An Innovative Strategy of Energy Generation using Piezoelectric Materials: A Review

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Abstract: ***Certain material when strained produce electric potential over their surface which is directly proportional to the amount of mechanical stress applied. These materials are known as piezoelectric materials and this effect is referred as a direct piezoelectric effect. Piezoelectricity is intensely used in the working of transducers, actuators, surface acoustic wave devices, frequency controls, etc. Use of piezoelectric material for power generation is now becoming a new promising area of its usage. Many countries like Japan, Israel India have already moved ahead in this direction with its wide range of experimentation and testing on using the material as a source for power generation. Also, with the advancement in the manufacturing and production capabilities of these materials the aspects like performance, affordability, reliability, easy implantation and longevity have greatly enhanced. This paper focuses on using the piezoelectric material as a power generating source and extension of its use in various areas.***

Keywords: Power generator, affordable, feasible, renewable

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1. Introduction

With the continuous development and advancement in technology the need for power consumption is increasing rapidly and on the other hand non-renewable sources of power are depleting. This calls for the need to concentrate on sustainable development so that the future generation would not be affected adversely by present day development. Clean, green and renewable sources of energy are required to be utilized wherever possible.

This review paper aims to concentrate our vision towards harvesting the energy of moving vehicles and moving people with the help of piezoelectric materials which not only meet the power needs but also meet the criterions of green energy source that is long lasting in use, safer in operation and provide promising solution to the growing needs of power.

India is aiming to build smart cities ….what if we built smart roads in these smart cities which can generate the electricity for its lighting and other requirements on its own with the help of piezoelectric material.

2. About Piezoelectric Material

2.1 History

In early 1880s, Jacques Curie and Pierre Curie demonstrated an effect which showed that when certain materials are subjected to mechanical stress an electric charge accumulation occurs at their surfaces. This phenomenon was coined as Direct Piezoelectric Effect and follows its direct translation from Greek word “pieze in”, meaning “pressure electricity”. This effect is also termed as “generator or sensor effect”, converts mechanical energy into electrical energy. The reversibility of this same effect was mathematically deduced by Lippmann in 1881 and the results were immediately confirmed by Curie brothers in their following publication (Curie and Curie 1881), which is understood as Inverse Piezoelectric Effect. This inverse effect causes material to change its physical dimensions e.g. length when an electrical voltage is applied across the material. This actuator effect converts electrical energy into mechanical energy [1, 5].

The first real time application of piezoelectric material is in SONAR, which further extended its use in microphone, transducers, signal filters, surface acoustic wave devices, frequency control and so on [3].

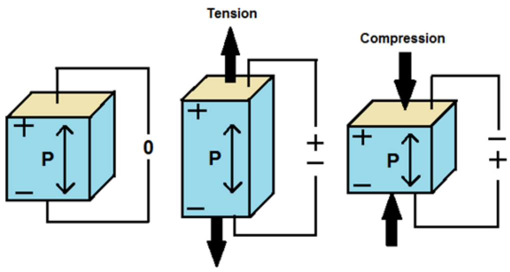

Figure1: Scheme of Piezoelectricity

2.2 Piezoelectric Effect and Materials

The piezoelectric effect is understood as the linear electromechanical interaction between the mechanical and the electrical state in crystalline materials with no inversion symmetry. The crystal cells that have inversions center cannot display this piezoelectric effect, in other words, Piezoelectricity behavior is displayed by all materials that have a non-centro-symmetric crystal structure [4].Some naturally occurring crystalline materials possessing these properties are quartz and tourmaline which consist of a mono-crystalline crystal structure. Piezoelectric effect in single crystals occurs because an asymmetry in the structure of the unit cells [5]. So when the external forces are applied in a specific direction, the structure distorts producing voltage in one specific direction.

