Power-On Failures in Tantalum and Aluminum SMT Capacitors

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Conflict

• With 100% Electrical Screening,
  – Surge Voltage Test
  – Surge Current Test
  – +85C Leakage @ Vr
  – +25C Leakage @ 1.32 Vr (twice)
• why are failures observed at less than Vr?
Outline

• 100% Electrical Screening
  – Surge Voltage Test
  – Surge Current Test

• Define mechanism for fault creation
  – CTE Mismatch
  – Time above Tg

• Crack Creation / Expansion
• Activating self-healing
• In-line IR-Exposed

Surge Voltage Pulse Train

Voltage applied through resistor. Voltage across resistor-capacitor may be constant, but voltage across capacitor may not be.
Electrical Conditioning

Healing Effect of MnO₂ Layer

Crack
Nickel
Ta

MnO₂
Mn₂O₃
Ta₂O₅

Scintillations

Graph showing DCV over time (Sec)
Surge Current Pulse Train

Voltage applied must appear across capacitor. High current leads to catastrophic failures – ignitions.

"Ignition"

1. Crack initiates current & heat
2. MnO₂ conversion starts - O₂ generated - Ta₂O₅ to crystalline
3. Oxygen feeds heated Ta
4. Ta + O₂ RAPIDLY combine = Ignition
Solder Heat Expansion

Changes in coefficients of thermal expansion cause stresses to build up within the structure, the mold compound tries to pull (shear) the capacitor apart!

Cooling and Contraction

Edges and corners are focal points of shrinkage forces. Crack can develop in pellet that fractures Ta$_2$O$_5$ dielectric sites. Full power application results in ignition - not self-healing.
Induced Process Stress - MnO$_2$

In tantalum anode pellet, areas of constriction exist where tantalum particles form a closed loop around an open channel. The MnO$_2$ filling this enclosure is a hard, crystalline material. Impregnation process involves dip at +25°C and conversion at +270°C. Stresses might be root of cracks created or extended in dielectric.

Variable Breakdown Levels
Post 100% Electrical Test

Breakdown Relationship to Crack Severity

- Scv @ 150%Vr
- Scv @ 200%Vr
- Scv @ 250%Vr
Variable Breakdown Levels Post Solder Process

Breakdown Relationship to Crack Severity

- Scv @ 200% Vr
- Scv @ 100% Vr
- Scv @ 50% Vr

IR Solder Profile

- Ideal 90 sec.
- Max. 120 sec.
Screening Clips Distribution Tail

Raw Distribution includes pieces below Screen Limit

Pre-screen Distribution

Breakdown Voltage

100% Screen Limit

As Packaged Distribution

100% Screen eliminates Distribution below Limit

Breakdown Voltage

100% Screen Limit
Redistribution

Forces create new, altered distribution after solder.

New Distribution now includes Pieces BELOW Limit

Application Voltage

In-line IR Reflow

An attempt to exercise the package expansion/contraction prior to customers solder process.
## Median Values

<table>
<thead>
<tr>
<th></th>
<th>MnO₂ Production (27 batches)</th>
<th>KO-CAP Production (37 batches)</th>
<th>AO-CAP Production (78 batches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 PPM @ (%Vr)</td>
<td>68%</td>
<td>114%</td>
<td>235%</td>
</tr>
<tr>
<td>FR @ 50%Vr (PPM)</td>
<td>9</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>FR @ 80%Vr (PPM)</td>
<td>226</td>
<td>5</td>
<td>0</td>
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<tr>
<td>FR @ 90%Vr (PPM)</td>
<td>478</td>
<td>19</td>
<td>0</td>
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<tr>
<td>FR @ 100%Vr (PPM)</td>
<td>1256</td>
<td>255</td>
<td>0</td>
</tr>
</tbody>
</table>

## Conclusions

- **The 100% electrical testing of these devices does not preclude faults from developing within the device.**
  - The mismatch of CTEs for the materials used in these devices can create forces large enough to create new cracks or extend existing cracks during the solder process.
  - The severity of the solder process will have a direct impact to the magnitude of power-on failures.
  - The voltage capability of the device is defined by the level of stress applied to the part after mounting (proof).
  - The closer the peak application voltage is to the rated voltage of the part, the greater the number of turn-on failures.
Recommendations

• Establish a voltage capability of the capacitor through a high resistance.
  – 1 kOhm resistor most common
  – Apply highest voltage that capacitor will ever see.
• Remove the resistance.
• Capacitor has been “proofed.”