



Introduction



- **Purpose**
 - Introduce arc-over discharge protection technology for surface mount multilayer ceramic capacitors (MLCCs)
- **Objectives**
 - Discuss the phenomenon of surface arcing in High Voltage MLCCs.
 - Discuss the benefits and issues associated with coating technologies.
 - Introduce and discuss KEMET ArcShield technology.
- **Content**
 - 15 pages
- **Learning Time**
 - 20 minutes

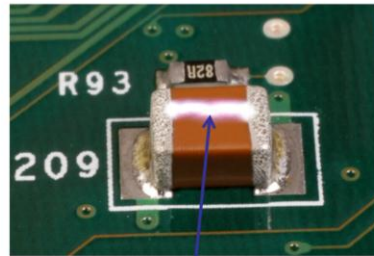
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Welcome to KEMET Electronics Corporation's introduction to protection against surface arcing on high voltage MLCC training module. This module will discuss the susceptibility of surface arcing on some high voltage multilayer ceramic capacitors (MLCCs) and the benefits of KEMET ArcShield technology. This module will also highlight the benefits of ArcShield Technology over coating technology.

What is MLCC Surface Arcing?

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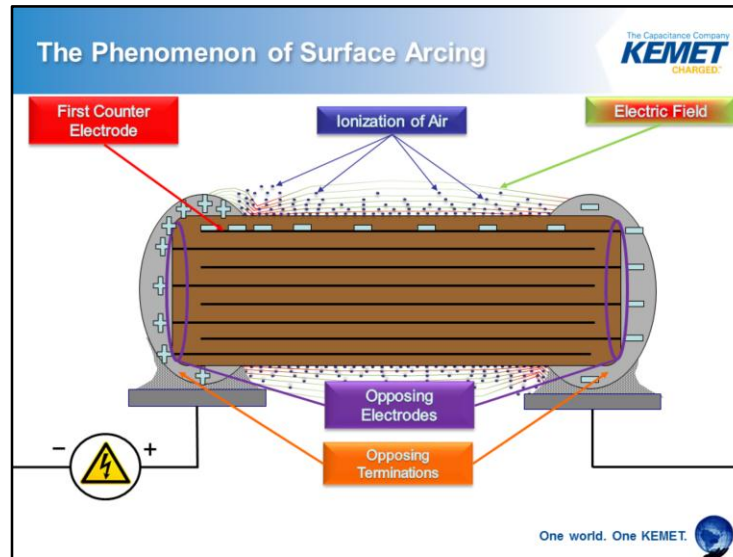
Surface arcing between termination surfaces on an MLCC. Also known as "arc-over discharge," "flash over" or "corona discharge"

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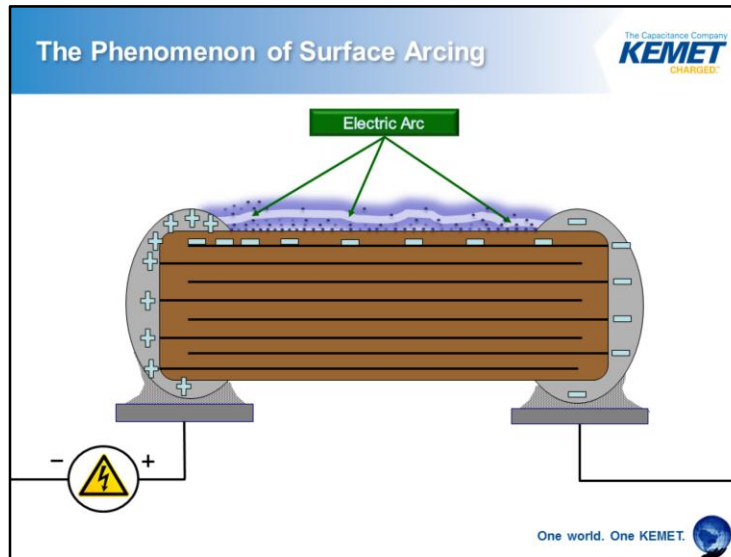


The phenomenon of surface arcing in multilayer ceramic capacitors is caused by a change in electric potential between the two termination surfaces, or between one of the termination surfaces and the internal electrode structure within the ceramic body. It occurs most frequently at application voltages that meet or exceed 300V. Other factors that contribute to surface arcing are high humidity environments, surface contamination and when there is minimal separation distance between the capacitors' two termination surfaces (also referred to as creepage distance). Higher capacitance devices are also more prone to surface arcing.

