ENERGY GENERATION USING PIEZOELECTRIC MATERIAL

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ABSTRACT

This study intended to take the present scenarios of energy crisis and falling resources for some time. It opens the doors of opportunities to the greener future. Piezoelectricity, a centuries old discovery, and it were still buried under grounds of doubt and inefficiency. The recent advents in the field of electronics and allied streams of electricity harnessing and storage technology have made it possible to capture the energy that always went unnoticed so far. Piezoelectricity can become a very reliable form of energy with proper optimistic advances in the field of research. So far, we humans have used the nature. It is time to replenish and refurbish, and to re-darken the fading line of ecological balance. This can only be made possible through newer ventures in green energy. For whom only sparks have been enough to produce what not, let this spark lead to greener strides in the world of energy.

1. INTRODUCTION

Electricity has become a lifeline of present day civilization and its demand enormous and is growing steadily. There seems no end to the different ways one can generate pollution-free electricity. At one hand, rising concern about the gap between demand and supply of electricity for masses has highlighted the exploration of alternate sources of energy and its (energy) sustainable use. On the other hand, traffic on road all over the world is increasing day by day and thus, congestion on roads is becoming inevitable with the fancy of masses towards personal transportation systems for their growing mobility. Energy demand and heavy traffic correlation motivate to dream about a device in the road that would harvest the energy from the vehicles driving over it. For this, piezoelectric material embedded beneath a road, the piezo-smart road, can provide the magic of converting pressure exerted by the moving vehicles into electric current. The system based on piezoelectricity, which uses pads of metallic crystals buried over hundreds of meters of road to generate electricity when put under the pressure of quickly moving traffic. With this technology, now, engineers are poised to harvest some of the spare energy of the world's moving vehicles. When a vehicle drives over the road, it takes the vertical force and compresses the piezoelectric material, thereby generating electricity.

The word piezoelectricity means electricity resulting from pressure. It is derived from the Greek piezo or piezein, which means to squeeze or press, and electric or electron, which stands for amber, an ancient source of electric charge.[2] Piezoelectricity was discovered in 1880 by French physicists Jacques and Pierre Curie.

Piezo‖ means pressure in Greek language. *Piezoelectricity is the relation between pressure (or mechanical stress) and electrical voltage*. When a force applied on a piezoelectric material, this results in the development of a charge in this material. When there is no applied stress, the material is in balance and the positive and negative charges are evenly distributed. During the application of force, the lattice of the piezoelectric material changed slightly, whereby

a charge imbalance created, which results in a potential difference. This resulting voltage can be as high as several thousand volts. Since the current is extremely small, the generated power is also limited. The electrical polarization of the material & the resulting voltage, are in proportion to the applied force. Tension and compression generated voltages of opposite polarity. This principle, of creating a charge difference in response to applied stress, known as the *direct piezoelectric effect*.

The process whereby the piezoelectric effect takes place based on the fundamental structure of a crystal lattice. Crystals generally have a charge balance where negative and positive charges precisely nullify each other out along the rigid planes of the crystal lattice. When an external force disrupts this charge balance, such as, applying physical stress to a crystal, energy transferred by electric charge carriers, creating a surface charge density, which can be collected via electrodes.

Fig. 2 Piezoelectric cells

2. PIEZOELECTRIC EFFECT

The piezo effect produced is due to the change in the electric polarization of the materials due to the applied stress, which leads to the production of electric current or voltage. The piezoelectric effect understood as the linear electromechanical interaction between the mechanical and the electrical state in crystalline materials with no inversion symmetry (notably crystals, certain ceramics, and biological matter such as bone, DNA and various proteins). The piezoelectric effect is a reversible process in that materials exhibiting the direct piezoelectric effect (the internal generation of electrical charge resulting from an applied mechanical force) also exhibit the reverse piezoelectric effect (the internal generation of a mechanical strain resulting from an applied electrical field).

