KEMET® TECH TOPICS

...The Leading Edge

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The electrical and physical performance of multilayer ceramic capacitors (MLCC) is heavily dependent on the characteristics and quality of the internal electrodes. Several electrode materials are available for manufacturing MLCCs, the most common being palladium, alloys of silver/palladium, and nickel. Each type of material places restrictions on the firing characteristics of the ceramic dielectric; therefore, complementary electrode/dielectric systems must be developed. The following article, written by Ray Cooper, an Engineer in KEMET's Ceramic Technology Development group and team leader of KEMET's Advanced Electrode Technology Team, discusses some of the key challenges that KEMET has faced in developing electrode technologies for it's high capacitance MLCC product line. By working closely with key raw material suppliers, KEMET has established itself as the technology leader in silver/palladium electrode MLCC.

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Electrode Development for Multilayer Capacitors

by Raymond J. Cooper

Manufacturers of multilayer ceramic capacitors (MLCC) are focused on increasing the capacitance per unit volume of ceramic chips. In a multilayer chip, this is accomplished by increasing the number of electrodes in a given chip size, and using thinner ceramic dielectric and electrode layers. This trend, in turn, has forced manufacturers to develop new quality standards for electrode pastes that include high purity materials and uniform dispersion of both metal and organic components of the pastes. **Figure 1** illustrates the multilayer construction of a ceramic chip capacitor, including the internal electrodes, which are typically made from palladium or silver palladium alloys (KEMET uses silver/palladium alloys with 70-75% silver content).

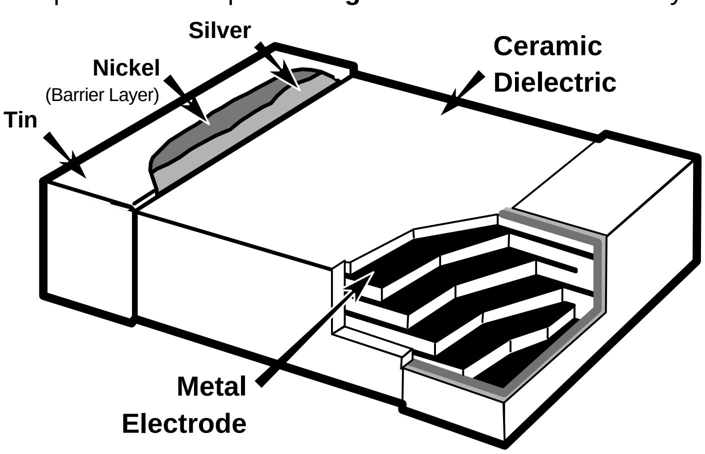

Figure 1. Ceramic chip construction

One thing that makes the drive for thinner electrodes more complicated is the trade off between metal electrode thickness and electrical performance. Thicker electrodes provide more continuous, higher conductivity paths for capacitor charging and discharging, but the additional thickness also increases the physical stresses that build up during construction and thermal processing of the multilayer capacitor. Consequently, thicker electrodes not only increase the cost of manufacturing by increasing the consumption of precious metals (silver/palladium), they also increase the level of internal defects (like cracks and delaminations), resulting in reduced product yields. These are the underlying reasons why KEMET is actively pursuing technologies for producing thin, continuous electrodes for product with high active layer counts. Currently, KEMET sells product with 6-7 micron fired ceramic dielectric thickness and 1.5 micron fired internal electrode thickness. This current status reflects a 40-50% reduction in electrode thickness over the last three years. Development efforts are now underway to produce high quality parts with 1-3 micron fired ceramic dielectric thickness and uniform, high conductivity internal electrodes that are 1 micron or less in thickness.

KEMET has taken a multi-faceted approach to developing thin electrode product capabilities that includes evaluating new printing equipment, printing procedures, paste making techniques, screen technologies, and high purity metal and organic materials. A printer utilizing a new squeegee design was designed specifically to print thin, uniform electrodes. Improved thin screen materials and new screen-making techniques have been developed to allow deposition of thinner electrodes while improving thickness uniformity. New high-purity and smaller particle size materials have been selected for paste making while new paste-making process equipment have been developed. This complete process approach has allowed KEMET to develop the capability to build production parts with over 150 printed layers. Production capability to build parts with 300 to 500 print layers is currently under development. **Figure 2** (See reverse side of this publication.) is an SEM photo showing the internal cross section of an MLCC with 300 active layers, each less than 3 microns thick (ceramic plus electrode).

