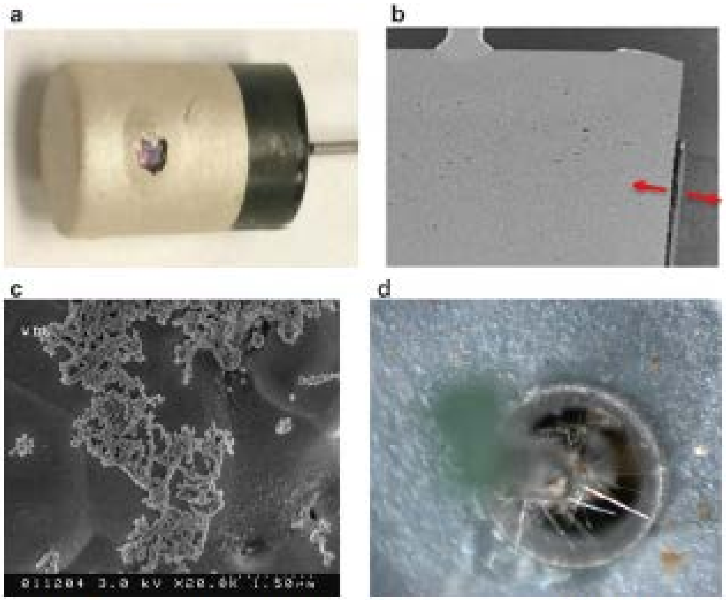
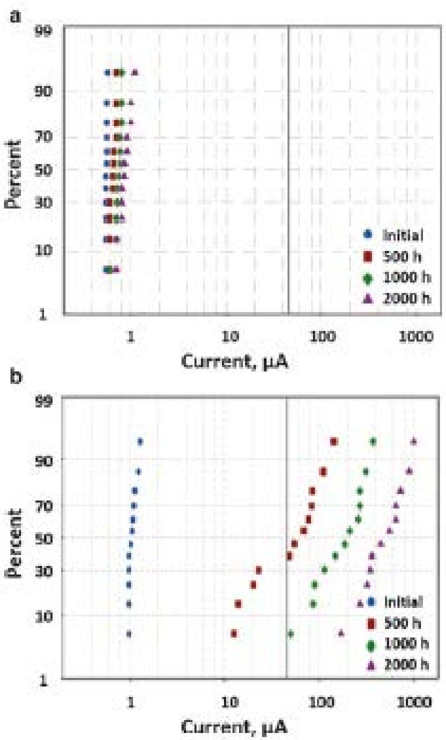


Fig. 3.49 Moisture-related failures in PHS tantalum capacitors: popcorn effect (a), delamination of the external carbon and silver layers (b), silver migration (c), and tin whiskers (d)