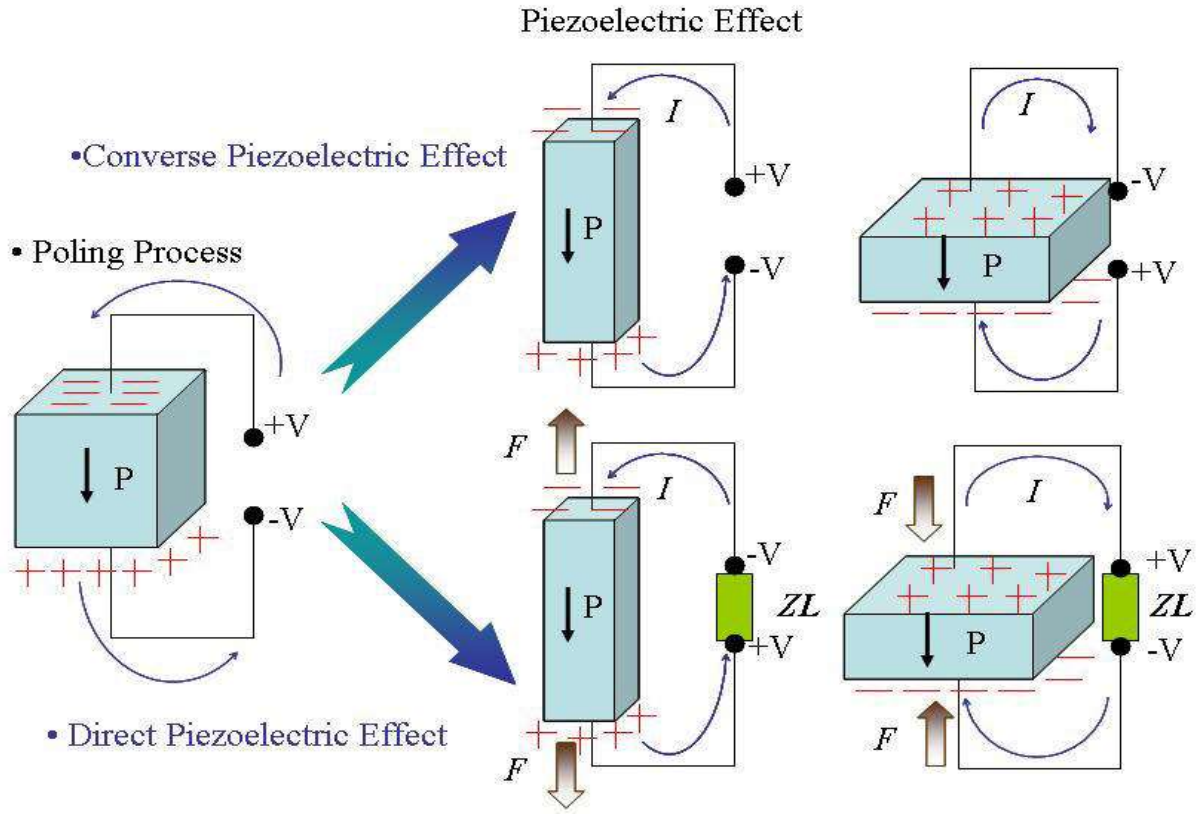

Fig. 2 Piezoelectric effect [8]

The piezoelectric effect is a reversible process in that materials exhibiting the direct piezoelectric effect (the internal generation of electrical charge resulting from an applied mechanical force) also exhibit the reverse piezoelectric effect (the internal generation of a mechanical strain resulting from an applied electrical field). For example, lead zirconate titanate crystals will generate measurable piezoelectricity when their static structure deformed by about 0.1% of the original dimension. Conversely, those same crystals will change about 0.1% of their static dimension when an external electric field applied to the material. The converse piezoelectric effect is used in production of ultrasonic sound waves.[4] The dipole density or polarization (dimensionality [Cm/m3]) may easily be calculated for crystals by summing up the dipole moments per volume of the crystallographic unit cell. As every dipole is a vector, the dipole density **P** is also a vector or a directed quantity. Dipoles near each other tend to be aligned in region called Weiss domains. The domains are usually randomly oriented, but can be aligned during poling (different from magnetic poling), a process by which a strong electric field is applied across the material, usually at elevated temperatures of decisive importance for the piezoelectric effect is the change of polarization **P** when applying a mechanical stress. This might caused by a re-configuration of the dipole-inducing surrounding or by re-orientation of molecular dipole moments under the influence of the external stress. Piezoelectricity may then manifest in a variation of the polarization strength, its direction or both, with the details depending on the orientation of **P** within the crystal, crystal symmetry and the applied mechanical stress. The change in **P** appears as a variation of surface charge density upon the crystal faces, i.e. as a variation of the electrical field extending between the faces, since the units of surface charge density and polarization are the same. In fact, however, piezoelectricity not caused by a change in charge density on the surface, but by dipole density in the bulk