This phenomenon can either damage surrounding components or lead to a breakdown of the MLCC's dielectric, resulting in a short-circuit condition or catastrophic failure.

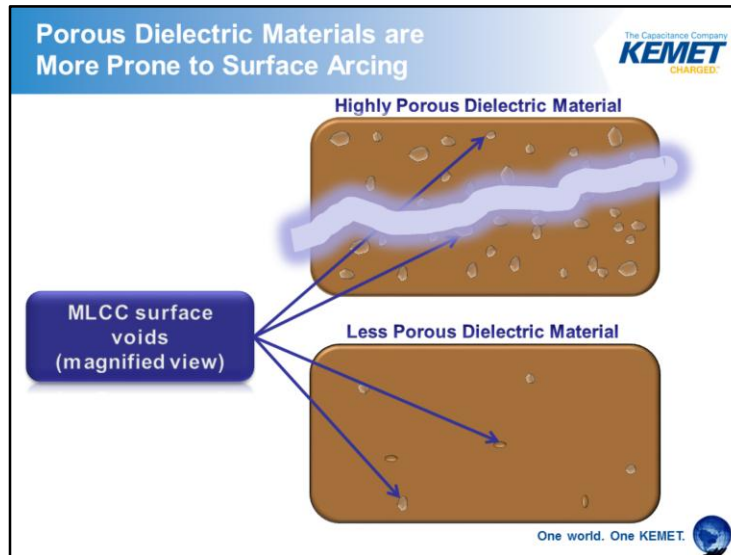


When a high voltage DC bias is applied to a high voltage MLCC, a potential difference is established between the opposing terminations and the opposing electrode structure. Simultaneously, an electric field concentration is localized in the termination area and respective first counter electrode within the MLCC. This difference in potential begins to build along the surface of the chip, ionizing the air above it.



Once the inception voltage of that ionized air is reached, a conductive path is created; allowing the energy in the concentrated electric field of the termination area to discharge. **This discharge of energy travels** through the air, along the surface of the capacitor and onto an area of lower potential, rather than *through* the capacitor. During discharge, there is a visible and audible electric arc across the surface of the chip.

Some high voltage ceramic capacitors will typically discharge (or arc), at applied voltages lower than the actual rated voltage of the capacitor.



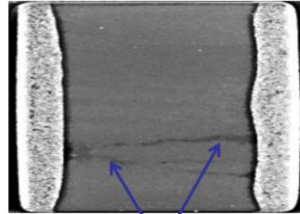
Surface arcing is more prevalent in high voltage capacitors manufactured using dielectric materials that exhibit greater surface porosity (surface voids). Materials such as X7R, Z5U and Y5V tend to possess a larger number of surface voids than lower dielectric constant materials such as NPO and C0G.

Air within a void is prone to ionize faster than the air across the smoother surface areas of the capacitor. As the inception voltage, or breakdown voltage, of the ionized air is reached, the air becomes conductive. Once conductive, an electric charge can be passed to and from a void and onto areas of lower potential. An increased number of voids increases the risk of passing this charge across the surface of the chip and bridging the gap between termination surfaces.

Dielectric materials with high porosity are also more susceptible to the migration of contaminants or moisture. Surface contamination such as solder balls and flux that have been deposited during board assembly can significantly reduce the inception voltage along the surface of the capacitor and increase the risk of arcing.

Surface Arcing Between MLCC Termination Surfaces

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Carbon traces left by
surface arcing on EIA
1812 case size MLCC

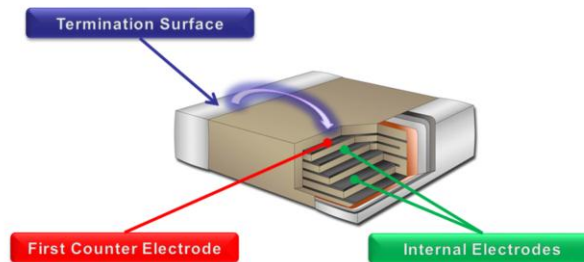
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Arcing will typically result in the creation of a conductive leakage path across the surface of an MLCC . This leakage path is a carbonized track also known as a “carbon trace”. As successive discharges occur across the surface of the chip, the insulated dielectric material will progressively deteriorate and ultimately breakdown. The breakdown of the dielectric material will typically result in an electrical short inside the capacitor.

