Lowest ESR at High Voltage - Multianode Tantalum Capacitors

I.Horacek, L.Marek, J.Tomasko, T.Zednicek, S.Zednicek
AVX Czech Republic s.r.o., Dvorakova 328, 563 01 Lanskroun, Czech Republic

ABSTRACT

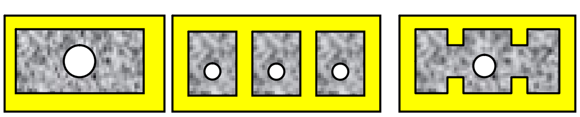
Power supply and networking applications require higher voltage range of tantalum capacitors with lowest possible ESR. The paper describes a new technology based on multi-anode construction that was developed in order to bring ESR of 25V and 35V parts to the currently lowest ESR level. The technology upgrade was possible only with modifications to the anode construction, sintering process, forming and manganizing. Special processes of formation were developed in addition to improved break down resistance at higher voltage.

INTRODUCTION

Tantalum capacitor technology has many characteristics ideal for filtering applications in DC/DC converters, power supplies and other applications. The most important and common characteristics are:

- Low and Stable ESR
- High Capacitance Retention at High Frequencies
- Low Failure Rate
- Wide Voltage Range
- Surge Robustness
- Environmental robustness (moisture/temperature)
- Low Cost

One of the most important parameters that have an effect on the characteristics above is the shape of the anode. The overall surface area of a tantalum capacitor anode, particularly its surface-to-volume ratio defines its ESR value - the higher the overall surface area, the lower the ESR.



a] single anode b] multi anode c] fluted anode

Figure.1. Anode design in cross section

The single anode (Figure 1a) is the standard used for general capacitor designs because of cost and performance efficiency. A multi-anode design (Figure 1b) offers the lowest ESR. The fluted anode design (Figure 1.c) is a compromise solution between single and anode design as regards low ESR and manufacturing cost. More references see [1], [2], [3].

Multianode construction with conventional MnO_2 second electrode system have a couple of advantages compared to emerging polymer multianode capacitors such as "true" lead-free reflow capability, better stability at humidity load and potential for higher voltage capacitors. Especially in high voltage fields like 25 to 50V multianode tantalum designs would offer the lowest ESR in the industry and help electronic device designers to develop new range of smaller and highly efficient power supplies. There are however some technology limitations that made preparation of such parts difficult. This paper describes new technology that enabled AVX to achieve the lowest ESR 25 to 35V capacitors with further potential towards 50V tantalum SMD multianode capacitors.

HIGH VOLTAGE MULTIANODE CAPACITOR

The development effort yielded a brand new category of low ESR high rated voltage tantalum capacitors. Frequency characteristic of E case 33uF 35 V multianode capacitor - see Figure 2. The ESR value at 100 kHz is about 40mOhms. But the way to achieve it was not straightforward.

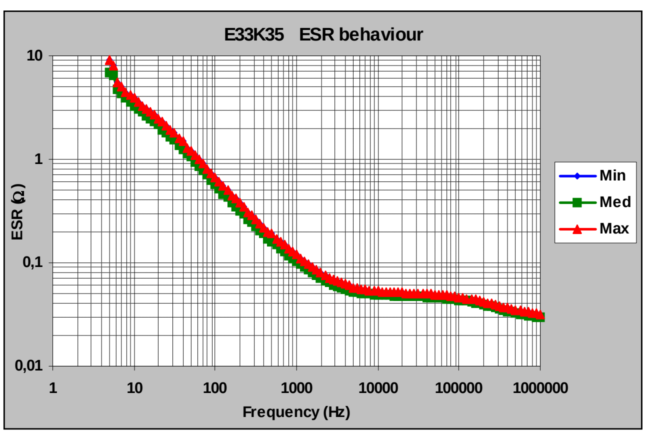


Fig.2. ESR vs frequency E 33uF / 35 V multianode tantalum capacitors.

PRESSING & SINTERING

It is necessary to sinter the capacitor pellet at quite high sinter temperature in order to produce high voltage parts with sufficiently robust inter-particle necks. If the necks are not thick enough, then they are disconnected or thinned too much during the dielectric forming and the part reliability become poor.

Unfortunately, such high temperature neck forming is accompanied by massive shrinkage of tantalum pellet. When the anode structure is not even and non-uniform shrinkage occurs then distortion can be achieved as seen in Figure 3. Such anodes are naturally unsuitable to be built in the anode multi package.

Figure 3. Non-acceptable anode shape post sintering.

