Solid Aluminum Capacitors

Design, Characteristics, and Manufacturing
Anode (Aluminum)

Dielectric (Anodized Aluminum)

Solid-State Polymer Electrolyte

Separator Film

Cathode (Aluminum)

Aluminum Polymer “V” Chip
Aluminum OS-CON

Anode (Aluminum) - Cathode (Aluminum)

Dielectric (Anodized Aluminum)

Solid-State Electrolyte
TCNQ Salt
Capacitor Construction

AO-Cap

Ta-MnO$_2$ & KO-Cap
## Comparative Properties

<table>
<thead>
<tr>
<th></th>
<th>AO-CAP</th>
<th>Ta-MnO₂ &amp; KO-CAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valve metal</td>
<td>Al</td>
<td>Ta</td>
</tr>
<tr>
<td>Physical form of metal</td>
<td>Etched foil</td>
<td>Sintered metal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>powder compact</td>
</tr>
<tr>
<td>Density of metal, g/cc</td>
<td>2.7</td>
<td>16.6</td>
</tr>
<tr>
<td>Metal oxide dielectric</td>
<td>Al₂O₃</td>
<td>Ta₂O₅</td>
</tr>
<tr>
<td>Dielectric growth rate,</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Å/V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dielectric constant</td>
<td>8.5</td>
<td>27.7</td>
</tr>
</tbody>
</table>
AO Cap Construction

AO-CAP Element

Edge Ag Paint
Better electrical connection between two sides

Carbon
Low resist connection between Polymer & Ag Paint

Conductive Polymer
Counter electrode

Al Foil
Anode & dielectric

Ag Paint
Electrical connection of surface

Mask
Etched / Formed

Web
AO-CAP Construction

D-Case – 3 x 3

- Ag Adhesive: Electrically connects elements & LF
- Mold Epoxy Resin: Physically protects capacitor
- Spacer: Aligns elements
- Lead Frame

(-) (+)
• Layers of anode foil and cathode foil are bonded using silver adhesive
• Design allows for introducing improvements to internal element construction and still maximize packaging efficiency
Copper Foil
Acts as current collector for element

Carbon
Low resist connection between Polymer & Ag Paint

Conductive Polymer
Counter electrode

Al Foil
Anode & dielectric

Web

Etched / Formed

Mask

Ag Paint
Electrical connection of surface

AO Gen II Construction
Gen I to Gen II

- Increase in number of active capacitor layers, 50% more layers (Cap/ESR capability)
- Increased length and width of active anode foil, 54% more area (Cap/ESR capability)
- Reduced variable cost and capital cost per unit output

Current - 300um Capability ~200um

AO Gen II Goals

Active Cap Region 6.3 mm

130-150um

Gen I to Gen II Goals
Basic – AO Cap Element

\[ R_{\text{AlWeb}} \]

\[ R_{\text{Poly}} \quad R_{\text{carbon}} \quad R_{\text{Ag Paint}} \]

\[ R_{\text{AgEdge}} \]
Simplified - AO Cap Element

\[ (+) \quad R_{AlWeb} \quad R_{Poly} \quad R_{C+AgPaint} \quad R_{AgEdge} \quad (-) \]
AO Cap 3 x 3 Array

- Silver paint acts as individual elements current collector
- Silver adhesive results in each element connected in series through the adhesive
Basic – AO Gen II Element

- Addition of cathode foil turns the silver paint and adhesive layer into parallel connections rather than series
- The cathode foil can be as much or more than 25X the conductivity of the silver filled systems
Gen II 6 layer array

- Edge resistance in each element of Gen I previously stacked to increase ESR
## AO Gen II Part Types

### Calculated Maximum Cap and ESR Values

<table>
<thead>
<tr>
<th>Case Size</th>
<th>Capacitance at Rated Voltage (μF)/ESR (mΩ) Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 V&lt;sub&gt;r&lt;/sub&gt;</td>
</tr>
<tr>
<td>7343-20</td>
<td>860</td>
</tr>
<tr>
<td>7343-15</td>
<td>560</td>
</tr>
<tr>
<td>7343-12</td>
<td>380</td>
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<tr>
<td>7343-10</td>
<td>270</td>
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<tr>
<td>3528-20</td>
<td>220</td>
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<tr>
<td>3528-15</td>
<td>150</td>
</tr>
<tr>
<td>3528-12</td>
<td>100</td>
</tr>
<tr>
<td>3528-10</td>
<td>68</td>
</tr>
</tbody>
</table>
Characteristics
To create conditions where scintillation or self-healing is minimized and failure is catastrophic. To simulate “Power-On” failure conditions.
Differences in Ta versus Aluminum Structure

No “Wedges” in Al Structure

- No Derating required at Max Temperature for Aluminum Polymers
ESR and Impedance vs. Frequency
AO Gen II vs. TA Polymer

Impedance and ESR vs. Frequency
A720V227M006ATE vs T520V227M006ATE012

0.0001 0.001 0.01 0.1 1 10

0.0001 0.001 0.01 0.1 1 10

100 1000 10000 100000 1000000 10000000

f (Hz)