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



ACC Control vs. New with Improved Anode

dV/dt = 120 V/s, V = 0.8 RV, T = 0º C

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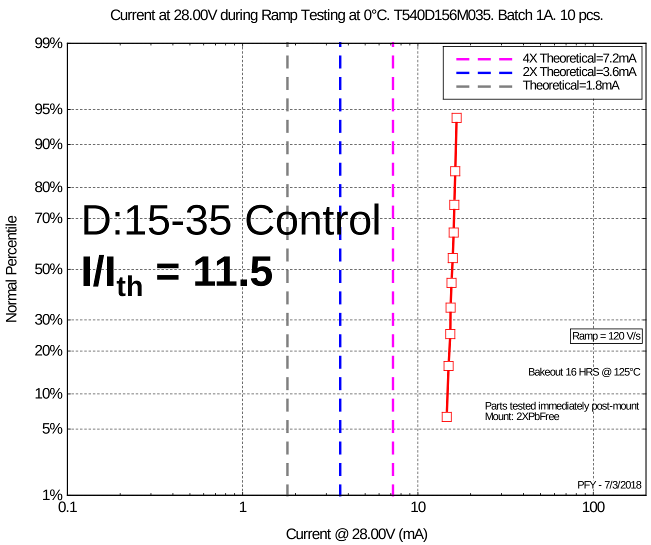
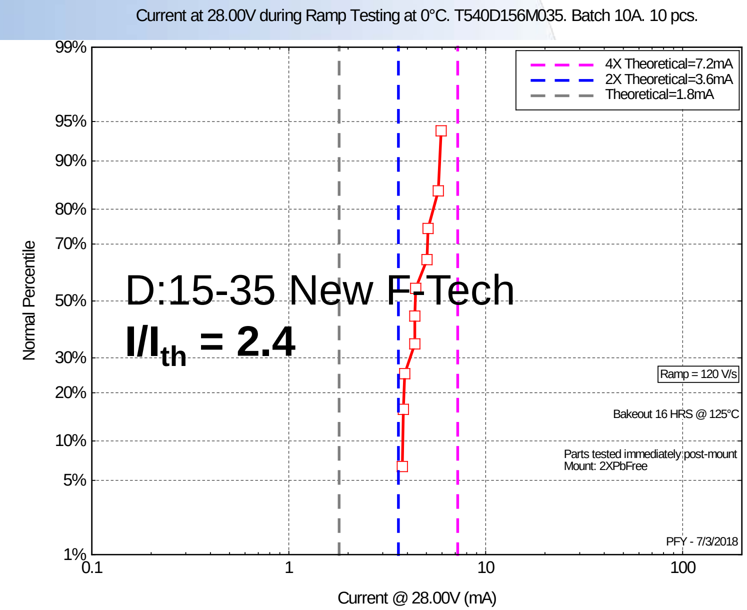
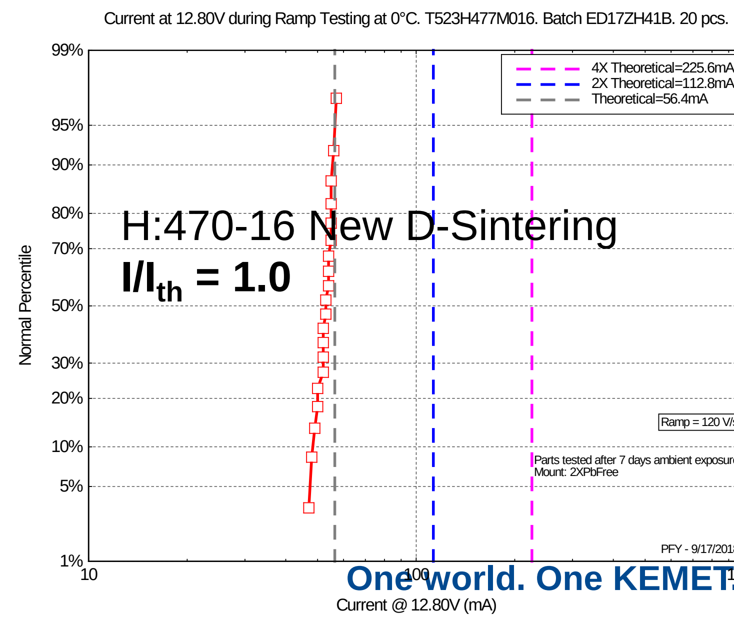
$$I_{th} = C*dV/dt$$







