Aluminum Capacitor Anode Foils for Miniaturized Applications

H. A. Post, G. Tempelman, M. van Zijtveld
Vishay BCcomponents, Aluminum Capacitors Division
Ceintuurbaan 15, 8022 AW Zwolle, The Netherlands.
Tel: +31-38-4575-297; Fax: +31-38-4575-462.
Email: henk.post@vishay.com

INTRODUCTION

Miniaturization is a trend since many years. Products become smaller and lighter all the time. For Aluminum Capacitors this means that among others anode foils with higher capacitance are needed. As strong player in Aluminum Capacitors for automotive electronics Vishay has its own in-house Aluminum Capacitor LV anode foil production. This in-house production favorably uses a proprietary technology. This results in mechanically strong foils with among others good high temperature properties. To keep this position in the ever changing world of miniaturization and increasing quality requirements there is a continuous effort in R&D on these LV anode foils.

The work presented here describes our recent progress made for aluminum capacitor LV anode foil of high capacitance.

DESCRIPTION OF THE ALUMINUM CAPACITORS

Non-Solid Aluminum Capacitors consist of electrochemically etched aluminum anode and cathode foils separated by a porous medium (mostly paper). The porous etch structure and separator medium is filled with a conductive fluid electrolyte. Foils and separator are wound to a cylindrical cell, impregnated with the electrolyte and put into an Aluminum can. The can is sealed by a disk or bung in combination with a rimming construction. The anode and cathode foils are connected to the external electrode terminations.
Different constructions exist which have different properties. The SMD version is shown in Figure 1.

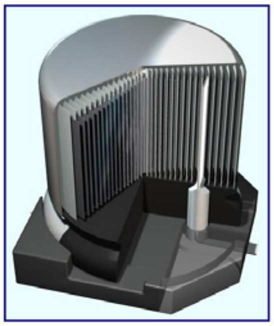

Figure 1. SMD version of an Aluminum Capacitor

A schematic presentation of a cross section through the interfaces of the foils and spacer is shown in Figure 2. The high capacitance value per volume is obtained by using highly etched aluminum anode foil on which a very thin dielectric barrier type aluminum oxide layer is formed. The thickness of the dielectric layer is roughly proportional to the forming voltage. The electrical contact to these layers is made through the use of a pore filling conducting electrolyte which electrically connects the two aluminum foils.

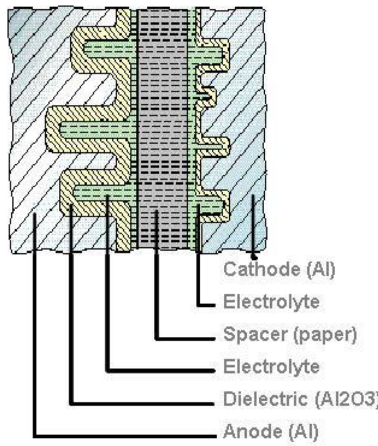

Figure 2: schematic structure of an aluminum capacitor

The ongoing miniaturization increases the demand for higher capacitance anode foils in order to reach the requested CV/volume.

LOW VOLTAGE ANODE FOILS

At our Vishay BCcomponents plant in Zwolle, Netherlands, aluminum Low Voltage anode foil (up to 160V forming voltage) is etched and formed. High purity (1199) aluminum plain foil is used as the starting material with a thickness of approximately 100 microns. The surface area of this foil is enlarged through anodic etching in chloride containing solutions using an interrupted direct current (‘DC-Pulse etching’) (Ref. 1). The obtained pore structure can be characterized by narrow long channels which, due to the interruptions of the current, repeatedly change their directions. The overall length of the pore sections, which have a diameter of approximately 0.2 micron, is more than 5 microns, see Figure 3.

