Mechanism of DC bias characteristics

When DC bias is applied to a high dielectric constant type ceramic capacitor (typically having $BaTiO_3$ as the main material and temperature characteristics of X5R, X7R, Y5V) its capacitance value changes with the bias. This is called DC bias characteristics. DC bias characteristic is a unique phenomenon of ferroelectric ceramics having spontaneous polarization, and is observed not only in Murata products but in all high dielectric constant type ($BaTiO_3$) ceramic capacitors in general.

<Spontaneous polarization and ferroelectricity of $BaTiO_3$ type ceramics>

As shown in Figure 1, $BaTiO_3$ ceramics possess perovskite type crystalline structure. It is cubic at temperatures over the Curie point (approx. 130 °C), and Ba is in peak, O is in face center and Ti is in body center.

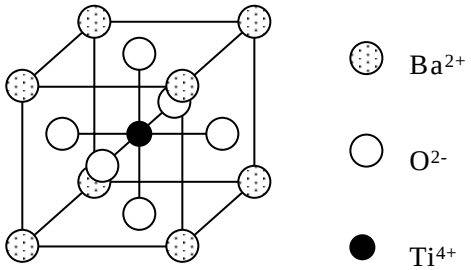


Figure 1 Crystalline structure of $BaTiO_3$ type ceramics

When within the normal temperature range is below the Curie point, one of the axes (C axis) stretches and other axes shrink slightly to become tetragonal (Figure 2). In this case, the Ti^{4+} ion will be positioned in the axial direction of the crystal unit away from the body center causing polarization to occur. In other words, polarization is caused by asymmetry in the crystalline structure, which exists from the outset without applying an external electric field or pressure. This type of polarization is called spontaneous polarization.

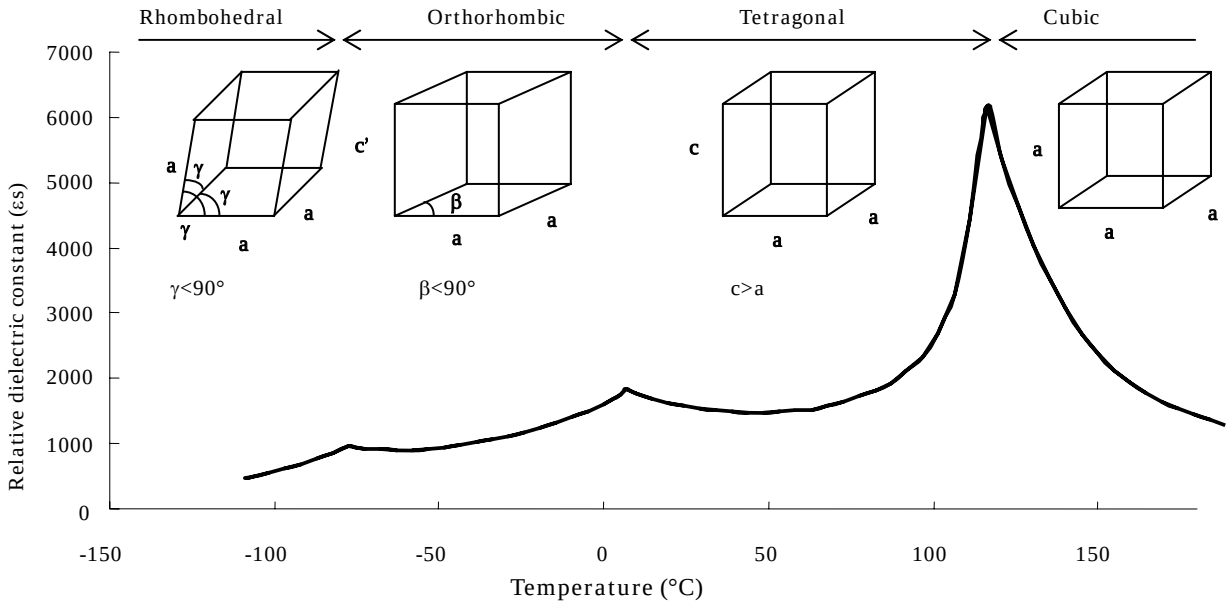
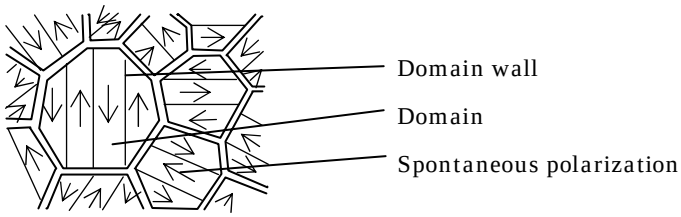


