Piezoelectricity: An Energy Source for Future Railway Station

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Abstract— At the time of increasing use/cost and diminishing supplies of non-renewable energy source, it has become necessary to make use of renewable energy resource. One such resource is piezoelectricity. This paper reviews some recent experimental analysis and then provides a proposal to supply electricity for railway stations, malls using piezoelectric materials as a source of renewable energy. Consideration of three various aspects in this proposal ensures highest amount of piezoelectric supply for the power demand of a malls, railway station, etc. It will also help preparing every station as energy or power independent in coming future.

Keywords: Renewable energy, Piezoelectricity, Piezoelectric materials

I. Introduction

French physicists Jacques and Pierre Curie founded piezoelectricity in 1880. Piezoelectricity is the electric current that accumulates in certain solid materials in response to applied mechanical strain or physical force. The word piezoelectricity means electricity resulting from pressure and inherent heat.

The piezo effect can be a reverse action: materials showing the piezo effect: the inner generation of electrical current resulting from an a mechanical stress also show the reverse piezo effect, the inner generation of a mechanical stress resulting from an applied electrical field. For example, lead titanate crystals will generate measurable piezoelectricity when their fixed structure is deformed by 0.1% of the original dimension. Conversely, those same crystals will change about 0.1% of their immobile dimension when an foreign electric field is applied to the material. The reverse piezoelectric effect is used in the production of ultrasonic sound waves.

The piezoelectric effect was observed in 1880, and was founded by the brothers Pierre and Jacques Curie. By adding their understanding of piezoelectricity, and knowledge about certain materials, the Curie brothers demonstrated the first piezoelectric effect by using materials such as crystals of tourmaline, quartz, topaz, cane sugar, and Rochelle salt. Their initial demonstration showed that quartz and Rochelle salt exhibited the most piezoelectricity capability at the time.

Over the next few years, piezoelectricity remained in the laboratory, something to be experimented on as more work was undertaken to explore the potential of the piezoelectric effect. During the World War I marked the introduction of the first practical application for piezoelectric devices, which was the sonar device.

During World War II, research groups in the US, Russia and Japan discovered a new class of man-made materials, called ferroelectrics, which exhibited piezoelectric constants many times higher than natural piezoelectric materials. Although quartz crystals were the initial commercially oppressed piezoelectric material and still used in sonar detection uses, scientists kept searching for higher performance materials. This research resulted in the development of barium titanate and lead titanate(III), two materials that had very specific properties suitable for particular applications.

II. Related Work

Innowattech, an Israeli company, has directed trials to show this importance at the Technion Institute of Technology in Haifa where a vehicle went over a street under which Innowattech Piezoelectric Electric Generators (IPEG) had been installed 6cm under the street level and at a length of 30cm separated (T. Henderson, 2009). In United Arab Emirates(UAE), there is a test to create energy or electricity from the Piezoelectric Roads. The reasearch was effectively led and now the down to real streets are advancing for development (P. G. Phatak et al., 2016). In certain schools of United States of America(USA), electricity is generated from Piezoelectric Tiles in the passage when students walk through them. Furthermore, East Japan Railway Company (JR East). It led an shows test from January 19 to March 7, 2008, at Yaesu North Gate, Tokyo Station, on power-producing floor. Introduced at the ticket door zone, it produces electricity from the vibrations made by travellers strolling through the ticket gates. The control creating floor is embedded with piezoelectric components, which are 35 millimeters in distance across, and circle formed parts utilized for amplifiers. It uses 600 of these components for every square meter. While the amplifier makes sound by changing over electric signs to vibrations, the floor accepts the switch component that produces energy by dealing with the vibrational power created from travellers' means. It is being created by JR East with the intention of making stations all the more ecologically agreeable and vitality effective (P. G. Phatak et al., 2016, P. Dhingra et al., 2009). An analysis work researching the bugetary, natural and social parts of introducing 1 Km trail using energy harvesting/conserving Pavegen piezoelectric tiles at the Railway Station of New Delhi (A. Singh a et al., 2016). The investigation discovered that the implementation of the Piezoelectric tiles would prompted the colossal reserve funds and would add to natural mindfulness by advancing manageability and efficient power vitality era, and the measures of power collected over their 5 years life expectancy could recoup the expenses of beginning purchase, transport, establishment, upkeep and transfer of the tiles.

III. Piezoelectric Materials

Piezoelectric materials are materials or compounds that produce an electric current when they are placed under mechanical stress or strain. The piezoelectric process is also reverse process, so if you apply an electric current to these materials, they will actually change shape slightly (a maximum of 4%).

There are several materials that we have known for some time that possess piezoelectric properties, including bone, proteins, crystals (e.g. quartz) and ceramics (e.g. lead zirconate titanate).

However, in May 2012, it was announced that University of California Berkeley lab scientists have found a mechanism of harnessing piezoelectricity from viruses. This is the first time an organic material has been used to make piezoelectricity.

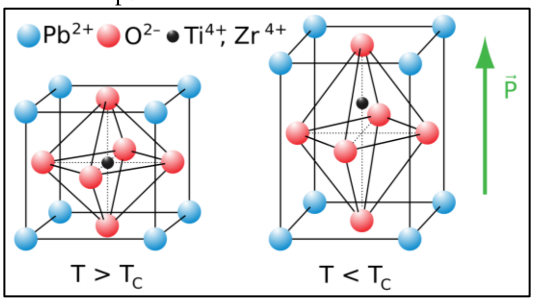
A. *Quartz*

Quartz is a solid, crystalline mineral made of silicon and oxygen atoms. The atoms are linked in a repeated framework of SiO4 silicon–oxygen tetrahedra, with each oxygen being shared between two tetrahedra, giving a chemical formula of SiO2. Quartz is the second most sufficient mineral in Earth's continental crust, behind feldspar.

