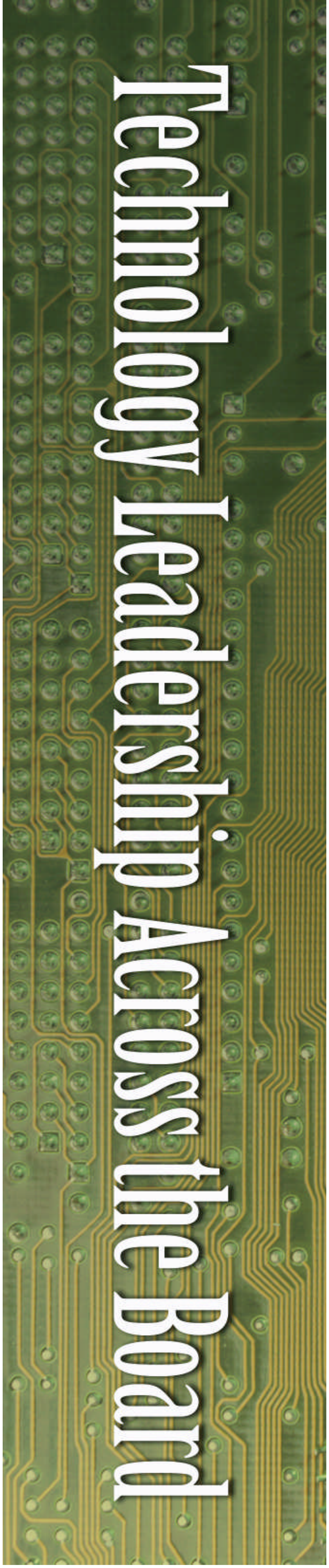

A KYOCERA GROUP COMPANY

Hermetically Sealed SMD Tantalum Capacitors

I. Zednickova, M. Biler, J. Petrzilek, T. Zednicek
AVX Czech Republic s.r.o., Dvorakova 328, 563 01 Lanskroun, Czech Republic
Tel.: +420 465 358 111, Fax: +420 465 358 701, e-mail: jan.petrzilek@eur.avx.com

ABSTRACT

The article presents improvement of stability parameters of tantalum surface mounted capacitors with manganese dioxide or conductive polymer cathode. Higher stability is achieved by placement of the capacitor into an SMD case filled by an inert atmosphere and hermetically sealed. The long term stability testing performed on such hermetically sealed capacitors has proven better stability of both studied types – manganese dioxide capacitor and conductive polymer capacitor. The safe working temperature of hermetically sealed capacitors is 230°C with manganese dioxide cathode and 175°C with polymer cathode.

INTRODUCTION

Tantalum surface mounted capacitors with solid electrolyte have been the favorite capacitor technology choice in many electronic devices for more than five decades thanks to its high stability, reliability and volumetric efficiency. The traditional cathode material - manganese dioxide - is providing good mechanical robustness, relative temperature and humidity stability that suits many applications. The major two disadvantages of the MnO_2 tantalum capacitors are the thermo runaway failure mode and relatively high ESR. Both of these issues have been overcome by using conductive polymers (PEDOT, PPY) as a cathode material. In addition, newly developed technologies using dispersed PEDOT are pushing the maximum levels of rated voltages of tantalum capacitors with solid electrolyte up to 125V.

On the other hand, the conductive polymer capacitors show some significant sensitivity to external conditions such as humidity, mechanical stresses and high temperature. These organic compounds can also exhibit its degradation at elevated temperatures, especially in presence of oxygen or humidity [1,2]. Such changes can encompass oxidation, morphology changes or other mechanisms of degradation which all lead to reduction of the cathode conductivity resulting in increase of ESR or drop of capacitance.

Even manganese dioxide based cathode systems are subject of potential degradation if exposed to extreme conditions. Molding epoxy resin degradation can also negatively influence capacitor performance during a long-term storage at temperatures above 125°C or even relatively short time exposition to very high temperatures exceeding the specification conditions [3].

