Ta SMD capacitors with Polymer Counter Electrode for Space Applications

Ana Tomás¹, Cristina Mota-Caetano¹, Dr. Denis Lacombe², Leo Farhat²

¹KEMET Electronics Portugal, S.A.; ²ESA/ ESTEC European Space Agency
Outline

- Tantalum Polymer Technology
- European Space Actual Offering
- European Space Future Offering/ T584 Series – Multianode
- Current Activities & Path Forward
Tantalum Polymer Technology

Product Hierarchy

- 100% Electrical Testing
- Non-Established Reliability
- Continuous Design Improvement
- Broadest Product Selection

Commercial
Tantalum Polymer Technology

Product Hierarchy

- Commercial Design, Change Notification
- AEC-Q200 Qualified
- Change Notifications Required
- PPAP Available
Commercial

Automotive

COTS

- Conservative Military Design
- Military Screening Options
- MIL-PRF “like” Qualification
- 100% Burn-In
- Established Reliability
- Certificate of Compliance
- What do you call this “tweener’?
Tantalum Polymer Technology

Product Hierarchy

- Commercial
  - Automotive
  - COTS
  - MIL-PRF
    - Conservative Military Design (SMD and Thru-Hole)
    - Qualification Per MIL-PRF
    - Mil Maintenance Program
    - Established Reliability
    - Certificate of Compliance
    - Group Data if Applicable
Tantalum Polymer Technology

Product Hierarchy

- **Commercial**
  - Conservative Military Design (SMD & Thru-Hole)
  - Per MIL-PRF & GR
  - Established Reliability
  - Screening Options
  - Certificate of Compliance
  - Data Package Options Available
  - Meets TOR Requirements

- **Automotive**

- **COTS**

- **MIL-PRF**

- **Space Grade**
Tantalum Polymer Technology

Product Hierarchy

- Commercial
- Automotive
- COTS
- MIL-PRF
- Space Grade
- Custom*

*Custom Testing Beyond MIL-PRF and Space Grade

- Custom In-Process Screening
- Custom Group Testing
- Application Specific SCD’s
- Group Data and Test Summaries
- Material Analytics & Test Reports
- Customer Designs (e.g., Stacked Capacitors, Modules)
KO-CAP® Polymer Capacitors

KO-CAP® Polymer Capacitors
History & NPD

Conductivity

- 2006: DLA Drawing Release 04051 and 04052
  - First Polymer for Mission Critical
- 2011: T540/541 – Hi-Rel Alternative
  - First-To-Market Series for MCA
  - 125°C
  - 100% Voltage Aging 24 Hours Minimum
  - 3σ Screen (DCL & ESR)
  - 100% X-Ray
  - Temperature Stability & Solderability
- 2013: T543 COTS
  - Sn/Pb Termination Std.
  - Surge Current Options
  - 105°C/125°C
- 2013: T550/T551 PHS
  - Highest voltage & lowest DCL
- **2015: T583 ESCC (ESA) EPPL**
- 2016: Established Reliability Available
  - T540 & T541
- 2017: T540/T541 85/85 Capability (1,000 hrs.)
- 2019: MIL-PRF Including T Level
  - Group C Testing Available Today (SCD)
- 2018: AUTOMOTIVE Grade COTS (85/85)
  - T598 Series with Sn/Pb Termination
  - Surge Current Options.
- 2018: SMD PHS
  - Surge Current Options
  - Special Boardmounting
- 2019: 150°C T599 Series COTS
  - T598 Series with Sn/Pb Termination
  - Surge Current Options.
- **2019: T584 ESCC (ESA) EPPL**

© KEMET Electronics. All Rights Reserved.
Basic Construction
Tantalum SMD Capacitors (MnO₂ & Polymer)

Tantalum

- Ta Metal
- MnO₂
- Cond. Poly
- Weld

Manganese Dioxide (MnO₂) or Conductive Polymer

Tantalum (Ta) & Ta₂O₅ Dielectric

Mold Epoxy

Silver Adhesive

Washer

Solder Coat

Tantalum Wire

Weld

Silver Paint

Carbon Ink

Lead-frame

Counter Electrode Penetration into Pores
(Manganese Dioxide (MnO₂) or Conductive Polymer (PEDOT))
Project Objective: Develop a very low ESR tantalum SMD chip capacitor manufactured in Europe for space applications using polymer technology as solid electrolyte cathode system.

Target Market: ESA OEM’s and ODM’s

<table>
<thead>
<tr>
<th>Capacitance $C_0$ ($\mu$F)</th>
<th>Rated Voltage $U_R$</th>
</tr>
</thead>
<tbody>
<tr>
<td>33</td>
<td>6.3V</td>
</tr>
<tr>
<td>47</td>
<td>10V</td>
</tr>
<tr>
<td>68</td>
<td>16V</td>
</tr>
<tr>
<td>45</td>
<td>60, 70</td>
</tr>
<tr>
<td>70</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>45, 60, 100</td>
</tr>
<tr>
<td>55</td>
<td>80</td>
</tr>
<tr>
<td>45</td>
<td>55</td>
</tr>
</tbody>
</table>

Download detail spec in:
https://escies.org/download/specdraftapppub?id=3230
European Space Future Offering
T584 ESA Poly Multianode SMD Capacitors

Project Objective: Develop an ultra-low ESR with maximum capacitance Polymer Multianode (MAT) SMD Capacitor for POL (‘Point of load’) solutions, $\text{ESR} \leq 15 \ \text{m} \Omega$, manufactured in Europe, adequate for space applications.

