# ELECTRICAL PROPERTIES OF CERAMICS

The following electrical properties are characteristic for ceramic materials:

- **Insulating properties**
- **Electrical conductivity**
- **Dielectric Strength**
- **Dielectric Constant**
- **Semi-conducting properties**
- **Superconducting properties**
- **Piezoelectric properties**
- **Magnetic properties**

## Insulating properties

In contrast to Metals Ceramics have very low electrical conductivity due to Ionic-Covalent Bonding which does not form free electrons.

## Electrical conductivity

**Electrical conductivity** is ability of material to conduct electric current.
The electrical conductivities differ by a factor as large as $10^{12}…10^{21}$ between metallic and ceramic materials.
Most of ceramic materials are **dielectric** (materials, having very low electric conductivity, but supporting electrostatic field).
Electrical conductivity of ceramics varies with the frequency of field applied and also with temperature. This is due to the fact that charge transport mechanisms are frequency dependent. Further, the activation energy needed for charge migration is achieved through thermal energy and immobile charge career becomes mobile. The activcation energy can be calculated very easily using the Arrheneous relation.
It is also possible to understand the type of mechanism responsible for conductivity from a.c conductivity data.

## Dielectric Strength

One of most important dielectric properties is **Dielectric Strength –** ability of a material to prevent electron conductivity at high voltage. Dielectric strength is determined as value of electric field strength (expressed in v/m) at which electron conductivity breakdown occurs.

## Dielectric Constant

Other important property of dielectric materials is **Dielectric Constant** - relative (to vacuum) ability of a material to carry alternating current (dielectric constant of vacuum equals to 1).

Capacitance of a capacitor is directly proportional to the dielectric constant of the dielectric material used in the capacitor.

Dielectric ceramics are used for manufacturing capacitors, insulators and resistors.

## Semi-conducting properties

Ceramics based on ZnO may possess semi-conducting properties when they are appropriately doped.

The semi-conducting ceramics are usually prepared by liquid phase sintering with control of grain boundary structure.
Semi-conducting ceramics are used for manufacturing varistors (resistors with non-linear current-voltage characteristic, which are used for over-voltage protection) and Positive Temperature Coefficient (PTC) Resistors.

## Superconducting properties

Despite of very low electrical conductivity of most of the ceramic materials, there are ceramics, possessing superconductivity properties (near-to-zero electric resistivity).

Lanthanum (yttrium)-barium-copper oxide ceramic may be superconducting at temperature as high as 138 K. This critical temperature is much higher, than superconductivity critical temperature of other superconductors (up to 30 K).

The critical temperature is also higher than boiling point of liquid Nitrogen (77.4 K), which is very important for practical application of superconducting ceramics, since liquid nitrogen is relatively low cost material.
Such ceramic superconductors are called High Temperature Superconductors (discovered in 1986 by Mueller and Bednorz).

## Piezoelectric properties

**Piezoelectric effects :**

- **Generating piezoelectric effect**: Mechanical stress, applied between two surfaces of a solid dielectric part, generates voltage between the surfaces.
- **Motor piezoelectric effect:** Voltage, applied between two surfaces of a solid dielectric part, results in contracting (expanding) of the part.

Some ceramics (lead zirconate titanate, barium titanrate, bismuth titanate, lead magnesium niobate) possess piezoelectric properties.

Piezoelectric ceramics are used for manufacturing various transducers, actuators and sensors like hydrophones, sonar, strain gauges, medical ultrasound equipment.

## Magnetic properties

Magnetic Ceramics are prepared by sintering technology from iron oxide and barium/strontium carbonate with small amounts of other metal oxides.

Magnetic Ceramics are called **Ferrites**.
There are two types of Magnetic Ceramics (Ferrites):

- Isotropic ceramic magnet with equal magnetic properties in all directions;
- Anisotropic ceramic magnets with magnetic properties in the direction of pressing.

Ferrites combine good magnetic properties (high magnetization) with very low electrical conductivity. Low conductivity of ferrites allows reducing energy loss, caused by eddy currents, induced in the material when it works in high frequency magnetic fields.

Therefore the widest field of application of ferrites is high frequency appliances: ferritic antennas, speaker magnets, TV deflection-yoke cores and convergence coil cores, Magnetic Resonance Imaging (MRI), audio-visual recording heads.

Source : http://www.substech.com/dokuwiki/doku.php?id=electrical_properties_of_ceramics