Polarization and Applications of Ferroelectricity

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Commentary

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DESCRIPTION

Ferroelectricity is a property of some materials that can have their spontaneous electric polarisation reversed when an external electric field is applied. With the added characteristic that their natural electrical polarisation is reversible, all ferroelectrics also have the properties of piezoelectricity and pyroelectricity. In ferromagnetism, a substance displays a persistent magnetic moment, the phrase is used as an analogy. When Joseph Valasek found ferroelectricity in Rochelle salt in 1920, ferrromagnetism was already well-known. Thus, despite the fact that the majority of ferroelectric materials don't include iron, the prefix ferro, which means iron, was chosen to define the attribute. Multiferroics are substances that have both ferromagnetic and ferroelectric properties.

Polarization

Since the induced Polarization (P), is almost inversely proportional to the applied External Electric Field (E), when most materials are electrically polarised, the polarisation is a linear function. Linear dielectric polarisation is the term for this. Some substances, referred to as paraelectric substances, exhibit enhanced nonlinear polarisation. The slope of the polarisation curve, which corresponds to the electric permittivity, is a function of the external electric field rather than being constant, as it is with linear dielectrics.

Ferroelectric materials exhibit a spontaneous nonzero polarisation even when the applied field E is zero, in addition to being nonlinear. Ferroelectrics are distinguished by the ability of the spontaneous polarisation to be reversed by an appropriately strong applied electric field in the opposite direction. As a result, the polarisation is reliant on both the current electric field and its history, producing a hysteresis loop. By comparison to ferromagnetic materials, which have spontaneous magnetization and show comparable hysteresis loops, they are known as ferroelectrics.

Applications

Ferroelectric materials' nonlinear properties can be exploited to create capacitors with variable capacitance. A ferroelectric capacitor typically consists of a layer of ferroelectric material sandwiched between a pair of electrodes. Ferroelectrics have a permittivity that may be adjusted and is frequently very high, especially when they are near the temperature of the phase transition. Ferroelectric capacitors are consequently physically smaller than dielectric (non-tunable) capacitors of equivalent capacitance. Ferroelectric capacitors are used to create ferroelectric RAM for computers and RFID cards because the spontaneous polarisation of ferroelectric materials suggests a hysteresis effect that may be employed as a memory function. Thin films of ferroelectric materials are frequently utilised in these applications because they enable the field necessary to alter the polarisation to be achieved at a moderate voltage. However, for devices to function consistently when using thin films, a lot of care needs to be paid to the interfaces, electrodes, and sample quality.

By virtue of symmetry considerations, ferroelectric materials must also be piezoelectric and pyroelectric. Ferroelectric capacitors are highly helpful, for example, in sensor applications, due to the combination of memory, piezoelectricity, and pyroelectricity. Ferroelectric capacitors are used in a variety of devices, including high-quality infrared cameras that can detect temperature differences as small as millionths of a degree Celsius, medical ultrasound machines that generate and then listen for ultrasound pings used to image the internal organs of a body, fire sensors, sonar, vibration sensors, and even fuel injectors on diesel engines. Another concept that has gained attention recently is the Ferroelectric Tunnel Junction (FTJ), in which a contact is created by sandwiching a ferroelectric film only a few nanometers thick between two metal electrodes. The ferroelectric layer's thickness is sufficiently thin to permit electron tunnelling. A Giant Electroresistance (GER) switching effect may result from the piezoelectric and interfacial effects, the depolarization field, and other factors.

Since 1952, when Parravano discovered anomalies in the CO oxidation rates over ferroelectric sodium and potassium niobates close to their Curie temperatures, ferroelectrics have been researched for their catalytic properties. The polarization-dependent charges that can dope the surfaces of ferroelectric materials and alter their chemistry are caused by the ferroelectric polarization's surface-perpendicular component. This makes it possible to carry out catalysis outside of what the Sabatier principle allows.