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Component size reductions and reliability improvements must go hand-in-hand for the continued success of the electronics industry. This month's Tech Topics examines some of the technical considerations which should be evaluated as manufacturers increase the capacitance-voltage product offerings of tantalum chip capacitors.

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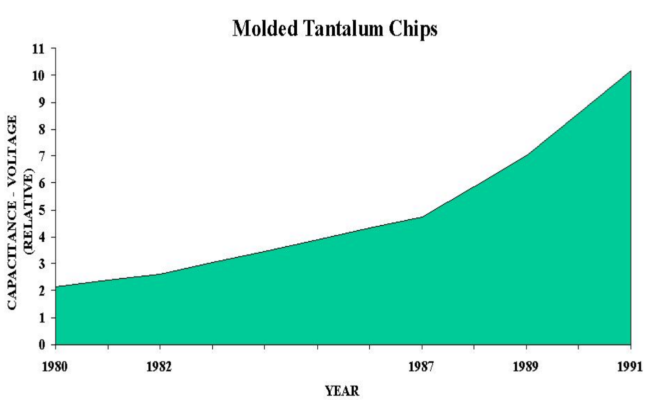
Molded Tantalum Chips – Capacitance Range Extensions

by John J. Moore

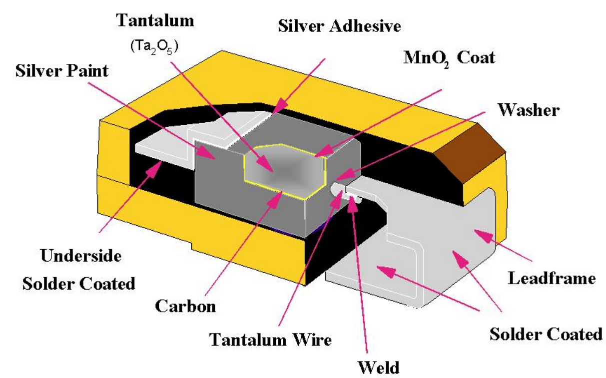
The electronics industry has traditionally driven to pack more and more function into less and less space, and nowhere is this more evident than in molded surface-mount tantalum capacitors. As telecommunications and disk drive manufacturers began to require additional capacitance per unit volume to meet their product designs, capacitor manufacturers have endeavored to increase the capacitance per case size of their product without reducing voltage (Figure 1). This practice - increasing capacitance in a given unit volume without concurrently decreasing the voltage rating - is called range extension. While this trend has resulted in cost savings for all electronics manufacturers by reducing the board area demanded by an individual function or component, range extensions can adversely affect product performance and reliability.

Figure 1 - Trend in Capacitance Increase



To understand the pitfalls of increasing capacitance within a given unit volume (or "case size") without reducing the voltage rating, it is helpful first to review the construction of a molded tantalum chip capacitor. Figure 2 is a cutaway view of

Figure 2 - Construction of KEMET T491 Molded Tantalum



a KEMET T491 capacitor. At the center is a porous, sintered pellet of tantalum metal powder, which acts as the anode or positive plate of the capacitor. When this pellet is anodized (or "formed"), a thin dielectric layer of tantalum oxide develops over the internal and external tantalum surfaces. This tantalum oxide surface is then coated with a layer of manganese dioxide (MnO_2), which fills the pores of the tantalum pellet and, as a semiconductor, is the cathode or negative plate of the capacitor. External metallizations connect the MnO_2 with a leadframe to form the negative terminal of the capacitor. A tantalum wire from the tantalum pellet is welded to another leadframe to make the positive terminal.

The capacitance (**C**) is directly proportional to the surface area (**A**) of the porous tantalum pellet and indirectly proportional to the thickness (**t**) of the tantalum oxide layer, as represented in the following formula:

$$C=\frac{kA}{t}$$

where **k** is the dielectric constant, a materials property of tantalum oxide. The voltage capability of a capacitor is determined by the thickness of the tantalum-oxide dielectric layer. Therefore, the inverse relationship between **C** and **t** dictates the range of maximum capacitance/voltage ratings available in each case size. For example, both 100 µF/4 volt and 22 µF/20 volt capacitors may be maximum ratings in the same physical package. Range extensions for each would be 150 µF/4 volt and 33 µF/20 volt, respectively.

To achieve more capacitance in a given case size, there are two options: decrease the dielectric thickness (**t**) or increase the tantalum surface area (**A**). The first choice is risky because it reduces the safety factor between dielectric formation voltage and rated voltage. Although design voltage stresses used for tantalum capacitors are usually quite conservative, the dielectric of a tantalum capacitor at rated voltage is very highly stressed (5000v/mil) compared to other capacitor types, such as multilayer ceramic (approximately 50v/mil) and metallized film (500v/mil). Life test reliability and surge current withstanding capability are among the sensitive functions of the dielectric thickness.

Increasing the tantalum surface area is a much more conservative approach. This can be accomplished in either of two ways:

a. *make the pellet larger*
b. *pack more tantalum surface area into the same size pellet.*

Larger pellets are undesirable because they quickly encroach on minimum epoxy wall thickness expectations. The difficulty of combining moisture, surface mounting, thin epoxy walls, and large insert areas has been amply described by the I/C industry (see References). Molded surface-mount capacitors face similar constraints.

The major technical opportunity lies in increasing the tantalum surface area of a sintered tantalum pellet without increasing overall external pellet dimensions. The industry measure of tantalum surface area per unit volume is called CV/CC, where CV is the product of capacitance and formation voltage, and CC is pellet volume. CV is divided by CC to determine the tantalum surface area per unit volume. Capacitor manufacturers and tantalum powder manufacturers have worked together for years to increase CV/CC. As Table 1 indicates, the design changes introduced to increase CV/CC all have potentially adverse effects on product quality and reliability. These effects must be overcome and eliminated before new range extensions are introduced to the marketplace.

"Downsizing" is a form of range extension that provides the specified capacitance and voltage requirement in a smaller case size. However, this option affects high-frequency equivalent series resistance (ESR) and impedance, which are largely determined by the interfacial resistances of the conductive layers on the exterior of the capacitor pellet. Reducing pellet size (by packing more capacitance and voltage into a smaller case size) results in decreased interfacial area and a corresponding increase in series resistance. Again, process and materials improvements are necessary to mitigate this geometric effect.

Capacitance/voltage range extensions and case downsizing are, and should continue to be, integral to increasing the utility and cost effectiveness of the chip capacitor. However, the necessary materials and process changes can have very adverse effects on product performance and reliability. KEMET's quality standards dictate rigorous internal qualification testing prior to the introduction of new products, processes, or materials changes to the marketplace. No range extension or downsizing can be considered successful until quality and reliability performance levels are equivalent or superior to the standard product. This conservative approach will en-sure KEMET's position as the quality leader in the tantalum capacitor industry.

References

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Table 1. Increasing CV/CC: Design Changes and Consequences

Design Requirement	Potential Consequences	Potential Quality Considerations
Increased tantalum surface/mount ratio	Increased oxygen content in tantalum pellet	Tantalum oxide dielectric quality (leakage, breakdown)
Decreased tantalum sintering temperature	Less removal of contaminants	Tantalum oxide dielectric quality (leakage, breakdown)
Decreased pellet pore dimension	High resistivity and/or chemical depletion in anodizing electrolyte path	Tantalum oxide dielectric quality (leakage, breakdown) High DF and ESR Capacitance loss with heat storage and at high frequencies Moisture sensitivity