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Eco-Friendly Electricity Generator Using Scintillating Piezo

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ABSTRACT
The concept is to capture the normally lost energy surrounding a system and converting it into electrical energy that can be used to extend the lifetime of that system's power supply or possibly provide an endless supply of energy to an electronic device which has led to power harvesting. One of the most interesting methods of obtaining the energy surrounding a system is to use piezoelectric materials. There exists variety of energy harvesting techniques but mechanical energy harvesting happens to be the most prominent. This technique utilizes piezoelectric components where deformations produced by different means are directly converted to electrical charge via piezoelectric effect. Subsequently the electrical energy can be regulated or stored for further use. The proposed work in this research recommends Piezoelectricity as a alternate energy source. The motive is to obtain a pollution-free energy source and to utilize and optimize the energy being wasted. In this paper important techniques are stressed upon to harness the energy generated from piezo crystals. Piezoelectric materials have a crystalline structure that provides a unique ability to convert an applied mechanical strain into an electrical potential or vice versa. These two properties allow the material to function as a power harvesting medium. In most cases the piezoelectric material is strained through the ambient vibration around the structure, thus allowing a frequently unused energy source to be utilized for the purpose of powering small electronic systems.
Keywords: Piezoelectric materials, Electrical energy, Piezoelectricity, Mechanical strain, Electrical potential, Pollution-free energy, Crystalline structure.

I. INTRODUCTION

Energy harvesting has been a topic of discussion and research since three decades. With the ever increasing and demanding energy needs, unearthing and exploiting more and more energy sources has become a need of the day. Energy harvesting is the process by which energy is derived from external sources and utilized to drive the machines directly, or the energy is captured and stored for future use. With the advent of technology, utilization of energy sources has increased by leaps and bounds. Piezoelectric Energy Harvesting is a new and innovative step in the direction of energy harvesting. Not many researches have been carried out till now in this field, hence it is a challenging job to extract energy from piezocyrstals. In this research paper, description of the basic working of a piezoelectric crystal is mentioned. Then later in the paper, the idea of combining energy from a number of piezoelectric crystals to obtain higher voltages is proposed. Certain ways of implanting the crystals at different places have also been sited in the paper.

1.1. Fundamentals of piezoelectric material

Piezoelectricity is the ability of some materials (notably crystals and certain ceramics) to generate an electrical 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 word piezien, which means to squeeze or press.The conversion of mechanical energy into electrical one is generally achieved by converters alternator type or commonly known dynamo. But there are other physical phenomena including piezoelectricity that can also convert mechanical movements into electricity. The phenomenon that produces an electric charge when a force is applied to piezoelectric material is known as the piezoelectric effect.The piezoelectric effect exists in two domains, the first is the direct piezoelectric effect that describes the material's ability to transform mechanical strain into electrical charge, the second form is the converse effect, which is the ability to convert an applied electrical potential into mechanical strain energy figure 1.1.

The direct piezoelectric effect is responsible for the materials ability to function as a sensor and the converse piezoelectric effect is accountable for its ability to function as an actuator. A material is deemed piezoelectric when it has this ability to transform electrical energy into mechanical strain energy, and likewise transform mechanical strain energy into electrical charge. The piezoelectric materials that exist naturally as quartz were not interesting properties for the production of electricity, however artificial piezoelectric materials such as PZT (Lead Zirconate Titanate) present advantageous characteristics. Piezoelectric materials belong to a larger class of materials called ferroelectrics. One of the defining traits of a ferroelectric material is that the molecular structure is oriented such that the material exhibits a local charge separation, known as an electric dipole.

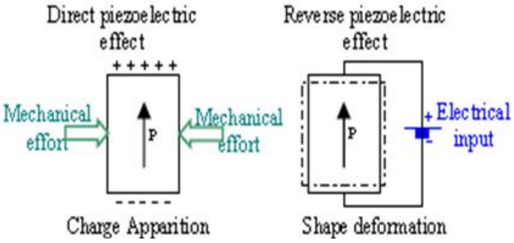

Fig1.1: Electromechanical conversion via piezoelectricity phenomenon.