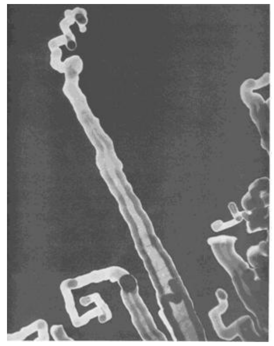

Figure 3: Transmission Electron Micrograph of a channel obtain through interrupted dc etching

Ways to influence the pore width in relation to the forming voltage have been described previously in Ref.2. The pore structures extend to a substantial depth from both sides of the entire foil surface, leaving an unetched compact aluminum zone in the middle of the foil cross-section.
A closer look at Figure 3 also shows the dielectric aluminum oxide layer on the pore surface which was obtained after anodic oxidation. The micrograph clearly reveals that at the channel tips where the inner diameter becomes smaller the oxide completely fills up the pore, thus decreasing the effective surface area. With increasing forming voltage the thickness of the oxide layer increases (1.0-1.4 nm/V) and more effective surface area is lost due to the filling of the channels.

In contrast to our proprietary DC Pulse etching process other mostly Asian anode foil manufacturers use an AC etch process. This AC etch process has a different pore structure. High capacitance anode foils can be made with this process.
The achieved development of the capacitance over time is shown for the Cap@50Vf in Figure 4 for Vishay as well as a leading Asian foil manufacturer. The 'jump' in the Vishay curve in 1981 is due to the introduction of the DC Pulse etching process. The capacitance increase afterwards is due to further improvements in both etching and forming processes. The most recently achieved capacitance increase of 2007 will be discussed below.

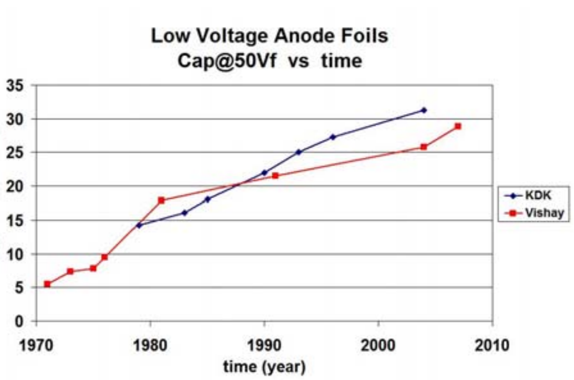

Figure 4. capacitance (50Vf) vs. time for Vishay as well as a leading Asian manufacturer.

RECENT IMPROVEMENTS IN LV ANODE FOIL TECHNOLOGY

The most recently achieved increase in capacitance values was obtained by optimization of the DC Pulse etching process. A number of important process parameters were optimized simultaneously. This resulted in a capacitance increase of 10% for formation voltages Vf ≤ 50 Vf. The resulting curve for CV(Vf) is shown in Figure 5. Also shown are the CV(Vf) curves for high capacitance anode foils of other manufacturers.

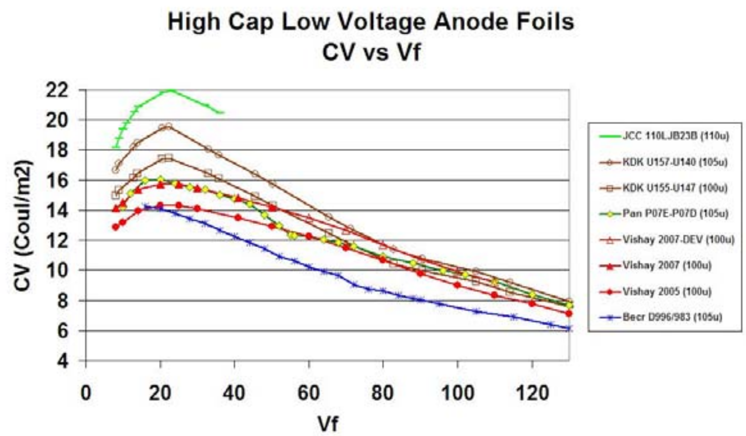

Figure 5. CV vs. Vf for Vishay as well as other manufacturers

To get a more clear picture of the differences the ratio of CV and CV-Vishay-2005 vs. Vf is shown in Figure 6. It shows that the new Vishay foil ('Vishay 2007') has equivalent or better capacitance than the Panasonic P07E type but still lower than the KDK types.
Further development work is under way to extend this 10% capacitance increase also to the higher Vf values.