To overcome this issue we had to optimize the tantalum powder mixing method using a special binder. Side pressing was employed due to better homogeneity along the anode length. Sintering operation had to be optimized as well to reduce non-linear shrinkage. Finally the optimal method for anode production was developed with good quality for later multi packing (Fig.4)

Figure 4. Acceptable anode shape post sintering.

DIELECTRIC FORMING

Dielectric formation is the most important operation during the tantalum capacitor production. Tantalum pentoxide is formed electrochemically as a n amorphous hydrated glass. Nevertheless some crystal seeds are always present at the tantalum surface as a product of oxygen post sinter precipitation. The dielectric crystal growth depends on temperature and time. Therefore carefull thermal management during the first forming is substantial for anode long-term reliability.

As anodes undergo thermal shocks in manganising they have to be pre-treated at forming. Therefore the forming is usually interrupted by high temperature baking. But in addition to the mechanical stress relaxation and dielectric mechanical breaks (due to the different thermal expansion of Ta and Ta_2O_5) the dielectric is being dehydrated at this operation. This is a serious phenomenon as it creates oxygen vacancies, which can take part in the dielectric electrical break down. The vacancies had to be chemically neutralized by oxygen donators. The thicker the dielectric the more serious the issues .

In the final capacitor construction, the anode outer surface is the most electrically stressed area and the edges are really critical, especially the sharp edges. The whole electrical charge going inside the anode has to be divided into streams at the surface. Therefore if an electrical break down appears, then it is frequently at the outer surface. Lower rated voltage codes use for protection of the outer surface a so-called "shell form", which means that the dielectric thickness is significantly increased selectively at the outer surface only.

So development of "shell formation" for high rated voltage codes like E 33uF/ 35 V (see Fig. 5) was another important step . When a conventional shell form approach was used, the resulting colour (result of light diffraction at thin dielectric layer) is somehow uneven, due to the volt drop along the anode during shell forming. Nevertheless the outer dielectric corresponds to the forming voltage 125 – 130 V in contrast to 104 V for the non-shell formed, for instance. This means that the surface dielectric electrical field intensity is decreased from 190 kV/mm to 150 kV/mm. By further mechanical and chemical development it has been achieved that the outer dielectric color is uniform and corresponds to an even higher voltage (140 V for instance) without additional capacitance drop. The electrical field intensity at the surface dielectric is further decreased to approximately 135 kV/mm.

The surface electrical stress reduction due to the shell is consequently apparent at the capacitor break down voltage distribution (Fig.6). With the shell the break down voltage distribution becomes narrower and shifted to the higher voltage value. That means the part reliability is improved in comparison to that of conventional forming methods.

Figure 5. [green] - non-shell formed anode (104 V); [red] - conventionally shell formed anode (125-130 V); [blue] - especially shell formed anode (140 V).

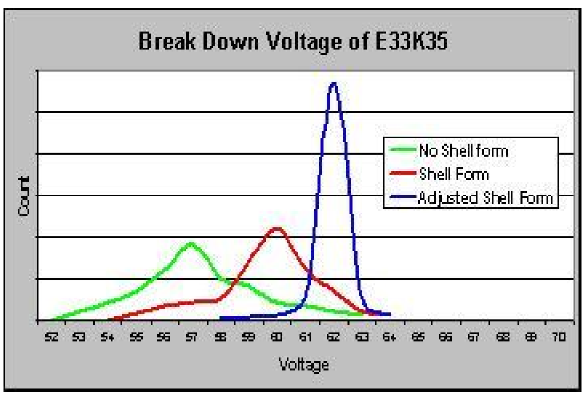


Figure 6.Break down voltage distributions on differently shell formed E33uF /35 V tantalum multianode capacitors.

MANGANISING

The anode structure of high rated voltage tantalum capacitors differs to the one of finer powders. The structure has different shape and broader inter particle channels, for instance. Therefore the manganese nitrate decomposition, as a chain reaction, takes place faster and is more vigorous than we usually observe at finer tantalum powder pellets. The inter-connective agglomerate channels act like “chimneys” where the nitric oxides collect and accelerate to the surface. The nitric oxides splash at the surface and form manganese dioxide creating “blow holes” and “blow hills”. As a result the outer layers of the manganese dioxide are often uneven and crusty (Fig.7).