3. PIEZO-SMART ROADS

The property of piezoelectric materials to produce electricity on compression employed to harness energy of vehicles moving on roads by making the roads "PIEZO-SMART". This revolutionary new surface uses piezoelectric crystals embedded in the asphalt to generate up to 400 kilowatts of energy from a 1 kilo meter stretch (a design, devised by Haim Abramovich, a developer at the Teknion-Israel Institute of Technology in Haifa, Israel) enough to run eight electric cars. Akilo meter of "Piezo-smart road" could generate enough power for 40 houses, and progress

in the technology could generate enough electricity to feed the national power grid. Private companies were competing in this sector but recently governments of developed countries are also taking notice to the developments in turning traffic rush into electricity and are funding many projects.

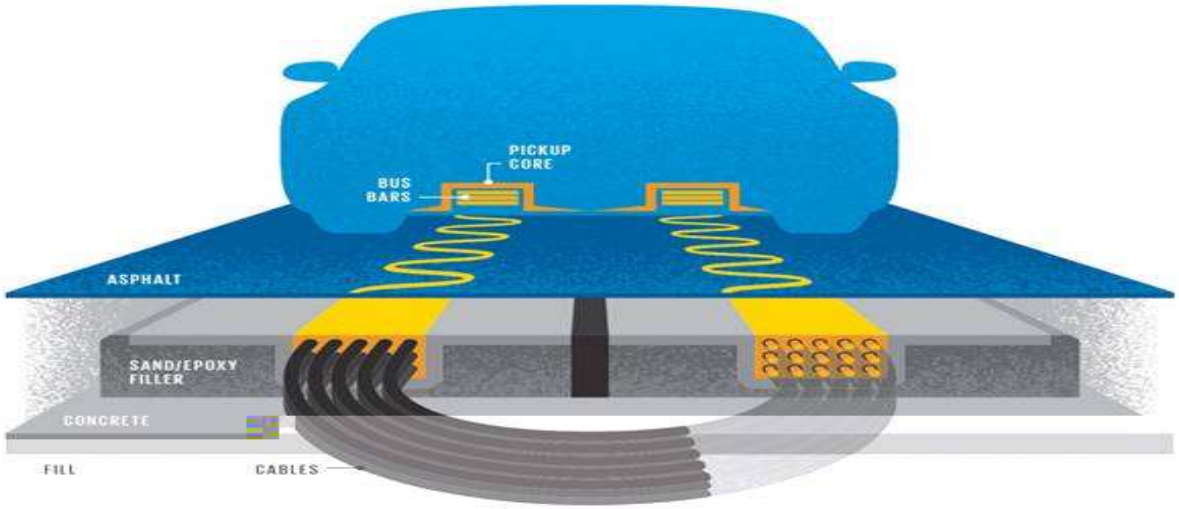

Fig.3 Schematic representation of piezo-smart road [9]

The energy consumed by the vehicle (sourced in the fuel combustion) utilized for a variety of applications; one of them is to overcome rolling resistance. A typical asphalt road can be described as a visco-elastro-plastic material, with elasticity being its dominant material characteristic. When a vehicle passes over a road, the road deflects vertically. This deflection released as thermal energy. For a road with embedded piezoelectric generators, part of the energy the vehicle expands on roads deformation is transformed into electric energy (via direct piezoelectric effect) instead of being wasted as thermal energy (heat).

