# Bringing the benefits of polymer tantalum capacitors to high-voltage, high-reliability markets

Polymer tantalum capacitor technology was developed in response to demands from the market to lower the ESR of tantalum capacitors while preserving their small case size and high reliability. KEMET's technology developments for these devices have led the industry since their introduction. KEMET is flattered that others in the industry, such as AVX[1], have chosen to follow our lead down this technological path as we will continue to set the standard for high performance tantalum capacitors in the coming months and years.

The cathode of Polymer tantalum devices is made from a highly conductive polymer material such as PEDOT, which is many times more conductive than the manganese dioxide traditionally used for this part of the device. The high conductivity of the polymer gives the capacitor its low ESR; the polymer's conductivity is also very temperature stable, meaning the ESR is temperature stable and the devices can withstand high ripple current as a result. These desirable characteristics have made polymer tantalum capacitors very popular for commercial low-voltage electronics systems, but historically, DC leakage and low breakdown voltage have held back adoption in high-voltage and high-reliability applications such as defence, aerospace and space.

It was therefore desirable to develop a high-voltage version of the tantalum polymer capacitor, keeping its low ESR properties and high reliability whilst improving its DC leakage current and breakdown voltage properties. KEMET's T550 series of polymer tantalum hermetically sealed capacitors meets these requirements – and more.

## Discoveries and Advances

Technology advances made by KEMET, in collaboration with the Holcombe Department of Electrical & Computer Engineering at Clemson University, South Carolina, USA, have solved some of the problems posed by the fabrication of high-voltage high-reliability polymer tantalum capacitors (in August 2012 KEMET and Clemson University published a paper on their discoveries in the *Journal of the Electrochemical Society*, Volume 159 issue 10, pp A1646 – A1651, under the headline "Electrical Characterization of High Voltage Polymer Tantalum Capacitors").

In combination with several proprietary cutting-edge KEMET developments, these technology advances have made the T550 series possible. A total of seven patented and patent-applied-for technologies went into the development and manufacturing of this polymer tantalum capacitor series.

The most important was the development of KEMET's F-Tech tantalum manufacturing technology, which is a way of producing a pure tantalum material low in oxygen and carbon. When the dielectric (tantalum pentoxide) is formed on the pure tantalum metal, it is free from defects like cracks, pores and crystalline oxide. Tantalum pentoxide dielectric material produced using a traditional process is shown in figure 1, while the results from the F-Tech process are shown in figure 2. The electron microscope pictures show a clear distinction

between the older technology, which resulted in tantalum anode material with cracks, pores and other defects, and the F-Tech anode which is practically defect-free.

F-Tech is based on KEMET's superior understanding of the chemical degradation mechanisms that affect tantalum capacitors. The technology actually comprises multiple processes which minimise the anode's carbon and oxygen content, as these contaminants can lead to crystallization of the anodic oxide dielectric. Another process strengthens the mechanical connection between the tantalum lead wire and the anode, enhancing reliability.

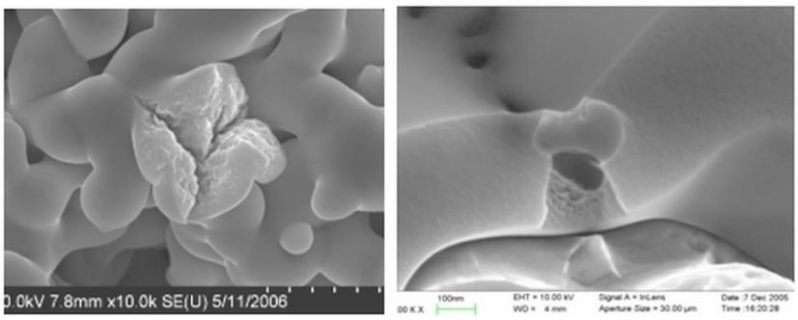


*Figure 1. The traditional process of fabricating the tantalum anode material resulted in cracks and pores.*