As a result, the maximum operating temperature in general types of tantalum surface mounted capacitors is limited to 125°C. Some application areas are demanding maximum temperatures exceeding 125°C. For example certain automotive applications (e.g., under the hood) require operating temperature range up to 175°C. There are some MnO_2 types SMD tantalum capacitors on the market that can be used up to 175°C, but there is no option with polymeric cathode available yet that would provide low ESR capabilities and thus superior performance for power supply applications. And there are even more challenging demands for operating temperature in applications like oil-drilling, where further increase of temperature above 200°C is required. Solution to the problem of limited stability in erratic high temperature environment is keeping the capacitor's internal structure away from humidity and oxygen. Since SMT technology is a standard assembly technique in the latest electronics and thus SMD hermetically sealed tantalum capacitors might bring new capability to designers of such equipments.

HERMETIC SEALING

New hermetically sealed SMD tantalum capacitor structure has been designed where the capacitor element is enclosed and hermetically sealed within a ceramic housing. Nitrogen as an inert gas inner atmosphere is used in addition inside the hermetic package to inhibit oxidation of the solid electrolyte.

A wide selection of different materials can be used to form the housing, such as metals, plastics, ceramics, etc. Ceramic packaging has been selected for initial studies due to its solid mechanical robustness and its hermetic sealing capabilities. There is also a wide field experience with other electronic components using this type of package for hermetically sealed cases.

The capacitor element is attached to the ceramic housing by a common anode termination. Cathode termination is then formed to make surface mounted capacitor. The particular configuration of terminations can be customized based on the application requirements. Typically, the ceramic housing and the capacitor element have the similar shape so that the capacitor element can be readily accommodated within the interior space to provide maximum volumetric efficiency.

The housing includes a lid that is placed on an upper surface of side walls after the capacitor element is positioned within the ceramic housing. The lid is typically made of ceramic or metal materials to achieve the appropriate hermetic performance.

The package is hermetically sealed after drying procedure via seam welding process within an inert atmosphere. Resistance seam welding process produces, in that case, a weld at the two surfaces (lid/sealing member) in contact along a length of a joint. 100% testing of hermeticity is performed on all manufactured parts in order to verify and guarantee the sealing quality.

RESULT AND DISCUSSION

Stability studies of tantalum capacitors hermetically sealed under an inert atmosphere in packages described in the above section have been performed. Both temperature and voltage derating combinations have been the subject of extensive studies for various types of capacitors. Specific results of standard manganese dioxide or high voltage polymeric capacitors are presented as an example of hermetic sealing effect in sections below.

Stability testing and analysis of tantalum surface mounted capacitors have been performed on 10μF/35V capacitors with manganese dioxide cathode as well as of those with conductive polymer PEDOT cathode. The test methods of electrical performance were applied at following conditions: For life testing purposes, the capacitors were placed in an oven at appropriate temperature (with an applied voltage equal to 50% of the rated voltage). Detailed description of all test methods is set below.

A. Operating Life A1: duration 2.000hrs, test temperature 150°C, 0.50 U_R
B. Operating Life A2: duration 2.000hrs, test temperature 175°C, 0.50 U_R
C. Operating Life A3: duration 2.000hrs, test temperature 200°C, 0.50 U_R
D. Operating Life A4: duration 2.000hrs, test temperature 215°C, 0.50 U_R
E. Operating Life A5: duration 2.000hrs, test temperature 230°C, 0.50 U_R
F. Moisture Resistance Test D: duration 64hrs, test temperature 120°C, test humidity 85%, U_R

Capacitance has been measured at 120Hz, 0.5RMS with DC bias of 2.2 volts. ESR was measured at 100kHz. All measurements were performed at ambient temperature to verify whether the part is exhibiting any degradation. The results are set forth below in Figures 1-4.

The hermeticity test was conducted using helium detector before and after the following individual test. Maximum helium leakage rate shall not exceed $1x10^{-8}$ atm cc/sec. of Helium. Hermeticity was checked before and after all performed tests to confirm quality of hermetic sealing.

