**Piezoelectricity**

**Introduction**

Piezoelectricity is the ability of some materials (notably crystals and certain ceramics) to generate an electric potential in response to applied mechanical **stress**. This may take the form of a separation of electric **charge** across the **crystal lattice**. If the material is not short-circuited, the applied charge **induces** a voltage across the material. The word is derived from the Greek piezein, which means to **squeeze** or press.

The piezoelectric effect is reversible in that materials **exhibiting** the direct piezoelectric effect (the production of electricity when stress is applied) also exhibit the converse piezoelectric effect (the production of stress and/or **strain** when an electric field is applied). For example, **lead** Zirconate Titanate crystals will exhibit a maximum shape change of about 0.1% of the original dimension. The effect finds useful applications such as the production and detection of sound, generation of high voltages, electronic frequency generation, microbalances, and ultra fine focusing of optical **assemblies**.

**Structure**

In a piezoelectric crystal, the positive and negative electrical charges are separated, but symmetrically distributed, so that the crystal overall is electrically **neutral**. Each of these sites forms an **electric dipole** and dipoles near each other tend to be aligned in regions called Weiss domains. The domains are usually randomly **oriented**, but can be aligned during poling (not the same as magnetic poling), a process by which a strong electric field is applied across the material, usually at **elevated** temperatures.

When a mechanical stress is applied, this symmetry is disturbed, and the charge asymmetry generates a voltage across the material. For example, a 1 cm cube of quartz with 500 lbf (2 KN) of correctly applied force upon it, can produce a voltage of 12,500 V.

Piezoelectric materials also show the opposite effect, called converse piezoelectric effect, where the application of an electrical field creates mechanical **deformation** in the crystal.

**Applications**

Piezoelectric crystals are now used in **numerous** ways; some of them are explained as follows:

►Probably the best-known application is the electric cigarette **lighter**: pressing the button causes a **spring-loaded** hammer to hit a piezoelectric crystal, and the high voltage produced **ignites** the gas as the current jumps over a small **spark gap**. The portable **sparker**s used to light gas **grill**s or stoves work the same way, and many types of gas burners now have built-in piezo-based ignition systems.

►A similar idea is being researched by DARPA (Defense Advanced Research Projects Agency) in the United States in a project called Energy **Harvest**ing, which includes an attempt to power **battlefield** equipment by piezoelectric generators **embedded** in soldiers' boots. However, these energy harvesting sources by association have an **impact** on the body. DARPA's effort to **harness** 1-2 Watts from continuous shoe impact while walking were **abandon**ed due to the **impracticality** and the discomfort from the additional energy **expend**ed by a person wearing the shoes.

►A piezoelectric transformer is a type of AC **voltage multiplier**. Unlike a conventional transformer, which uses magnetic coupling between input and output, the piezoelectric transformer uses **acoustic** coupling. An input voltage is applied across a short length of a bar of piezo-ceramic material such as PZT, creating an alternating stress in the bar by the inverse piezoelectric effect and causing the whole bar to vibrate. The vibration **frequency** is chosen to be the resonant frequency of the block, typically in the 100 kilohertz to 1 megahertz range. A higher output voltage is then generated across another section of the bar by the piezoelectric effect. **Step-up** ratios of more than 1000:1 have been demonstrated. An extra feature of this transformer is that, by operating it above its resonant frequency, it can be made to appear as an inductive load, which is useful in circuits that require a controlled **soft start**. These devices can be used in DC-AC inverters to drive CCFLs (Cold cathode fluorescent lamps). Piezo transformers are some of the most compact high voltage sources available.

►Quartz clocks employ a **tuning fork** made from quartz that uses a combination of both direct and converse piezoelectricity to generate a regularly timed series of electrical pulses that is used to mark time. The quartz crystal (like any elastic material) has a precisely defined natural frequency (caused by its shape and size) at which it prefers to oscillate, and this is used to **stabilize** the frequency of a periodic voltage applied to the crystal.

►Piezoelectric sensors especially are used with high frequency sound in **ultrasonic** **transducers** for medical imaging and also industrial nondestructive testing (NDT).

For many sensing techniques, the sensor can act as both a sensor and an **actuator** - often the term transducer is preferred when the device acts in this dual capacity, but most piezo devices have this property of reversibility whether it is used or not. Ultrasonic transducers, for example, can **inject** ultrasound waves into the body, receive the returned wave, and convert it to an electrical signal (a voltage). Most medical ultrasound transducers are piezoelectric.