B. *Lead titanate*

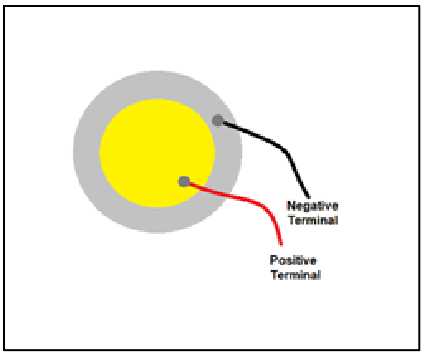
Lead(II) titanate has a chemical formula of PbTiO3 . It is an inorganic compound and is the lead salt of titanic acid. Lead titanate is insoluble in water and is of yellow colour.

At high temperatures, lead titanate adopts a cubic perovskite structure. At 760 K, the compound undergoes a second order phase transition to a tetragonal perovskite structure which shows ferroelectricity. Lead titanate is one of the end members of the lead zirconate titanate system, which is technologically one of the most vital ferroelectric and piezoelectric ceramics; Lead(II) titanates has a high ratio of k33 to kp.



C. *Topaz*

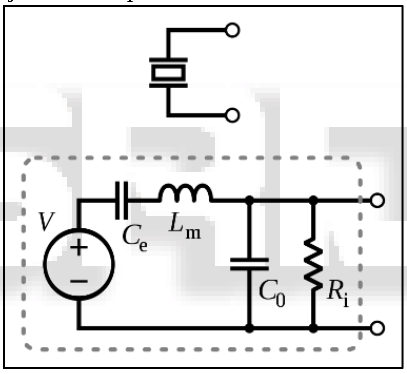
Topaz [Al2SiO4(F, OH)2] is a silicate mineral of aluminium and fluorine. It crystallizes in the orthorhombic system, and its crystals are mostly pearly discharged by pyramidal. It is one of the hardest and concentrated naturally occurring minerals (Mohs hardness of 8) and is the hardest of any silicate mineral.



IV. PIEZOELECTRIC SENSOR

A piezoelectric sensor is made up of quartz (most used). It used to convert the mechanical stress into electrical current. The output of the Piezoelectric Sensor is AC. We need a full bridge rectifier to convert it into DC. The output voltage of the sensor is less than 30Vp-p, you can feed the output of piezoelectric sensor or can conserve or harvest it into battery or other storage devices. The impedance of the piezoelectric sensor should be less than 500 ohm. The operating and storage temperature range is -20°C~+60°C and 30°C~+70°C respectively.

Schematic symbol and piezoelectric sensor model



V. PROPOSED SYSTEM(FOOTSTEP POWER GENERATION)

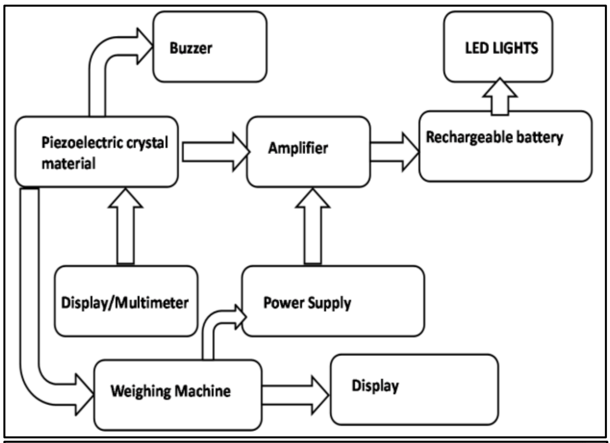
Footstep power generator system generates voltage using footstep(mechanical) force. Footstep power generator system serves as a medium to develop electric current or charge using non-conventional sources (force) and store and utilize it. The project is designed to be useful at crowded places like railway stations, malls etc where a lot of people keep walking through all day. For this reason, we use piezoelectric sensors which use piezo effect in order to measure acceleration, pressure, force by its conversion into electric signals. We here attach a voltmeter in order to measure its output and small led lights for presentation. We also use a battery for energy harvesting and weight measurement unit for better demonstration and optimization of the system.

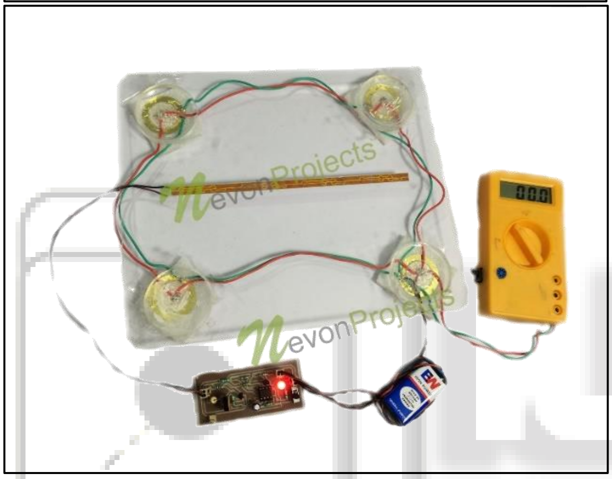
A. *Hardware Requirements:*

- Piezoelectric crystals
- Resistors
- Diodes
- Capacitor
- Cable and Connectors

- LED
- Transistors
- Battery

B. Block Diagram





VI. CONCLUSION

In times of increasing needs and less supplies of non-renewable energy resources and increasing cost it's time we find a solution for these social and environmental problem and renewable energy resources such as piezoelectricity could help us have a better, greener and cleaner future. We engineers could help such system as the footstep power generator for a better future.

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