KEMET Electronics Corp.

Conductive Polymer Capacitors for Lead Free Processing (260°C)

The conductive polymer capacitor is a solid-state device in which the cathode material of Tantalum-MnO_2 is replaced with a conductive polymer coating (Figure 1). This replacement was initialized as the polymer affords a higher conductive material, thus lowering the ESR of the device (Figure 2). As the ESR is lowered, capacitance roll-off associated with this device still occurs, but the roll-off is moved to a higher frequency. As such, the capacitance available from two capacitors of identical ratings from these offerings at a given frequency may be substantially higher with the conductive polymer as opposed to those of the MnO_2 construction (Figure 3). For the 330-uF capacitors plotted here, the MnO_2 devices decay to about 50 uF at 100 kHz, whereas the conductive polymer devices retain over 220-uF capacitance at 100 kHz. Based on this capacitance difference (4 to 1) and the ESR difference (1 to 5 for standard MnO_2 versus standard polymer), a design at 100 kHz that required 4 of the MnO_2 capacitors might now be reduced to a single capacitor.

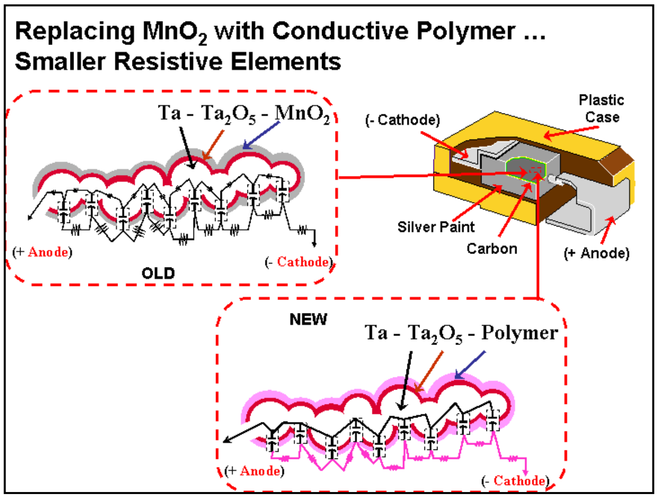

Figure 1. Cathode system change to conductive polymer.

A secondary benefit achieved with this substitution relates to the MnO_2 being chemically classified as an oxidizing agent, which contributes to an exothermic reaction that takes place (ignitions) when the device failed. The polymer material is almost oxygen free, and with this characteristic, the exothermic reaction is eliminated.

When these parts were released to the market nearly five years ago, they were intended for tin-lead solders and the reflow temperature requirements were 235°C. For all the benefits of the conductive polymer, the drawback with these devices was their inability to withstand the rigors of 260°C reflow conditions – until now. The problems created in the solder reflow are attributable to the package complexity of this device. Though nearly a duplicate of the MnO_2 package, the conductive polymer presented challenges to this design as the mismatches of coefficients of thermal expansion (CTE) created huge shear forces during the heat application and hold, and compressive forces during the cool-down. The main failure modes for these devices are power-on failures, high leakage, and a shift in ESR after the reflow process and subsequent board testing. The integrity of the MnO_2 structure and contact appeared to be better as the devices were not as prone to power-on failures and the ESR did not shift with these devices.

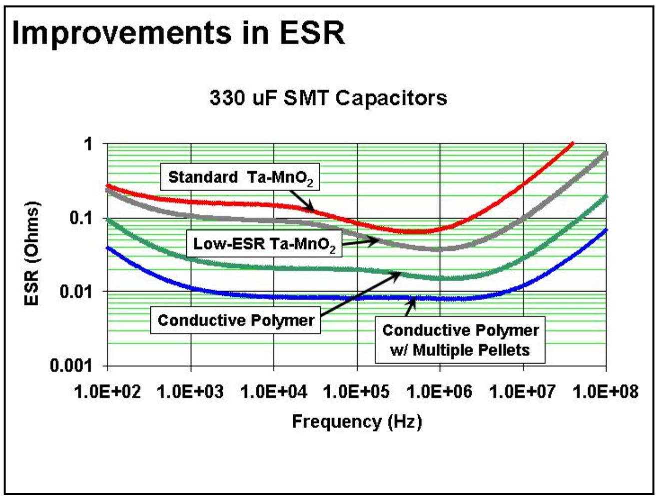

Figure 2. ESR versus frequency plots.

