Tantalum Dielectric Produce Superior Capacitors

By Mark Obuszewski, AVX Product Manager

One common trend in switch-mode power supply, microprocessor, and digital circuit applications is to achieve reduced noise while operating at higher frequencies. To this end, a new generation of low ESR tantalum chip capacitors has been developed utilizing a low resistivity MnO_2 electrolyte, enabling very low component ESR, excellent field performance, environmental stability and high electrical and thermal stress resistance in a wide voltage range from 4 V to 50 V.

MnO_2 Conductivity

Research focused on improving the conductivity of MnO_2 electrolyte has resulted in a significant overall ESR reduction in Ta chip capacitors. It was thought that the limit for this technology had been reached, however, recent studies of the underlying physics behind MnO_2 conductivity processes have shown that ESR levels below 50 mΩ for tantalum capacitors can be achieved without the need of either conductive polymer or multi-anode solutions.

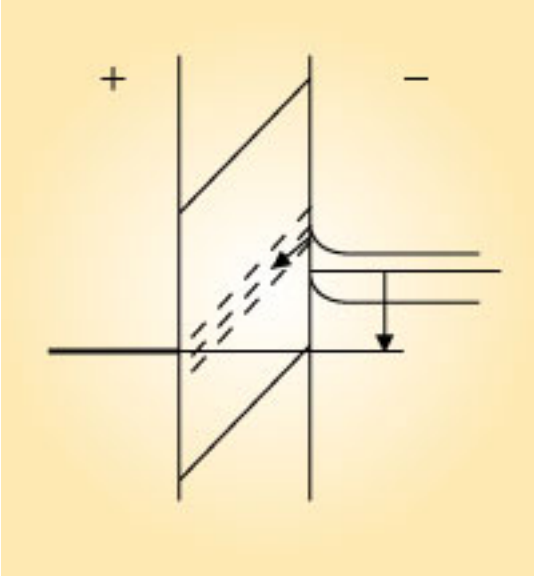

Figure 1. Band diagram of tantalum capacitor in normal mode.

Current research suggests that the capability for MnO_2 to achieve high conductivity in tantalum capacitors has been underestimated. Now, based on a better understanding of the physical mechanisms involved, we are able to demonstrate that ESR values can be significantly improved by modification of MnO_2 technology in accordance with the energy level diagram shown below:

Lower ESR in tantalum capacitors is also associated with lower capacitance loss at higher frequencies and higher continuous ripple current ratings. These effects depend on the actual ESR level. For example, D case capacitors made with MnO_2 or conductive polymer materials exhibiting a 100 kHz ESR of 50 mΩ will show about the same capacitance loss at higher frequencies and will feature equivalent ripple current ratings.

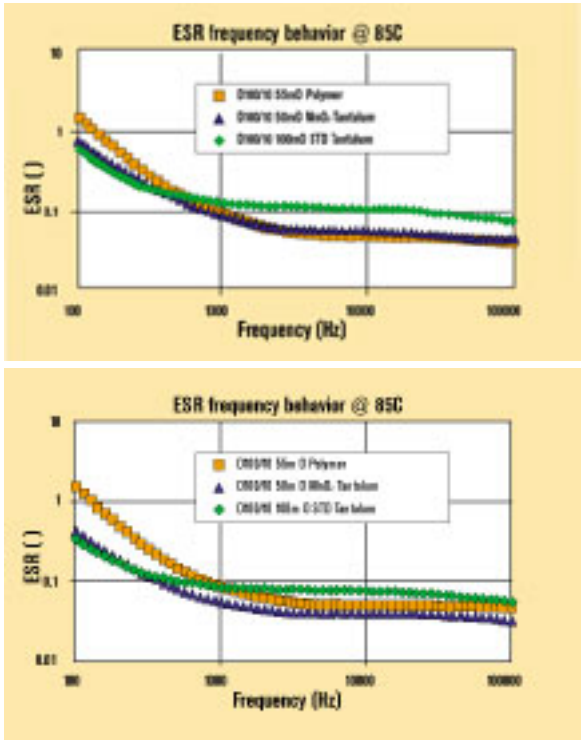

Figure 2. Comparison of Standard Tantalum, MnO_2 and Polymer vs. frequency @ 25&#176C & 85&#176C.