4. ENERGY HARVESTING

Energy harvesting defined as the process in which energy extracted from some external energy sources and stored for future use. This concept of energy harvesting even helps in reducing the environment waste i.e. caused due to the use of the batteries that needs to be replaced after certain period and even the cost of replacing batteries after certain time is reduced. Vibration to electrical energy converted by using three different concepts i.e. Electromagnetic, Electrostatic, and Piezoelectric. Among these three techniques piezoelectric is the most efficient technique used. In piezoelectric technique, piezoelectric materials are play a vital role as the amount of stress or pressure applied is directly proportional to the electrical energy produced. Moreover, piezoelectric devices can be fabricated at both macro as well as micro level the amount of energy harvested depends upon the type of harvester used and depends on the application for which the harvested energy is about to use. Moreover, piezoelectric devices can be fabricated at both macro as well as micro level the amount of energy harvested depends upon the type of harvester used and depends on the application for which the harvested energy is about to use. In this process, the energy is first produced, stored in capacitors or super capacitors, and used in form of energy whenever it is needed. Radiation, Photovoltaic, piezoelectric, and pyro electric are the major sources of energy harvesting. Various other sources from where energy can be harvested are magnetic induction, atmospheric pressure change, electrostatics, thermoelectric etc. energy can also be harvested from various human activities biomechanical, pedal power, pedal electricity generators etc.

5. FABRICATION AND CONSTRUCTION

Both roadway and railway systems considered in this report but there are more reference materials available for a roadway system. Therefore, it is not possible to provide as much information about the cost of energy for a railway system, although the capital and installation costs of railway systems are less than the costs for roadway systems.

The following sections estimate the cost of roadway energy harvesting systems using the evaluations of vendor claims as well as simplified traffic models.

Table no. 1 Data summary for piezoelectric materials and installations [8]

Parameter	Low Estimate	High Estimate	Source	Objectivity Ranking (1=low, 3=high)
Optimal vibration frequencies (Hz)	100	120	Cook-Chennault	3
Tested wheel speeds (mph)	7.5	15	Virginia Tech	3
Voltages (V)	400	700	Virginia Tech	3
Amperage (mA)	0.2	0.35	Virginia Tech	3
Power Duration (s)	0.1	0.2	Virginia Tech	3
Maximum measured power per event, (W)	0.08	0.14	Virginia Tech	3
Virginia Tech Traffic Flow speed (mph)	40		Virginia Tech	3
Virginia Tech Traffic Flow rate (vehicles per day)	4000		Virginia Tech	3
Oregon DOT Traffic Flow Rate (vehicles per hour)	600		Oregon DOT	3
Energy Generated for 1.0 km, Oregon (kWh/month)	350,000		Oregon DOT	3
Number of harvesters, Oregon DOT	6000		Oregon DOT	3
Parameter	**Low Estimate**	**High Estimate**	**Source**	**Objectivity Ranking (1=low, 3=high)**
Vehicle speed for micro harvesters (m/s)	25		S.F. Ali, et al	3
kW per km	0.0018		Berkeley	3

Circuit design

Fig. 7 Piezoelectric cells

6. FABRICATION OF PLASTICATED ROAD

Step 1

Plastics waste (bags, cups, thermocole) made from PE,PP and PS cut into a size between 2.36mm and 4.75mm using shredding machine, (PVC waste should be eliminated).

Fig. 8 Plastic waste [10]

Step 2

a: The aggregate mix is heated to 165°c (as per the HRS specification) and transferred to mixing chamber.

Fig. 9 Road construction using plastic waste [10]

b: Similarly the bitumen is to be heated up to a maximum of 160°c (HRS Specification) to have good binding and to prevent weak bonding. (Monitoring the temperature is very important).

Step3: At the mixing chamber, the shredded plastics waste is to be added. It gets coated uniformly over the aggregate within 30 to 60 seconds, giving an oily look.

