Tantalum Capacitors in Space Applications

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Efficiency

With permission from Medtronic Corporation

Charge time $\leq 8s$
Entropy (instability) increases with dielectric thickness (voltage)
F-Tech and SBDS

Conventional Technology

Ta(C)

Ta(O)

100% Simulated Breakdown Screening (SBDS)

F-Tech

(verified on every production lot)

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

“Tail” removed

Population not affected
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
Hi-Rel and COTS vs. Commercial (Automotive)

<table>
<thead>
<tr>
<th>KEMET Series</th>
<th>MIL-PRF-55365 T-Level</th>
<th>MIL-PRF-55365</th>
<th>COTS</th>
<th>Commercial</th>
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<tbody>
<tr>
<td>DPA</td>
<td>X</td>
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<tr>
<td>100% X-ray</td>
<td>X</td>
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<tr>
<td>Group C Testing</td>
<td>X</td>
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<tr>
<td>+3 Std Dev Screening</td>
<td>X</td>
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<tr>
<td>Established Reliability</td>
<td>B, C, D</td>
<td>B, C, D</td>
<td>B, C</td>
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<tr>
<td>Surge Current</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
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<tr>
<td>Mil Maintenance</td>
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<td>F-TECH</td>
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<tr>
<td>SBDS</td>
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</tbody>
</table>

Automotive: moisture resistance

Made in USA

Ta-Ta2O5-Cathode

Make “New Space” with reliable parts
Cost Reduction

Powder cost = \( \text{price} \times \text{weight P} \)

\[ P = \text{const} \times CV \times \frac{V_f / V}{CV_f / g} \]
Anomalous Charge Current (ACC)
Bake out 125°C for 24 h plus two Pb-free reflow

Slurry PEDOT
In-situ PEDOT

JES 2014 - record number of citations
Effects of Moisture

Negative

Positive

![Image of 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)]

![Graph showing DCL during life test at rated voltage and 85 °C in 100% 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 = 0°C

\[ I_{th} = C \cdot dV/dt \]

D:15-35 Control
\[ I/I_{th} = 11.5 \]

D:15-35 New F-Tech
\[ I/I_{th} = 2.4 \]

H:470-16 New D-Sintering
\[ I/I_{th} = 1.0 \]

From high to low/no ACC with top reliability due to the anode improvement
Evolution of Tantalum Capacitors

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

• Entropy (thermodynamic instability) of amorphous Ta$_2$O$_5$ 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.