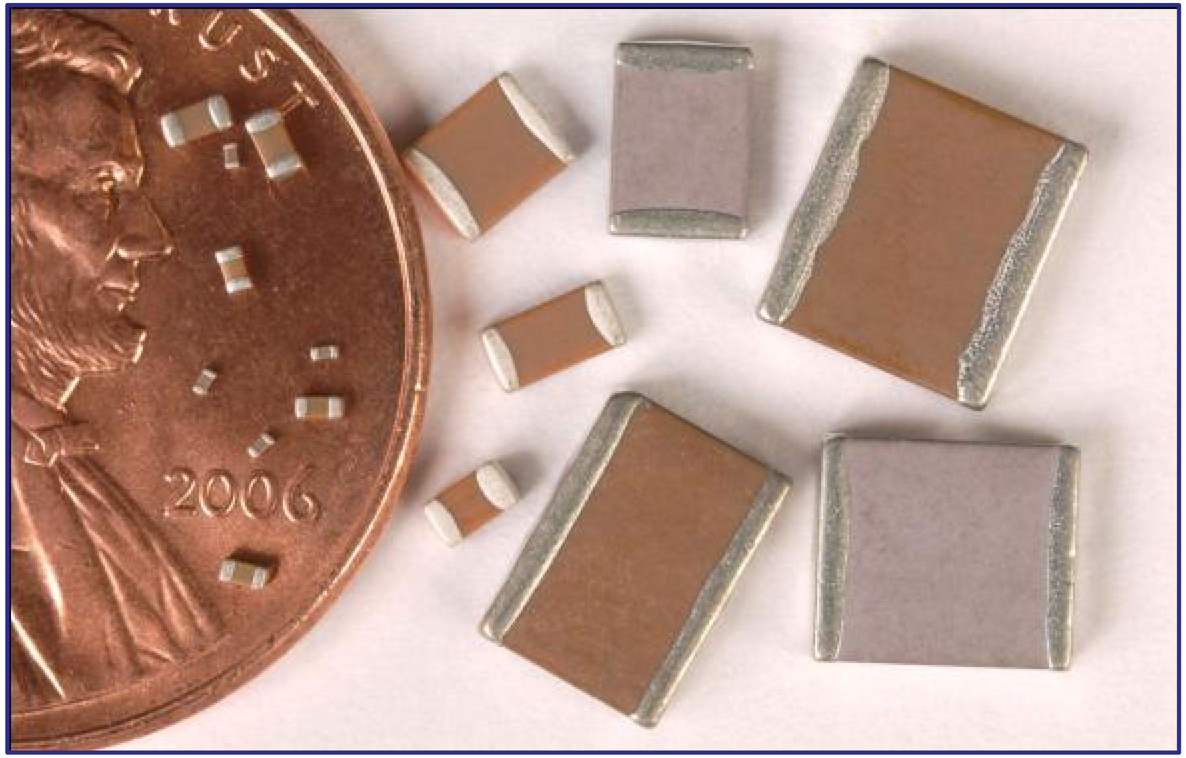
Electronic Components

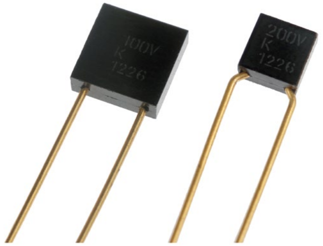
KEMET CHARGED.®

Multilayer Ceramic Capacitors (MLCCs)

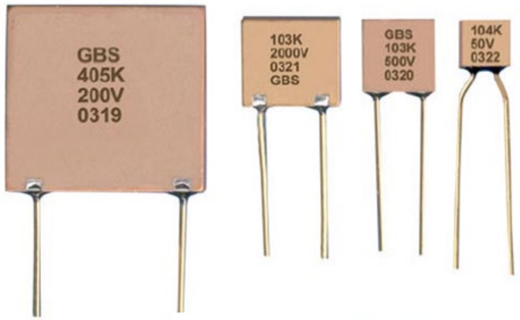
Design and Characteristics

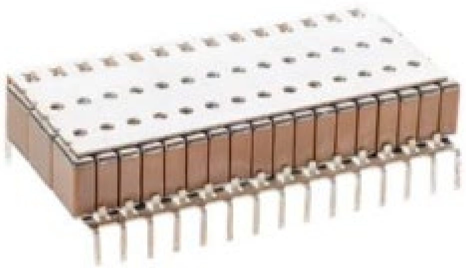
Form Factor

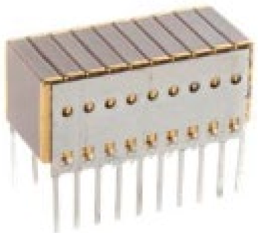

2006

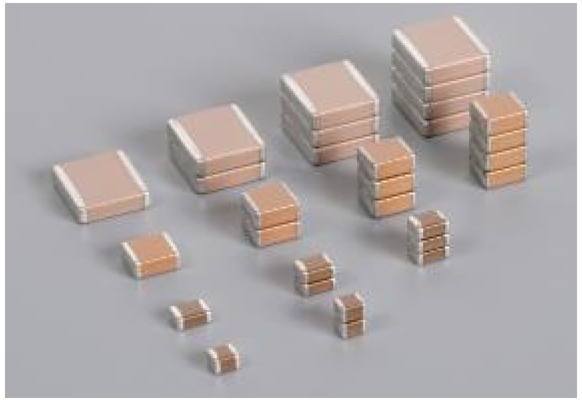



KHR
222K


GBS
405K
200V
0319
103K
2000V
0321
GBS
GBS
103K
500V
0320
104K
50V
0322

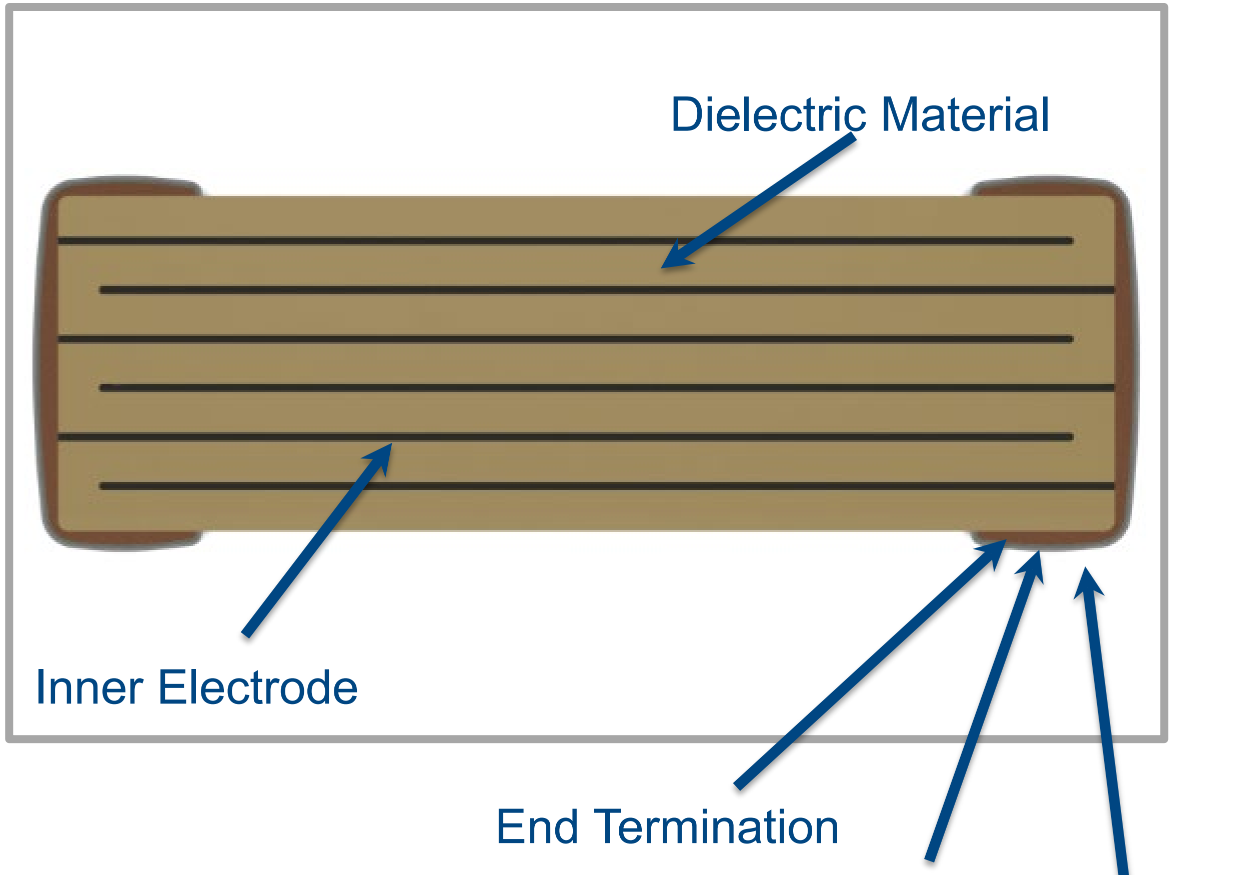






Design

MLCCs



C = Design Capacitance

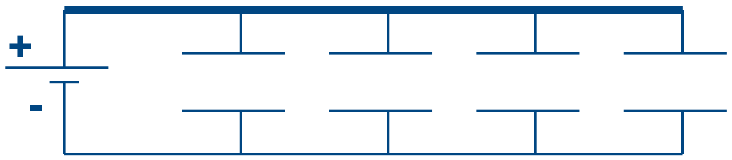
K = Dielectric Constant

A = Overlap Area

d = Ceramic Thickness

n = Number of Electrodes

$$C = \frac{\varepsilon_0 K A (n-1)}{d}$$



Capacitances in parallel are additive

$$C_T = C_1 + C_2 + C_3 + \ldots C_n$$

Common Failure Modes

Ceramic Materials are Inherently Brittle

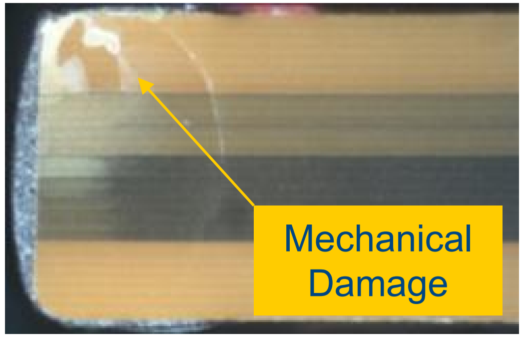
Ceramic Properties

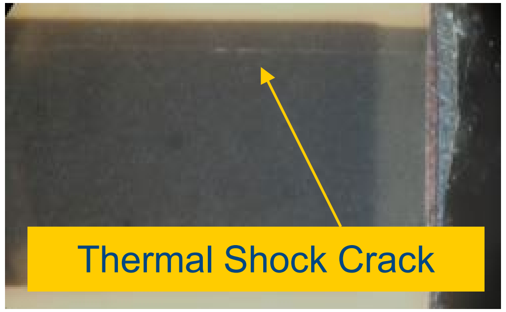
- High chemical bond strength
- High Elastic Modulus
- Low Ductility
- Very Hard

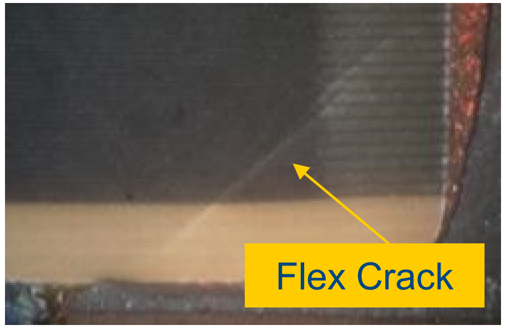
Typical Crack Signatures

The major sources of MLCC cracks are:

- Mechanical damage (impact)
  - Aggressive pick and place
  - Physical mishandling
- Thermal shock (parallel plate crack)
  - Extreme temperature cycling
  - Hand soldering
    - *Do not touch electrodes while hand soldering!*
- Flex or Bend stress
  - Occurs after mounted to board
  - Common for larger chips (>0805)



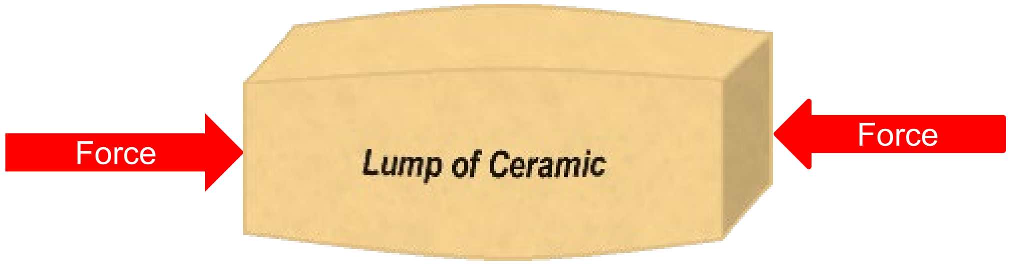




Failure is **not always immediate**!