From high to low/no ACC with top reliability due to the anode improvement

Evolution of Tantalum Capacitors

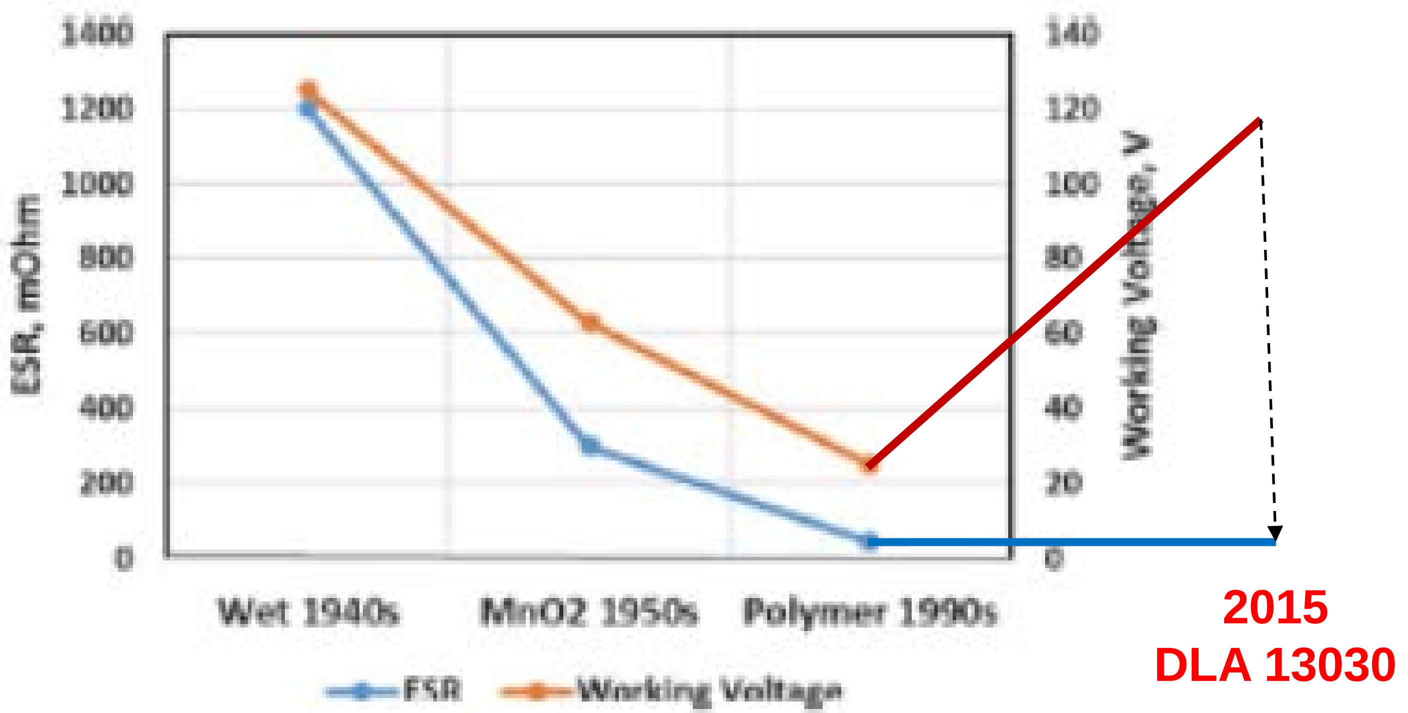


Fig. 4 ESR and maximum working voltage in different types of tantalum capacitors

PHS: on par with Wets in Voltage,
10x-100x lower ESR, MIL Qual

Conclusions

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- Entropy (thermodynamic instability) of amorphous Ta_2O_5 increases with voltage (thickness of the dielectric). Advanced technologies like F-Tech/SBDS stabilize the dielectric, screen hidden defects, and provide high reliability to higher voltage parts.

- 50% de-rating of Ta caps cuts efficiency 90%, approaching efficiency of ceramic caps. 20% de-rating of Ta caps with advanced technologies provides high efficiency and high reliability plus non-ignition failure mode in Polymer caps.

- Only parts with established reliability (Hi-Rel and special COTS) are recommended for the space application. Commercial (automotive) parts can vary materials and processes, increasing risk of failure in space application.

- Low/no ACC and high reliability in higher voltage Polymer parts can be achieved by improvements in all the layers of the basic capacitor structure (not just Poly) instead of de-rating 50+% and losing 90+% efficiency.