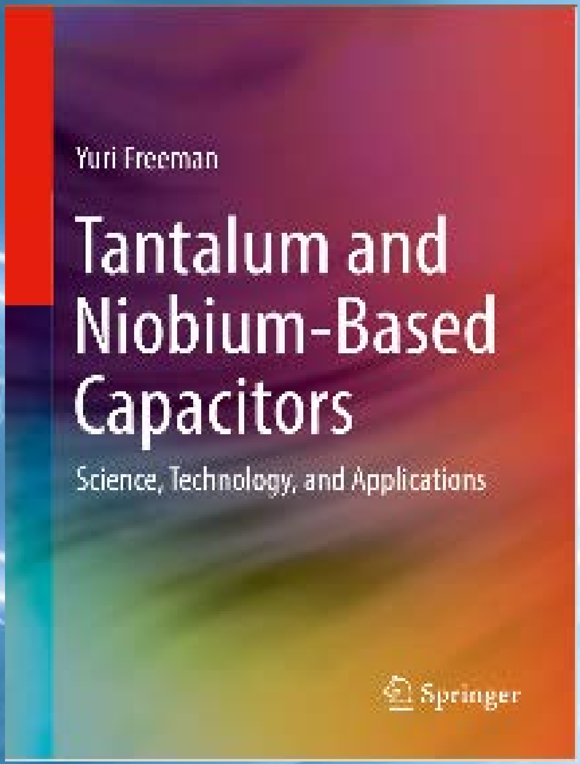

Electronic Components
KEMET
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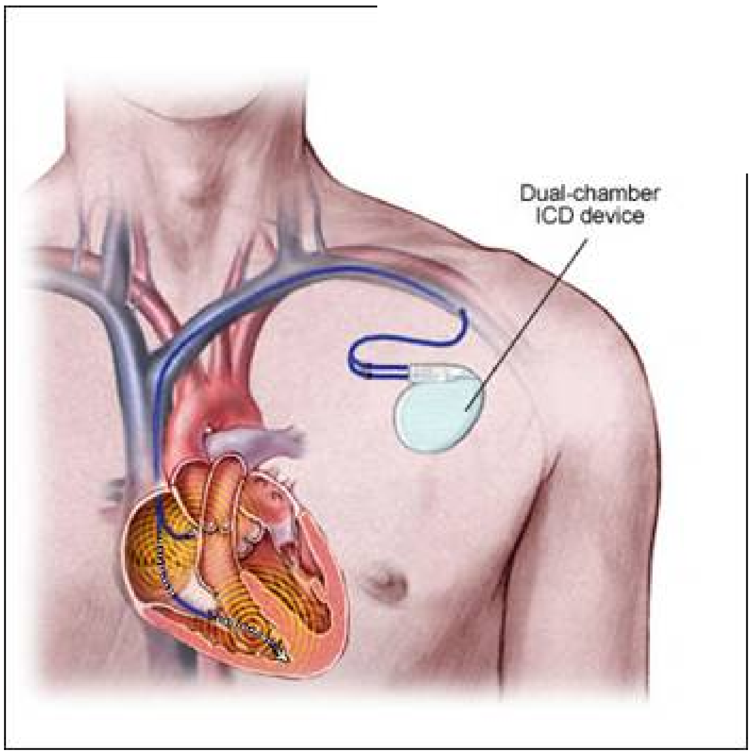
Tantalum Capacitors in Space Applications