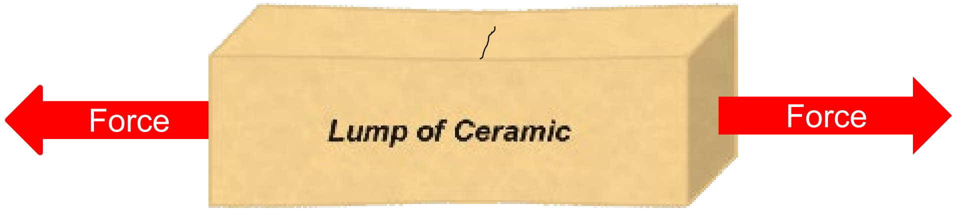
External Forces on Ceramic Material

Compression

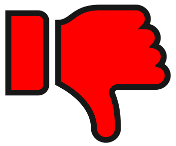


Strong under compression

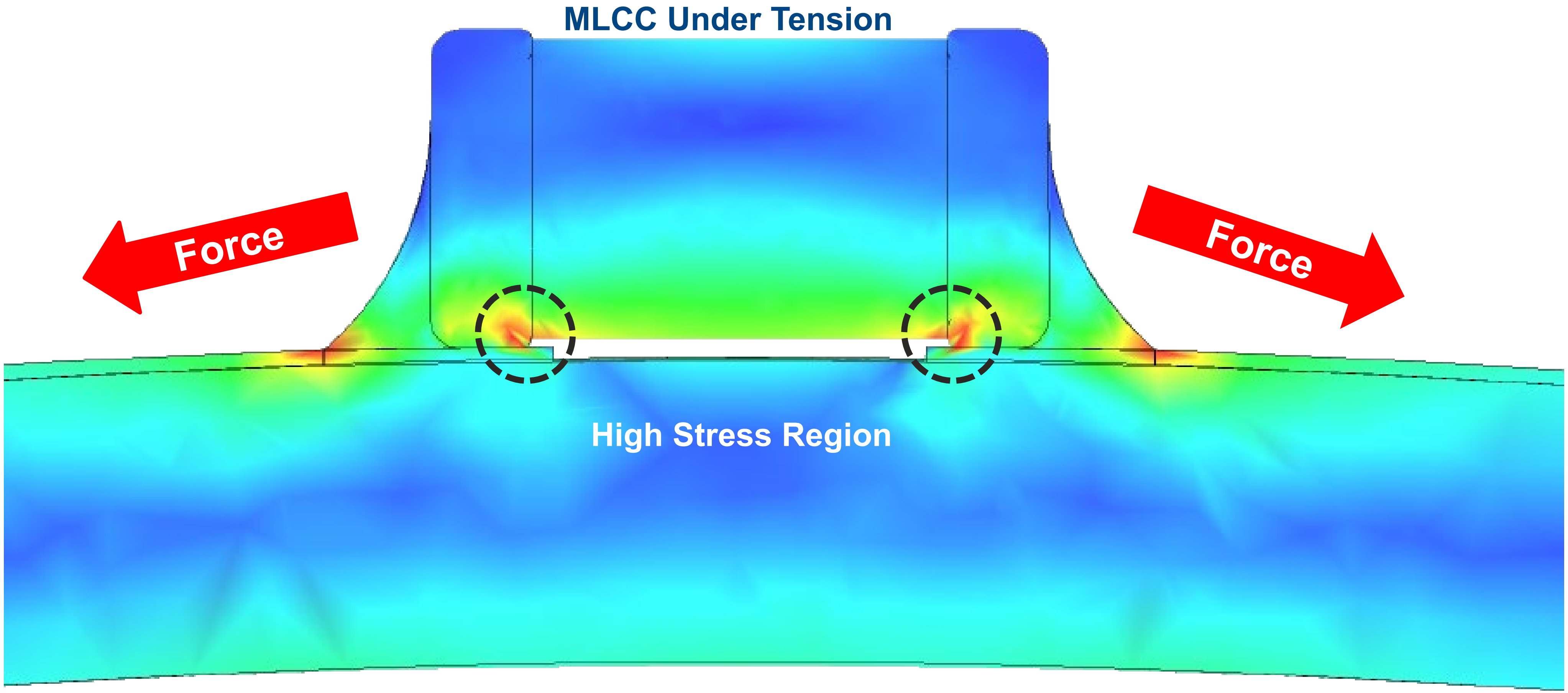
Tension



Weak under tension



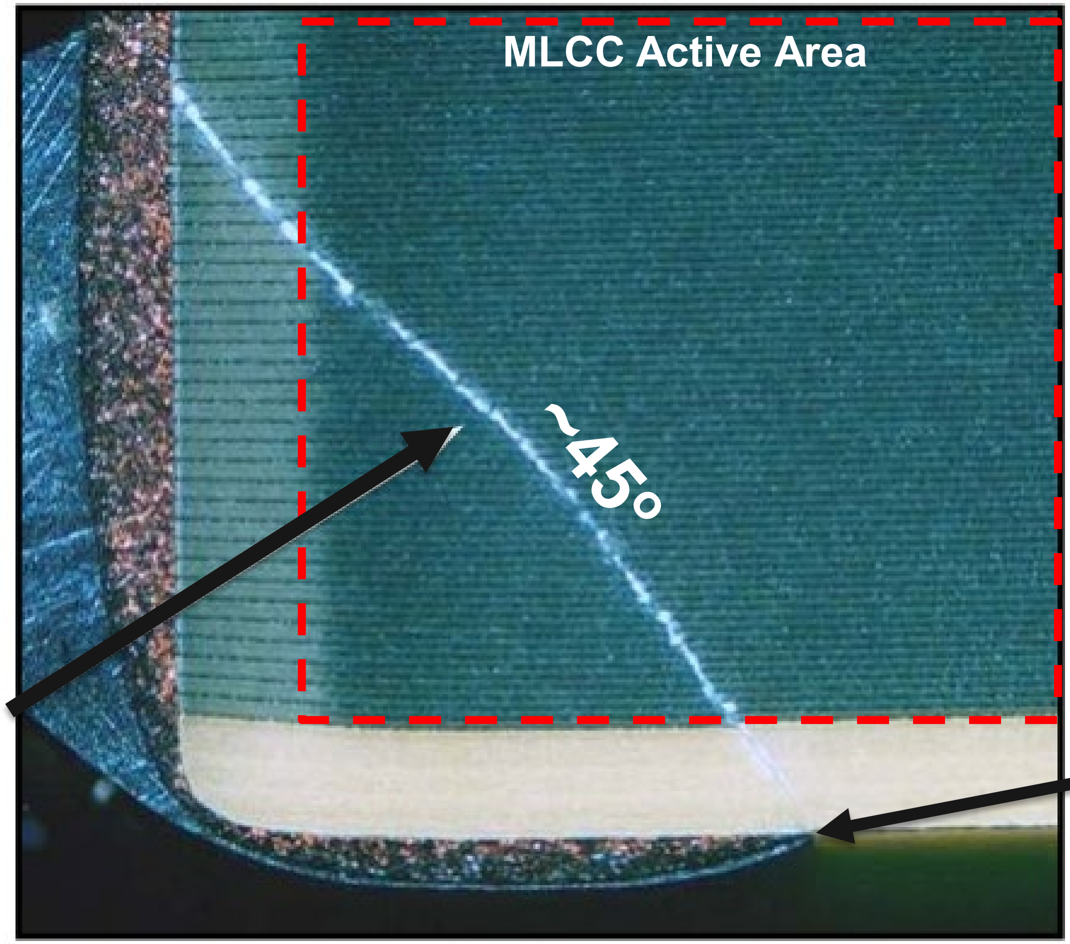
Flex Cracking
Excessive Bending



Finite Element Analysis

Flex Cracking
Excessive Bending

Flex crack signature

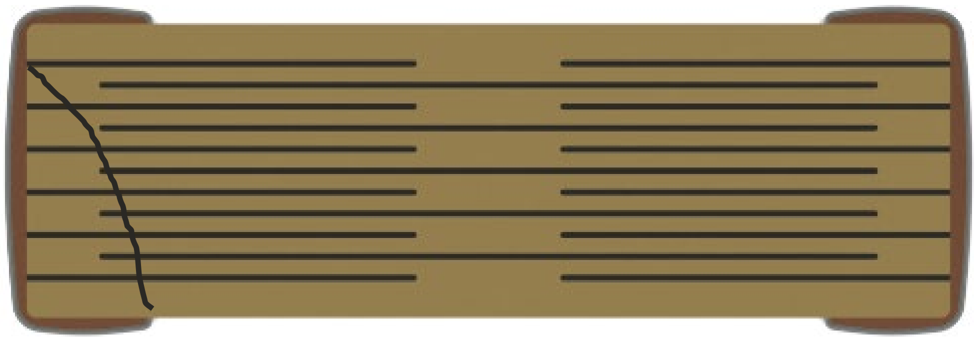


Starts here

Capacitor Mitigation Solutions

Level 1 Protection – Basic Level of Crack Protection

Floating Electrode

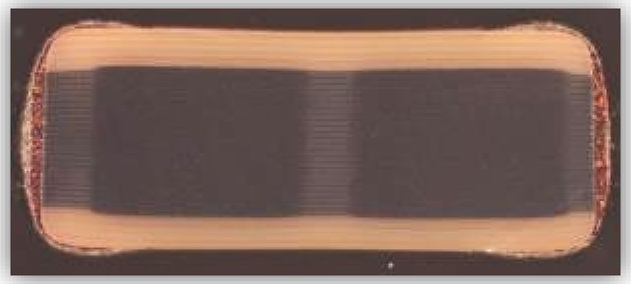


Pros

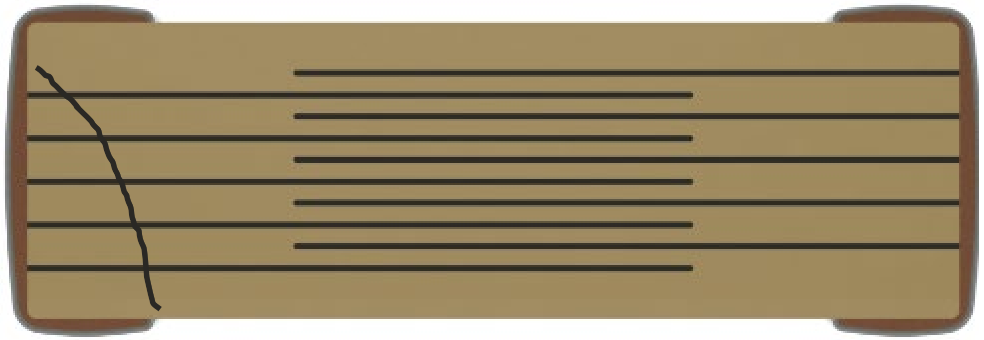
- Serial design
- Fails open

Cons

- Reduced capacitance in the same volume



Open Mode

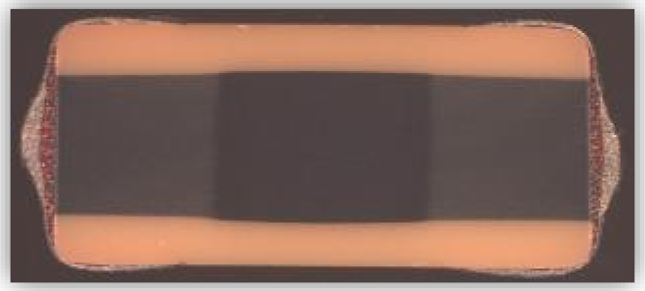


Pros

- Crack doesn't go through active area
- Fails open