Throughout the artificial piezoelectric material composition the electric dipoles are orientated randomly, but when a very strong electric field is applied, the electric dipoles reorient themselves relative to the electric field; this process is termed poling. Once the electric field is extinguished, the dipoles maintain their orientation and the material is then said to be poled. After the poling process is completed, the material will exhibit the piezoelectric effect. The mechanical and electrical behavior of a piezoelectric material can be modeled by two linearized constitutive equations. These equations contain two mechanical and two electrical variables. The direct effect and the converse effect may be modeled by the following matrix equations:

Direct Piezoelectric Effect: $D = d \cdot T + \varepsilon T \cdot E$ (1)
Converse Piezoelectric Effect: $S = sE \cdot T + dt \cdot E$ (2)

Where D is the electric displacement vector, T is the stress vector, εT is the dielectric permittivity matrix at constant mechanical stress, sE is the matrix of compliance coefficients at constant electric field strength, S is the strain vector, d is the piezoelectric constant matrix, and E is the electric field vector. The subscript t stands for transposition of a matrix.

When the material is deformed or stressed an electric voltage can be recovered along any surface of the material (via electrodes). Therefore, the piezoelectric properties must contain a sign convention to facilitate this ability to recover electric potential.

1.2. Advantages of Using Piezoelectric Materials

- Small size
- Broad frequency range
- Light weight
- 2-wire operation
- Ultra low noise
- Wide dynamic range
- Wide temperature range
- Simple signal conditioning
- Cost effective implementation

1.3. Description of the project

A piezoelectric material is made up of both positively and negatively charged particles arranged in such a way that all the positively-charged particles and all the negatively-charged particles are grouped about the same central point. If two opposite faces of a crystal are placed under pressure, the crystal can be slightly flattened and distorted, and the charged particles making up the crystals are pushed together and spread out sideways. The change is such that the average position of the negatively-charged particles shifts slightly with respect to the average position of the positively-charged particles. This means there is, in effect, a separation of positive and negative charges and a potential difference is therefore created between two faces of the crystal causing the

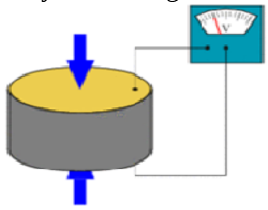

Fig. 1.3.1.: Pressure Applied Generating Energy.

Output voltage and power is directly proportional to the pressure applied or in other words the weight of the person walking on it and the time the person is standing on it. The energy harvesting via Piezoelectricity uses direct piezoelectric effect. The phenomenon will be clear from the Fig.1.3.2.

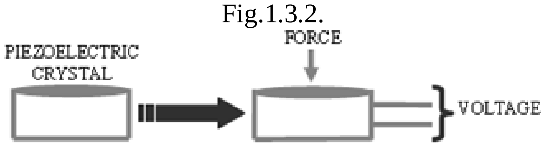

Fig.1.3.2: Principle of Direct Piezoelectric Effect

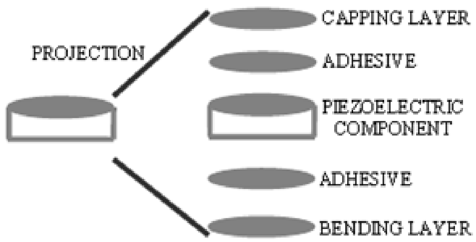

Fig.1.3.3: Fig shows the structure of a piezoelectric component being used for energy harvesting.