Y. Freeman

October 2018

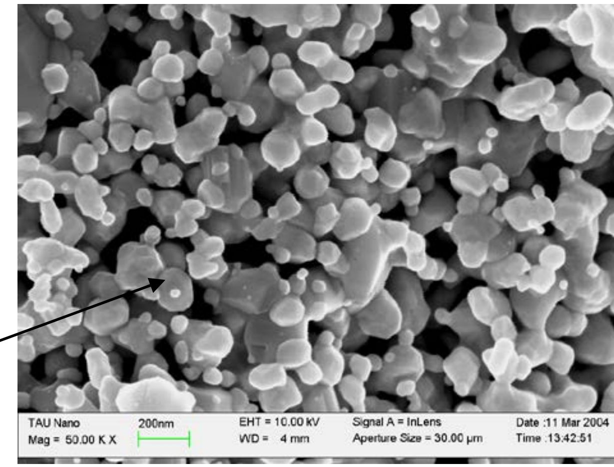
Efficiency

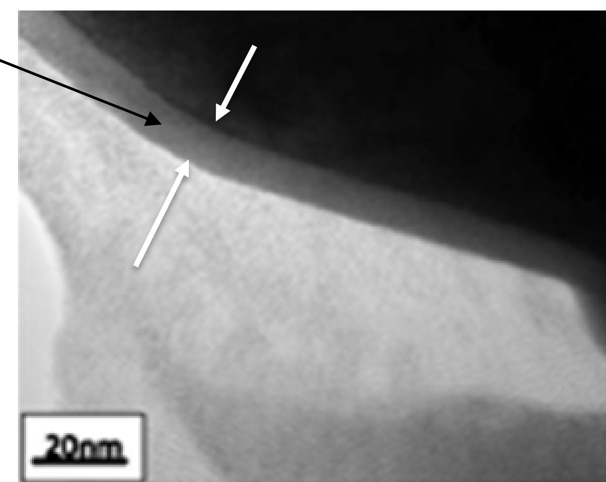
Fig. 1 Medtronic cardio implant with tantalum capacitors