Cons

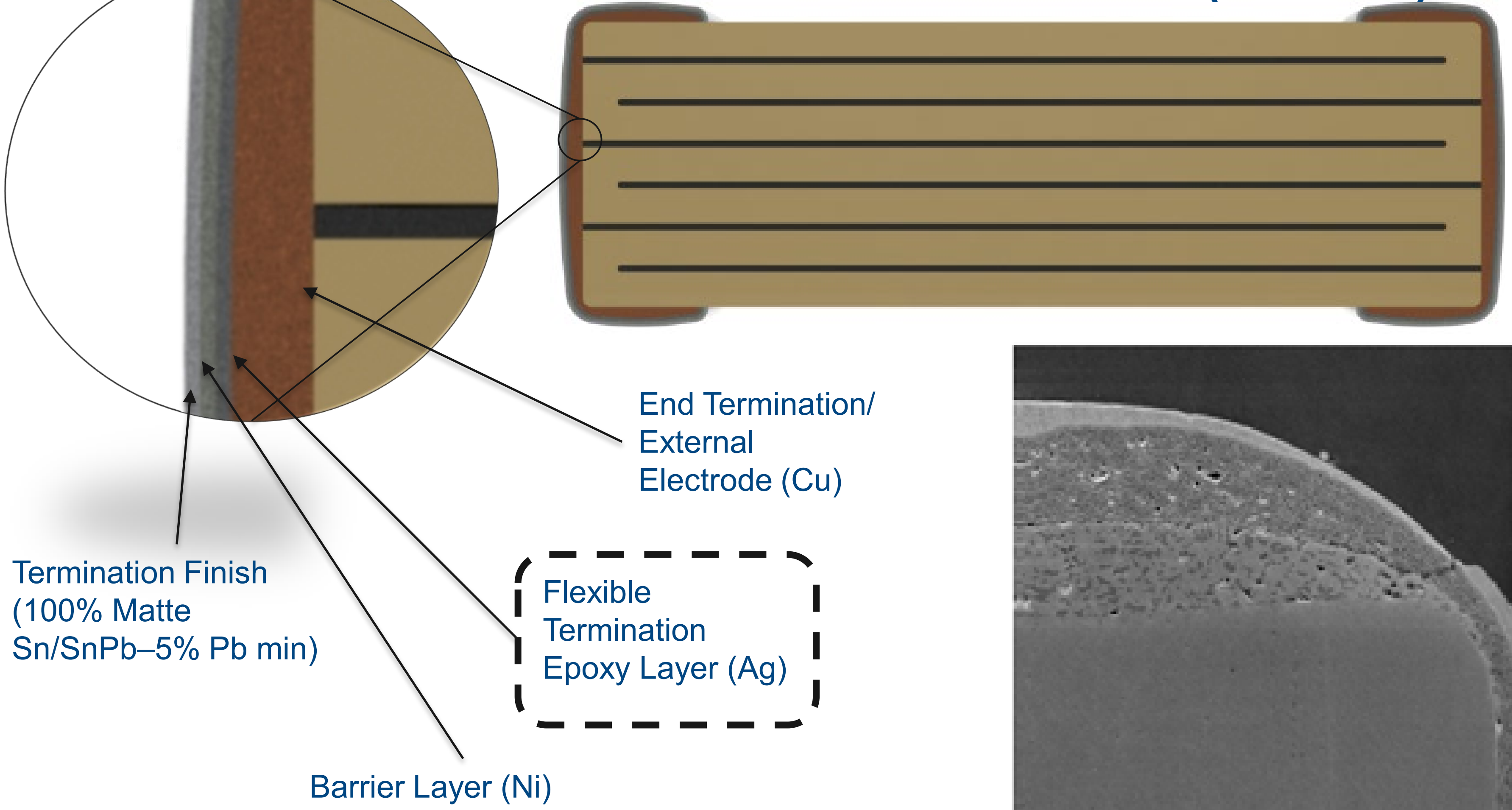
- Reduced capacitance in the same volume



Capacitor Mitigation Solutions

Level 2 Protection – Intermediate Level of Crack Protection

Flexible Termination (FT-CAP)

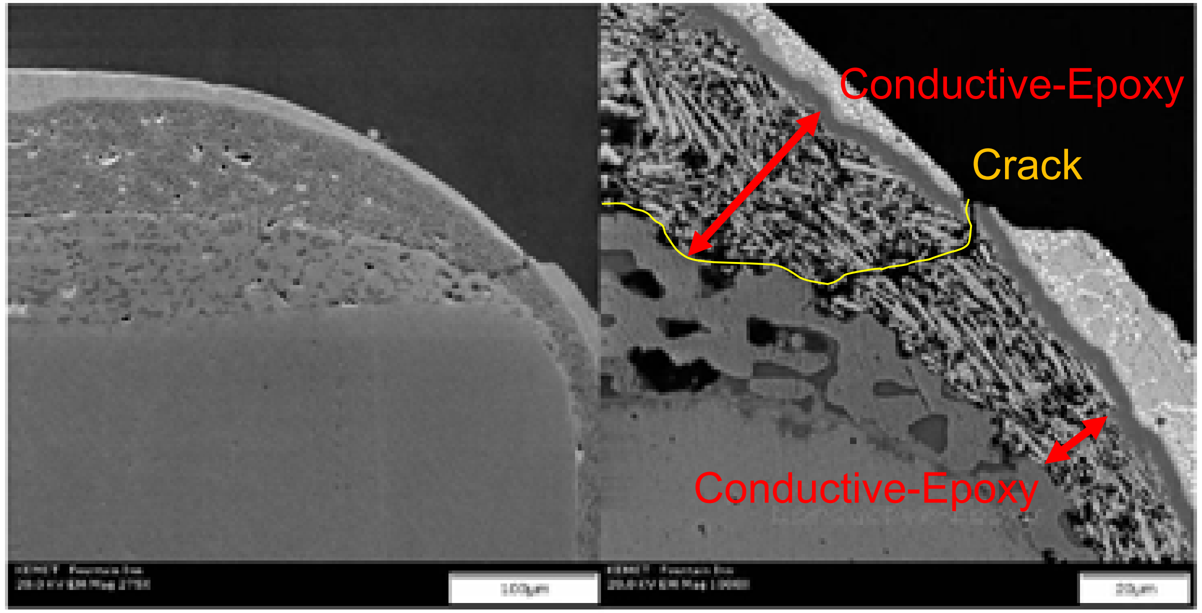


Pros

- Increased flex capability
- High volumetric efficiency

Cons

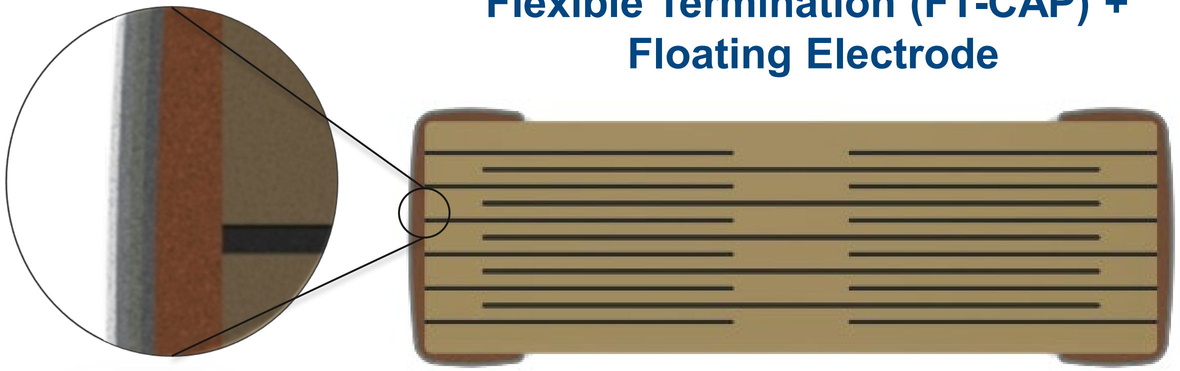
- Fail short



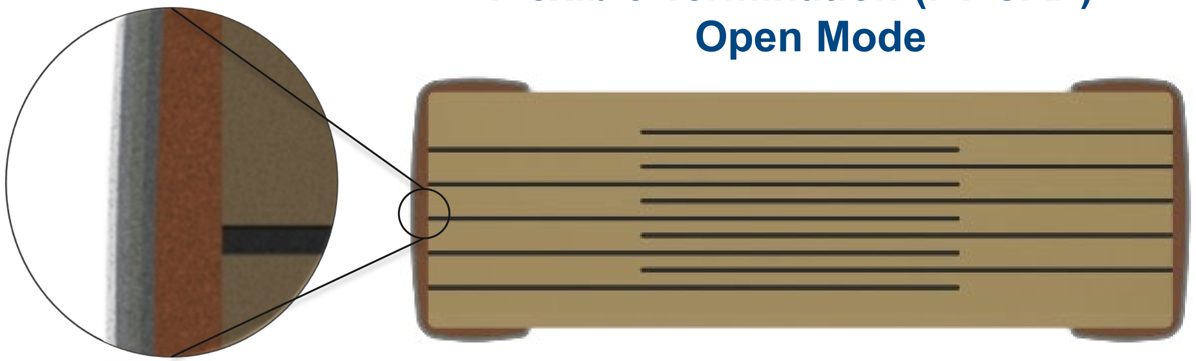
Capacitor Mitigation Solutions

Level 3 Protection – High Level of Crack Protection (Hybrid Technology)

Flexible Termination (FT-CAP) + Floating Electrode



Flexible Termination (FT-CAP) + Open Mode



Pros

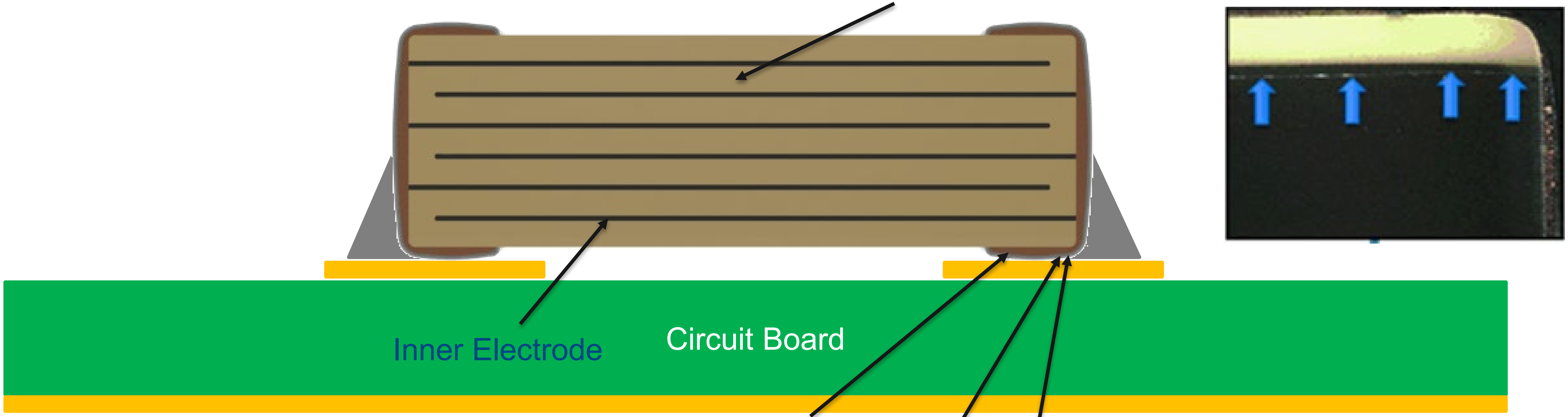
- Increased flex capability
- Floating Electrode design
- Fail Open

Cons

- Reduced capacitance in the same volume

Thermal Shock

Why is it an issue?