Figures 1 and 2 are showing electrical results (capacitance and ESR) of tantalum surface mounted capacitors in hermetically sealed ceramic housing at temperatures from 150°C to 230°C @ 0.50 U_R for duration of 2.000 hours. It has been proved that capacitors with manganese dioxide cathode are stable up to temperature of 230°C with 50% voltage derating. Capacitors with conductive polymer PEDOT cathode are stable up to temperature of 175°C with 50% voltage derating. Polymer capacitors are exhibiting some increase of ESR and capacitance drop at temperatures above 175°C. Failure analyses confirmed that the phenomenon is connected directly to the changes of the capacitor element – the polymer cathode layer. The mechanisms of conductive polymer degradation at temperatures above 175°C in hermetic package could be explained by chemical or morphology changes in connection to purity of materials used, technological processing or leakage current of the capacitor. Further modification of materials and process optimization may resolve these issues and increase the capacitor operation temperature to even higher level. Conductive polymer capacitors should be capable to achieve acceptable stability of parameters in inert atmosphere up to 230°C in near future based on the performed investigation and experiments.

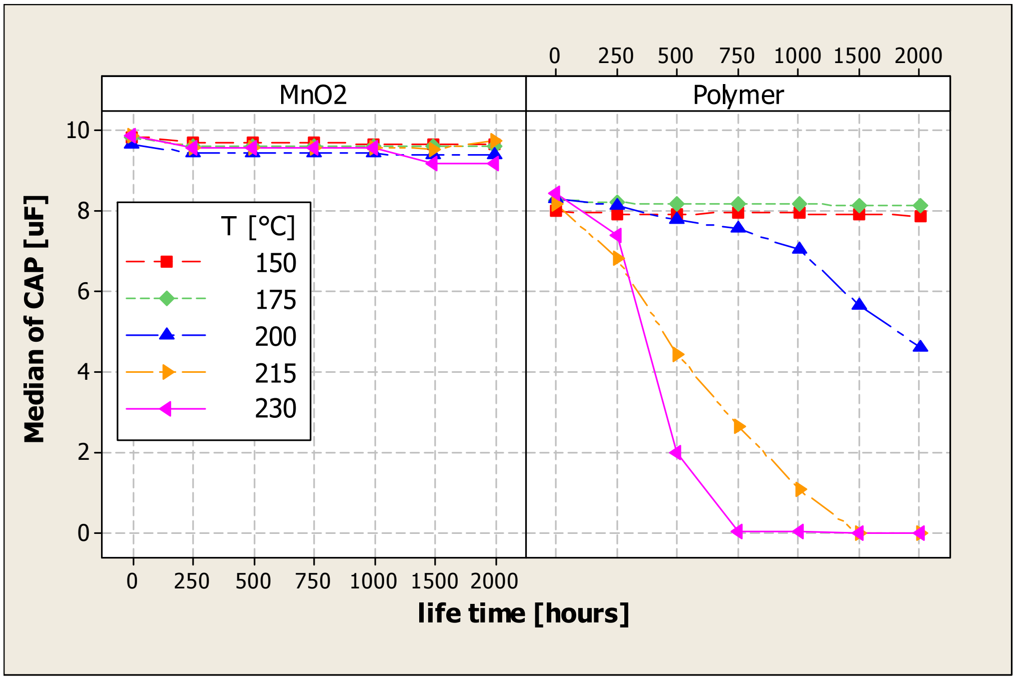

Figure 1 – temperature stability results of capacitance during 2.000 hours @ 0.5 U_R of 10µF/35V capacitors with manganese dioxide and conductive polymer PEDOT cathodes hermetically sealed in ceramic housing