The image seen here shows carbon traces on the surface of an MLCC. This capacitor’s performance began to deteriorate due to repeated surface arcing and eventually failed.

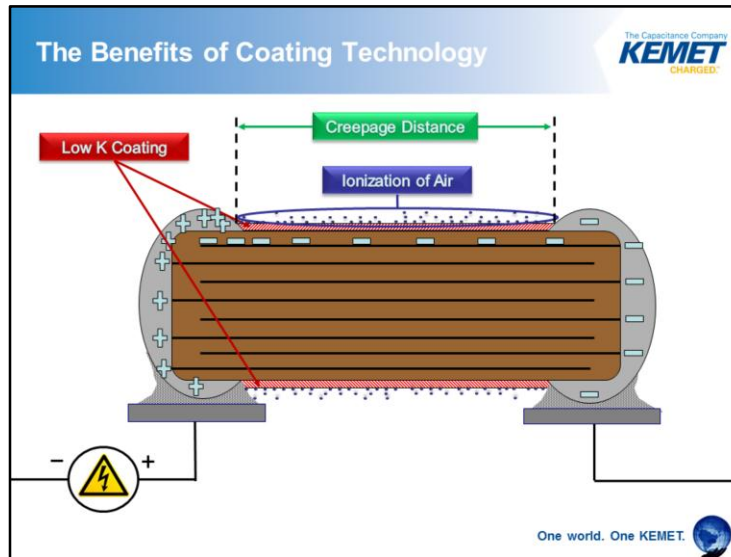
Surface Arcing Between MLCC Termination Surface & Internal Electrode Structure?

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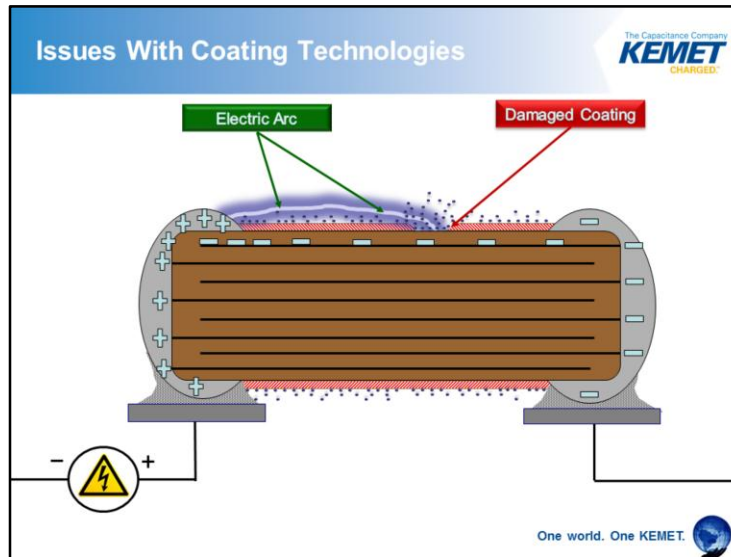


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The image seen here illustrates the potential of arcing between a termination surface and through the dielectric material of the ceramic body to the first internal counter electrode. This type of arcing usually results in dielectric breakdown of the capacitor, also resulting in a short-circuit condition (catastrophic failure).



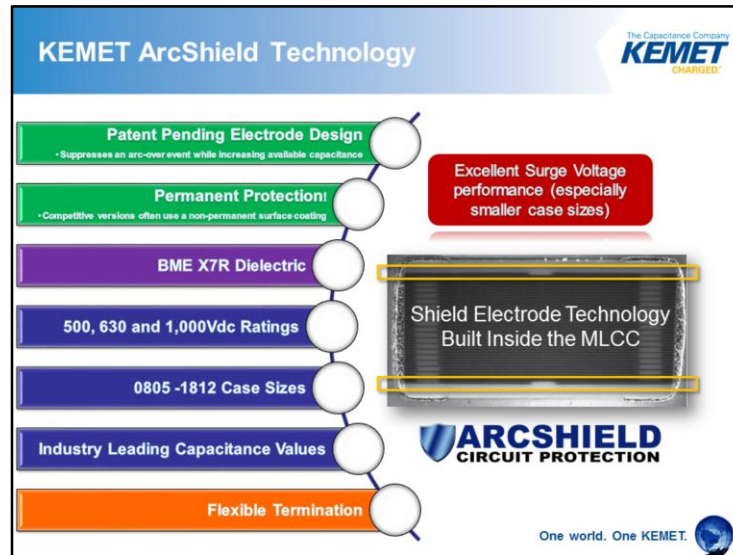
To address the phenomenon of surface arcing, some capacitor manufacturers have turned to coating technologies. Polymer or glass coatings are applied along the surface of the chip to fill the voids and provide a smooth surface with better creepage distance capability. Filling these voids with insulating material also reduces the potential for the entrapment of contaminants and improves the dielectric stability across the surface of the chip. Improving this stability reduces the ionization of the air and increases the inception voltage along the surface, thereby reducing the potential for arcing and improving the voltage performance of the capacitor.



