High Voltage in Aluminum Capacitors

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Capacitor Workshop

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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

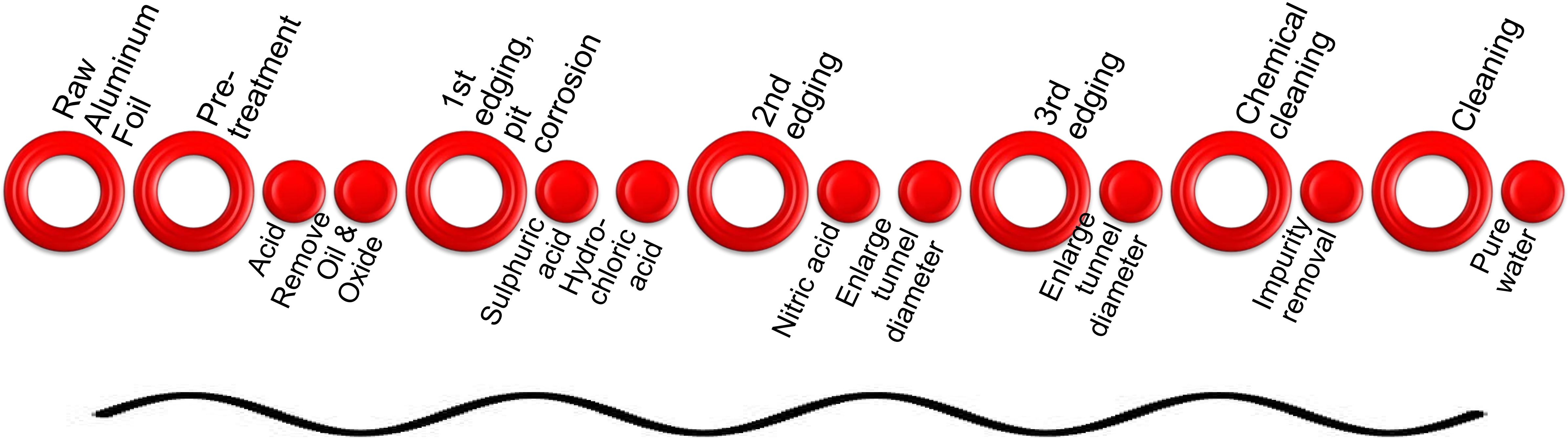
Agenda

- **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**



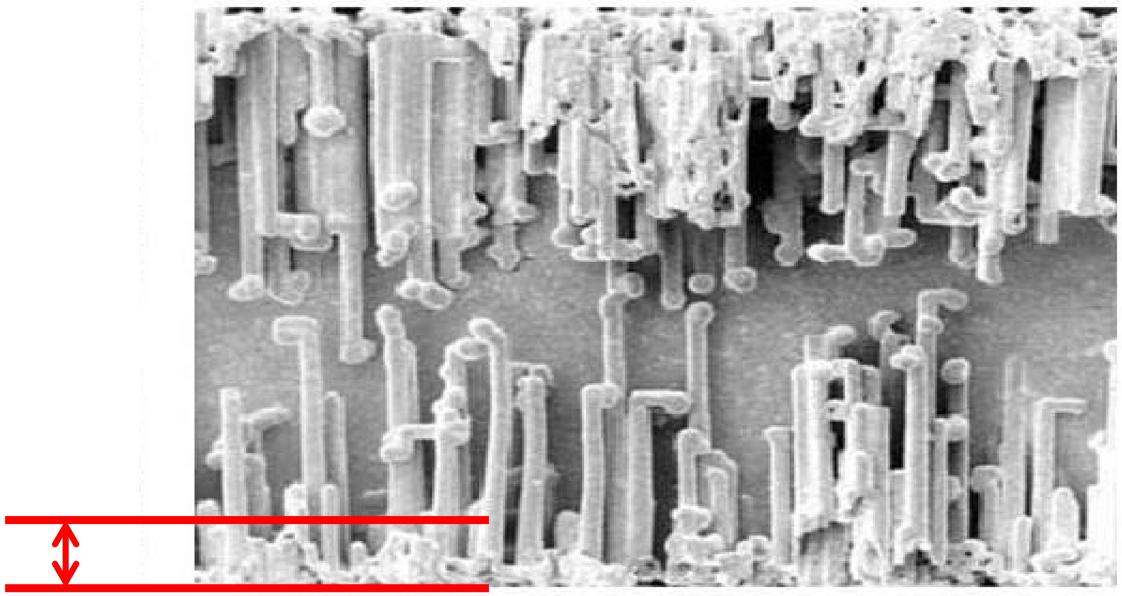
Importance of the Base Aluminum Foil

- 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

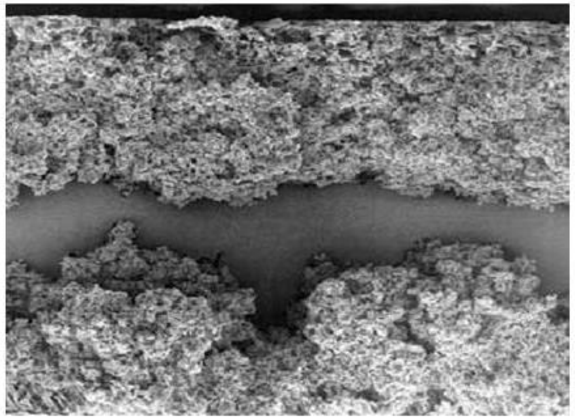
- High voltage results in high roughness
- Limitation is residual thickness
- Forming voltage for a 550V capacitor
  - Up to 850V
- Fine surface etching
  - Accomplished mainly by AC electrolysis
- Tunnel etching
  - Accomplished mainly by DC electrolysis