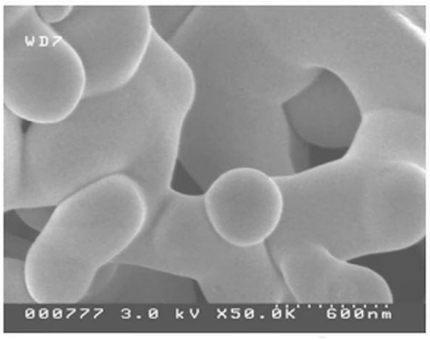


*Figure 2. KEMET's new process created an ideally formed dielectric with practically no defects.*

Another KEMET discovery relates to the interface between the dielectric and the polymer cathode. This interface is important because any defects here can greatly affect the capacitor's electrical properties. A pre-polymerized PEDOT is applied to the dielectric, which meant that an in-situ chemical reaction to create the interface was not required. Bi-products of this in-situ reaction, which lead to contamination, were therefore avoided, resulting in a higher quality interface. This higher quality interface between the dielectric and the polymer cathode helps increase the breakdown voltage of the device, as well as reducing its DC leakage current.

A new screening technique is also used to guarantee reliability for the T550 series. Traditional DC leakage tests cannot detect small defects in the dielectric, and performing these tests under accelerated conditions can actually introduce defects. KEMET believes breakdown voltage is the ultimate test of a capacitor dielectric, with a high breakdown

voltage indicating excellent reliability in the field. 100% of T550 products sold are tested using KEMET's patented testing technique called simulated breakdown screening (SBDS), which simulates the capacitor's breakdown voltage without damaging it. This type of testing allows KEMET to supply only the most reliable devices from any given lot.

The T550 series also features hermetically sealed packaging as part of another patented KEMET development. A controlled amount of humidity is introduced into the package. The humidity significantly increases the reliability of the capacitor.

## The T550 series in detail

Combining these discoveries and technologies has led to the development of KEMET's T550 series of polymer tantalum capacitors which feature record low DC leakage, which stays low even with increasing voltage. This series is available with rated voltage up to 75V and can be used at up to 80% of rated voltage. As an example, the DC leakage of a 75-V rated 75µF capacitor (B case size) is 42.2µA. All the devices in the series have DC leakage between 6.3 and 45.0µA at 25°C. A full range of DC leakage specifications is shown in table 1.

The devices' ESR is the lowest in the industry for their type, and as illustrated in figure 3, ESR is consistently low, even at high temperatures and across a wide frequency range. ESR of the devices ranges between 90 and 200mΩ (at 25°C and 100kHz), with the ESR of the entire series shown in table 1.

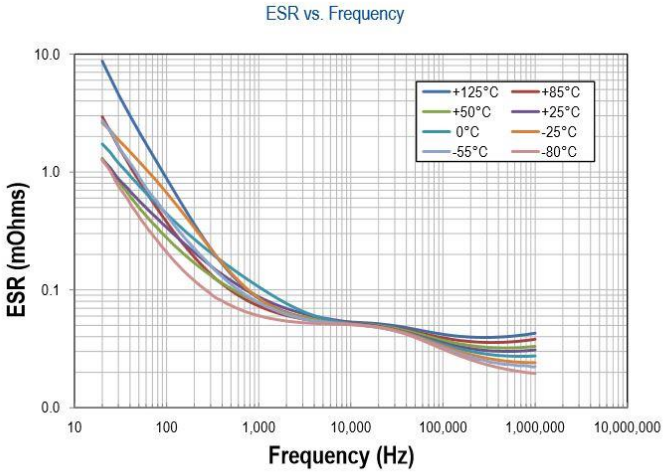


*Figure 3. The T550 series maintains its low ESR over a wide range of temperatures and frequencies.*