With permission from Medtronic Corporation

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

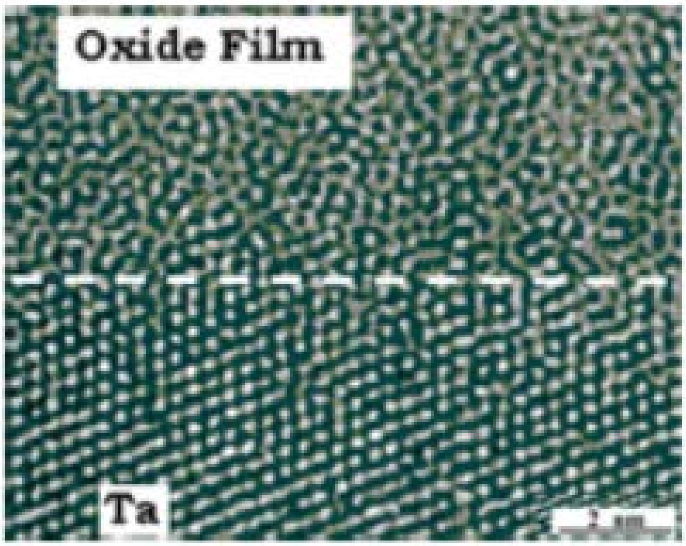




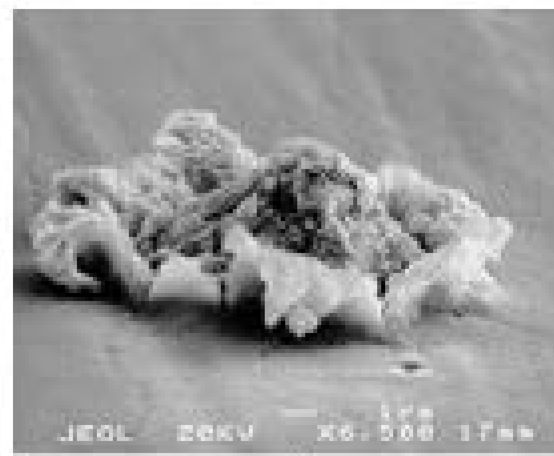
Charge time ≤ 8s

Entropy

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



Entropy



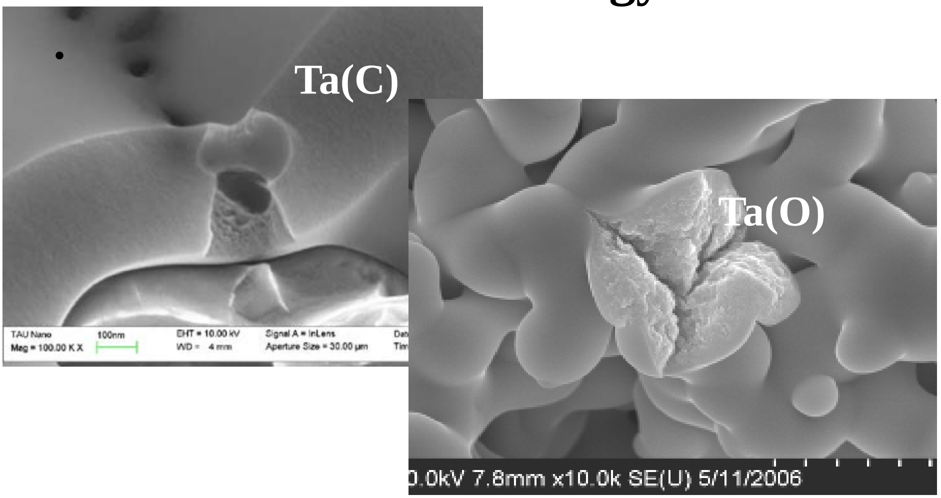
a

Fig. 1.14 SEM image of the anodic oxide film

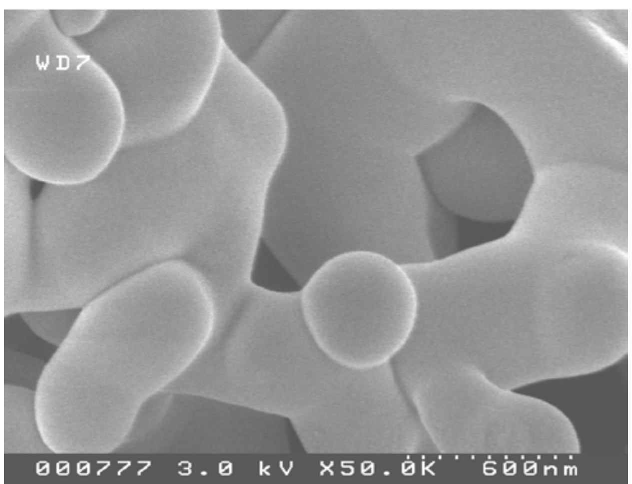
Entropy (instability) increases with dielectric thickness (voltage)

F-Tech and SBDS

Conventional Technology

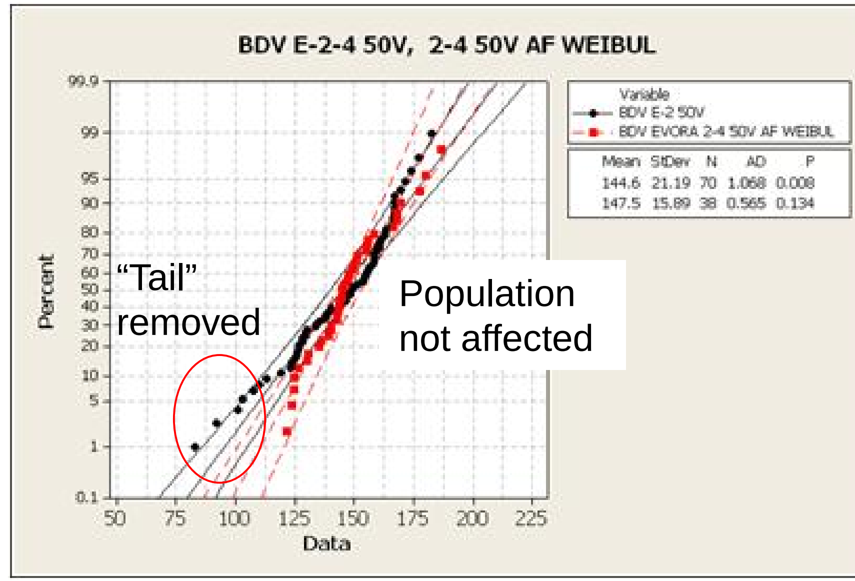


F-Tech



(verified on every production lot)

100% Simulated Breakdown Screening (SBDS)