Designers have used surface coatings on PCBs in high voltage applications for decades. It is a proven technology that does improve performance in high voltage applications. The primary disadvantage of this technology is the cost. Although sometimes necessary to meet specific electrical safety standards, most designers choose to avoid this costly measure whenever possible.

Another disadvantage associated with coating technology is its permanence. During the handling and assembly process surface coatings can be damaged, reducing the creepage distance capability along the surface and leaving the capacitor susceptible to the same contamination and arc-over concerns as a non coated device.

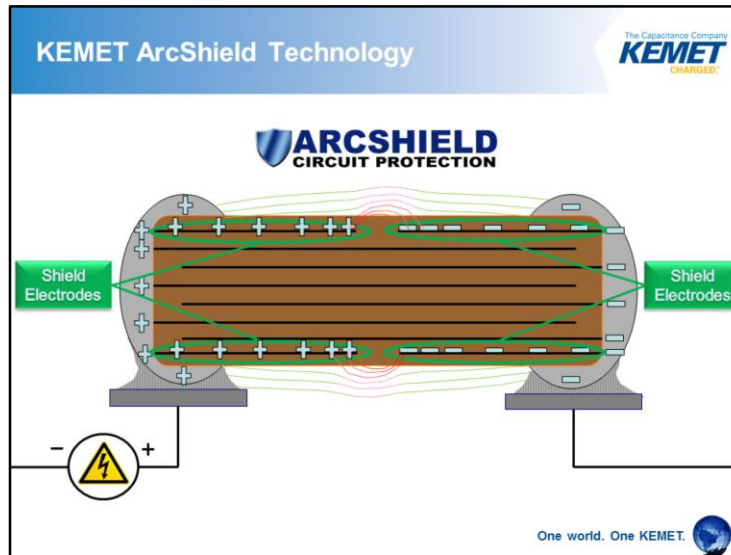
When choosing devices that use coating technology, it is important to ensure that the coating material is compatible with all applicable assembly materials, processes and conditions. Incompatibility could result in damage or premature failure of the surface coating.



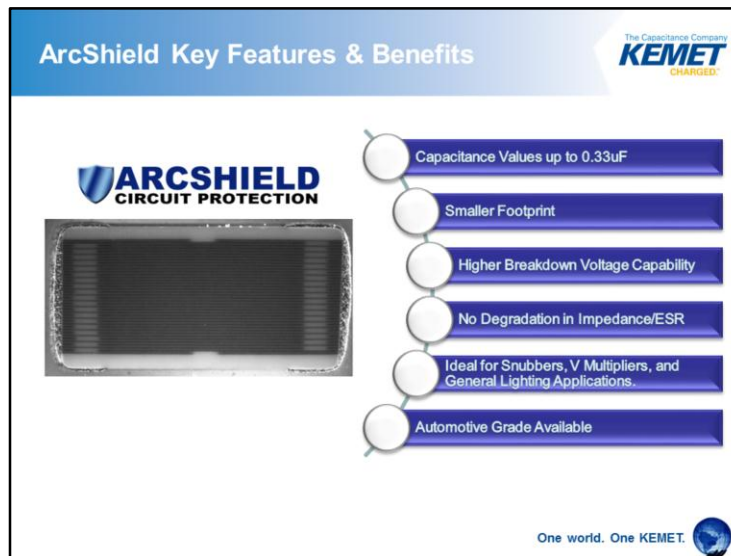
In response to the concerns associated with coating technology, Kemet Electronics Corporation has developed a patent pending, permanent solution to surface arcing in high voltage MLCCs.

Kemet's arc prevention technology, also known as ArcShield, is centered around a unique internal shield electrode design that suppresses an arc-over event without the use of external coatings. This technology was developed using KEMET's extremely reliable base metal electrode dielectric system and in the highest capacitance values available in the industry. These devices offer excellent surge voltage performance and are available in case sizes ranging from 0805 thru 1812 and in voltage ratings of 500, 630 and 1000Vdc.

