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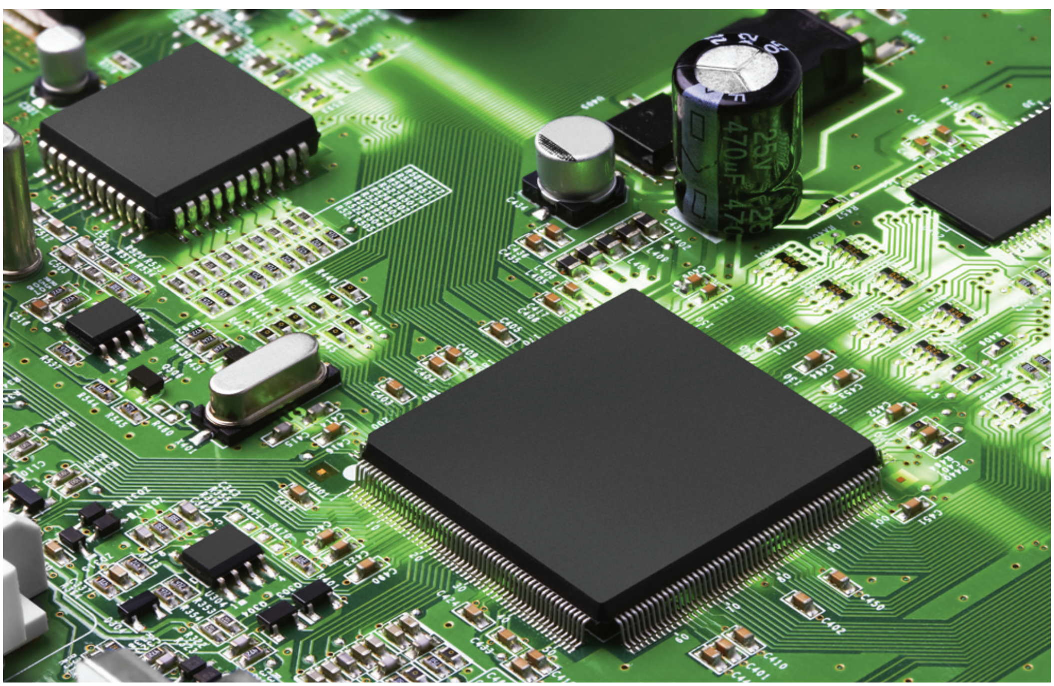
Improving the Reliability and Lifetime of Ceramic Capacitors

Ceramic capacitors serve as critical energy storage and management devices in consumer electronics; a multi-billion dollar industry. Research at the Center for Dielectric and Piezoelectrics (CDP) has lead to improved understandings of the mechanisms that control the reliability and lifetime of multilayer ceramic capacitors (MLCC) under electric fields.

New characterization methods have been developed to study dielectric degradation in highly accelerated lifetime testing conditions. The work has provided insights into the electrochemical processes responsible for degradation and breakdown. These breakthroughs have enabled the development and deployment of modified materials and processes to enhance the reliability of base metal electrode (BME) MLCC. In addition, the work has lead to new quality assurance methods that can identify capacitors predisposed to premature failure.



Accelerated testing of multilayer ceramic capacitors at temperatures and voltages that exceed their rated values has long been used to estimate component lifetime under actual operating conditions. Until recently, a relatively simple model provided acceptable correlations between accelerated and normal operating conditions. But in recent years, to increase the energy storage capabilities and device minaturization, dielectric layer thicknesses have been reduced, the number of dielectric layers has increased, and operating voltages have been reduced. In addition, nickel electrodes have replaced costly precious-metal electrodes. As a result, the effectiveness of the previous model substantially declined.

The CDP research team has developed more complete and accurate understandings of the underlying degradation mechanisms. The breakthrough has led to more accurate predictions of capacitor lifetime in typical device operating conditions. The work has also enabled dramatic improvements in the lifetime and reliability of MLCCs through refinement of both material composition and processing conditions.

End-user product/processes affected: The CDP work has primarily impacted the ceramic capacitor industry, but may also benefit other types of capacitors (such as tantalum or aluminum electrolytic capacitors) and other electronic ceramic devices such as actuators, sensors and micro-electro-mechanical (MEMs) devices.

The aforementioned work has further enabled the ongoing increases in capacitive volumetric efficiency of base metal electrode multilayer ceramic capacitors; thus enabling more capacitance per unit volume for continued capacitor miniaturization without sacrificing reliability. This makes possible smaller, thinner, lighter and more powerful electronic devices (cell phones, tablets, cameras, etc.) The work has also extended the useful temperature and voltage operating ranges of BME MLCCs. This allows them to perform in increasingly demanding applications such as on-engine-control, down-hole drilling of oil/gas wells, as well as military and aerospace applications.

> **Economic impact**: Global sales of MLCCs is estimated to be $10 billion annually. It can safely be assumed the impact of this breakthrough will exceed millions of dollars per year in sales. It is more difficult to estimate how the related improvements in MLCC performance will impact the performance and sale of the billions of electronic devices in which MLCC are essential components.

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