Short Introduction of Today‘s Presenter

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Background:
• More than 25 years of work experience in electronics industry
• Background in Management & Business Administration, Electronics, Global Supply Chain Management and Supply Chain Risk Management
• In charge for strategic conception & development of capacitor division at WE
Agenda

• Aluminum Base Foil

• Differences Between Low Voltage & High Voltage

• High Voltage Aluminum Polymer Capacitors?

• Future Developments
Aluminum Base Foil
Everything starts with the Aluminum Foil

- From raw aluminum to edged anode foil
- Process time varies between low voltage & high voltage
Importance of the Base Aluminum Foil

• Surface treatment (electrolysis)
• Anode foil low rated voltage looks like a sponge or coral
• Anode foil high rated voltage looks like mountains / stalagmites

• Minimum foil thickness => mechanical and voltage strength
Importance of the Base Aluminum Foil

- High voltage results in high roughness
- Limitation is residual thickness
- Forming voltage for a 550V capacitor
  - Up to 850V
- Fine surface etching
  - Accomplished mainly by AC electrolysis
- Tunnel etching
  - Accomplished mainly by DC electrolysis
Low Voltage vs.
High Voltage Foil
Difference between Low Voltage & High Voltage Foil

• Low Voltage Anode Foil

After edging, before forming

• High Voltage Anode Foil

After forming, oxide layer

- Aluminum Foil after forming process
- Existing dielectric layer - AL₂O₃
Difference between Low Voltage & High Voltage Foil

• Low Voltage Anode Foil

  • Controlled hole size / porosity to enlarge the surface
  • Allow thin oxide layer for low voltage capabilities without closing the holes
  • Final hole diameter incl. the oxide layer has to allow an influx of the electrolyte to use and activate the surface area

• Hole / opening of the tube too small – oxide layer will close the hole, low effectiveness

• Hole / opening of the tube in right size – oxide layer will be formed inside the whole tube and will increase the surface area significantly, high effectiveness
Difference between Low Voltage & High Voltage Foil

- High Voltage Anode Foil
  - Surface of the high voltage foil with narrow aluminum spikes, low effectiveness as the oxide layer will cover more than just one spike
  - Maybe same oxide layer thickness but less C per mm²

- Controlled porosity and minimum base foil thickness
- Allow thicker oxide layer for high voltage capabilities without damaging the base film

- Surface are with spikes that allow a more thick oxide layer, high effectiveness for higher working voltage capabilities
Working Voltage
Surge Voltage
Forming Voltage
An aluminum capacitor will be rated with its working voltage
- Headline – e.g. 63V 220µF 105°C
- Cap should not be applied to voltage above working voltage frequently or long time to avoid any overheating or fatal damage

A surge impulse however may not damage the cap depending on its energy

See datasheet surge voltage values

Approx. $U_S = 1.1$ to $1.2xU_R$

### Electrical Properties:

<table>
<thead>
<tr>
<th>Properties</th>
<th>Test conditions</th>
<th>Value</th>
<th>Unit</th>
<th>Tol.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacitance</td>
<td>0.25 V/120 Hz/ +20 °C</td>
<td>820</td>
<td>µF</td>
<td>±20%</td>
</tr>
<tr>
<td>Rated Voltage</td>
<td>$U_R$</td>
<td>250</td>
<td>V (DC)</td>
<td>max.</td>
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<tr>
<td>Surge Voltage</td>
<td>$U_S$</td>
<td>288</td>
<td>V (DC)</td>
<td>max.</td>
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<tr>
<td>Leakage Current</td>
<td>5 min./+20 °C</td>
<td>$I_{leak}$</td>
<td>1358</td>
<td>µA</td>
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<tr>
<td>Dissipation Factor</td>
<td>0.25 V/120 Hz/ +20 °C</td>
<td>DF</td>
<td>15</td>
<td>%</td>
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<tr>
<td>Ripple Current</td>
<td>120 Hz @105 °C</td>
<td>$I_{Ripple}$</td>
<td>2.78</td>
<td>A</td>
</tr>
</tbody>
</table>
Working Voltage vs. Surge Voltage vs. Forming Voltage

- No standard for the ratio between $U_S$ & $U_R$
- Check and compare competitor’s datasheets
- Forming voltage however is the voltage applied to the anode foil during forming process
- Form the $\text{Al}_2\text{O}_3$ layer
- $U_F$ approx. 1.5x $U_R$
Inside Voltage Handling
Regular Voltage Handling Between Anode & Cathode

Anode (Foil)  \[ \text{Al}_2\text{O}_3 \text{ Layer / Dielectric} \]

Separator with Electrolyte

Cathode (Foil)
Oxide Layer Reduction

While in storage conditions - no voltage applied – no usage, the electrolyte will reduce the oxide layer over time.
Oxide Layer Importance

- Much higher voltage across the electrolyte to the cathode foil
- Electrolyte (chemicals with water inside) will start boiling immediately
- Gas will escape abruptly – by explosion
- Vent will open
Oxide Layer Importance

• In a working system the oxide layer will more or less remain its thickness and function
• A reduced oxide layer can be refreshed with controlled scenario – low voltage applied / ramp up
• Oxygen inside the electrolyte will allow a self-healing of the AL$_2$O$_3$ layer over time
• The higher the working voltage the more thicker the oxide layer needs to be
• There is a correlation between forming voltage and thickness of the dielectric layer – about 1V to 1nm AL$_2$O$_3$ layer construction
High Voltage Polymer?
High Voltage Polymer?

- High voltage may harm the polymer structure
- No or very limited self-healing capabilities of solid polymer capacitors
- No oxygen because – no electrolyte inside the solid polymer tape capacitor
- Solution could be a Hybrid Polymer Capacitor
- Polymer flakes in a liquid will create a combination – advantages from electrolyte (self-healing capabilities) and higher voltages with lower ESR than regular electrolytic
- R&D already has a 400V polymer hybrid type under test conditions
- Highest possible voltage of electrolytes still “far” away from polymer capabilities
Future Trends
Future Developments

- Increasing market requirements for higher voltages
- New Energy power converters
  - 550WV to 750WV
  - Close to 1kV FV
- More stable electrolytes
- High charge & discharge currents
- Long lifetimes with 20,000 up to 50,000hrs
- Temperature stability up to 150°C
- High vibration resistance
Thanks for your attention!