ESR A720  Z A720  ESR T520  Z T520

GWH
6/7/2013
Capacitance vs. Frequency

AO Gen II vs. TA Polymer

Capacitance vs. Frequency
A720V227M006ATE vs T520V227M006ATE012

GWH 6/7/2013
Live Test Example
Gen II AO, 220uF Rated at 6.3V

105°C Life Test @ Vr
700V227M006/006 E009 Q3222001A

Percent

% of Nominal CAP
Gen I Manufacturing
AO-CAP Product Flow

Al Foil Etching
Formation & Slitting

Al Foil Supplier
Similar to processes for electrolytic capacitors

Stacking
Molding

Racking Edge Formation
Polymerization Carbon/Silver Solid Test

DPD/Aging
AKO Testing
Form and Tape

Similar to processes for electrolytic capacitors.
AO-CAP Product Flow

Racking – Places Al elements on SS process bars for mass handling

- Key Parameters:
  - Foil length
  - Pitch
  - Weld strength
  - Cut quality
AO-CAP Product Flow

Masking – Controls edge formation electrolyte and polymer height

Key Parameters:
- Mask line position
- Coverage
AO-CAP Product Flow

Edge formation - Repairs edge slitting:

- Key Parameters:
  - Dielectric thickness
  - End current

Cross-sections of formed layers (x60,000) (formed at 250 Vfe after hydration treatment)

Porous oxide edge protection

Barrier oxide
AO-CAP Product Flow

- **Racking / Masking**
- **Edge Formation**
- **Polymerization**
- **Reformation**
- **Carbon / Silver Solid Test**
- **Stacking**
- **Molding**
- **DPD / Aging**
- **AKO Testing**
- **Form and Tape**

- **Key Outputs**
  - Face coverage
  - Poly thickness
  - Poly weight pickup
  - Edge coverage thickness
AO-CAP Product Flow

Racking / Masking
Edge Formation
Polymerization

Reformation
Carbon / Silver
Solid Test

Stacking
Molding

DPD / Aging
AKO Testing
Form and Tape

Reformation: Heals leakage sites generated during polymerization:

• Key Parameters:
  – Voltage
  – Electrolyte
  – Temperature
  – End current

[Graph showing voltage and current over time]
AO-CAP Product Flow

- **Key Parameters:**
  - Viscosity
  - Dip depth
  - Dwell time
  - Withdraw rate
- **Key Output:**
  - ESR
  - ESR shift
AO-CAP Product Flow

- **Racking / Masking**
  - Edge Formation
  - Polymerization

- **Reformation**
  - Carbon / Silver
  - Solid Test

- **Stacking**
  - Molding

- **DPD / Aging**
  - AKO Testing
  - Form and Tape

- **Key Parameters:**
  - Viscosity
  - Dip depth
  - Withdraw rate

- **Key Output:**
  - ESR
AO-CAP Product Flow

Solid Test – Tollgate electrical & physical test:

- Key Parameters:
  - LCDE
  - Thickness
AO-Cap Product Flow

- Racking / Masking
- Edge Formation
- Polymerization
- Reformation
- Carbon / Silver
- Solid Test
- Stacking
- Molding
- DPD / Aging
- AKO Testing
- Form and Tape

Key Parameters:
- Ag adhesive dot size
- Element placement
- Weld strength
- Stack height
AO-Cap Product Flow

- Leadframe carrier to mold chaise
- Pressure + Heat, Plastic flows over body
- Heat + Time = Cure
- Deflash, Dejunk, Singulate

Key Characteristics:
- Temp
- Pre-heat
- Transfer speed
- Pressure
- Cure time
Testing and Finishing

Post Mold Cure - Stabilizes the molding epoxy

Deflash Print Dejunk - Removes excess flask, prints, & singulates

Aging - Conditions parts and heals Lkg sites created during processing.

Reflow - Exposes parts to customer conditions and increase electrical screening efficiency.

100% Electrical Testing AKO - LCDE test and removes failed parts.

SMT Test - Tollgate sample simulating customer conditions.

Form and Tape 100% Electrical Testing - Forms leads and retest 100% of parts for LCDE
Testing and Finishing

AKO Tester

100% Electrical screen

- Lkg – V rated
- Cap – 120 Hz
- DF – 120 Hz
- ESR – 100KHz

TFT & 2nd 100% Electrical screen

- Lkg – V rated
- Cap – 120 Hz
- DF – 1000 Hz
- ESR – 100KHz
Gen II Process
Process Flow

Aluminum foil welded to process bar

Shape of element is stamped

Formation and Anode/Cathode isolation

Polymerization/Carbon/Silver
Process Flow

Element with silver

Copper foil

Elements and copper foil combined together with silver adhesive
Process Flow

- Over-molding
- Saw Dicing
- Laser ablation
- Nickel plating
- Terminal Attachment
Thank You!