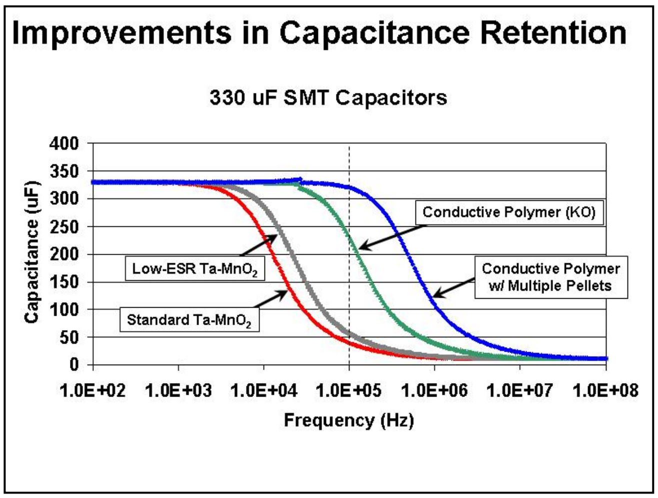

Figure 3. Capacitance versus frequency.

Instead of abandoning the huge benefits of the improved ESR and capacitance retention achieved with the conductive polymer, special attention was given to the other packaging elements. The carbon overcoat, conductive silver paste applied to the outer portion of the anode pellet, the conductive adhesive between the pellet and leadframes, and the mold compound of the plastic encapsulant were studied in an attempt to improve the devices capability. Slight modifications of these materials and the application processes have been studied and optimized to generate an enormous shift in failure rates. The conductive polymer now shows much better performance than its MnO_2 counterpart does.

Consider the power-on failures. This failure is normally detected at initial electrification of the component after mounting. These failures may be detected with an ICT system looking for shorts and opens, or more likely will be detected at a functional test when the application voltage is applied. These faults were not in the part when it was removed from the tape, but were created during the reflow solder process. With the move to lead-free solders, the process now involves a higher peak temperature (260°C versus 235°C), longer soaks at the peak temperatures (25 seconds versus 10 seconds), and these result in increased CTE mismatch forces. This increased force generated on the internal components showed the failure rates to initially increase.

After optimization of the processes and materials involved (carbon, silver, adhesive, and mold compound), the failure rates are now appreciably lower, In Figure 4, the failure rates are shown for our internal board mount tests using the lead-free solder process at 260°C. The failure rate has dropped from well over 250 PPM to well below 50 PPM. Retesting the parts for MSL capability, using J-STD-020C conditions and requirements, these devices are now capable of meeting MSL-Level 2A. Testing on the original product showed the parts to be of MSL-Level 3, and that was at the 235°C reflow conditions. With the improved materials, we achieve a better rating even though we are testing at a higher temperature.

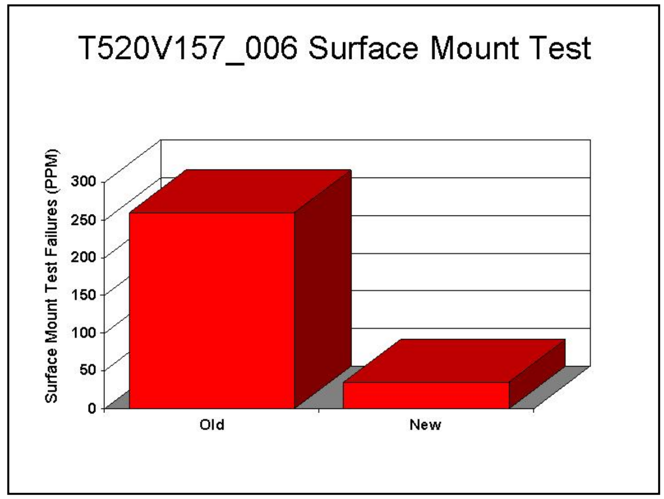

Figure 4. PPM failures of Old versus New, but at higher reflow temperatures.

The transition to these materials and process variations will take place in a timely fashion among this product's different case sizes. Contact your KEMET representative to obtain the latest schedules.

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