The output voltage obtained from a single piezoelectric crystal is in millivolts range, which is different for different crystals. And the wattage is in microwatt range. So in order to achieve higher voltages, the piezoelectric crystals can be arranged in cascading manner, that is, in series. The energy thus obtained is stored in lithium batteries or capacitors. This is the working principle behind piezoelectric energy harvesting system. Now the extreme engineering lies in optimization of piezoelectric energy, which is done in various ways. A lot of studies are being carried out in order to know which crystal will be the best to obtain maximum output voltage, what should be the structure of piezoelectric component, which type of circuit should be used at the output terminals of piezoelectric crystal in order to have maximum wattage. In the next section, a number of sources of vibration which are already being used for piezoelectric energy harvesting and a new idea in this direction has been proposed.

1.4. Results

Through the excitation of a piezoelectric plate, it is demonstrated that a 40 mAh battery can be charged in less than half an hour at resonance or in only a few hours.

Fig.1.4: Result of Project or Experiment Performed

II. REVIEW ON IMPLEMENTATION PIEZOELECTRICITY

2.1. POWER GENERATING SIDEWALK

The piezoelectric crystal arrays are laid underneath pavements, side walks , speed breakers for maximum voltage generation. The voltage thus generated from the array can be used to charge the chargeable Lithium batteries, capacitors etc. These batteries can be used as per the requirement[2].

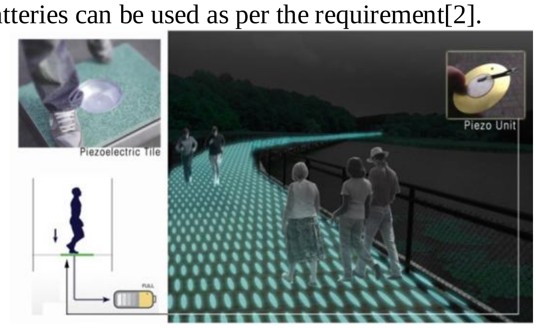

Fig.2.1: Pathways with Piezo material generating electricity.

2.2. POWER GENERATING BOOTS OR SHOES

In United States Defense Advance Research Project Agency (DARPA) initiated a innovative project on Energy harvesting which attempts to power battlefield equipment by piezoelectric generators embedded in soldiers' boots [3]. However, these energy harvesting sources put an impact on the body. DARPA's effort to harness 1-2 watts from continuous shoe impact while walking were abandoned due to the discomfort from the additional energy expended by a person wearing the shoes[2].

Fig.2.2: Shoes with Piezoelectric material.

2.3.. GYMS AND WORKPLACES

Researchers are also working on the idea of utilizing the vibrations caused from the machines in the gym. At workplaces, while sitting on the chair, energy can be stored in the batteries by laying piezoelectric crystals in the chair. Also, the studies are being carried out to utilize the vibrations in a vehicle, like at clutches, gears, seats, shock-ups, foot rests[2].

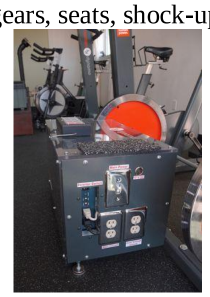

Fig.2.3: Piezoelectric material in machines in gyms.

2.4. PEOPLE POWERED DANCE CLUBS

In Europe, certain nightclubs have already begun to power their night clubs, strobes and stereos by use of piezoelectric crystals. The crystals are laid underneath the dance floor. When a bulk of people use this dance floor, enormous amount of voltage is generated which can be used to power the equipments of the night club[2].

Fig.2.4: Dance floors with Piezoelectric material.

Imagine a dance floor packed with moving bodies where the energy from the dance which previously seemed to be impractical now produces electricity enough to run the entire club.

III. PROPOSED WORK

3.1. Power Generating Roads

The greatest untapped sources of piezo-electric energy are freeways and busy roads. If piezo-electric mats were installed under the busiest sections [a little ways under the surface], the thousands of tons of vehicles passing over each day would generate massive amounts of electricity for the city's use.