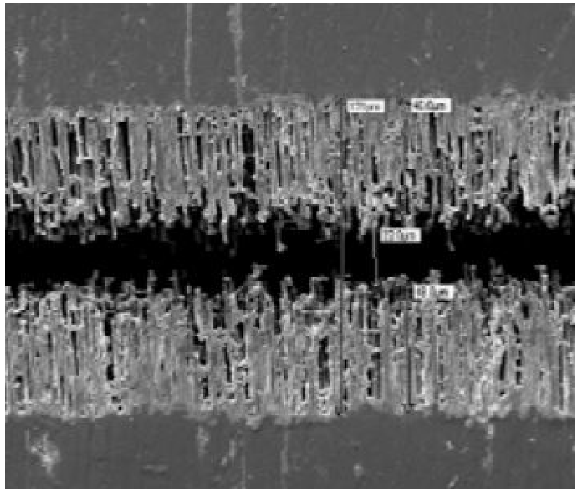
Low Voltage vs.
High Voltage Foil

Difference between Low Voltage & High Voltage Foil

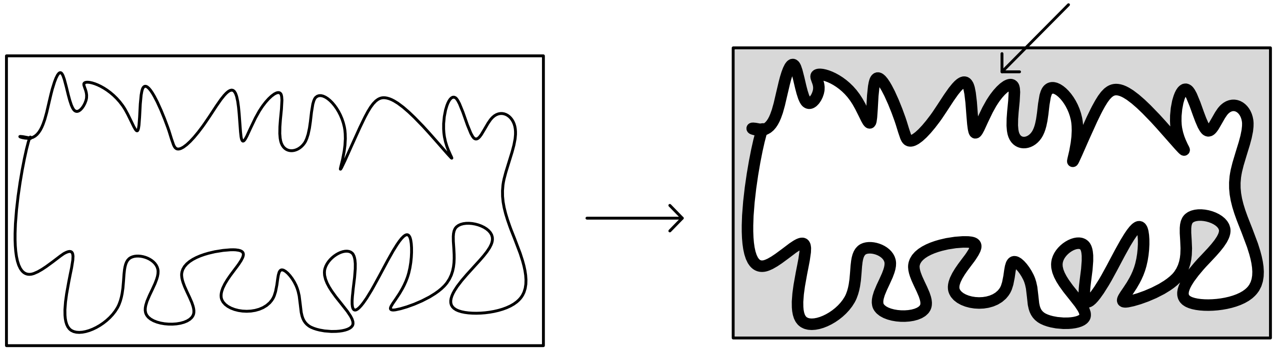
- **Low Voltage Anode Foil**



- **High Voltage Anode Foil**



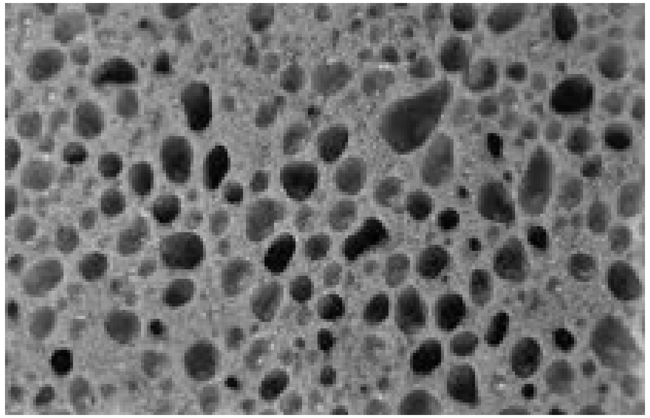
After edging , before forming **After forming, oxide layer**



- **Aluminum Foil after forming process**
- **Existing dielectric layer - AL_2O_3**

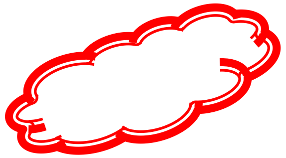
Difference between Low Voltage & High Voltage Foil

- **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

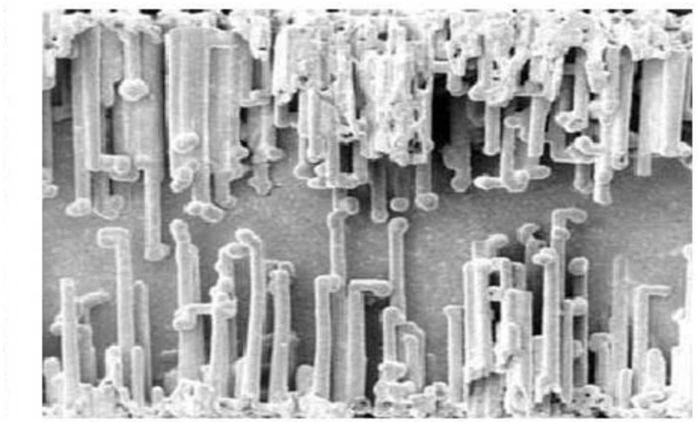
- Hole / opening of the tube too small – oxide layer will close the hole, low effectiveness



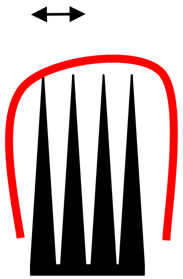
- Hole / opening of the tube in right size – oxide layer will be formed inside the whole tube and will increase the surface area significantly, high effectiveness

