

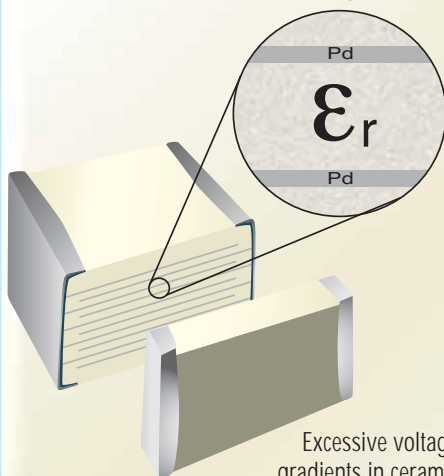
# CIRCUIT DESIGNER'S NOTEBOOK

## Capacitor Dielectric Properties

Dielectric materials play a major role in determining the operating characteristics of ceramic chip capacitors. Accordingly, they are formulated to meet specific performance needs. The following definitions are provided as a general overview of pertinent dielectric design parameters.

**Dielectric Constant:** Also referred to as relative permittivity ( $\epsilon_r$ ), a dielectric property that determines the amount of electrostatic energy stored in a capacitor relative to a vacuum. The relationship between dielectric constant and capacitance in a multilayer capacitor can be calculated by,  $C = \epsilon_r (n-1) A/d$ , where  $\epsilon_r$  is the dielectric constant,  $n$  is the number of electrodes,  $A$  is the active electrode area and  $d$  is the dielectric thickness.

**Dielectric Strength:** The dielectric's ability to safely withstand voltage stresses. This is determined primarily by the dielectric formulation and electrode spacing.

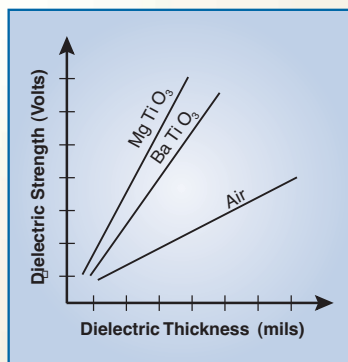


Excessive voltage gradients in ceramic capacitors will cause the dielectric to lose its insulating properties, resulting in catastrophic failure. The dielectric voltage breakdown characteristic is also affected by environmental conditions such as operating temperature, humidity, and atmospheric pressure as well as the physical spacing between the capacitor's terminations.

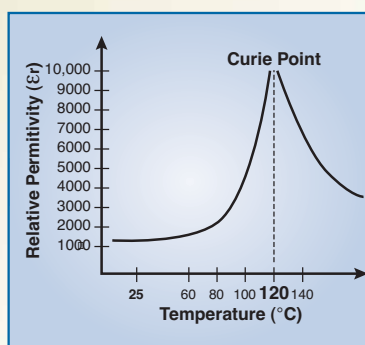
**Internal breakdown:** An internal failure condition that occurs when the applied voltage exceeds the dielectric strength, generally shorting the capacitor.

**External breakdown:** A failure condition that occurs when the applied voltage exceeds the breakdown path on the outside of the case between terminations.

**Dielectric Thickness:** This parameter defines the distance between any two internal electrodes after the ceramic has been sintered to its final state. This is a major factor in determining the voltage rating and parallel resonant frequency characteristics.



**Dielectric Formulations:** Formulations used in the design of ceramic capacitors are typically alkaline earth titanates, the most common of which is Barium Titanate (BaTiO<sub>3</sub>). Electrical properties such as voltage rating, dissipation factor, insulation resistance, temperature coefficient, as well as dielectric constant, are determined by the dielectric formulation. These properties are tailored to specific applications through the addition of appropriate chemical modifiers such as alkaline earth elements and transition element oxides.



**Curie Point:** The temperature at which the ceramic material will exhibit a peak or sudden increase in dielectric constant is the Curie Point. Chemical agents may be added, to shift and/or depress the Curie Point. This is a major consideration in designing for specific Temperature Coefficient of Capacitance (TCC) limits.

**Grain:** A particle of ceramic material exhibiting a crystalline or polycrystalline structure. Electrical properties such as dielectric strength, dielectric constant, and voltage sensitivity are directly related to this parameter. Grain size also affects other electrical properties since it plays an important role in the formation of microstructural characteristics such as ceramic porosity and shrinkage related anomalies.

**Temperature Coefficient of Capacitance (TCC):** The maximum change of capacitance over the specified temperature range is governed by the specific dielectric material.

**Insulation Resistance (IR):** The DC resistance offered by the dielectric which is commonly measured by charging the capacitor to rated voltage for one minute and measuring the leakage current flow.

**Dissipation Factor (DF):** Denotes that portion of the total energy in the capacitor that is lost as internal heat or the ratio of energy dissipated to the energy stored.

**Dielectric Aging:** The gradual decrease of dielectric constant leading to loss of capacitance over time for certain ceramic formulations. This loss is logarithmic with time and is most pronounced shortly after manufacturing.

ATC's: Design Philosophy - ATC capacitors are designed and formulated in such a manner as to optimize all performance characteristics. As an example, using closely spaced electrodes, i.e., thin dielectric sections, will generally increase the parallel resonant frequency but will also decrease the maximum voltage rating. In this instance, dielectric spacing and active electrode overlap areas are balanced for the best combination for the specific application category. Another example may involve the inclusion of additives to adjust the TCC of a given dielectric class. This is accomplished by optimizing TCC while maintaining good insulation resistance and dissipation factor characteristics.

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