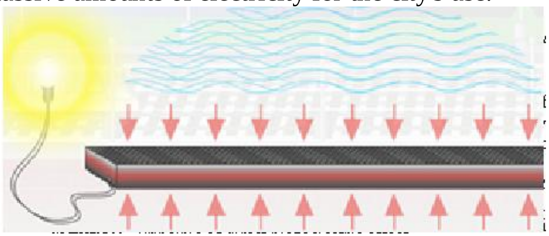

Fig.3.1.1: The basis of this system is that they have uniqueabilities to harvest energy from weight, motion, vibration and temperature changes.

The energy generated from the moving vehicles is stored in huge batteries and from the batteries the energy is used for the city's energy consumption. This can be used for example to light the street lights at night from the entire energy stored in the batteries. It can also be used for powering the household gadgets and in short the city as a whole saving lots of fuel used in electricity generation in an eco-friendly way.

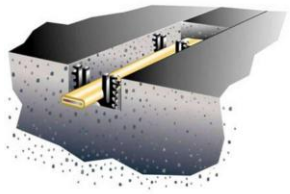

Fig.3.1.2: Piezoelectric material in the Roads to generate electricity.

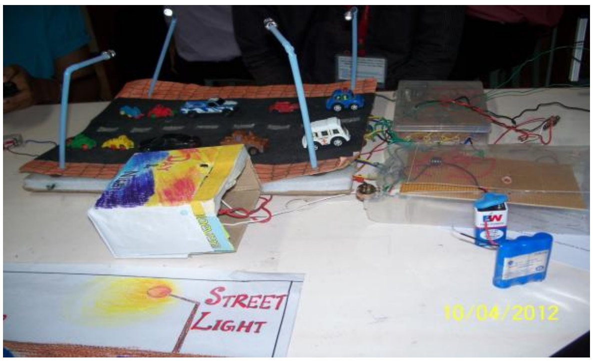

Fig.3.1.3: Implementation of the proposed work on miniature project model giving results upto 25V from a single Piezo chip. This estimates the calculation that a single human step can flicker 60W bulb for 1sec. Therefore, for a crowd in motion, multiply with 28527* times, which can move a train for 1second by calculation for a complete strip layout of Piezo material.

3.2. MOBILE KEYPAD AND KEYBOARDS

The piezoelectric crystals can be laid down under the keys of a mobile unit and keyboards. With the press of every key, the vibrations created can be used for piezoelectric crystal and hence can be used for charging purpose[5]. The energy produced from the mechanical pressure on the buttons is directly stored in the systems battery passing through a rectifier.

Fig.3.2: Keyboard with Piezo material.

3.3. FLOOR MATS, TILES AND CARPETS

A series of crystals can be laid below the floor mats, tiles and carpets which are frequently used at public places and the output energy is used for the consumption of electricity of that particular place[2].

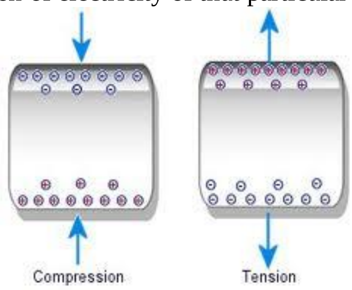

Fig.3.3.1: Compression and Tension on piezo material in tiles.

IV. OUTPUT STAGE OF PIEZOELECTRIC ENERGY HARVESTING SYSTEM

The output of a piezoelectric crystal is alternating signal. In order to use this voltage for low power consuming electronic devices, it has to be first converted into digital signal [3]. It is done with the help of AC to DC converter shown in Fig. 4.1.

