Ceramic Resonators

PZT Piezoceramic:

In the 1880's. Pierre and Jacques Curie discovered Piezoelectricity. Piezoelectricity is the phenomenon when certain crystalline internal structure changes shape, causing dimensional deformation when subjected to an electric field. When a piezoceramic element is stressed electrically by applying a electric potential, it produces a mechanical stress in the material and its dimensions change. This is commonly referred to as "motor effect". Conversely, if an electric charge is produced when mechanical stress is applied, this is called "generator effect".

The piezoelectric effect are found in some naturally occurring crystalline materials, such as quartz and tourmaline. Some artificially produced piezoelectric crystals are: Rochelle salt (sodium potassium tartrate), ammonium dihydrogen phosphate and lithium sulphate. Another class of materials possessing these piezoelectric properties is polarized polycrystalline piezoelectric ceramic. By the late 1950s, newer ceramics are dominant in the electroacoustic field from United States, typically referred to as ferroelectric materials such as lead zirconate titanate $Pb(TiZr)O_3$, barium titanate, lead titanate and lead metaniobate $PbNb_2O_6$.

Recent advances in Piezoelectric Ceramics are first reported by Robert Pohanka and Paul Smith from the Naval Research Laboratory in detail sonar applications. Lead zirconate titanate (commonly known as PZT Ceramics) has been most widely used polycrystalline piezoelectric ceramic since its discovery more than 30 years ago. Applications for PZT include sonar projectors, humidifiers, biomedical ultrasound, nondestructive testing, ignitor, accelerometers, and micropositioners. Special emphasis is given to composite hydrophones, piezoelectric motors, electrostrictive actuators and other developments in the past decade.

Ceramic Process:

Production of piezoelectric ceramic materials involve detailed complex processing and close control over impurities. Material properties may be altered by modifying the chemical composition and manufacturing processes. This provides the means of tailoring the material properties to the application. Polycrystalline ceramic are very versatile. The hard, dense ceramics can be manufactured in almost any given shape or size. They are chemically inert, and immune to moisture and other atmospheric conditions.

Many processes are involved in the production of piezoelectric ceramics. The first ceramic process consists of mixing the raw materials, with small additions of niobium, strontium, barium, lanthanum and antimony serve as modifiers. The powders are then heated which reacts the constituent materials into a compound. This common powder process is commonly referred to as "calcining" (CMO). The calcined powders are then ground into very fine particles, typically 3 to 6µm size at 3 minutes of calcining. The production of ceramic shapes requires that a binder be added. The binder holds the part together prior to firing. A more recent process development is the molten salt synthesis (MSS) method of synthesizing PZT powder/ X-ray diffraction has shown this powder size at 0.2µm.

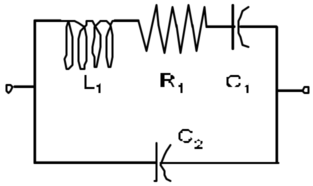
The PLZT ceramic parts with Lanthanum are formed into many shapes and sizes, such as disc, and plates. The formed parts are then bisque fired at low temperature in order to drive off the binders and provide some mechanical strength. The second firing, or "high firing" completes the chemical bonding of the constituent material dimensions. Electrodes are attached to designed surfaces.

Poling and Aging:

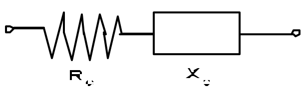
Activation of the piezoelectric ceramic properties is called the "poling" process preferably close to Curie point, in elevated temperature . A high DC electric field is applied across the electrodes resulting in an aligning of the dipoles orientation within the material. The material is now fully activated. From the moment the activated ceramic material is removed from the poling apparatus the material properties undergo changes. This process of change is referred to as "aging". Aging of the ceramic occurs very rapidly in the first few hours. After a few days the changes in the material properties are very small and decrease logarithmically. The aging process can be attributed to the relaxation of the dipoles in the material. The longer the time period after poling, the more stable the material becomes. Depolarization of the piezoelectric ceramic can result if it is exposed to excessive heat, electrical drive or mechanical stress or any combination thereof. The temperature at which piezoelectric ceramic will be totally depoled is defined as the "curie point", typically at 340°C.

Resonance Measurement:

Accurate measurements of piezoelectric constants depend on the electric effects in piezoelectric bodies vibrating near principal mechanical resonance frequencies. When the electrical impedance of a crystal is measured as function of frequency, apparent capacitance increases to very high values as the resonance frequency is approached. At this frequency the impedance is first at pure resistance, then becomes inductive. With further increase of frequency, the impedance becomes once more pure resistance but at a much higher resistance level, and then returns to capacitive. Resonant Frequency constant is defined with the controlling dimension of the piezoceramic element.



The properties of mechanically vibrating system, piezoelectrically excited through electrodes which form a two terminal network, can be represented near resonance by an equivalent circuit. This circuit consists of a series capacitance C_1, inductance L_1, and resistance R_1, shunted by a second capacitance C_2. L_1 and C_1 are related to the mass and elastic compliance of the crystal, multiplied by a factor representing the piezoelectric effect. The ratio of the inductive impedance to R_1 is given by the mechanical quality factor which is the reciprocal of the mechanical damping factor. C_2 represents the capacitance of the crystal if the piezoelectric effect were suppressed. This discussion does not include the internal builtin load capacitors, which is inside separate compartment of the ZTS ceramic resonators.



The piezoceramic resonator represented by the four constant parameters are independent of frequency only for a narrow range of frequencies near the resonant frequency. The impedance magnitude Z of the equivalent network is defined by its series resistive component R_e, its series reactive component X_e, and the reactance of X_1 of the L_1, C_1, R_1 branch are plotted as functions of frequency. The frequency at low absolute impedance is the resonance frequency (? $_o$)and the frequency at high impedance is the antiresonance.

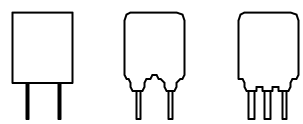
$$f_o = \frac{1}{2\pi\sqrt{L_1C_1}}$$

$$Q = \frac{\sqrt{L_1/C_1}}{R_1}$$

The vibrational resistance R_1 in the equivalent circuit represents the mechanical loss of the piezoelectric resonator. A dimensionless measure of the dissipation is the mechanical quality factor, Q.

Microcontroller Clocks:

Integrity Technology Corporation offers ZTS and ZTSC Ceramic Resonator series with built-in 30pF capacitors especially for low cost microcontroller clocks applications, such as 8051/48/31, PIC16/17, 68HC05/08/11, Z8, SMC62, COP8, MSM64/65, H8, SMC62, ...etc. Numerous useful frequencies, such as Baud rate frequencies can simply programmed without floating point math to generate RS232 serial communication and I/O timing. Binary bit rate frequencies are available for even Hexadecimal value timing for precise I/O ports. Integrity Technology ZTA, ZTS and ZTSC surface mount ceramic resonators have frequency range from 1.79 to 50MHz. ZTB ceramic resonators have frequency range from 400 to 1300KHz.



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