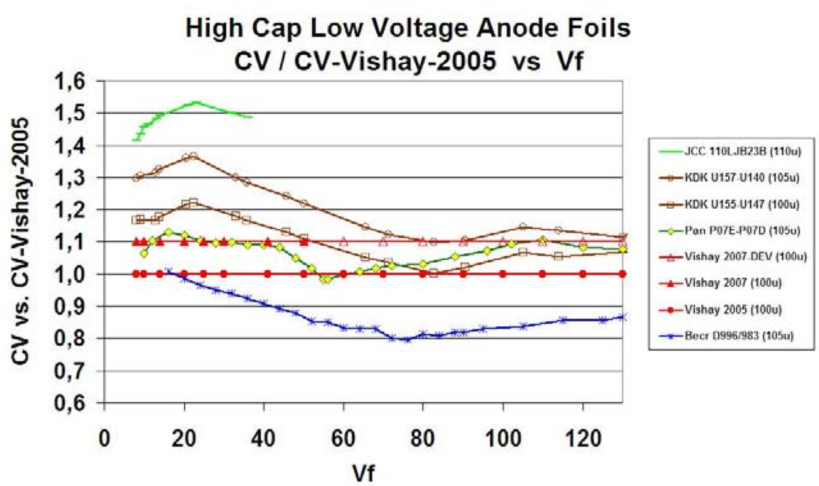

Figure 6. Ratio of CV and CV-Vishay-2005 vs. Vf for Vishay as well as other manufacturers.

MECHANICAL PROPERTIES

It is always possible to increase the foil capacitance by etching 'deeper', i.e. increasing the etching time and so the total etching charge applied under given process conditions. However, in such cases the mechanical strength of the foil will be reduced as is shown in Figure 7. That the newly developed etching process provides inherently better mechanical properties for a given capacitance value is also shown in Figure 7. This enables the use of the new etching process conditions generating an increased capacitance value and still good mechanical properties.

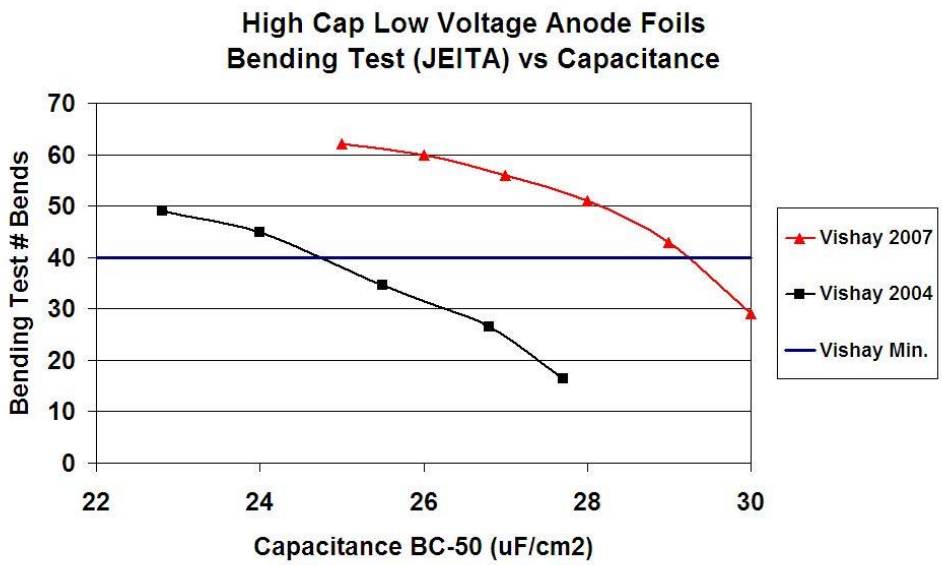

Figure 7. Bending Test results acc. the JEITA method as function of capacitance at 50 Vf for the Vishay 2004 as well as the new 2007 etching process.

SUMMARY AND OUTLOOK TO THE FUTURE

A new etching process has been developed enabling an increase of capacitance value with another 10% for the Vishay Low Voltage anode foil types for the formation voltages Vf ≤ 50 Vf. The newly developed Vishay foil has equivalent or better capacitance than the Panasonic P07E type but still lower than the KDK types.
Further development work is under way to extend this 10% capacitance increase also to the higher Vf values.

REFERENCES

1. R.P.T Ruijgrok and G. Tempelman, US Patent 04484252.
2. P. Bressers, Aluminum Anode Foil for Low Voltage Electrolytic Capacitors, CARTS-Europe 2002 Proceedings of the 16th European Capacitor And Resistor Technology Symposium, p. 68 (2002).