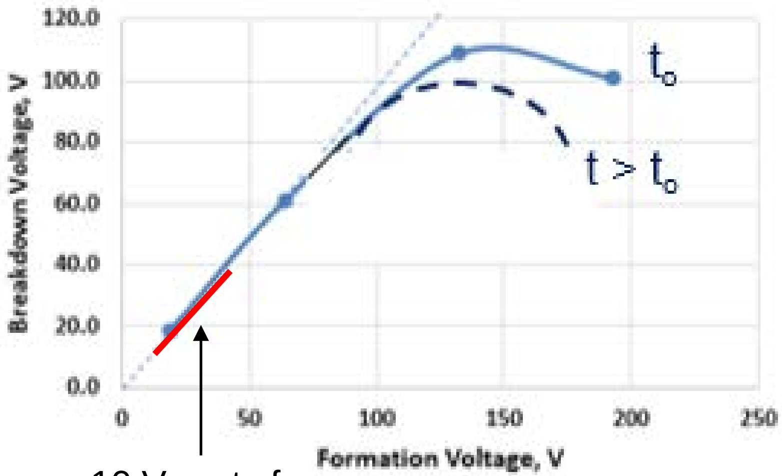


Crystallization will happen, but this can occur in 100 hours or 100 years

De-rating

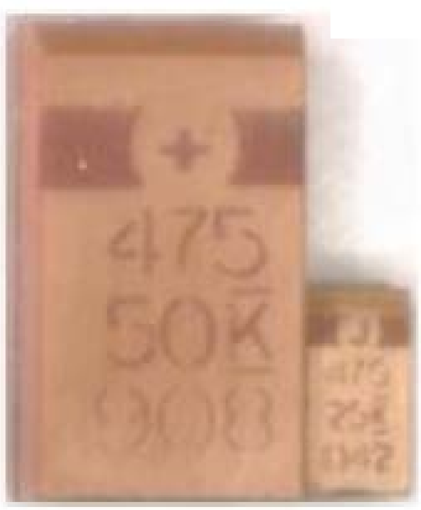
$$\frac{t_1}{t_2} = \left(\frac{V_2}{V_1}\right)^n exp\left[\frac{E_a}{kT}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)\right]$$

$$V_{50}/V \approx 10$$



10 V parts for
3.3 V application

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)

The Capacitance Company KEMET CHARGED.™

	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

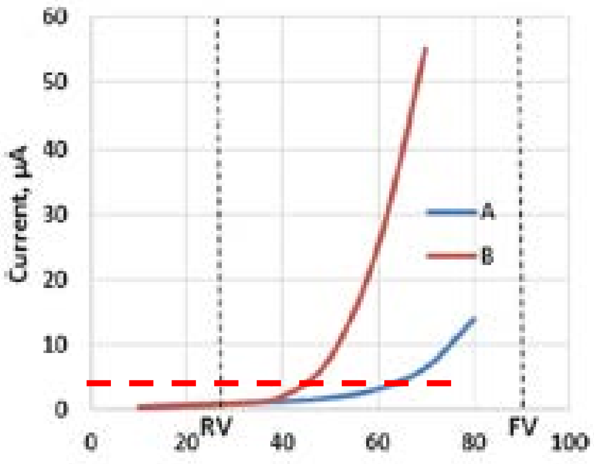
Cost Reduction

The Capacitance Company KEMET CHARGED.

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



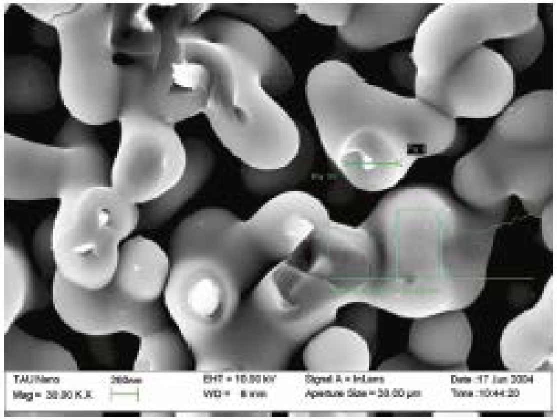


Fig. 3.3 Breakage of the tantalum anode sintered with 50,000 µC/g tantalum powder and formed to 75 V

One world. One KEMET.