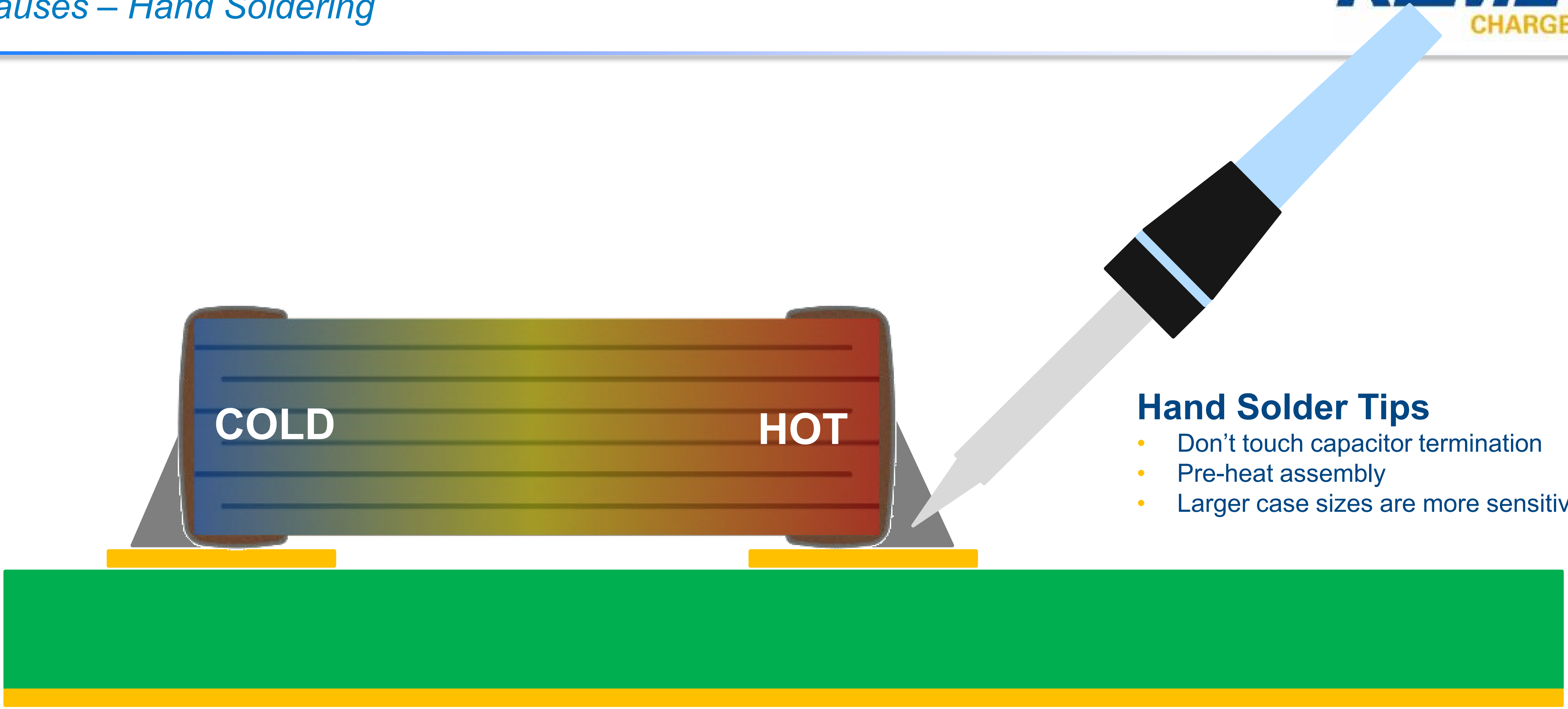


CTE – Coefficient of Thermal Expansion

Thermal Shock Cracks → CTE Mismatch

Thermal Shock

Causes – Hand Soldering



Hand Solder Tips

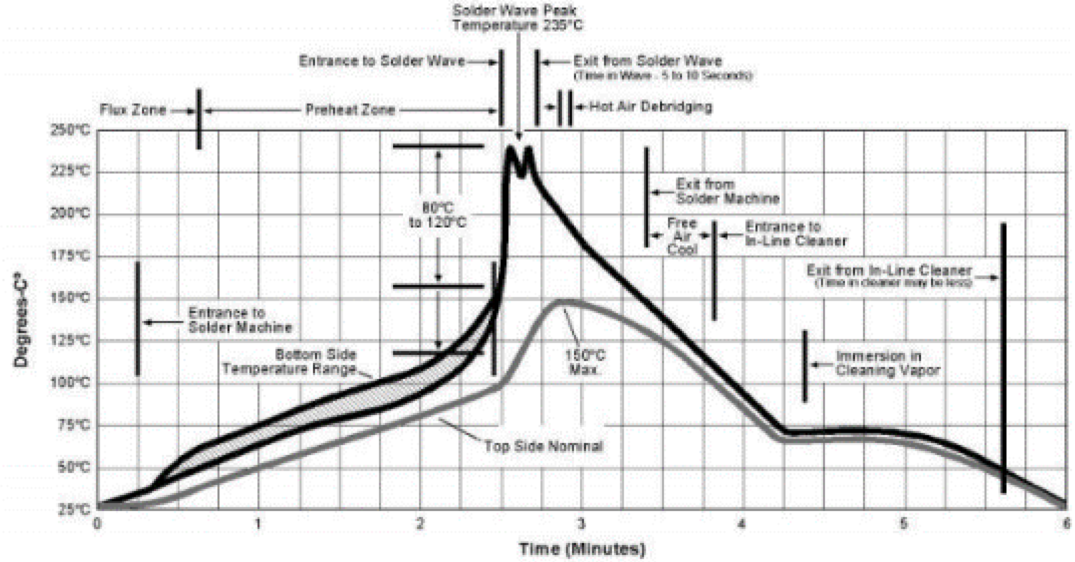
- Don't touch capacitor termination
- Pre-heat assembly
- Larger case sizes are more sensitive

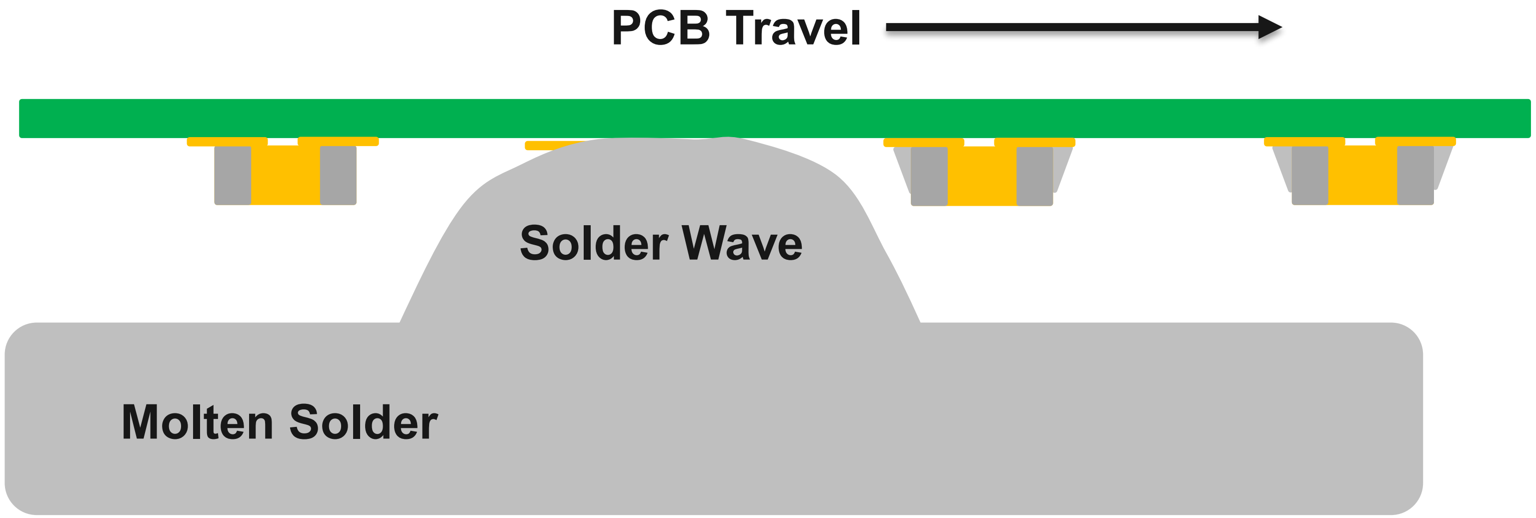
Internal Temperature Gradients

Uneven Expansion and Contraction

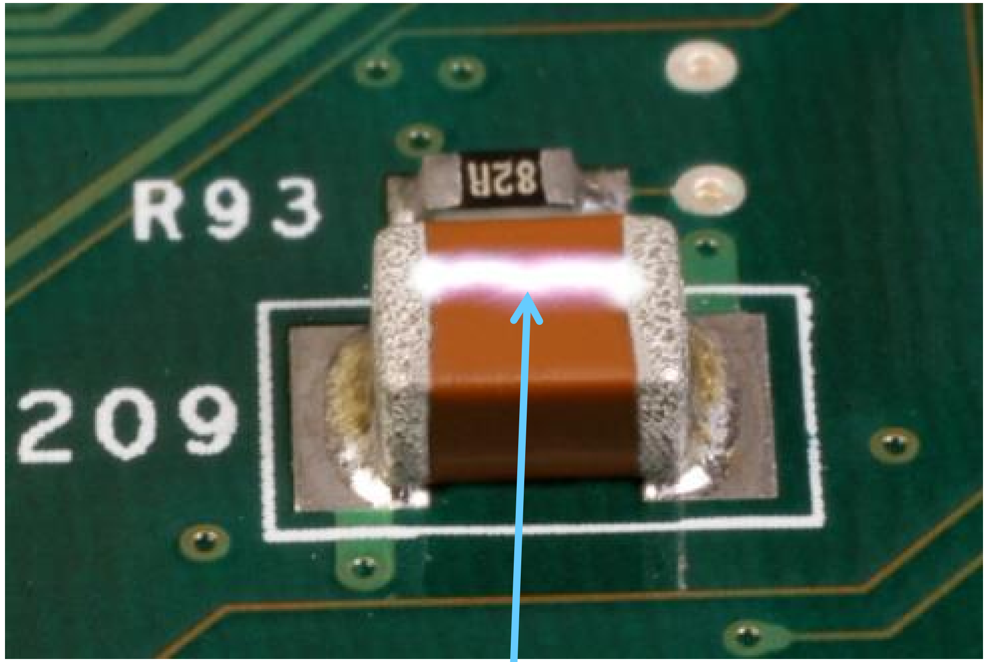
Thermal Shock

Causes – Solder Wave





What is MLCC Surface Arcing?

