

Piezoelectricity or the Piezoelectric Effect (August 2019)

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This is an article which has covered the definition of piezoelectricity, piezoelectric materials and the usage of this phenomenon in daily basis and also scientific, industrial etc. fields.

***Index Terms*— actuator, electrical energy, mechanical energy, Piezoelectricity, Piezoelectric effect, Piezoelectric material, sensor, transducer**

I. INTRODUCTION

It's been couple of months I've been working on an interactive art project, a semi-generative pattern study, to show the interaction between humans and Islamic geometric patterns.

We wired the project to the floor with a piezo so as the viewer walks close by the installation the whole pattern (visual and sound) reacts to the movement around. In other words, we simply took advantage of piezoelectricity to convert mechanical energy of the audience walk, to the electrical signals. In this article I tend to acknowledge the usage of Piezoelectricity in our project.

II. WHAT IS PIEZOELECTRICITY

Piezoelectricity or the piezoelectric effect, is the ability of certain materials such as quartz. Certain ceramics, and surprisingly bones, silks and even woods, to generate a coupling between the electrical and the mechanical state of the material. This phenomenon commonly known as generating an AC voltage when subjected to mechanical stress or vibration, or vice versa to vibrate when subjected to an AC voltage, or both.

III. PIEZOELECTRIC MATERIALS

why don't all materials exhibit this property? The reason for that is that for piezoelectricity to appear, the material must be crystalline but not have a symmetry center. a crystal is the scientific name for any solid whose atoms

or molecules are arranged in a very orderly way based on endless repetitions of the same basic atomic building block- called the unit cell. In most crystals (such as metals), the unit cell (the basic repeating unit) is symmetrical; in piezoelectric crystals, it isn't. Normally, piezoelectric crystals are electrically neutral: the atoms inside them may not be symmetrically arranged, but their electrical charges are perfectly balanced: a positive charge in one place cancels out a negative charge nearby. However, if you squeeze or stretch a piezoelectric crystal, you deform the structure, pushing some of the atoms closer together or further apart, upsetting the balance of positive and negative, and causing net electrical charges to appear. This effect carries through the whole structure so net positive and negative charges appear on opposite, outer faces of the crystal.

The reverse-piezoelectric effect occurs in the opposite way. Put a voltage across a piezoelectric crystal and you're subjecting the atoms inside it to "electrical pressure." They have to move to rebalance themselves—and that's what causes piezoelectric crystals to deform (slightly change shape) when you put a voltage across them.

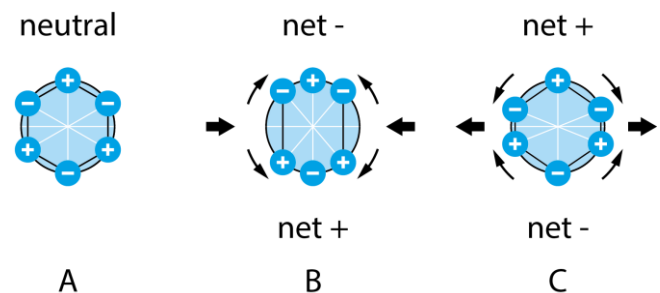


Figure 1. A schematic illustration of how piezoelectricity works

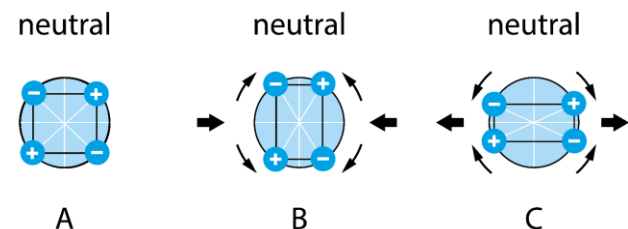


Figure 2. A schematic illustration of the charge distribution in the unit cell of a material with a symmetry center

IV. WHAT IS PIEZOELECTRICITY USED FOR?

Piezoelectric effect has spread into various applications and is widely used. From a quartz watch, piezoelectricity is what helps it keep regular time, to the usage of piezoelectric transducers in medical instruments as well as telecommunications, military equipment, and so forth. In this article I tend to classify the usage of Piezoelectricity due to whether it has subjected to mechanical power or to an electrical one.