Anomalous Charge Current (ACC)

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

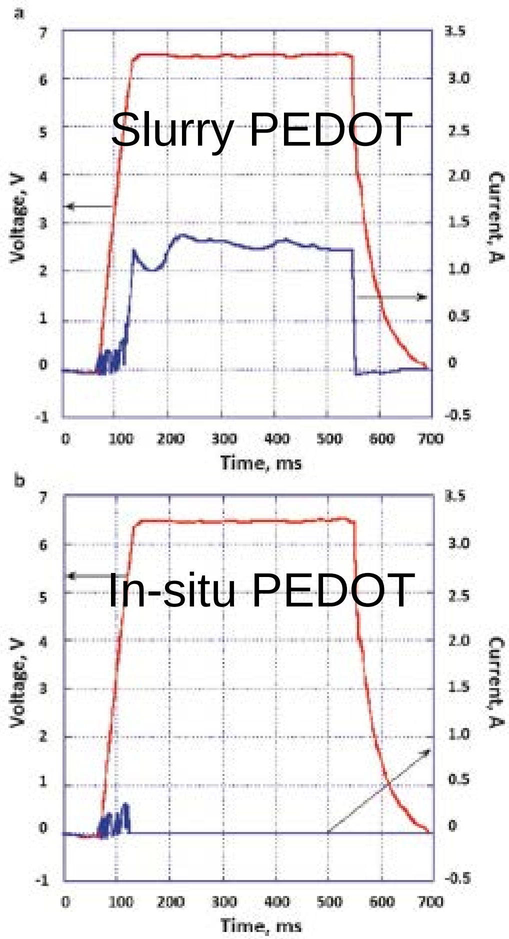
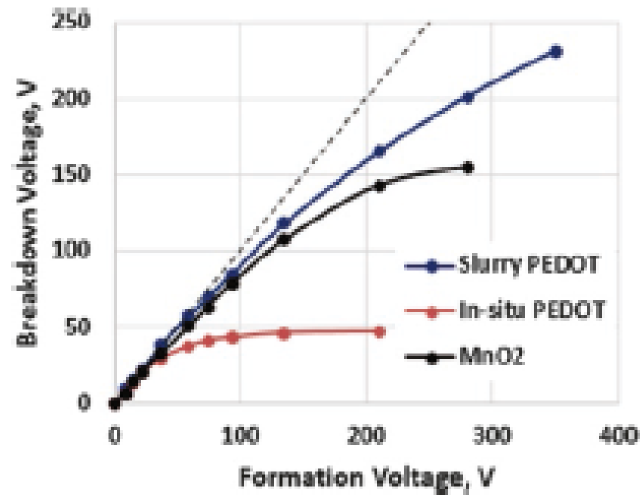


Fig. 3.54 I(t) response to one pulse, V(t), applied at ~200 °C to a W-case 470 μF – 6.3 V hybrid (a) and pure in situ (b) polymer tantalum capacitors

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

Effects of Moisture

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Negative

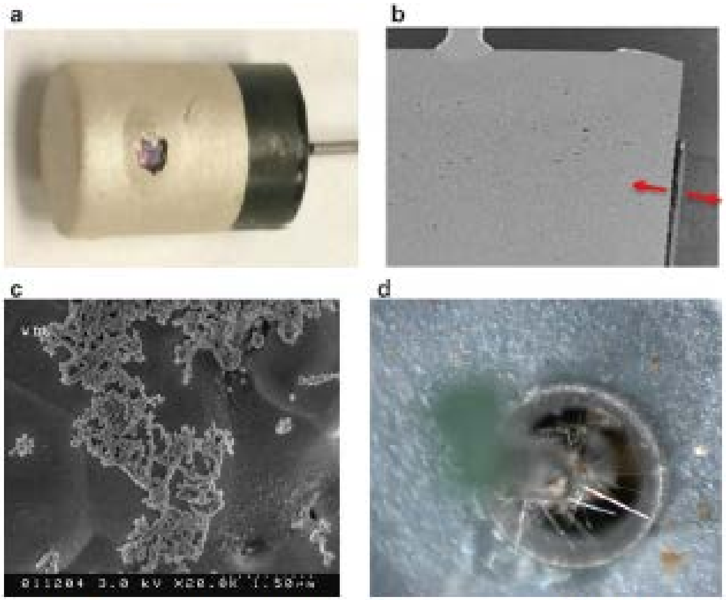
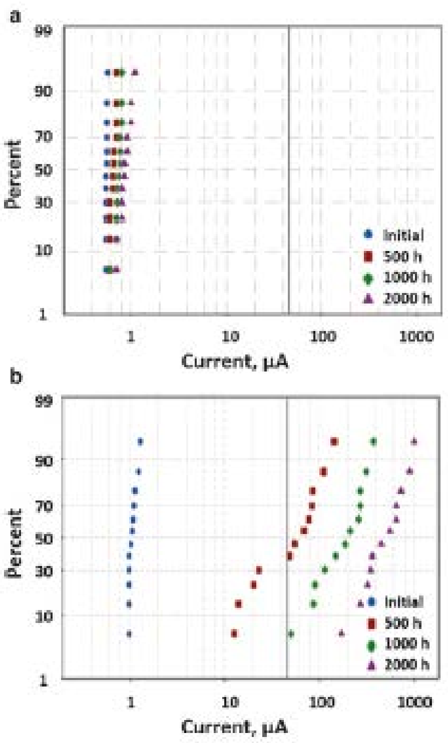