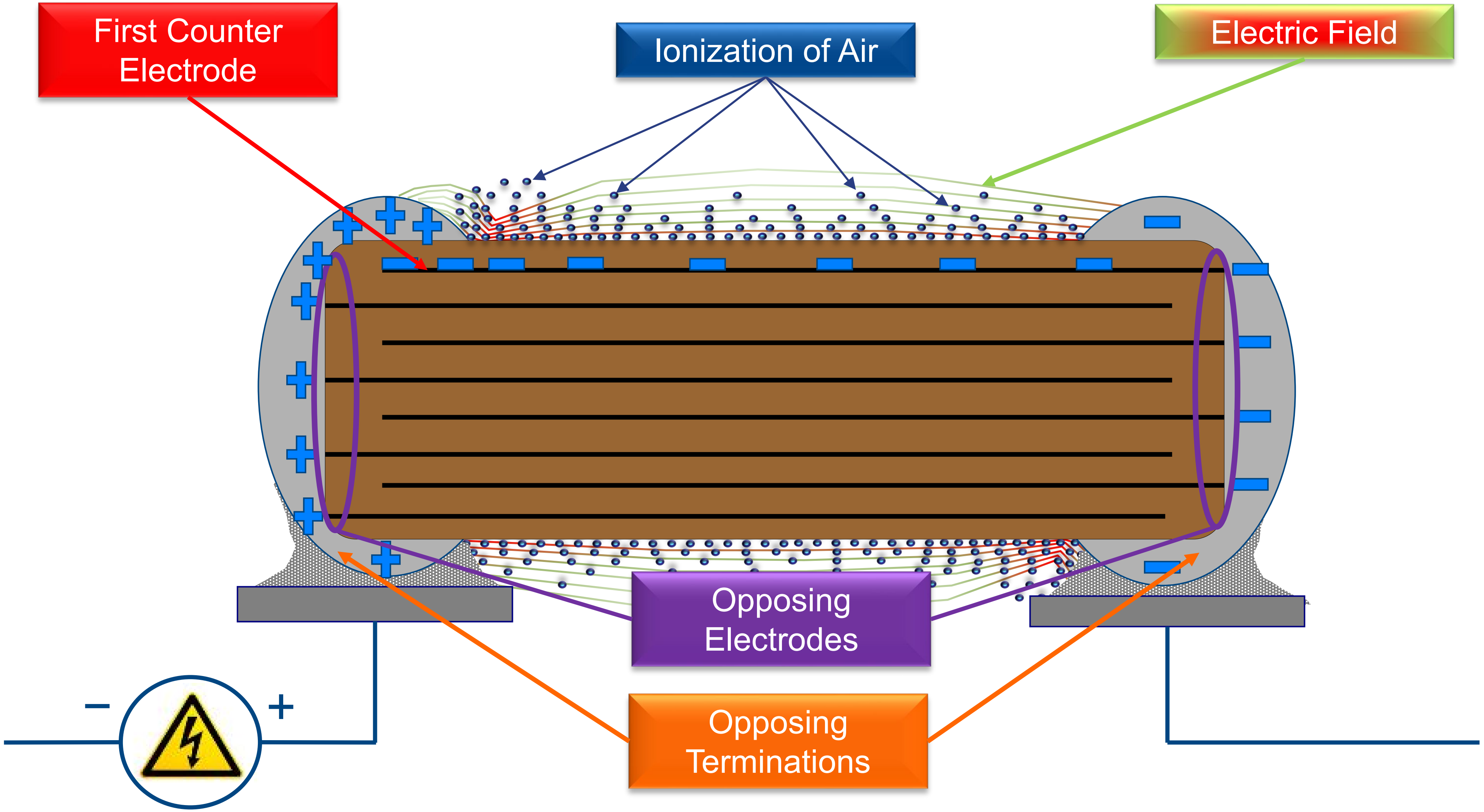


Electrical breakdown between the two MLCC terminations or between one of the terminations and the internal electrodes of the capacitor within the ceramic body.