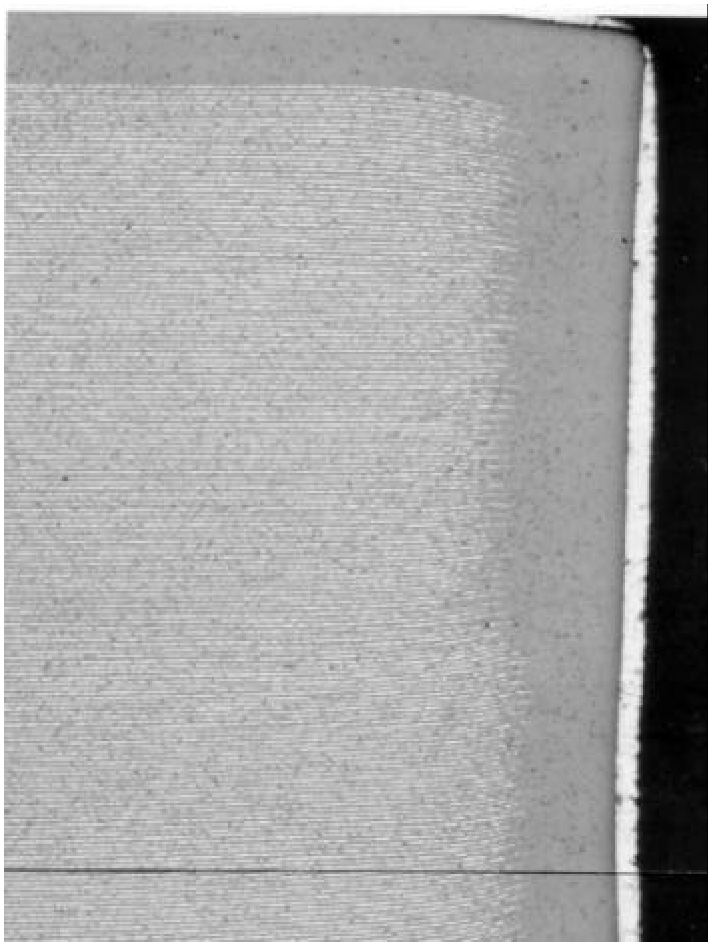

Figure 2. SEM photo of internal cross section of MLCC

Figures 3a & 3b are photos comparing the surface of a traditional internal electrode (magnified with a scanning electron microscope) with that for an electrode produced through the improved technologies. The physical height and contour of the electrode becomes very important in high layer count parts with thin dielectric layers, because lumps with dimensions of only 1 micron create physical stress points and potential electrical shorts between layers. Much effort has been spent to develop materials and processing technologies which achieve the thin, smooth electrode surfaces.

In summary, the electrode development progress reported in this paper has provided KEMET with product quality improvements, reduced manufacturing costs, and the capability to produce high layer count MLCC product with silver/palladium electrodes. In addition, paste technology developed for thin electrode continuity and uniformity has also provided opportunities to improve paste making for all KEMET MLCC product. These electrode development efforts are providing the impetus for continuous process and quality improvement, helping to ensure that the quality and performance of KEMET's MLCC products remain the best in the industry.

Figure 3a. Traditional internal electrode magnified using SEM

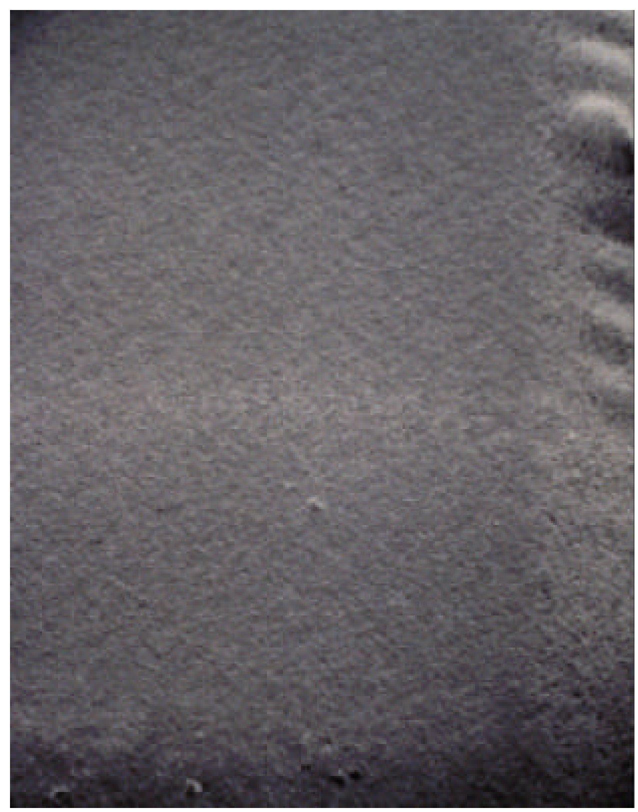

Figure 3b. Internal electrode magnified through improved technologies