The conductivity of MnO_2 increases as temperature increases. When MnO_2 is used as the counter-electrode material in tantalum capacitors, this provides lower ESR as temperature increases. This is a significant difference from the ESR characteristic of polymer counter-electrode systems, which do not provide increased conductivity. This is an important consideration in applications with higher operating temperatures.

Efficient Self-Healing

Tantalum capacitors are well known for superior reliability characteristics, no dielectric wear-out mechanism and their decreasing failure rate with time under steady state conditions. The self-healing process of MnO_2 is responsible for this behavior. Current flowing through a defect site in Ta_2O_5 dielectric heats MnO_2 at the interface. At temperatures of approximately 400&#176C, the conductive semiconductor MnO_2 will change to Mn_2O_3, a material that features much higher resistivity. This process can isolate the failure site and self-heal the capacitor. Mobile oxygen atoms, a side product of this reaction, are also an important element in the self-healing process of MnO_2 tantalum capacitors. This oxygen is responsible for decreasing the failure rate with time as it continually dopes the Ta_2O_5 dielectric and maintains its dielectric features. There are self-healing mechanisms known for different technologies such as aluminum, plastic film and polymeric capacitors; however, the decreasing failure rate with time is solely a characteristic of the traditional MnO_2 tantalum capacitor system. The importance of this mechanism cannot be overestimated &#151 it is solely this mechanism that allows the tantalum dielectric to operate at high field strength and enables manufacture of medium and high voltage tantalum ratings.

Larger concentrations of oxygen produced by self-healing during high surge overload can result in thermal runaway of the capacitor. Hence, surge limitation and/or appropriate derating is recommended for low impedance applications to

protect the capacitor against overload. The availability of high voltage, Low ESR ratings makes it easy for the design engineer to realize these requirements. During overload, the internal thermal impedance of the tantalum anode is important in providing superior surge robustness of these very low ESR parts. In MnO_2 tantalum capacitors, a special mix of tantalum particle sizes is used to enable greater internal heat dissipation and ensure no &quotweak links&quot occur as thermal runaway paths are generated. Further protection is provided by an internal silicone barrier layer, unique to MnO_2 technology, that also limits external overheating.

Low Leakage Current (DCL)

The general specification for leakage current of MnO_2 tantalum capacitor ratings is 0.01xCV (0.01 &#215 capacitance &#215 voltage rating) equation. For example, 100 &#956F 10 V capacitor will have 10 MA DCL specification limit. The same capacitor with conductive polymer has a ten times higher DCL limit at 100 MA. It is possible to explain the difference in leakage current between these two by the different work functions of MnO_2 and CP (conductive polymer) materials. This can be understood by reference to the MIS (metal/insulator/ semiconductor) structure.

Voltage Range

The new MnO_2 tantalum capacitors comprise a full voltage range from 4 V to 50 V, as with most MnO_2 technologies. This series provides the lowest ESR available for high voltage parts &#151 especially when considering 20 V to 35 V ratings demanded by power supply applications.

Wide Temperature Range

Wide temperature range operation is one of the additional requirements of power converter designers. MnO_2 tantalum capacitors are specified within operating temperatures from -55°C up to +125°C in accordance to working range of MnO_2 capacitors. This range allows standard operation at higher temperatures (125&#176C) compared to the current polymer solutions of other various capacitor technologies (usually +105&#176C maximum).

Conclusion

Advanced MnO_2 tantalum chip capacitors feature innovative electrical characteristics. Developed to provide design engineers with low ESR, wide voltage range, excellent stability and high reliability at a low-cost, the MnO_2 tantalum chip capacitors utilize MnO_2 technology in conjunction with tantalum dielectric to fulfil the requirements of switch-mode power supply, micro-processor and digital circuit applications. By providing the lowest ESR tantalum capacitor in the industry, the new MnO_2 technology allows for high reliability performance in these applications. MnO_2 tantalum chip capacitors offer the reliability of standard tantalum with the field performance, stability and electrical/thermal stress resistance of traditional MnO_2. This superior combination results in the added benefits of reduced DC leakage, a wide voltage range and operating temperatures of up to 125&#176C. Unlike polymer counter-electrode systems, when MnO_2 is used as the counter-electrode material in tantalum capacitors, its conductivity increases as temperature increases. This results in lower ESR at elevated temperatures. These features provide design engineers with superior circuit design solutions that relieve them from resorting to more costly and lower performance polymers.