Difference between Low Voltage & High Voltage Foil

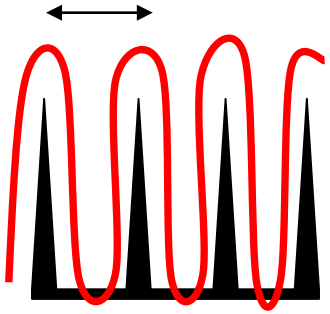
- **High Voltage Anode Foil**



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



- 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 mm^2



- Surface are with spikes that allow a more thick oxide layer, high effectiveness for higher working voltage capabilities

Working Voltage
Surge Voltage
Forming Voltage

Working Voltage vs. Surge Voltage vs. Forming Voltage

- An aluminum capacitor will be rated with its working voltage
  - Headline – e.g. 63V 220µF 105°C
  - Cap should not 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

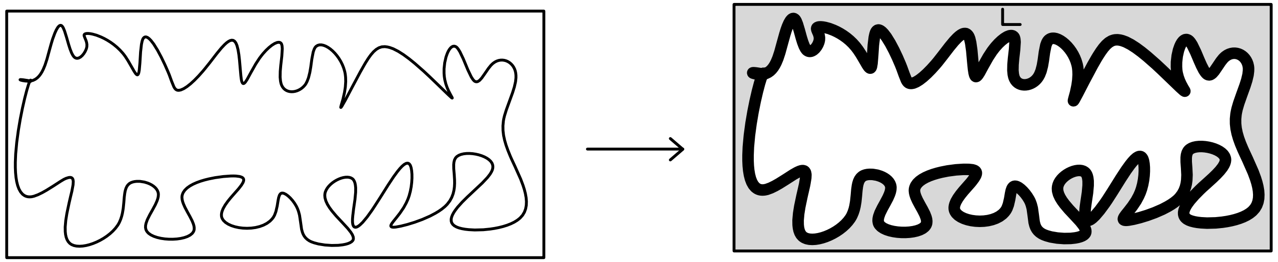
- See datasheet surge voltage values
- Approx. $U_S = 1.1$ to $1.2xU_R$

