Conductive Polymer Based Tantalum Capacitor for Automotive Application

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Conductive Polymer Based Tantalum Capacitor for Automotive Application

- Introduction of KO-CAP®
- Development Roadmap and Target
- Technical Challenges
- Solutions and Results
- Path Forward

KO-CAP is a registered trademark of KEMET Electronics Corporation.
KEMET Organic Polymer Electrolytic Capacitors
KO-CAP Basic Construction

- Polymer / $\text{Ta}_2\text{O}_5 / \text{Ta}$
- Silver Paint
- Carbon
- Leadframe (- Cathode)
- Tantalum Wire
- Weld
- Leadframe (+ Anode)
- Silver Adhesive
- Lead Protection
KO-CAP Process

- More than 200 steps

**Ta Anode Manufacturing**
- Ta Powder Blending
- Anode Pressing
- Delube
- Sintering

**Electro-Chemical Processing**
- Dielectric Formation
- Polymerization
- Wash and Reformation
- Cathode Coatings (Carbon/Silver Layer)

**Assembly and Encapsulation**
- Assembly
- Molding

**Aging, Burn-in, Testing and Finishing**
- Aging
- In-line Burn-in
- Testing
- Packaging

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Automotive Initiative Roadmap

T591 Series
- 125°C/105°C/85°C
- SMD
- Low ESR
- High ripple current capability
- Benign failure mode
- 85°C/85%RH 500 Hours

T598 Series
- 125°C
- SMD
- Low ESR
- High ripple current capability
- Benign failure mode
- 85°C/85%RH 1000 Hours
- Full AEC-Q200

T599 Series
- 150°C capability
- SMD
- 85°C/85%RH 1000 Hours
- Full AEC-Q200

Capabilities Development

FOCUS NOW

2013 2014 2015 2016…
Development Target

• 3000 to 5000 Capacitors per vehicle
## Challenges to Meet AEC-Q200

<table>
<thead>
<tr>
<th>Stress Test Name</th>
<th>Conditions</th>
<th>AEC - Q200</th>
<th>KO Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Temp Exposure (Storage)</td>
<td>125° C, Unbiased, 1000 Hrs</td>
<td>✓</td>
<td>depends</td>
</tr>
<tr>
<td>Temperature Cycling</td>
<td>-55° C to 125° C, 1000 Cycles</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Biased Humidity</td>
<td>85° C, 85% RH, Biased, 1000 Hrs</td>
<td>✓</td>
<td>X</td>
</tr>
<tr>
<td>Operational Life</td>
<td>125° C, Biased, 1000 Hrs</td>
<td>✓</td>
<td>depends</td>
</tr>
<tr>
<td>Resistance to Solvents</td>
<td>Mil-Std-202, Meth. 215</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Mechanical Shock</td>
<td>Mil-Std-202, Meth. 213, Cond F</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Vibration</td>
<td>Mil-Std-202, Meth. 208, 5G’s-20min</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Resistance to Soldering Heat</td>
<td>Mil-Std-202, Meth. 210, Cond D</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>ESD</td>
<td>AEC-Q200- 002 or ISO/DIS 10605</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Solderability</td>
<td>J-STD-002</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Terminal Strength</td>
<td>AEC Q200-006</td>
<td>✓</td>
<td>✓</td>
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</table>

Ref. 11 Jayson Young and Javaid Qazi, Polymer Tantalum Capacitors for Automotive Applications CARTS International 2014
ESR Concern under 85°C, 85% RH, Biased

- Example of KOCAP EIA 7343-28 33uF 25V

- Greater ESR shift than that under 60°C, 90% RH, Biased
Failure Analysis of High ESR
85° C, 85% RH, Biased

- Typical Example EIA 7343-28 33uF 25V ESR0.06Ω

- Post test ESR reading > 0.1Ω at 100kHz
- Delamination and crack were detected
Failure Analysis of High ESR
85°C, 85% RH, Biased

- Typical Example of EIA 7343-28 33μF 25V ESR 0.06Ω

- Post test ESR reading > 0.1Ω at 100kHz

- Delamination confirmed with ion milling cross section SEM by NEC-Tokin lab

- Good connection of good ESR or improved samples

Delamination and cracks of cathode material is responsible for higher ESR parts
DC Leakage Concern
KO-CAP 85°C, 85% RH, Biased

- KOCAP 7343-28 33uF 25V 0.06ESR

- Leakage tailed up to 0.5CV
- Short circuit occurred in extreme cases
The Cu found in the Ta wire imprint appeared typical of a migration pattern usually found as a result of moisture penetration in a biased part.
Simulation of Copper Migration

PCT 121°C C 85%RH 1.7 Atmosphere for 42Hrs

- EIA 7343-28 33uF 25V ESR 0.06Ω
  - 64 pieces

- Assembled with copper alloy based leadframe before encapsulation

- A low concentration of ferric tosylate solution was applied to the strips and dried to simulate the chemical residuals from polymerization of PEDOT

- Pre-treated strips were placed into a chamber of 121 °C 85% RH with a pressure of 1.7 atmosphere for 42Hrs. 0.67Vr applied

- Electrically and Physically Inspected

Leadframe corrosion and copper migration was observed
Mechanism Summary

1. Moisture Adsorption
2. Swelling of layer
3. Crack / GAP
4. De-depoing with DC
5. ESR Failures

- Ion dissolution (Cl, Ferric)
- Anodic of Copper with DC
- Copper ion move to cathode
- Copper ion reduction to metal
- Dendrites growth
- Conductor bridge (Path)
- Moisture
- CTE/CME Stress
- Short Circuit
Design Actions Implemented

• Factor 1: Moisture
  – 1) Use lower moisture permeability mold compound
  – 2) Optimize the application of moisture barrier to polymer capacitors

• Factor 2: Ionic Contaminations
  – 3) Further optimize wash process
  – 4) Reduce ionic species in molding

• Factor 3: Leadframe Substrate
  – 5) Use alloy with less copper content, more resistant to corrosion

• Factor 4: Distance between conductors
  – 6) Improve the wire laser clean technology
Improvement Results
85°C, 85% RH Biased, 1000 Hours

- Example of EIA7343-28 100uF 16V ESR 0.05Ω
Example of EIA7343-28 100uF 16V ESR 0.05Ω
Path Forward

• **Expand** the T598 product line with additional part numbers

• **Develop** a new series (T599) that has 150 °C 1000 hour life in addition to the specification of T598 in the near future

• **Enlarge** the application of tantalum polymer capacitor in the automotive and other market where harsh operating environment is of concern
Thank You!

Team
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https://ec.kemet.com/wp1017