Fig. 3.49 Moisture-related failures in PHS tantalum capacitors: popcorn effect (a), delamination of the external carbon and silver layers (b), silver migration (c), and tin whiskers (d)

Positive

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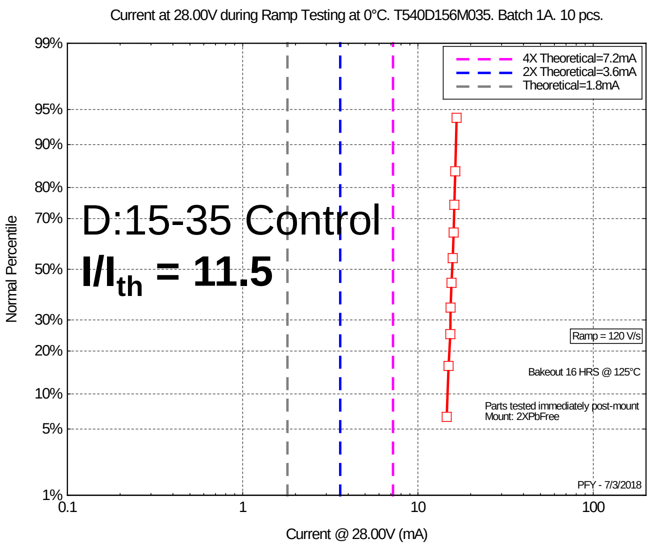
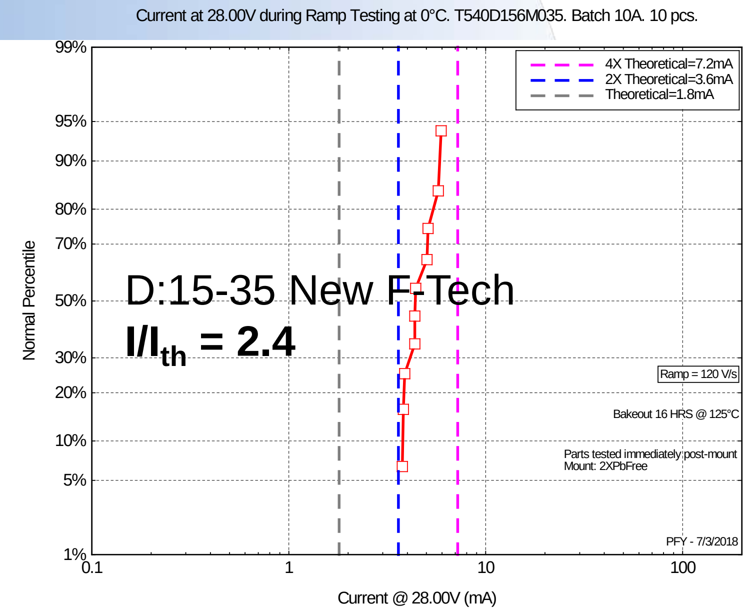
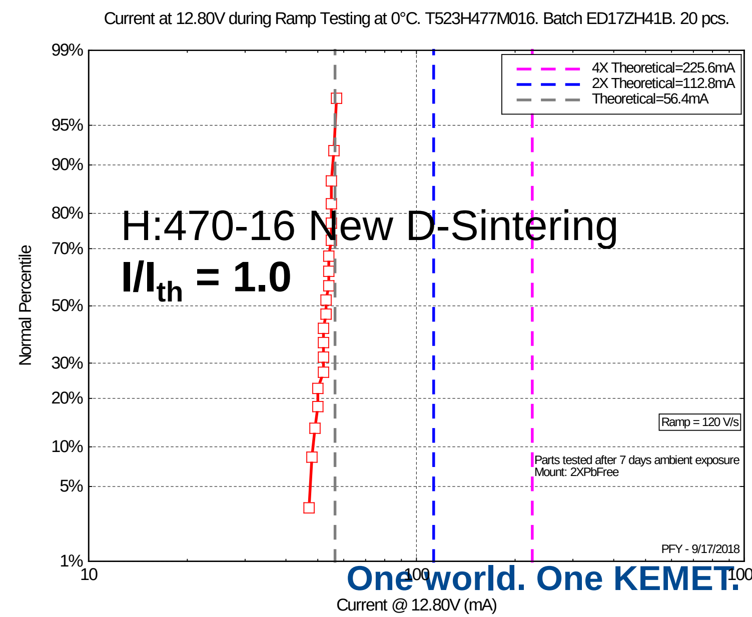
$$I_{th} = C*dV/dt$$