Fig.4.1 shows a simple diode rectifier to convert AC to DC. This is followed by a capacitor, which gets charged by the rectifier upto a pre-decided voltage, at which the switch closes and the capacitor discharges through the device. In this way, the energy can be stored in the capacitor, and can be discharged when required. But the energy harvesting capacity of this circuit is not appreciable. Hence, a DC to DC converter is used after bridge rectifier stage, which has been demonstrated in Fig.4.2. The addition of DC-DC converter has shown an improvement in energy harvesting by a factor of 7. A non-linear processing technique "Synchronized Switch Harvesting on Inductor" (SSHI) was also proposed in 2005 for harvesting energy [4]. It consists of a switching device in parallel with the piezoelectric element. The device is composed of a switch and an inductor connected in series. The switch is in open state except when the maximum displacement occurs in the transducer. At that instant, the switch is closed and the capacitance of the piezoelectric element and inductor together constitute an oscillator. The switch is kept closed until the voltage on the piezoelectric element has been reversed. This circuit arrangement of the output circuit is said to have a very high energy harvesting capacity. Fig. 4.3[4].

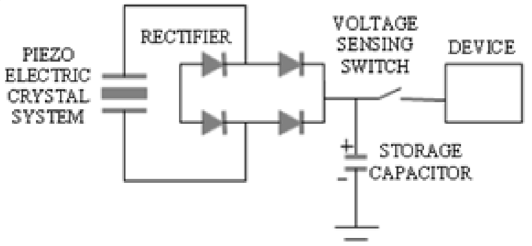

Fig.4.1: Bridge Rectifier type AC to DC coverter

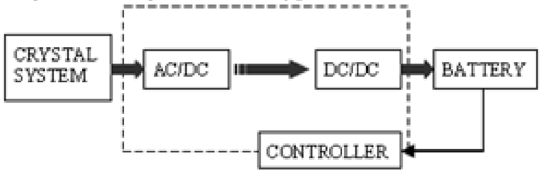

Fig.4.2: Energy Harvesting Circuit.

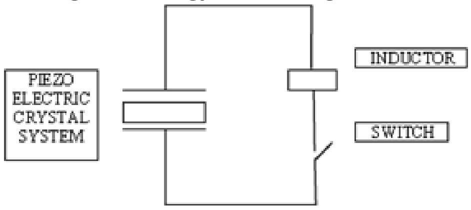

Fig.4.3: SSHI (Synchronized Switch Harvesting on Inductor) Technique.

V. FUTURE SCOPE

The proposed work portrays the concept of Piezoelectric Energy Harvesting and the results obtained after the implementation are very encouraging. Future work of the proposed idea encompasses further amplification of the crystal output to a greater extent. Future lies in the inclusion of advanced material used to design the piezoelectric crystal which further amplifies the crystal output in terms of voltage as well as current. A study could be carried out from the variety of piezoelectric crystals and after comparing the results, the choice of the optimum material for the best performing crystal could be devised[2].

Growing population which is considered to be a bane is used advantageously with piezo application. In an era where the significance of renewable energy is well proved, piezoelectricity is a promising alternative source of energy. At present the usage of piezoelectricity seems far from practicality for portable gadgets. But designers concerned about the energy crisis are working to enhance its utility for portable gadgets and beyond. Piezoelectricity shall definitely have huge impact in near future. At present it finds numerous applications, which will increase further owing to the desirable characteristics of the technology. Piezoelectric devices embedded in highways are used for electricity generation. In the detection and identification of sonar waves also piezo electric elements find significant application.

VI. CONCLUSION

A non-conventional, nonpolluting form of energy can be harvested, maintaining the economic standards of common laymen. The electricity is produced from the mechanical stress on the crystals due to piezoelectric effect and thus it generates the energy needed for charging battery to light streetlights at night and also for the city consumption of electricity. Regardless of this project, the future of piezoelectric materials looks bright, with studies focusing on their properties and applications even in nanotechnology. If a compromise between the hardness of the road and the make-up of the small devices is reached, then undoubtedly the system will benefit both drivers and the national power grid.
The assembly developed using series and parallel combination of piezo-crystals is very cost effective. A single crystal costs around 23 – 25 Rupees, and hence the cost of whole assembly is very less. It is very encouraging to get a good voltage and current at such a low cost at the same time utilizing the waste energy. So, the assembly improves on the concern of cost effectiveness to a great extent and the work is on to further improve upon the results of the system.

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