Electrical Properties:

Properties	Test conditions		Value	Unit	Tol.
Capacitance	0.25 V/ 120 Hz/ +20 °C	C	820	µF	±20%
Rated Voltage		U_R	250	V (DC)	max.
Surge Voltage		U_S	288	V (DC)	max.
Leakage Current	5 min./ +20 °C	I_{Leak}	1358	µA	max.
Dissipation Factor	0.25 V/ 120 Hz/ +20 °C	DF	15	%	max.
Ripple Current	120 Hz @ 105 °C	I_{RIPPLE}	2.78	A	max.

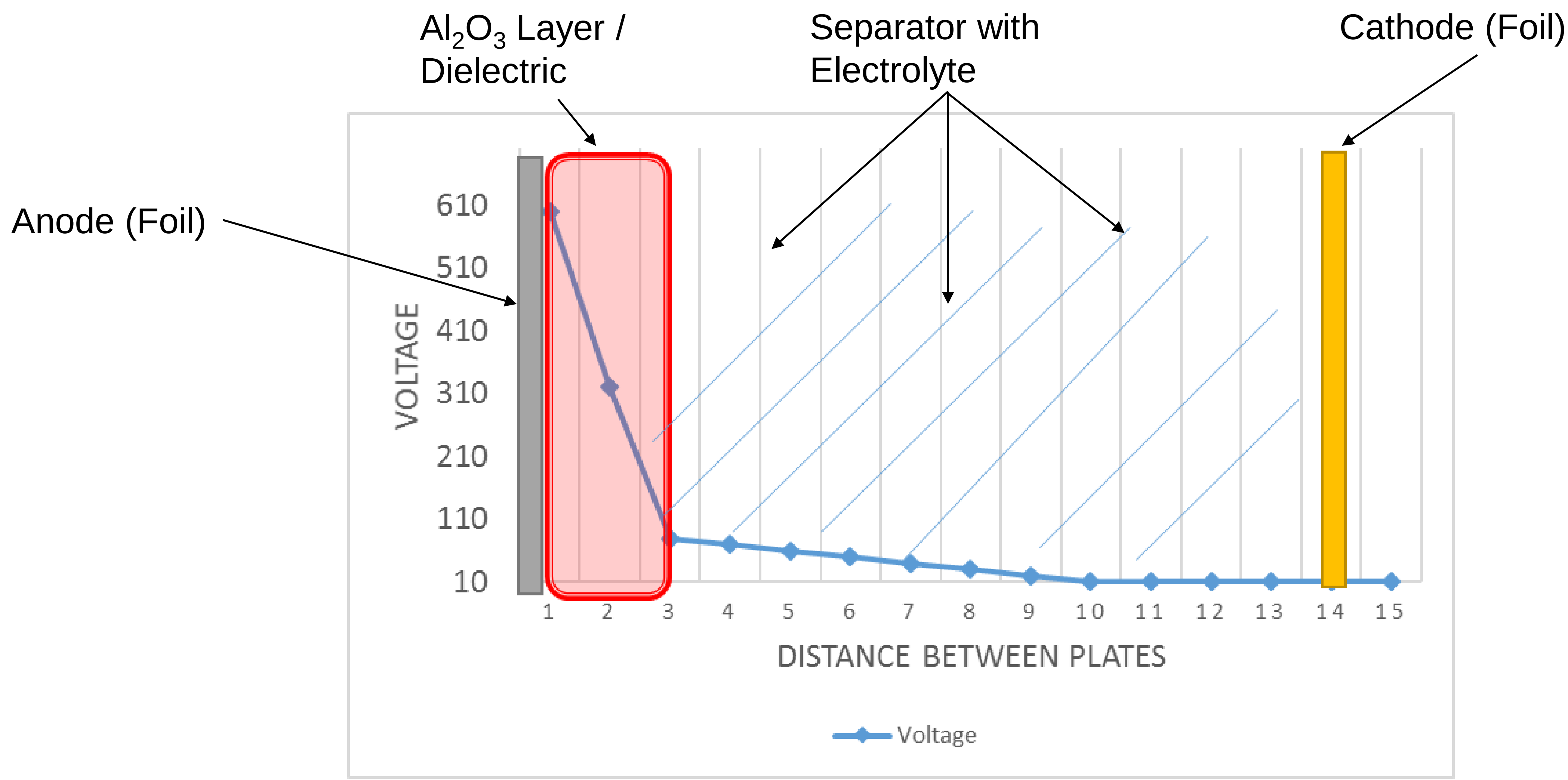
Working Voltage vs. Surge Voltage vs. Forming Voltage