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

Evolution of Tantalum Capacitors

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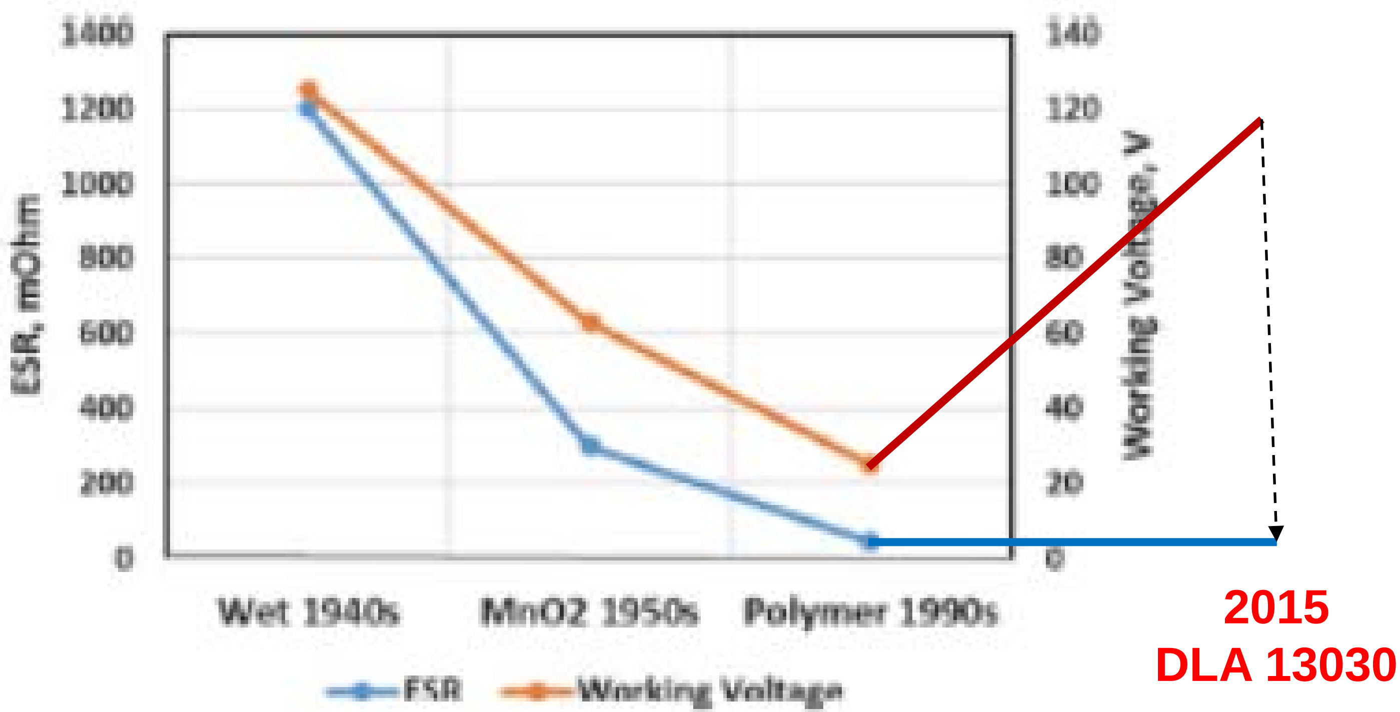

Fig. 4 ESR and maximum working voltage in different types of tantalum capacitors

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.