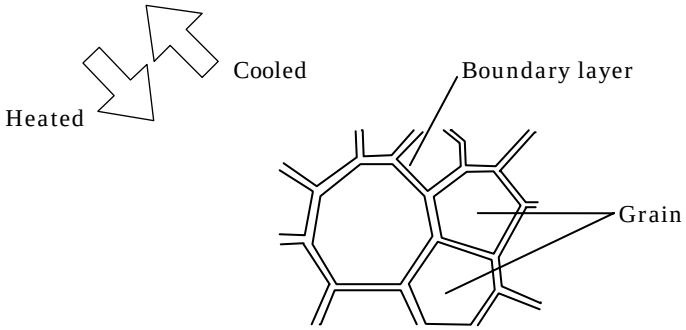
Figure 2 Change in crystalline structure and relative dielectric constant on temperature change (pure $BaTiO_3$)

The direction of spontaneous polarization (position of Ti^{4+} ion) for $BaTiO_3$ type ceramics can be easily reversed with application of an external electric field. The characteristics of having spontaneous polarization, and ability to reverse the direction of polarization with an external electric field is specifically called Ferroelectricity. $BaTiO_3$ is a typical type of ferroelectric ceramics.

$BaTiO_3$ type ceramics are an aggregation of micro crystallites (polycrystalline) having sub-μm diameter as shown in Figure 3. These micro crystallites are called grains, and their crystalline structures are neatly aligned as shown in Figures 1 and 2. Those grains are divided into many domains at temperatures below the Curie point. Within each domain, there is a common direction of crystals, therefore the direction of spontaneous polarization is the same as well.



Initial condition of the structure (tetragonal) at temperature below Curie point



Condition of the structure (cubic) at temperature above Curie point

Figure 3 Micro structure of $BaTiO_3$ type ceramics

When $BaTiO_3$ type ceramics is heated above the Curie point, the crystalline structure goes through a phase transition from tetragonal to cubic. With this, spontaneous polarization the domains also disappear. When cooled below the Curie point, phase transition from cubic to tetragonal takes place near Curie point, and the C axis stretches in the axial direction. The other axes shrink slightly to form spontaneous polarization and domains. Simultaneously, grains receive stress from the distortion of its surroundings. At this point, several small domains in grains are generated, and spontaneous polarization of each domain can be easily reversed with a low electric field. Since relative dielectric constant corresponds with the reversal of spontaneous polarization per unit volume, it is measured as higher capacitance.

<DC bias characteristics>

When spontaneous polarization in dielectric bodies can be easily reversed, higher capacitance can be gained. Spontaneous polarization is free without bias. When you apply an external bias a spontaneous polarization within a dielectric body is formed in the direction of the electric field, making the free reversal of spontaneous polarization more difficult. As a result, the capacitance gained is lower compared with the capacitance before the application of the bias.

This is the reason why capacitance decreases when DC bias is applied.

Figure 4 indicates types of temperature characteristics for the DC bias characteristics of monolithic ceramic capacitors at normal temperature. The main component of temperature compensation type capacitors (C0G, U2J characteristics, etc.) is paraelectricity ceramics, and capacitance does not vary due to DC bias. Conversely, the capacitance of a high dielectric constant type capacitor (X5R, X7R, Z5U, Y5V characteristics, etc.) decreases due to DC bias, especially with Y5V characteristics.

■ Capacitance - DC Voltage Characteristics

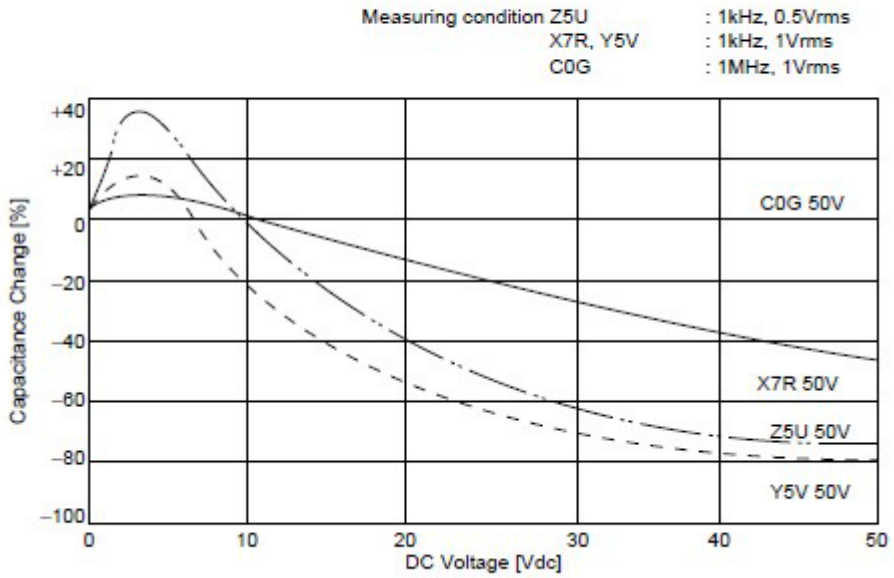


Figure 4 DC bias characteristics