A. Convert mechanical energy into electrical signals which called *SENSOR*:

- In a microphone, piezoelectric crystals convert sound energy (waves of pressure traveling through the air) into electrical energy
- The "needle" in a gramophone: As the diamond-tipped needle rides along the spiral groove in your LP, it bumps up and down. These vibrations push and pull on a lightweight piezoelectric crystal, producing electrical signals that your stereo then converts back into audible sounds.
- Piezoelectricity is also used, in spark lighters for gas stoves. Press a lighter switch and you'll hear a clicking sound and see sparks appear. What you're doing, when you press the switch, is squeezing a piezoelectric crystal, generating a voltage, and making a spark fly across a small gap.
- energy harvesting, for storing energy with hidden piezoelectric devices, from shoes that convert your walking movements into heat to keep your feet warm, and cellphones that charge themselves from your body movements, to roads that power streetlights, contact lenses that capture energy when you blink, and even gadgets that make energy from the pressure of falling rain.
- piezoelectric pickups for acoustic-electric guitars: sound waves bend the piezoelectric material, creating a changing voltage.

B. Convert electrical energy into mechanical energy which called an *Actuator*:

- In a quartz clock or watch, the reverse-piezoelectric effect is used to keep time very precisely. Electrical energy from a battery is fed into a crystal to make it oscillate thousands of times a second. The same principle is used in some radio transmitters and receivers, and in computers where it creates a clock pulse.
- As very high electric fields correspond to only tiny changes in the width of the crystal, this width can be changed with better-than- μm precision, making piezo crystals the most important tool for positioning objects with extreme accuracy:

- In Piezoelectric motors, Piezoelectric elements apply a directional force to an axle, causing it to rotate. Due to the extremely small distances involved, the piezo motor is viewed as a high-precision replacement for the stepper motor.
- this feature of Piezoelectric crystals are widely used in laser mirror alignment, atomic force microscopes, inkjet printers, X-ray shutters, High-intensity focused ultrasound for localized heating or creating a localized cavitation and so forth.
- A recent application of piezoelectric ultrasound sources is piezoelectric surgery. It is a minimally invasive technique that aims to cut a target tissue with little damage to neighboring tissues.
- In Loudspeakers, Voltage is converted to mechanical movement of a metallic diaphragm.
- Refreshable braille display. A small crystal is expanded by applying a current that moves a lever to raise individual braille cells.
- Ultrasound equipment, a piezoelectric transducer converts electrical energy into extremely rapid mechanical vibrations—so fast, in fact, that it makes sounds. These ultrasound vibrations can be used for scanning, cleaning, and all kinds of other things:
 - Ultrasonic transducers that transmit sound waves through air had existed for quite some time but first saw major commercial use in early television remote controls.
 - The ultrasonic transducer can be used for easy measurement of viscosity and elasticity in fluids and solids. Ultrasonic time-domain reflectometers (which send an ultrasonic pulse through a material and measure reflections from discontinuities) could find flaws inside cast metal and stone objects, improving structural safety.

C. Both:

For many sensing techniques, the sensor can act as both a sensor and an actuator, 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.
- Piezoelectric elements are used in the detection and generation of sonar waves, by emitting a high-frequency pulse from the transducer, and measuring the amount of time it takes to hear an echo from the sound waves bouncing off an object, one can calculate the distance to that object.
- ultrasound transducers now are mounted on several car models as an echolocation device, helping the driver determine the distance from the car to any objects

that may be in its path.

- Different teams of researchers have been investigating ways to reduce vibrations in materials by attaching piezo elements to the material. When the material is bent by a vibration in one direction, the vibration-reduction system responds to the bend and sends electric power to the piezo element to bend in the other direction. Future applications of this technology are expected in cars and houses to reduce noise. Further applications to flexible structures, such as shells and plates, have also been studied for nearly three decades.

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