| Rated Voltage | Rated Capacitance | Case Size | KEMET Part Number | DLA (DSCC) Drawing Number | DC Leakage | DF | Maximum ESR | Ripple Current |
|---|---|---|---|---|---|---|---|---|
| (V) 85°C | µF | KEMET/EIA | (See below for part options) | (See below for part options) | µA @ 25°C Maximum/5 Minutes | % @ 25°C 120 Hz Max | mΩ @ 25°C 100 kHz | mArms @ 85°C/40 kHz |
| 6 | 140 | B | T550B147(1)006A(3) | N/A | 6.3 | 5.0 | 120 | 1510 |
| 6 | 820 | B | T550B827(1)006A(3) | N/A | 36.9 | 5.0 | 90 | 1750 |
| 8 | 220 | B | T550B227(1)008A(3) | N/A | 13.2 | 5.0 | 120 | 1510 |
| 8 | 680 | B | T550B687(1)008A(3) | N/A | 40.8 | 5.0 | 90 | 1750 |
| 10 | 100 | B | T550B107(1)010A(3) | N/A | 7.5 | 5.0 | 140 | 1400 |
| 10 | 180 | B | T550B187(1)010A(3) | N/A | 13.5 | 5.0 | 110 | 1580 |
| 10 | 560 | B | T550B567(1)010A(3) | N/A | 42.0 | 5.0 | 90 | 1750 |
| 15 | 70 | B | T550B706(1)015A(3) | N/A | 7.9 | 5.0 | 140 | 1400 |
| 15 | 120 | B | T550B127(1)015A(3) | N/A | 13.5 | 5.0 | 110 | 1580 |
| 15 | 390 | B | T550B397(1)015A(3) | N/A | 43.9 | 5.0 | 90 | 1750 |
| 25 | 50 | B | T550B506(1)025A(3) | N/A | 9.4 | 5.0 | 170 | 1275 |
| 25 | 100 | B | T550B107(1)025(2)(3) | 13030-01(1)A(4)(5)(6) | 18.8 | 5.0 | 190 | 1200 |
| 30 | 40 | B | T550B406(1)030A(3) | N/A | 9.0 | 5.0 | 170 | 1275 |
| 30 | 68 | B | T550B686(1)030A(3) | N/A | 15.3 | 5.0 | 140 | 1400 |
| 40 | 100 | B | T550B107(1)040(2)(3) | 13030-02(1)A(4)(5)(6) | 30.0 | 5.0 | 150 | 1350 |
| 40 | 120 | B | T550B127(1)040(2)(3) | 13030-03(1)A(4)(5)(6) | 36.0 | 5.0 | 120 | 1510 |
| 50 | 25 | B | T550B256(1)050A(3) | N/A | 9.4 | 5.0 | 170 | 1275 |
| 50 | 47 | B | T550B476(1)050A(3) | N/A | 17.6 | 5.0 | 150 | 1350 |
| 50 | 100 | B | T550B107(1)050(2)(3) | 13030-04(1)A(4)(5)(6) | 37.5 | 5.0 | 130 | 1450 |
| 50 | 120 | B | T550B127(1)050(2)(3) | 13030-05(1)A(4)(5)(6) | 45.0 | 5.0 | 90 | 1750 |
| 60 | 20 | B | T550B206(1)060A(3) | N/A | 9.0 | 5.0 | 200 | 1175 |
| 60 | 39 | B | T550B396(1)060A(3) | N/A | 17.6 | 5.0 | 160 | 1310 |
| 60 | 100 | B | T550B107(1)060A(3) | N/A | 45.0 | 5.0 | 100 | 1660 |
| 75 | 75 | B | T550B756(1)075A(3) | N/A | 42.2 | 5.0 | 110 | 1580 |

*Table 1. Electrical characteristics of the T550 series of hermetically sealed high-voltage polymer tantalum capacitors.*

This series features the highest ripple current capability in its class; all the devices in the series can withstand at least 1175mA$_{RMS}$ (at 85°C, 40 kHz), with some withstanding up to 1750mA$_{RMS}$ under the same conditions.

The T550 series comes in capacitance values between 20µF and 820µF, with capacitance tolerances of either K (10%) or M (20%). Temperature stability meets MIL-PRF-39006 over the devices' operating temperature range of -55°C to +105°C. These devices suit high voltage power management applications such as buck-boost converters, filtering, hold-up capacitors and other high ripple current applications. Availability in hi-rel versions with up to space-grade reliability means they are also suitable for defence and aerospace applications.

## Conclusion

Developments like KEMET's F-Tech manufacturing technology are pushing the limits of what tantalum capacitors can do, illustrated by the T550 series. Technology advancements like these are driving the tantalum capacitor industry, and KEMET is proud to be leading the way.

## References

[1] J. Petrzilek, M. Biler, , T. Zednicek: Hermetically Sealed Conductive Polymer Tantalum Capacitors, CARTS International (2014).