- **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 AL_2O_3 layer**
- **U_F approx. 1.5x U_R**

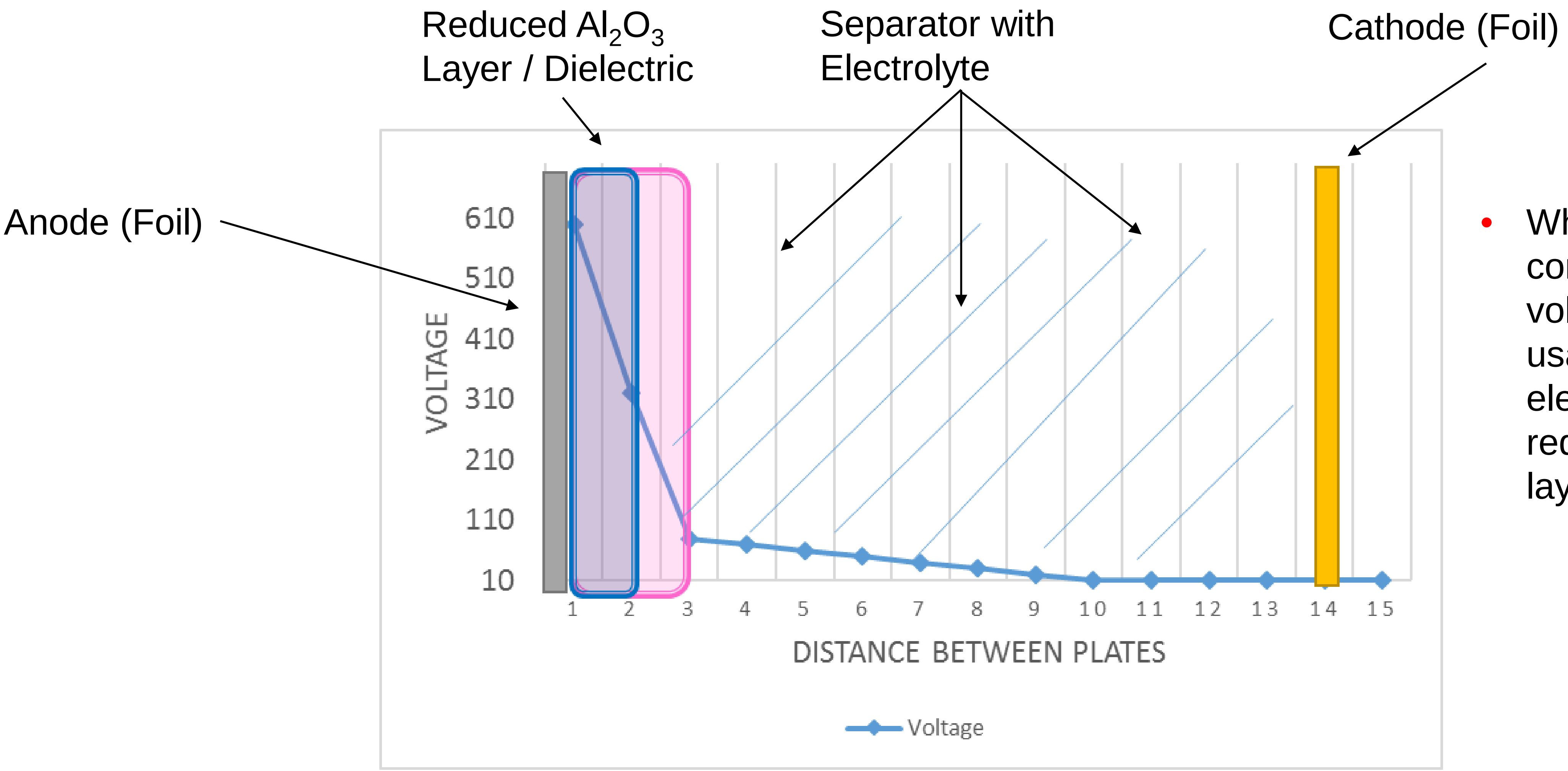


Inside Voltage Handling

Regular Voltage Handling Between Anode & Cathode