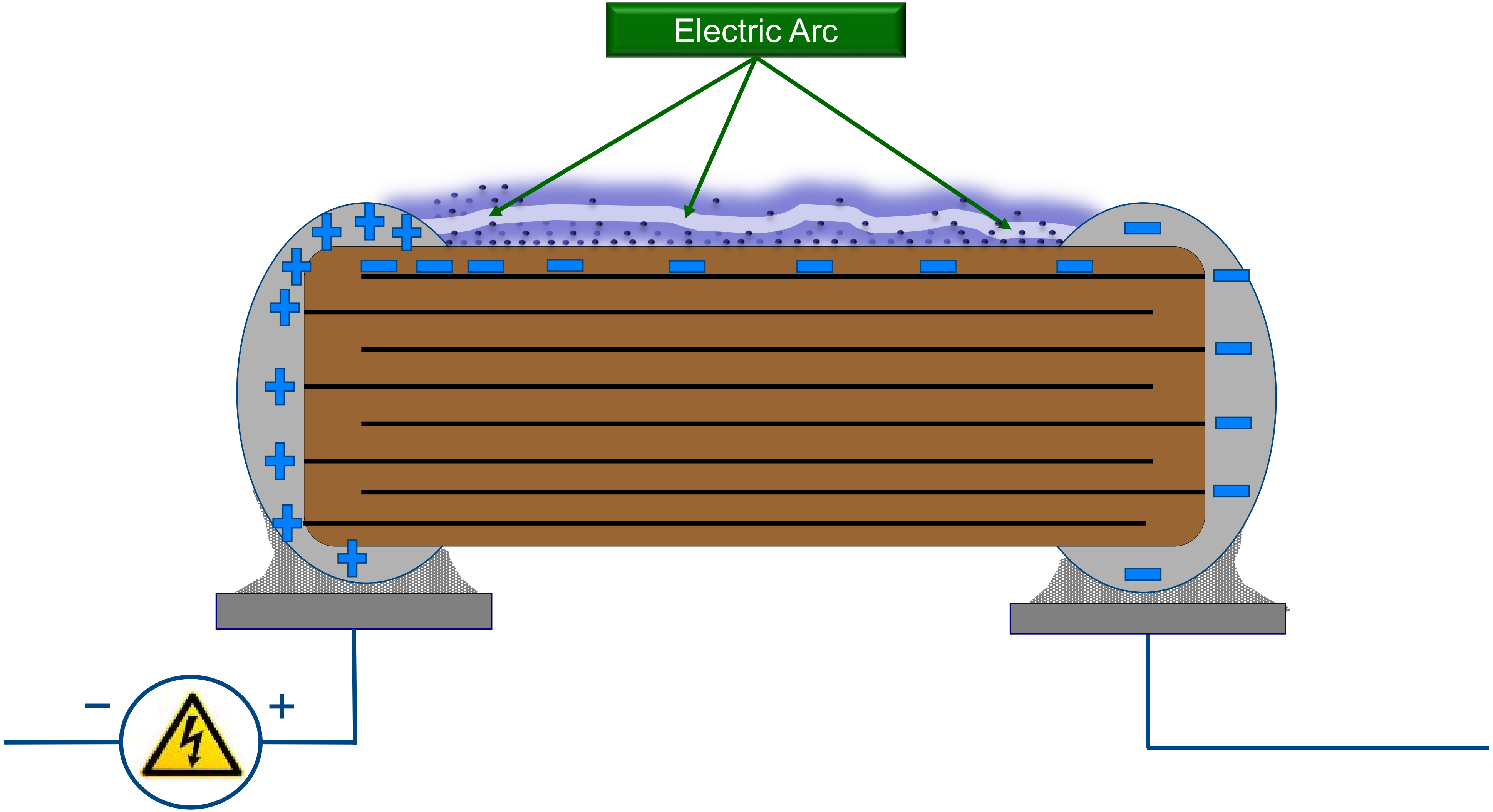
Influences

- Humidity
- Surface Contamination
- Creepage Distance

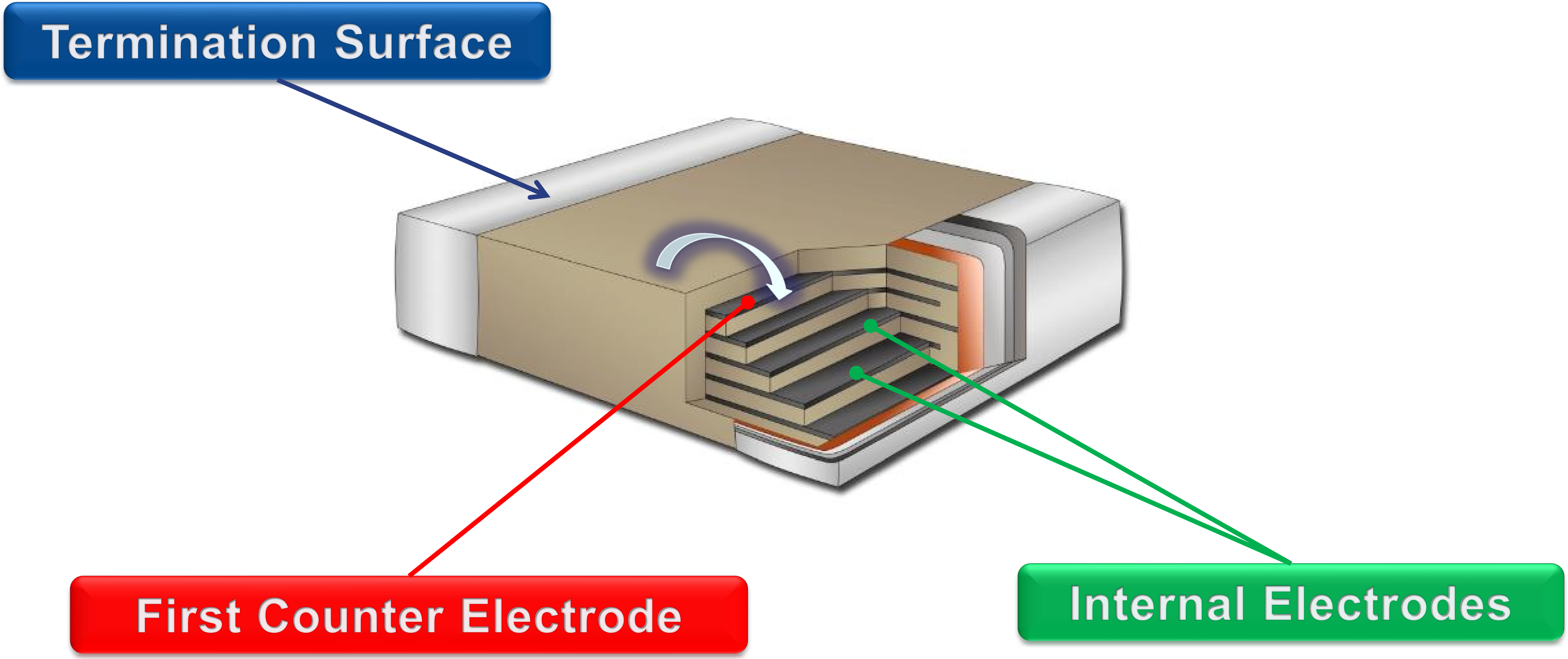
The Phenomenon of Surface Arcing



The Phenomenon of Surface Arcing



Surface Arcing Between MLCC Termination and the Internal Electrode Structure

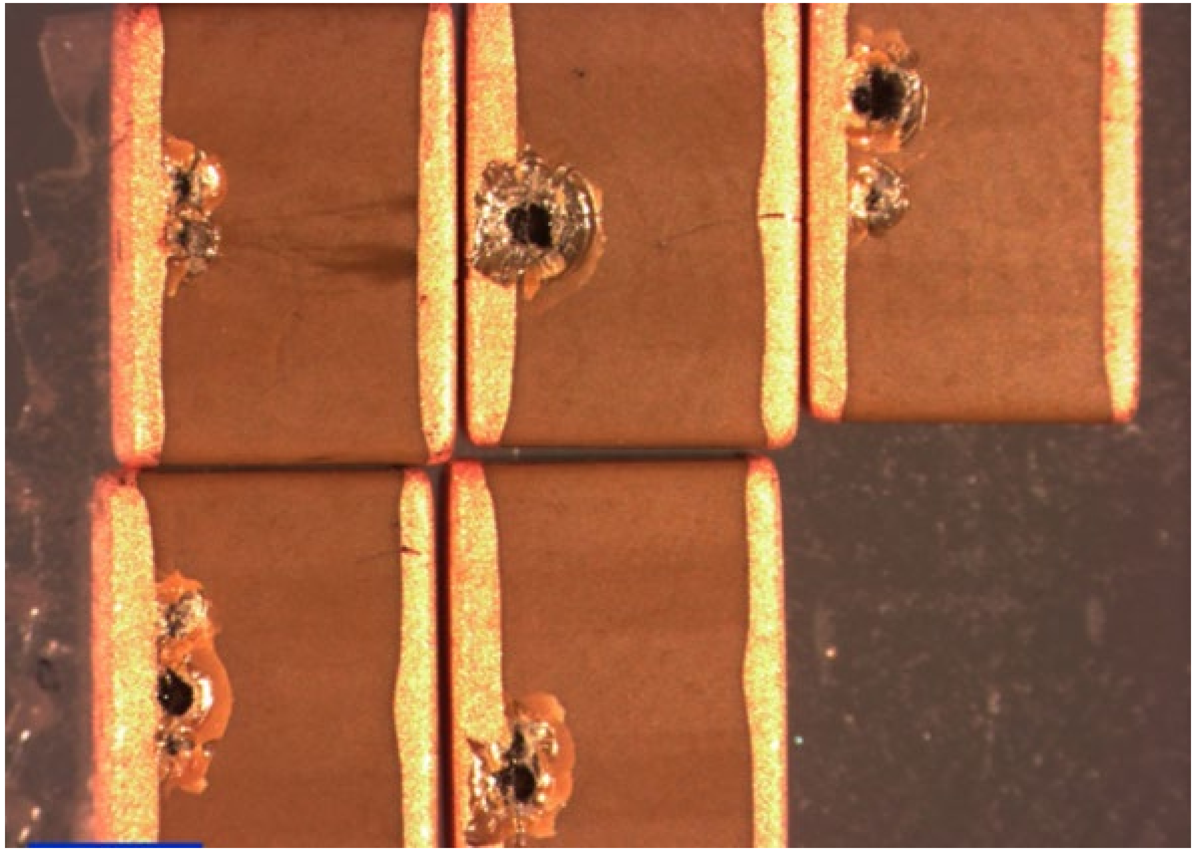


Surface Arcing Failure Modes

Terminal-to-Terminal Arcing

Carbon Traces

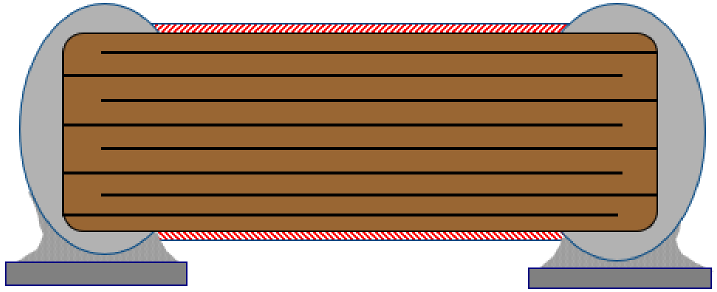
Terminal-to-Active Arcing



Voltage Breakdown Failures

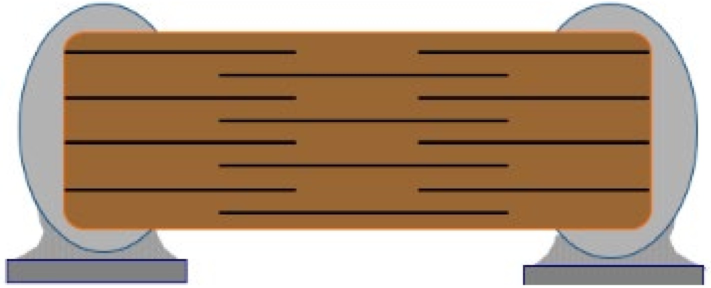
Solutions for MLCC Surface Arcing

Surface Coatings



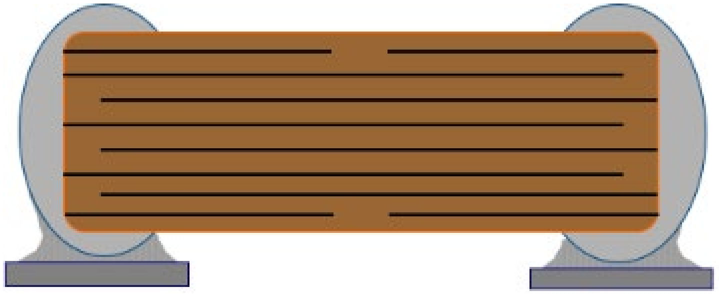
- MLCC Coating
  - Added by MLCC supplier
  - Additional process step
  - Critical that there is no damage to or air gap under the coating
- PCB Coating
  - Added after PCB assembly
  - Additional process step
  - Added cost
  - Cannot rework

Serial Electrode Designs



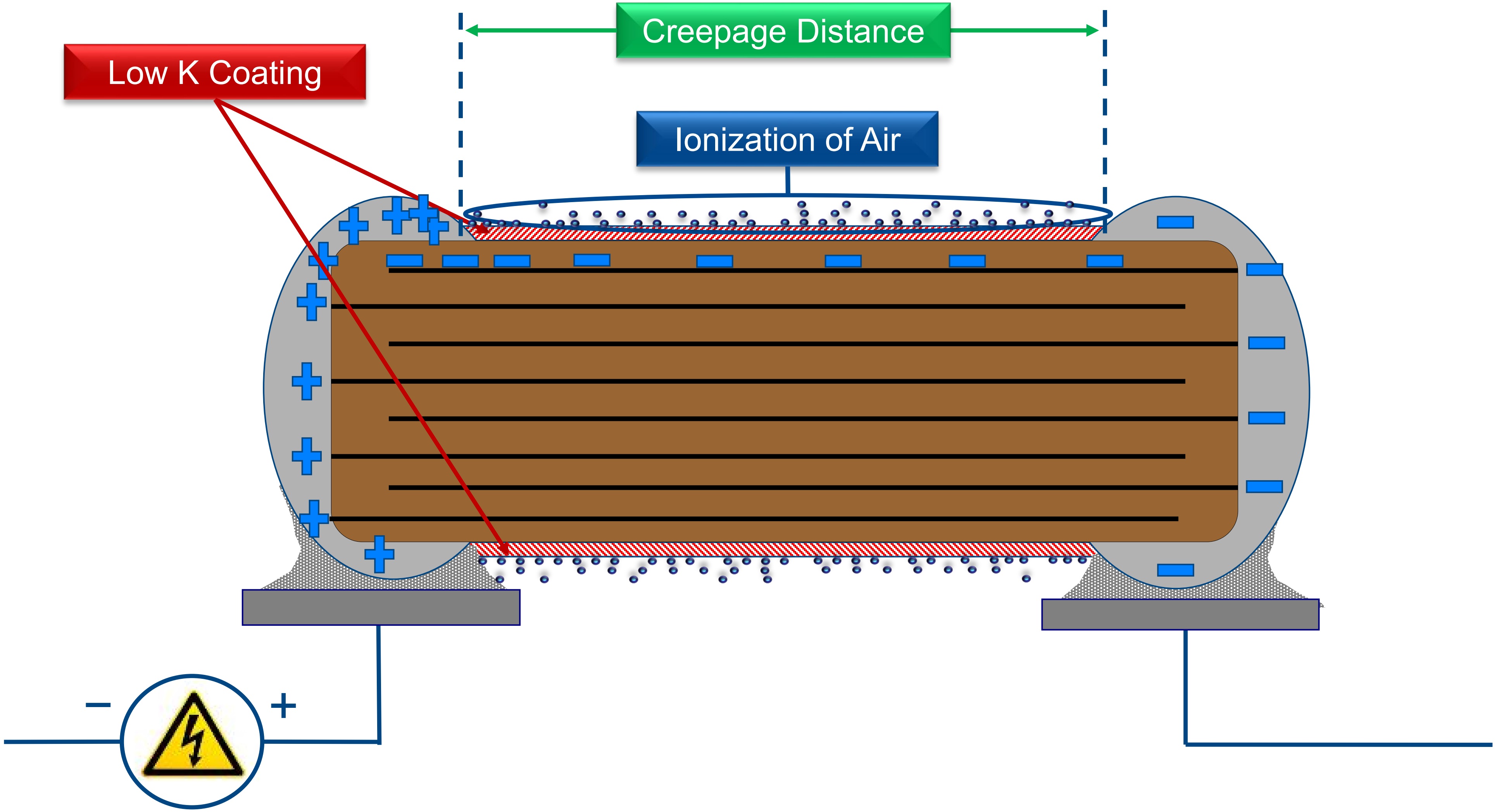
- Reduce electric field strength
  - Available capacitance in a MLCC package size is lowered
  - Allows for higher voltage capability
  - Reduces the probability of MLCC failure due to flex crack

ArcShield Designs

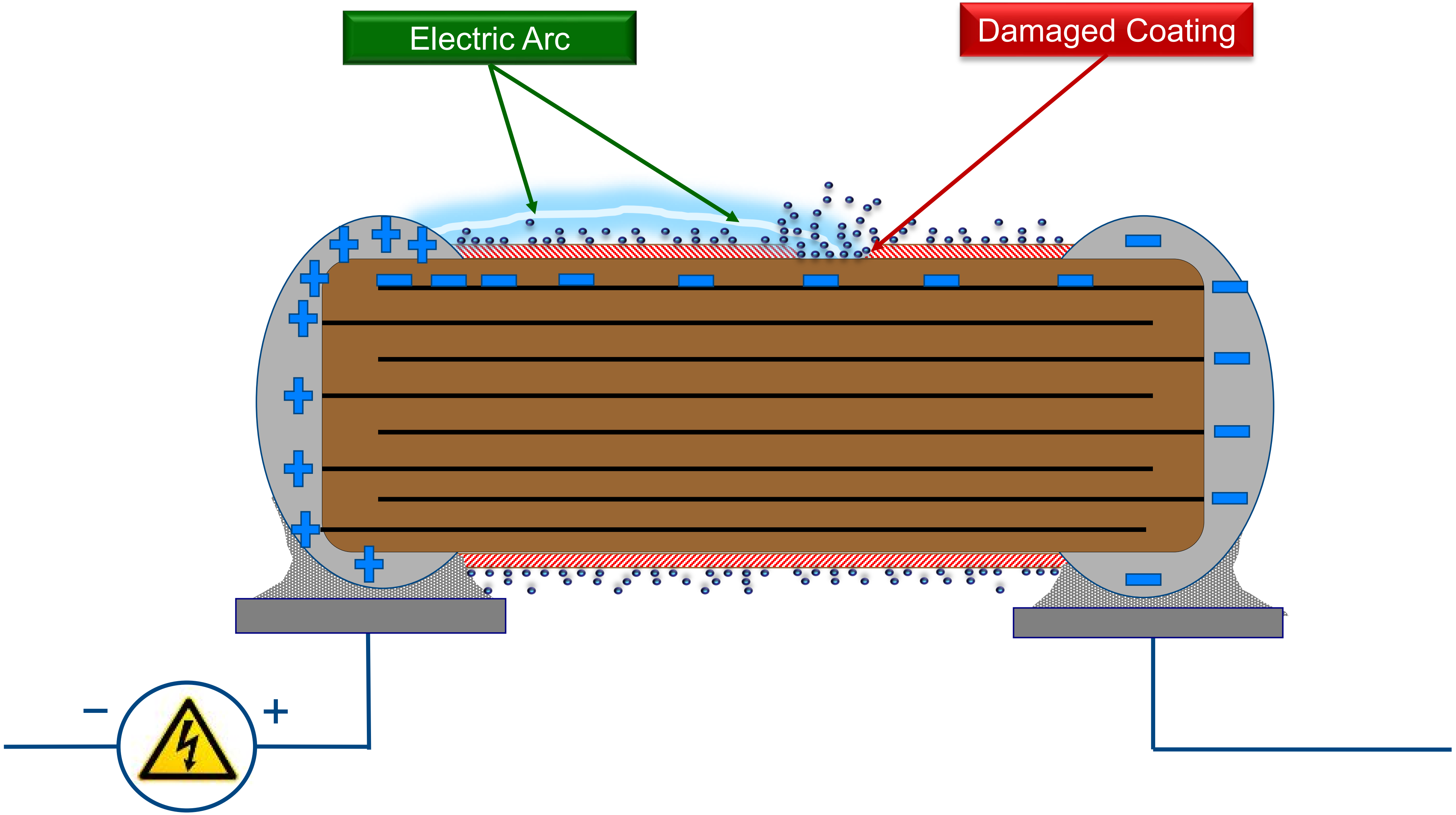


- Reduce electric field strength
- Reduce ionization of air at MLCC surface
- Maximizes available capacitance in a MLCC package size