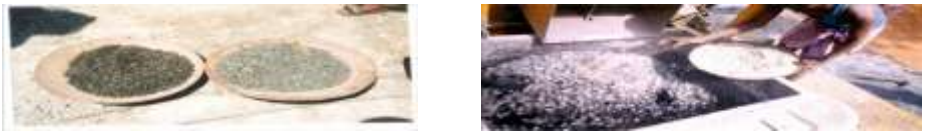

Fig. 10. Proper handling of waste [11]

Step 4:

The plastics waste coated aggregate mixed with got bitumen and the resulted mix is used for road construction. The road laying temperature is between 110°c to 120°c. The roller used is 8-ton capacity.

Fig. 11Laying of plasticated road [11]

7. PRESENT USE OF PIEZOELECTRIC MATERIAL

Tiles made up of many layers of rubber sheeting, to absorb the vibrations and ceramic; underneath piezoelectric crystals placed which can be used to generate electricity by movements on them. When such tiles installed in locations where large crowd movements are expected like in Railway & Bus stations, Airports, Malls etc, and a person steps on them, than by piezoelectric effect small charge is built up on surface of crystals. Though energy generated by one person would be too less but if number of steps on such tiles increase than energy produced by it would increase too. One more way to increase energy by use of such tiles is to increase pressure on them i.e. to use them for road construction. When a person steps on such tiles piezoelectric crystal underneath it experiences mechanical stress, which creates electric charge, built up on crystal's surface which can be collected by use of electrodes. Such energy can be stored in capacitors and power can be channelled to energy deficient regions. Japan has already started experimenting use of piezoelectric effect for energy generation by installing special flooring tiles at its capitals' two busiest stations. Tiles installed in front of ticket turnstiles. Thus every time a passenger steps on mats, they trigger a small vibration that can be stored as energy. Energy thus generated by single passenger multiplied by many times over by the 400,000 people who use Tokyo station on an average day, according to East Japan Railway, which generates sufficient energy to light up electronic signboards. An average person weighing 60 kg will generate only 0.1 watt in the single second required to take two steps across the tile, but when they are covering a large area of floor space and thousands of people are stepping or jumping on them, then significant amount of power can be generated. This energy created is sufficient to run automatic ticket gates and electronic displays.

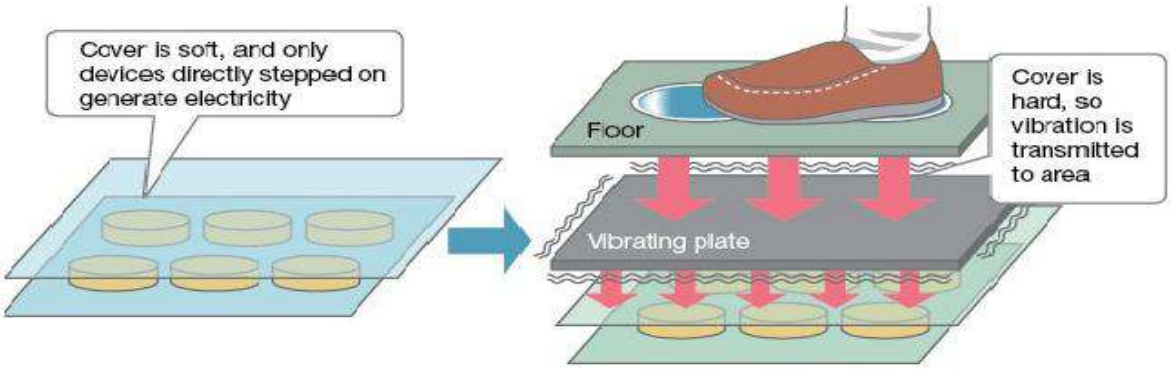

Fig. 12 Special flooring tiles with piezoelectric crystals. [9]

Constructing special types of roads that generates electricity just by driving over them is next step towards use of piezoelectric crystals. The system works by embedding tiny piezoelectric crystals into the road. When cars drive over such roads crystals embedded in them squeeze and thus generate a small electrical charge. Though small charge is generated by single car but 1 km stretch of such road could generate around 400kW-enough to run eight small cars. Such experimenting have already started in Israel. According to the Environmental Transport Association (ETA), if such system was installed on every stretch of British motorway it would generate enough energy to run 34,500 small cars. Certain vehicles could thus be powered entirely by road on which they drive.