Target Market: ESA OEM’s and ODM’s

- Taking Advantage of:
  - Cumulative Charge Storage Characteristics
  - Cathode Material Low Resistivity
  - Geometry of the paths within its elements.
  - Better Frequency Performance
  - “No ignition” Benefit
The deepest capacitive element is the one that defines the worst or highest resistive connection to these elements and is the first element to stop responding at increasing frequencies, continuing to the outermost capacitive elements.

- Reduce Resistance
- Reduce the penetration depth by one third
T584 Series – Multianode
Experimental Plan Outline

For POL
EIA 7343-43 330μF 10V
ESR ≤ 15 mΩ

T583 Series under Detailed Spec ESCC 3012/005
Knowledge & Technology

Experimental Plan

Equipment

Evaluation Test Program (ETP)

EPPL Proposal

Prototype Characterization

QPL Proposal

ESCC full Qualification

Pilot Series Manufacture & part Screening

Electrical Characterization

© KEMET Electronics. All Rights Reserved.
T584 Series – Multianode

Prototype Build

Equipment

Prototype build

Intermediate Measurements

Electrical data & Character.

ETP

Top X-Ray
Side X-Ray
Finished Capacitor
T584 Series – Multianode

Prototype Build

- Indicator & first control of the parts electrical quality before Assembly:
T584 Series – Multianode
Prototype Build

• 100% Electrical Screening:

• SMT – Surface Mount Test:
  – LCDR before and after assembled components on PCB.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>T584X337M100AH010P000</th>
<th>TEST1809Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lkg mean (μA)</td>
<td>45.25</td>
<td></td>
</tr>
<tr>
<td>Cap mean (μF)</td>
<td>300.36</td>
<td></td>
</tr>
<tr>
<td>DF mean (%)</td>
<td>1.54</td>
<td></td>
</tr>
<tr>
<td>ESR mean (Ω)</td>
<td>0.0079</td>
<td></td>
</tr>
</tbody>
</table>
• **SSST** (Surge Step Stress Test):

Low resistance, high current test that subjects the components to increasing voltages until failure. This is a destructive supplementary test that is a good indicator of dielectric stability.
• Frequency Characterization:

⇒ Typical polymer Ta Cap behavior of Capacitance in frequency

Result of the high conductivity of the organic polymer conductive coating, combined with the previously described advantages of a multianode construction

⇒ ESR decreasing up to 100KHz and remaining low and stable at higher frequencies

Results from the higher contribution of oxide losses to ESR at lower frequencies, which become smaller with increasing frequency.
• Temperature Characterization (-55°C to 105°C):

Consistent with technology

Slight ESR increase ⇒ Metal resistance contributions
T584 Series – Multianode
Prototype Build - ETP

Evaluation Test Program

- Dimensional Control
- Elect. Parameters (Go/NoGo)
- Extended Visual Inspection
- Radiographic Inspection
- Marking and Serialization

Initial Electrical Measurements

- Control Group
  - Thermal Shock
  - Construction Analysis -DPA

- Destructive Tests
  - SSST

- Endurance Testing
  - Acc. Life Tests T1,V1 400h *
  - Acc. Life Tests T2,V2 700h *
  - Acc. Life Tests T3,V3 1000h *

© KEMET Electronics. All Rights Reserved.
T584 Series – Multianode
Prototype Build - ETP

• Thermal Shock

No indication of issues in the device construction or materials.
T584 Series – Multianode

Prototype Build - ETP

• SSALT (Steady Steate Accelerated Life Tests):
  – Same conditions as evaluated T583 single Anode

SSALT presented a good behaviour up to the estimated failure time. Extended to 1000 & 2000 hrs.
T584 Series – Multianode
Prototype Build - ETP

• SSALT (cont.)

115°C Ur

Probability Plot of Delta Cap
Normal

Probability Plot of TAN %
Normal

Probability Plot of ESR Ohm
Normal

Probability Plot of IR uA
Lognormal
T584 Series – Multianode

EPPL – PART 2 Application

- ESCC 3012/007 under approval

T584 Series – product portfolio:

<table>
<thead>
<tr>
<th>Variant Number</th>
<th>Case Code (Style) (Note 1)</th>
<th>Capacitance Values Cn (μF) (Note 2)</th>
<th>Rated Voltage U_R (V)</th>
<th>Maximum Equivalent Series Resistance ESR (mΩ)</th>
<th>Weight Max (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>X (7343-43)</td>
<td>220</td>
<td>10</td>
<td>10, 12, 15</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td></td>
<td>330</td>
<td>6.3</td>
<td>10, 12</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10</td>
<td>10, 12, 15</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>470</td>
<td>6.3</td>
<td>10, 12</td>
<td></td>
</tr>
</tbody>
</table>
Space Series /ESCC Activities
Current Activities & Path Forward

**T583 Series**
- ESCC Detail Specification 3012/005 up to 16V
- Low voltage QPL Testing/ Submission for Q1’19
- Higher than 20V Voltage Portfolio extension / EPPL Submission Q2’19

**T584 MAT Series**
- ESCC Detail Specification for T584 series (3012/007) submitted – Sep.’18
- EPPL –part 2 application submitted - Sep.’18
- QPL Testing/ Submission – Q2’19

**Future**
- T583/T584 Product Portfolio extension acc. Customer needs.
Mission critical electronics

High-performance power management

Where failure is not an option

Breakthrough technology

Unparalleled borderless service

Smart people

Innovative products that solve customer challenges

Thank You!