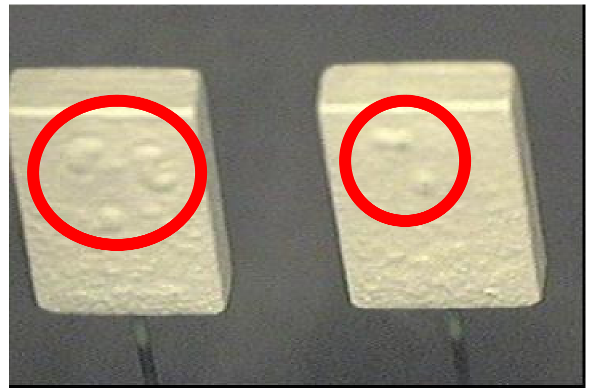


Fig. 7. Unacceptable outer manganese layers for anodes going to the multi-pack

Such crustiness influences not only the successful assembly of tantalum multi-anode capacitors but can also effect the final part performance. The silver diffusion penetration probability increases in blowhole areas strongly.

Even and homogeneous manganese dioxide coat had to be developed especially for the high rated voltage parts (Fig.8.). The optimization covered the manganese nitrate concentration and application sequences but especially the conditions during the manganese nitrate decomposition.

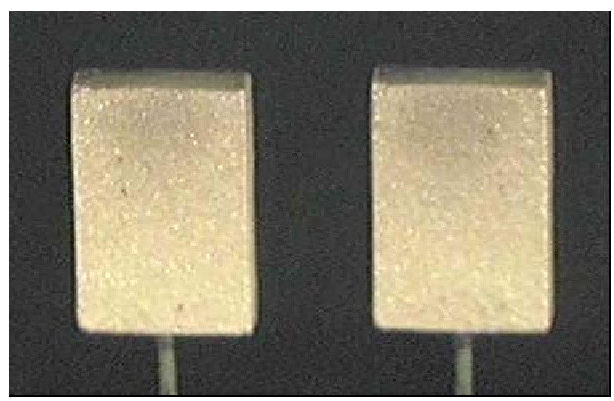


Figure 8. The right shape of high rated volt anodes post manganising.

SILVER AND GRAPHITE

A unique system securing low ESR and superior stability in humidity was developed for fluted low ESR capacitor design [1] and the same system was used for multi-anode concept as well. The great stability in humidity of E 33uF / 35 V tantalum multianode capacitor is documented in Fig.9.

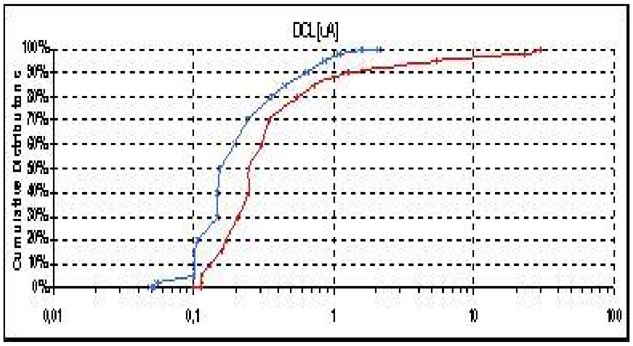


Figure 9. E33uF / 35 V tantalum multianode capacitor humidity stability before (red) & after (blue) special graphite-silver layer introduction [1000 pcs, post 85°C, 85 % RH, 250 hours, 20 s measurement soak time]

APPLICATIONS

The process described above has been applied to capacitors with rated voltage 25 to 35V with further potential to increase the voltage to 50V in near future. The key application area will be in telecommunication / base stations, power supply and automotive industries where small, high efficiency power supplies are needed. 25 to 35V tantalum multi-anodes will offer the lowest ESR in the industry to support these applications for typical operating voltages 12 to 24V. The ESR level for E 68uF 25V part is as low as 55mOhm and for E 33-47uF 35V 65mOhm.

.

SUMMARY & CONCLUSION

A new technology for conventional tantalum multianode has been developed in order to increase voltage range of the series . More technology modifications had to be adjusted that includes:

- Anode design
- Pressing & sinter
- Dielectric forming
- Manganising
- Silver & graphite system

REFERENCES

1] I.Horacek at col. "Improved ESR on MnO2 tantalum capacitors at wide voltage range" CARTS USA 2002, Proceeding

2] E.Reed, J.Marshall "18mOhms and Falling – New Ultra Low ESR Tantalum Chip Capacitors" CARTS USA 1999 New Orleans pp 133-141

3] J.Ladd, "Lowest Available ESR Conformally-Coated Multiple-Anode Tantalum Capacitor" CARTS USA 2000 California pp 228-233