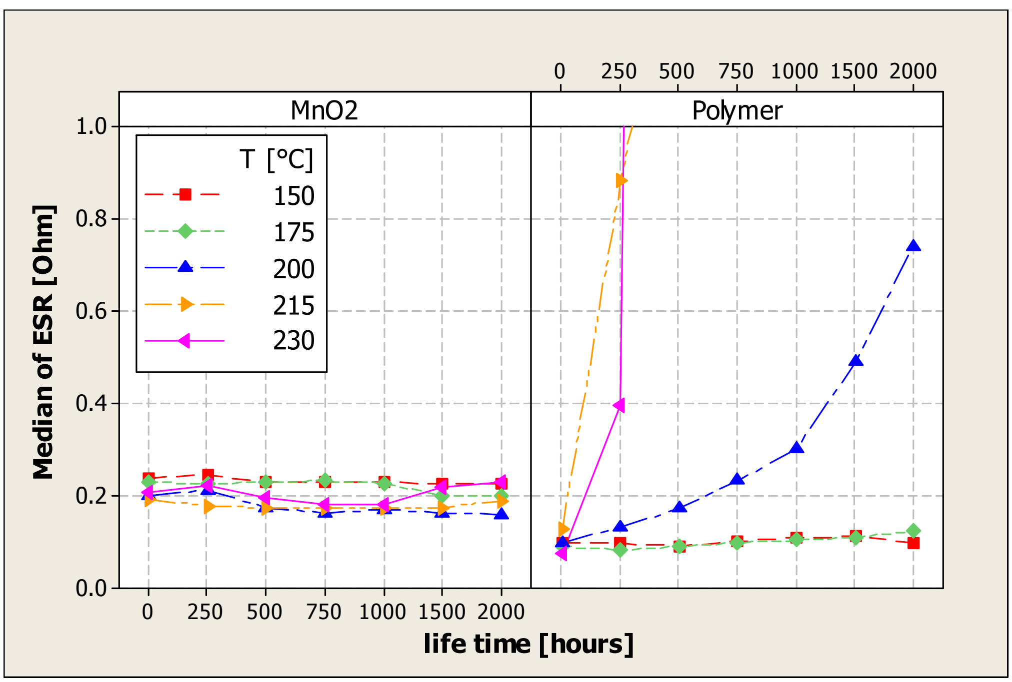

Figure 2 – temperature stability results of ESR during 2.000 hours @ 0.5 U_R of 10µF/35V capacitors with manganese dioxide and conductive polymer PEDOT cathodes hermetically sealed in ceramic housing

Figures 3 and 4 show electrical results (capacitance and ESR) of tantalum conductive polymer PEDOT surface mounted capacitors with/without hermetic sealing in a ceramic housing at 120°C @ U_R for duration of 64 hours. It can been observed that the standard capacitors show typical change of capacitance due to the humidifying as well as ESR increase caused by the cathode degradation. Capacitors sealed in inert atmosphere are exhibiting very small change of capacitance and ESR, which might be explained by incomplete drying before hermetical sealing.

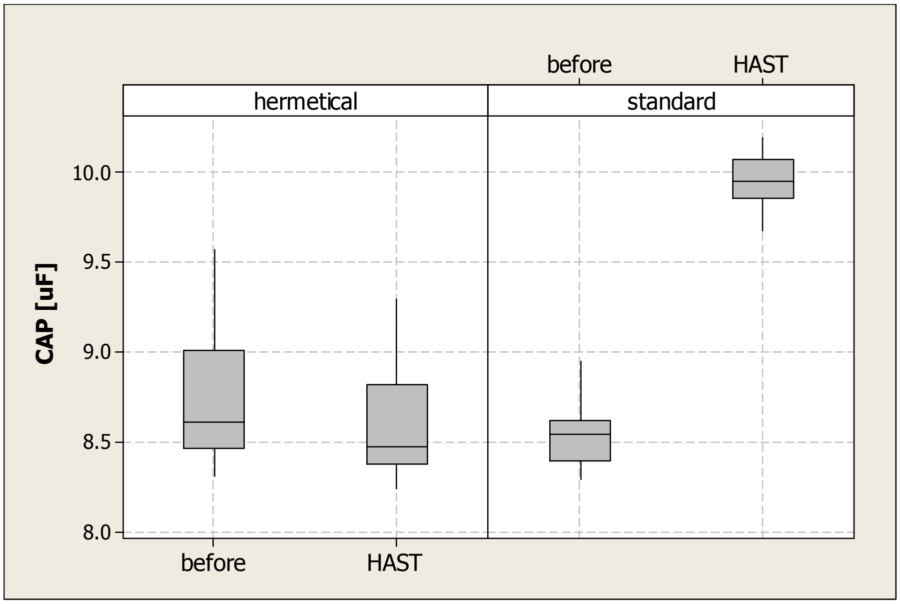

Figure 3 – humidity stability results of capacitance after 64 hours @ U_R of 10μF/35V capacitors with conductive polymer PEDOT cathode hermetically sealed in ceramic housing vs. capacitors assembled via standard production procedure