The Benefits of Coating Technology



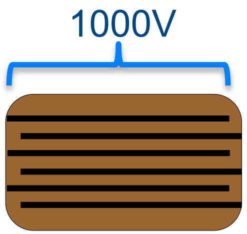
Issues With Coating Technologies



Serial Electrode Design

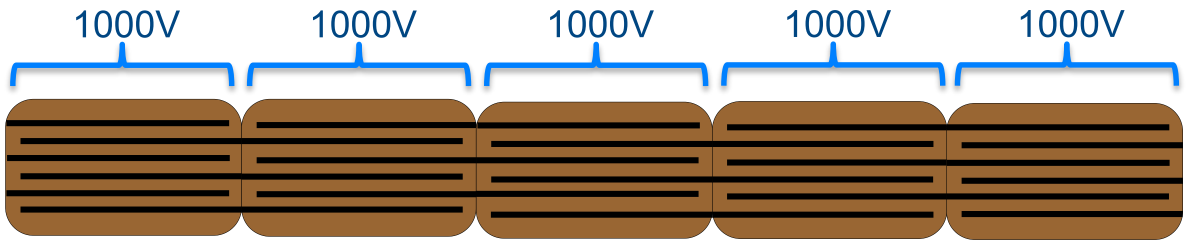
Reduction of Electric Field

Single MLCC



1uF 1000V

Five Series MLCCs

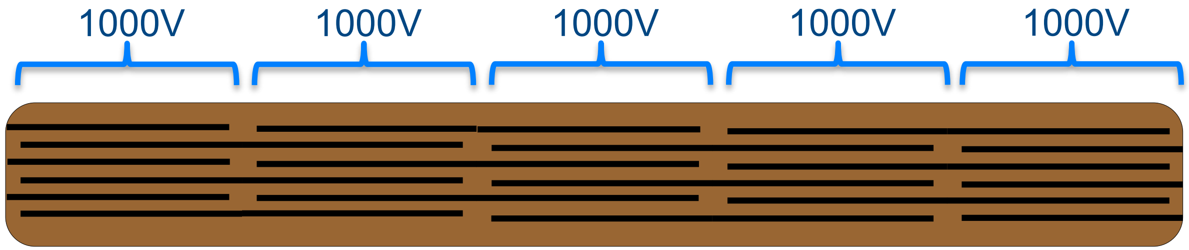


Electric Field Distributed Across Individual MLCCs

$$\frac{1}{Ceff} = \sum \frac{1}{C_N}$$

0.22uF 5000V

Single Monolithic Structure (Serial Design)



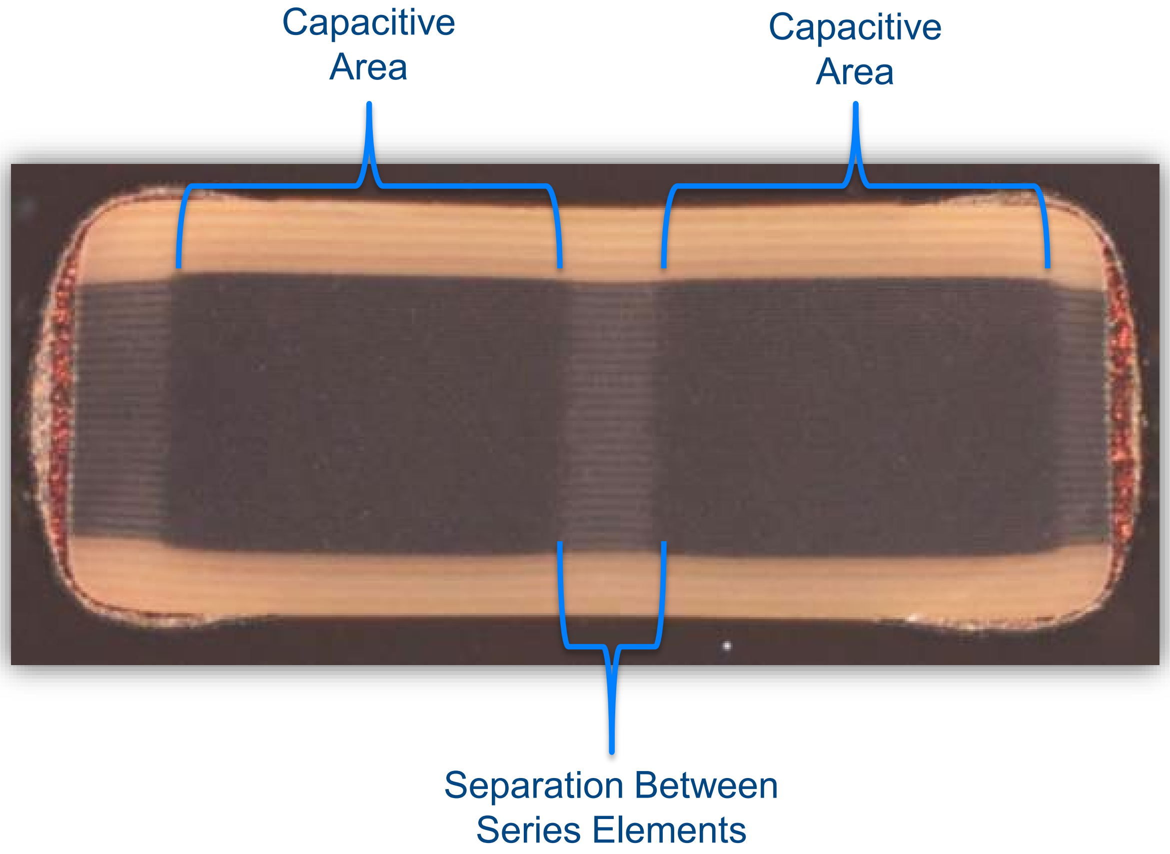
Electric Field Distributed Across Each Serial Design

0.22uF 5000V

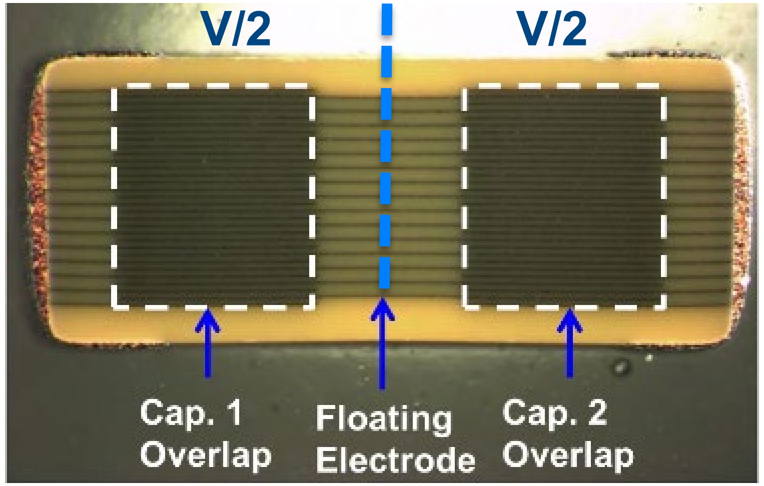
Serial Electrode Design

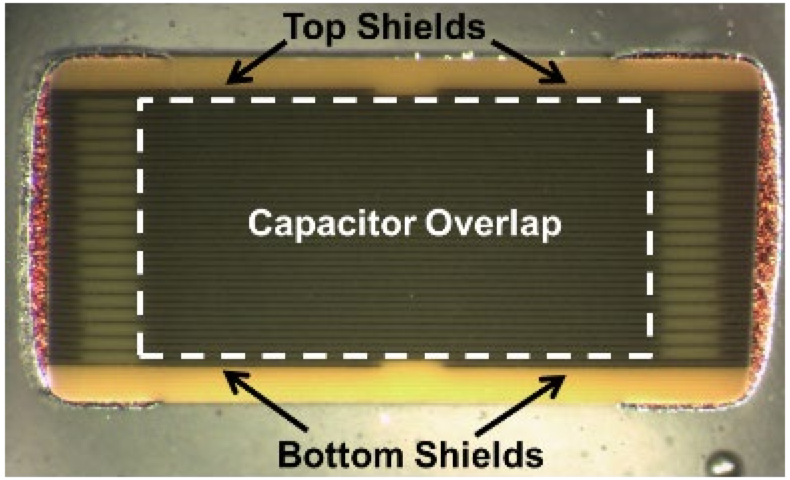
High-Voltage Ceramic

Also known as "Floating Electrode" or "Cascade Electrode" designs



"Serial" to "Shield" Design Comparison





"Serial" Design

- With capacitors (N) in series, the acting voltage on each capacitor is reduced by the reciprocal of the number of capacitors (1/N).
- Effective Capacitance is reduced:

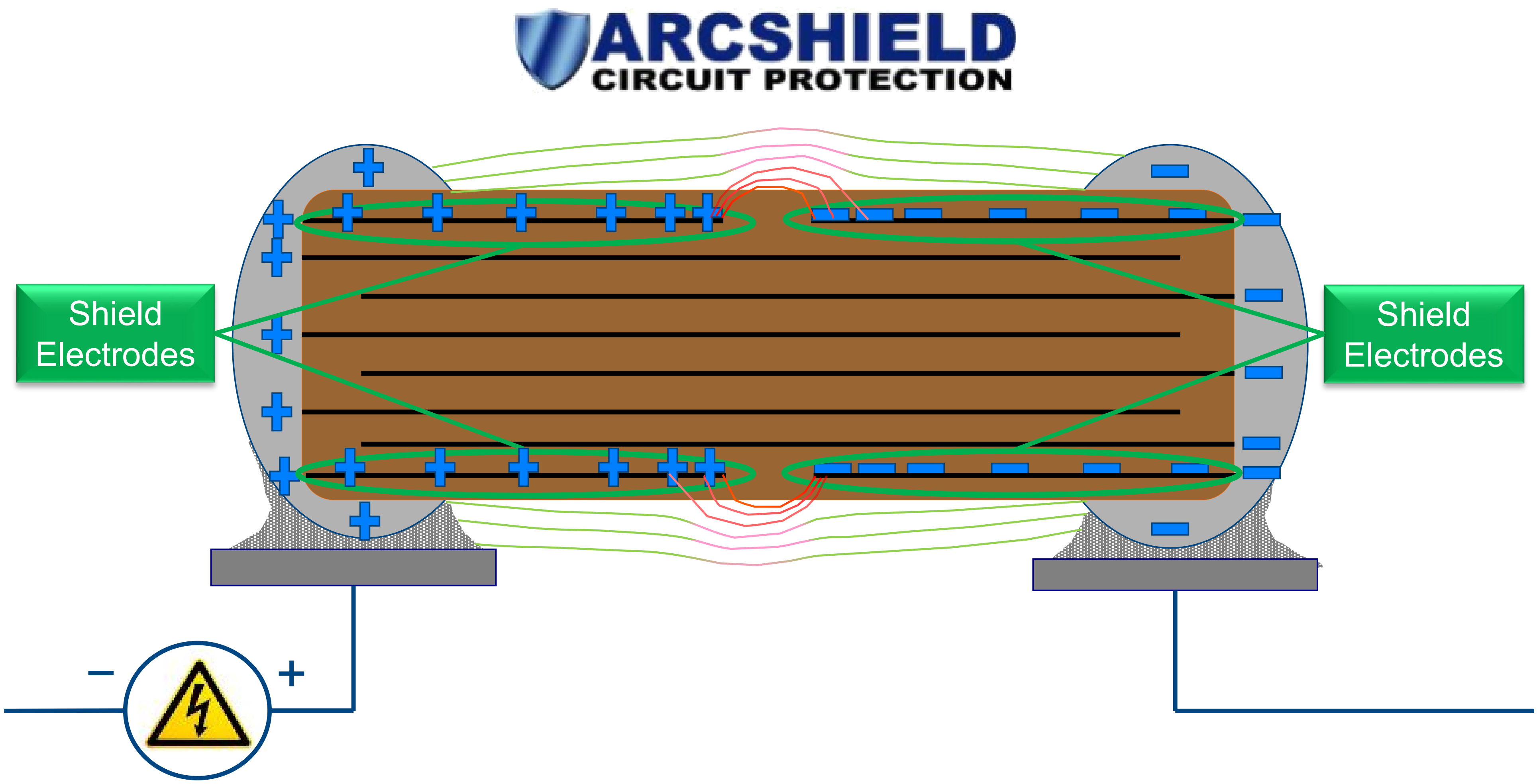
$$\frac{1}{Ceff} = \sum \frac{1}{C_N}$$

"Shield" Design

- Larger electrode area overlap **A** so higher capacitance while retaining high voltage breakdown.
- Thickness d between opposing electrodes increased:

$$C = \frac{\epsilon_o KNA}{d}$$

KEMET ArcShield Technology

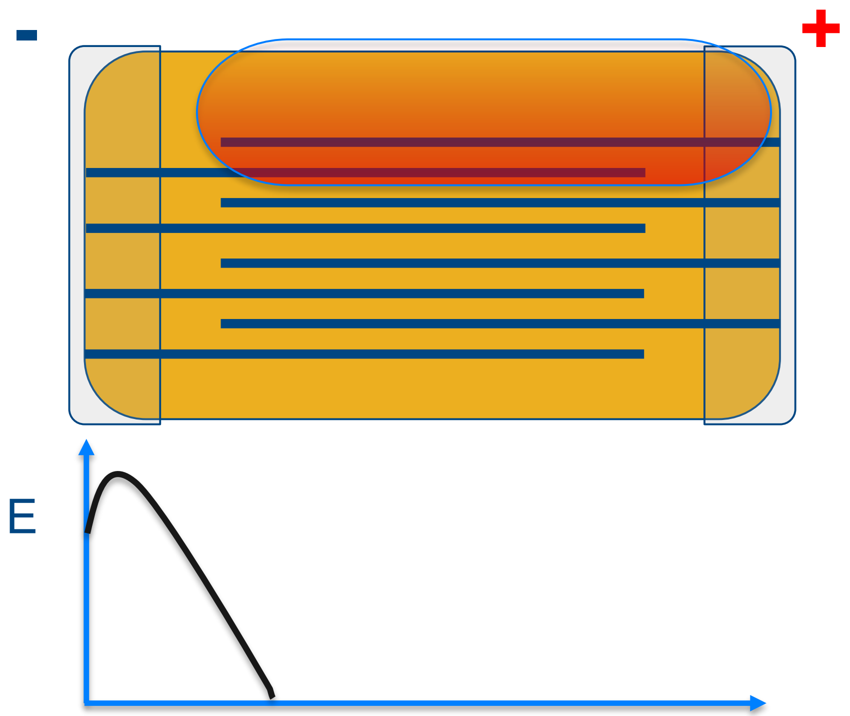


Explanation of Shield Design

Reduction of Electric Field

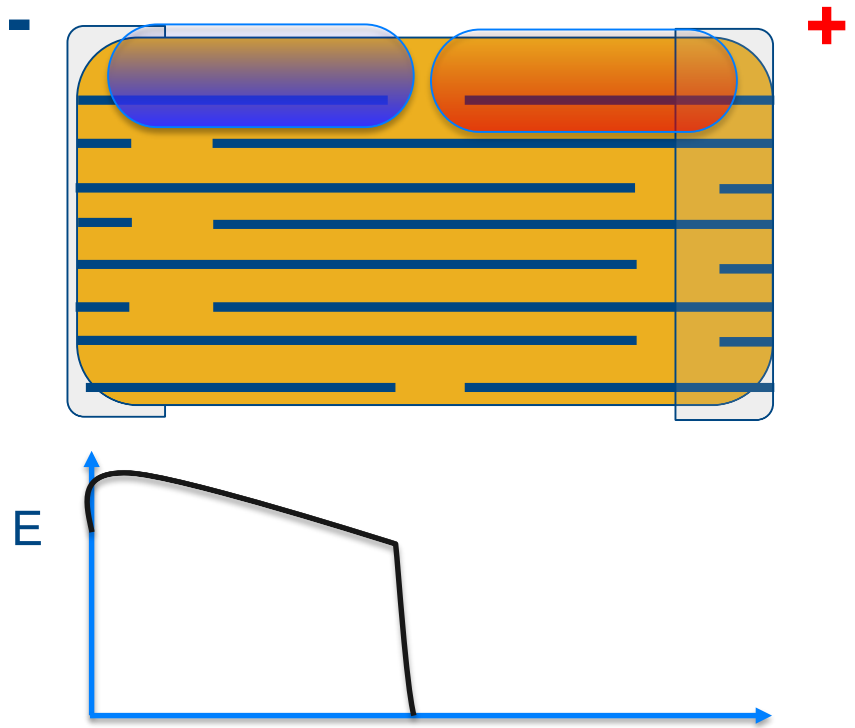
Terminal-to-Terminal Arcing
Standard Design

- Opposite Field extends close to terminal of opposed polarity so low energy barrier



Terminal-to-Terminal Arcing
ArcShield Design

- Opposite Field is longer distance from terminal of opposed polarity increasing size of energy barrier

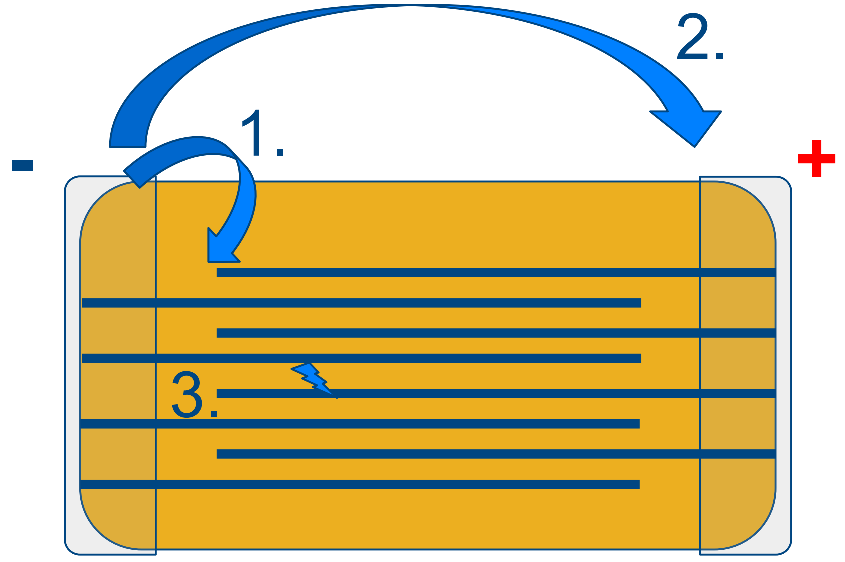


Explanation of Shield Design

Designed for Higher Voltage

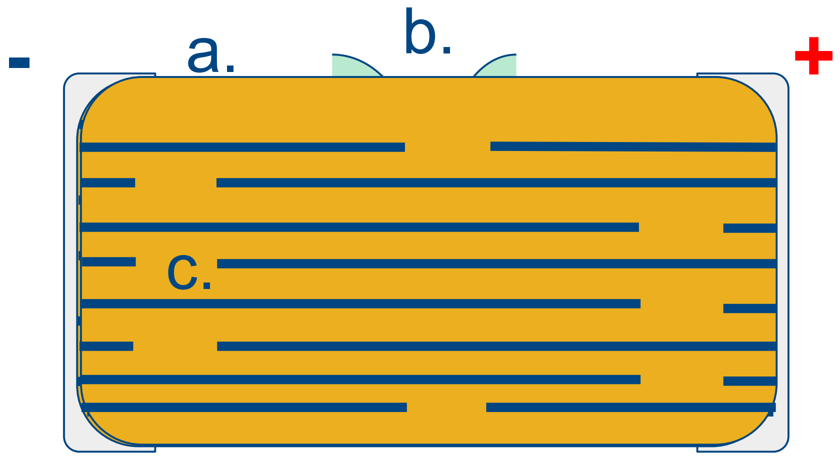
Consider a Standard Design

- In a standard overlap X7R MLCC there are 3 ways of failing high voltage:
    1. Arcing between terminal and 1st electrode of opposite polarity
    2. Arcing between terminals
    3. Internal breakdown



Shield designs solve these voltage breakdown issues by:

  a. Adding a shield to prevent 1.
  b. The shield also creates a barrier to 2.
  c. Thicker actives for higher breakdown 3.



KEMET ArcShield Technology

Summary

- Permanent Protection
- No protective coating necessary
- Higher breakdown voltage capability than similarly rated devices using coating technology.
- Downsizing and board space saving opportunities.

ArcShield Key Features and Benefits

Electronic Components KEMET CHARGED.

Patented Electrode Design
- Suppresses an arc-over event while increasing available capacitance

Permanent protection!
- Competitive versions often use a non-permanent surface coating

BME X7R Dielectric

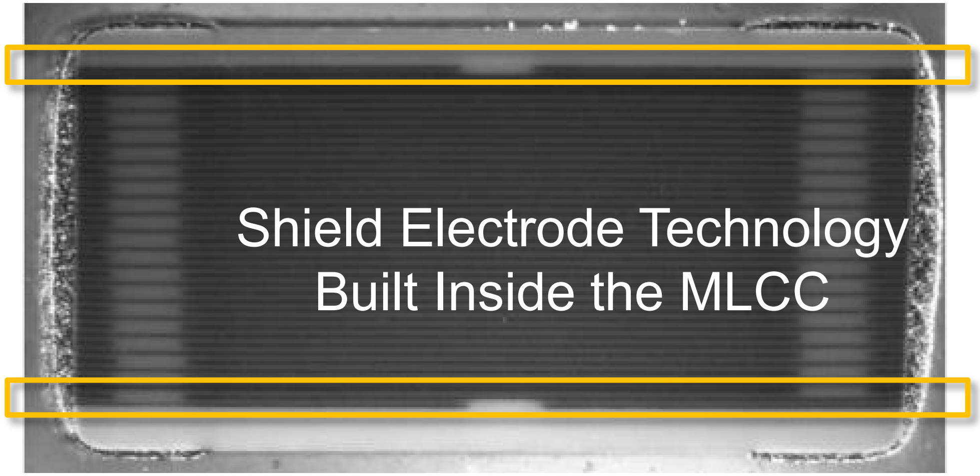
500, 630 and 1,000Vdc

0603 - 2225 Case Sizes

1.0nF – 560nF

Flexible Termination Available

ARCSHIELD CIRCUIT PROTECTION



"The World's Smallest High Voltage MLCC's"

RoHS

BME

Thank You