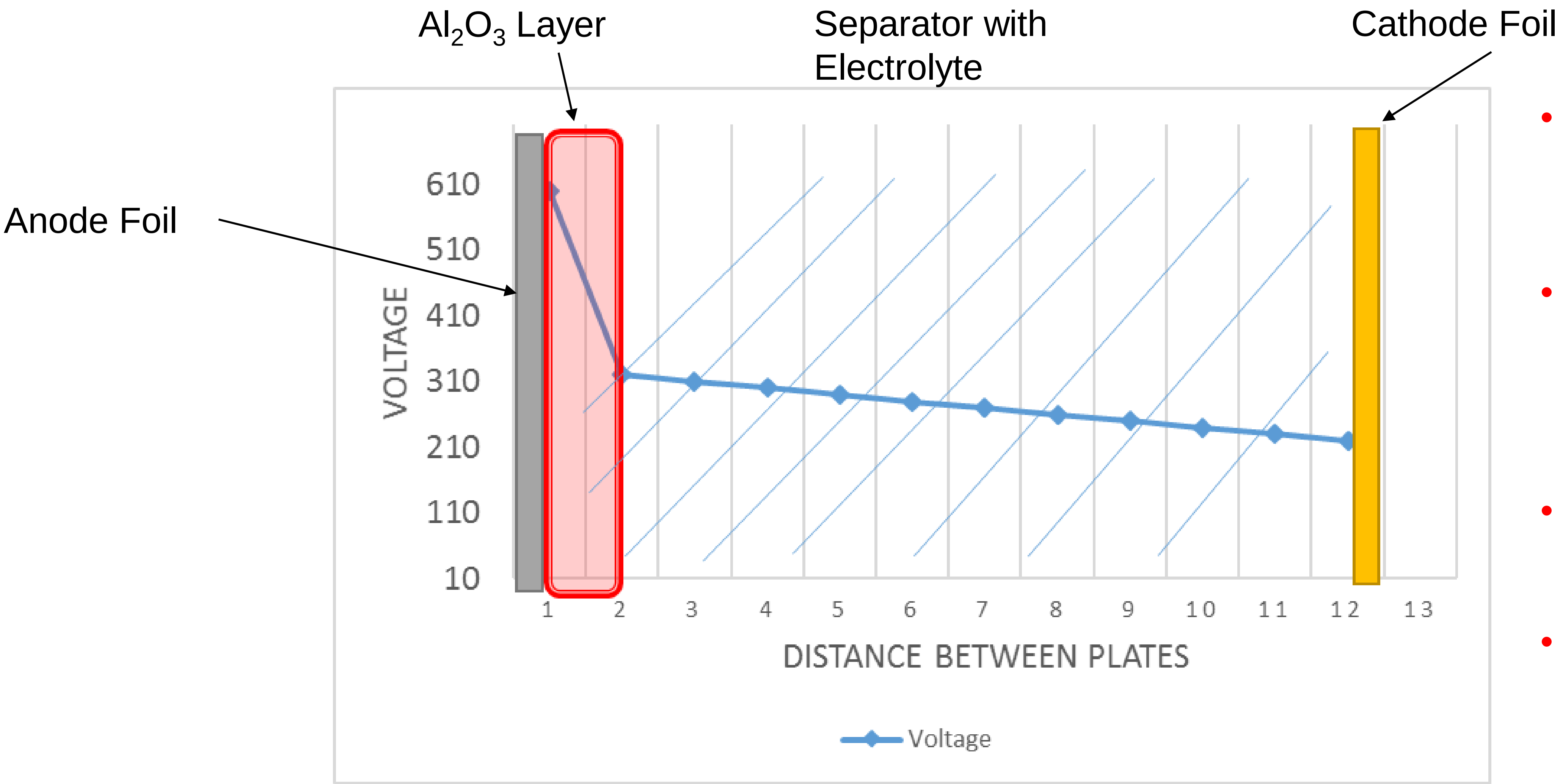


Oxide Layer Reduction



- 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_2O_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_2O_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!