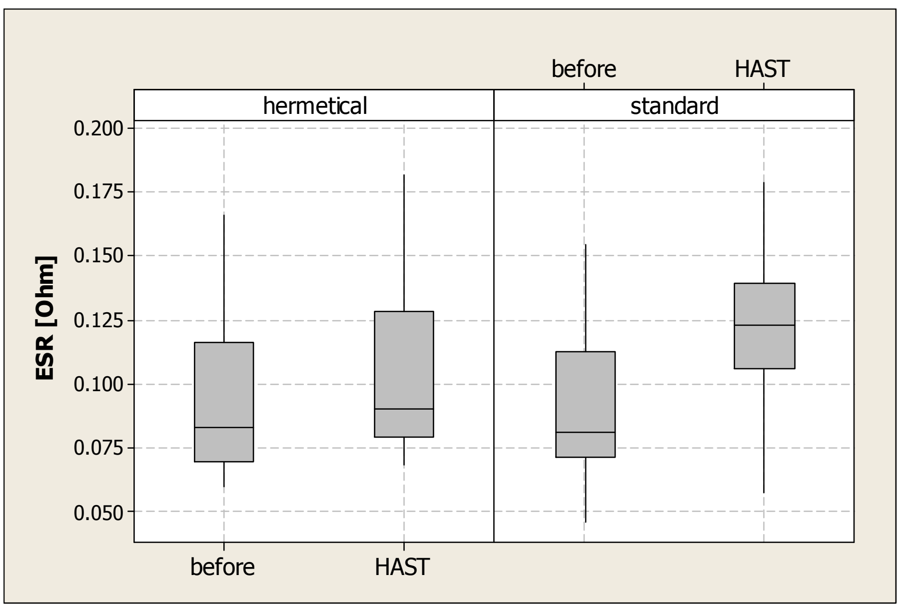

Figure 4 – humidity stability results of ESR after 64 hours @ U_R of 10μF/35V capacitors with conductive polymer PEDOT cathode hermetically sealed in ceramic housing vs. capacitors assembled via standard production procedure

CONCLUSIONS

New hermetically sealed SMD tantalum capacitor design has been introduced and tested. The tests performed on both manganese dioxide and polymer surface mounted tantalum capacitors hermetically sealed under inert atmosphere have proven excellent performance in comparison to the same capacitors molded in standard epoxy resin. Above all, as expected, the hermetic case minimizes influence of humidity so that fluctuations of capacitance due to moisture variation are significantly suppressed. The effect of extreme humidity conditions during HAST test (120°C/85% RH/rated voltage) on ESR was also diminished when hermetic package was used compared to the standard parts with molding resin.

For both MnO_2 and polymer technologies the hermetic packaging pushes the current temperature limits to significantly higher levels. The current state of technology allows use of SMD tantalum capacitors with 230°C operating temperature with manganese dioxide cathode or at least 175°C with conductive polymer cathode when hermetically sealed in inert atmosphere.

The new low ESR hermetically sealed tantalum capacitors in SMD friendly design are extending today's application area of tantalum capacitors especially in high reliability applications. The new features – low and stable ESR of polymer capacitors and continuous operation at 230C in combination of uncompromising long life operation are opening new capabilities for High Reliability electronic device designers impossible to achieve by the product available on the market at present time.

REFERENCES

[1] H.S.Nalwa: Handbook of Organic Conductive Molecules and Polymers, Willey&Sons (1997).
[2] A. Skotheim, J.R.Reynolds: Conjugated Polymers, CRC Press (2007).
[3] T.Zednicek, J.Sikula, H.Leibovitz; A Study of Field Crystallization in Tantalum Capacitors and its effect on DCL and Reliability; CARTS USA (2009).