Fig. 12 Specially designed road which generates electricity.[9]

8. FUTURE ASPECTS

In India, maximum public movements is observed in Railways stations and holy places, hence, such places can be Exploited for use of piezoelectric crystals for generation of electricity.

Fig. 13 Use in railways [8]

Gathering ranging from thousands to millions observed in holy places, thus installation of piezoelectric Crystals at floorings would generate enough power to light up Lights of temples as well as air circulation systems. While studying use of piezoelectric crystals embedded in Shoes and roads, idea struck in our mind that piezoelectric Crystals can be replaced with small hydraulic pumps in heels of Shoes and large pumps in case of bridges. While stepping such hydraulic pumps at heel of our shoes would get Compressed and this compressed air can be used to rotate small Electric generators at heel of shoes. Thus, our daily movement can be used to run small electric devices. Though such Generators would be able to generate small power but on large Scale i.e. If used in bridge construction than massive energy can Be generated. Similarly by driving on such road & bridge, due To compression the hydraulic pump can to rotate generators in Turn generate electricity.

Other idea that struck our mind while studying alternative Source of energy was use of thermocouple to generate Electricity. In regions where temperature falls below zero Degree, use of thermocouple can be implemented to generate Electricity. Idea is to use human body as a hot junction while Atmospheric temperature as cold junction. Thus thermocouple In form of jackets can be used with thermal insulation between Hot plate in contact with human body (specifically chest and Back because human body emit more heat from chest compared To other part of body) and cold junction (exposed as external Surface).Though small voltage in range of millivolts could be Generated with temperature difference of 50° C by use of type T thermocouple which can be experimented to get more output. Though this is just our ideas, real implementation and Conceptualization would require some time and efforts on our Part

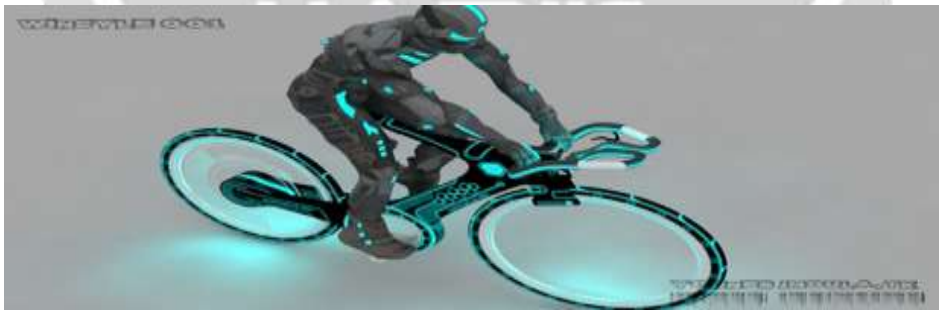

Fig. 14 Use of piezo material in every vibrating gadget[2]

i. The sound pollution in the road converts into electric energy to use for signals, lightning on road by using piezoelectric material.
ii. The sound pollution in industries used to produce electrical energy.
iii. The lost heat in home, hotel, and industry could be used to convert electrical energy and use for low voltage apparatus.

9. CONCLUSION

Generating capacity and profitability are two important factors to consider in choosing this energy alternative. There is currently a significant cap on the generating capacity. Net profits will only be seen after at least 12 years, as an underestimate. There are also many more "costs," besides the financial costs of manufacturing and installation, to consider, such as the environmental impact of manufacturing the PZT ceramics used in Innowattech's devices. While piezoelectric devices are gaining popularity, they are less capable than previously claimed because of physical limitations.

Some of the conclusions are as follows: -

1. As sound and heat more amount energy with it, it could be used by converting into electric energy for various purposes
2. According to law of thermodynamics sound energy could be converted into electric energy
3. Piezoelectric crystals are which converts sound energy to electric energy
4. Two dissimilar materials are which converts heat energy to electric energy
5. Lot of research is to be done on piezoelectric and thermoelectric materials but on positive note this could surely be done which could solve the energy problem of the entire world in small amount.

10. REFERENCES

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