For added reliability, KEMET's Flexible Termination technology is an available option that provides superior flex performance over standard termination systems.



When a high voltage bias is applied to an ArcShield MLCC, a potential difference is established between the opposing terminations and the opposing electrode structure, but the electric field concentration is localized in the shield electrodes rather than the termination surface and respective first counter electrode. This minimizes the difference in potential along the surface of the chip and drastically improves the creepage distance capability of smaller case size devices and those constructed of high porosity dielectric materials.



The key features and benefits associated with ArcShield Technology include:

- 1) ArcShield devices are available with capacitance values up to a 0.33uF. Maximum capacitance offerings include a 0.33uF @ 500Vdc, 0.15uF @ 630Vdc and 0.10uF @ 1000Vdc
- 2) These devices offer design engineers a space saving alternative to ceramic and film through-hole capacitors and provide downsizing opportunities for larger case size devices with the same capacitance and voltage rating.
- 3) This technology allows for higher voltage breakdown capability in air when compared to arc prevention devices using coating technology. It also improves breakdown voltage performance by a minimum of 1000V over non-coated devices
- 4) ArcShield capacitors have similar ESR and Impedance performance to standard High Voltage MLCCs.
- 5) These devices are ideal for use as Snubbers, in voltage multiplier circuits, and in general lighting applications.

6) ArcShield is available in Automotive grade.

ArcShield Ordering Information



C	1812	V	334	K	C	R	A	C	TU
Ceramic	Case Size (L" x W")	Specification/ Series	Capacitance Code (pF)	Capacitance Tolerance	Voltage	Dielectric	Failure Rate/ Design	Termination Finish ¹	Packaging/Grade (C-Spec) ²
	0805 1206 1210 1808 1812	V = ArcShield W = ArcShield w/Flexible Termination	2 Sig. Digits + Number of Zeros	J = ±5% K = ±10% M = ±20%	C = 500V B = 630V D = 1000V	R = X7R	A = N/A	C = 100% Matte Sn L = SnPb (5% min)	Blank = Bulk TU = 7" Reel Unmarked TM = 7" Reel Marked AUTO = Automotive Grade 7" Reel Unmarked

¹ Additional termination finish options may be available. Contact KEMET for details.

^{1,2} SnPb termination finish option is not available on automotive grade product.

² Additional reeling or packaging options may be available. Contact KEMET for details.

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ArcShield capacitors are currently available in X7R dielectric, and in a variety of popular EIA standard case sizes. Standard termination finishes include both 100% matte tin as well as tin-lead (SnPb). The tin-lead finish option is not available on automotive grade product. Please note that the ordering code is similar to most KEMET surface mount ceramic capacitors. The sixth character position, as highlighted above, identifies the product series. A “V” should be used when placing an order for ArcShield product without the flexible termination option, and a “W” when ordering product with the flexible termination option.

For more information on KEMET’s Flexible Termination technology, please visit our product training module titled “Ceramic Capacitor Flex Crack Mitigation”.

Summary



- Permanent protection against arc-over discharge without the need of a protective coating.
- Eliminates need for material qualification and process validation associated with coating technologies.
- Eliminates the need for expensive post assembly coating of PCBs (Except when necessary to meet specific electrical safety standards)
- Higher breakdown voltage capability than similarly rated devices using coating technology.
- Downsizing and board space saving opportunities.
- Automotive Grade is available.

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In summary, Kemet's ArcShield surface mount MLCCs offer permanent protection against arc-over discharge without the need of a protective coating; pre or post assembly. This saves the customer the associated material qualification and/or process validation costs. In addition to offering higher breakdown voltages than similarly rated devices using coating technology, ArcShield capacitors offer design engineers a space saving alternative to ceramic and film through-hole capacitors, or downsizing opportunities for larger case size MLCCs. In addition to commercial grade, ArcShield capacitors are available in automotive grade and meet the demanding Automotive Electronics Council's AEC-Q200 qualification requirements.

KEMET High Voltage & ArcShield Microsites

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www.kemet.com/highvoltage

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For more information on ArcShield technology or to review KEMET's complete line of high voltage ceramic capacitor solutions, please visit our microsites @ www.kemet.com/highvoltage and www.kemet.com/arcshield.