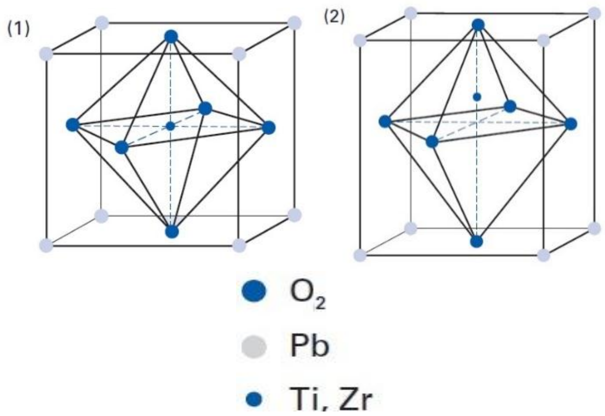

Figure2: (1) Crystal structure of PZT
(2) Distorted structure of PZT under the application of external force

Some artificially manufactured piezoelectric crystals are Rochelle salt, Ammonium dihydrogen phosphate, Lithium sulphate and a new class of material known as polarized piezoelectric ceramic materials. The most widely produced piezoelectric ceramics are Lead zirconate titanate (PZT), Barium titanate and Lead titanate. Piezoelectric effect exhibited by ceramics materials tends to induce higher voltages [4]. This occurs because, in addition to the asymmetric crystal structure, ceramic material also possesses some net spontaneous polarization effect; i.e. the charger concentration of the unit cell separates in the direction of spontaneous polarization.

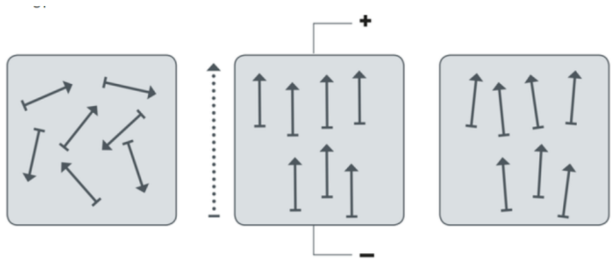

Figure3: Poling of Piezoelectric Ceramic Material

A typical piezoelectric ceramic material consists of a polycrystalline crystal structure that consists of small crystallites, each containing their net dipole moment in some specific direction. These lattices are randomly oriented which gives the material zero net polarization. Henceforth, to orient the dipoles in one specific direction a strong electric field is applied across the material, leading to remnant polarization of the material.

For any case of the piezoelectric material, working temperature below Curie temperature (T_c) is a prerequisite for the piezoelectric effect to occur in the first place [5]. Apart from exhibiting higher piezoelectricity, ceramic materials also inherit several other advantages over single crystal, especially the ease of fabrication into a variety of shapes and sizes, where in contrast a single crystal must be cut along a specific crystallographic direction [4].

General classification of piezoelectric material is done on the extent of doping done in these materials, that are named as hard piezoelectric material and Soft piezoelectric materials.

Hard Piezoelectric materials are suitable for the application that demands material resistant to high electrical and mechanical stresses particularly in the application of dynamic/on-resonance. Also, these materials are not easy to be poled or depolarize except at elevated temperature. In contrast to this, Soft piezoelectric materials are used in actuators and sensors that are suitable for static or semi-static application that requires extra precision. However, when operated in dynamic mode soft piezo ceramic material suffer more dielectric losses and high dissipation factors, which lead to overheating over a prolonged application [8, 4].

Table1: Comparison of the characteristics of the Hard and Soft doped piezoceramic material.Source: - [5, 6]

Material properties	Soft	Hard
Piezoelectric Constant	Larger	Smaller
Permittivity	Higher	Lower
Di-electric Constant	Larger	Smaller
Di-electric Losses	Higher	Lesser
Electro Mechanical Coupling Factor	Larger	Smaller
Electrical Resistance	Very High	Very Less
Mechanical Quality Factor	Lower	Higher
Linearity	Poor	Better
Polarization / Depolarization	Easier	Difficult

3. Present day applications

Today, all over the world, people are studying and working on power generation solutions that are eco-friendly, reliable, long lasting, and at the same time available and affordable by all. Scientists and Engineers around the world are brainstorming and experimenting to discover more sustainable energy sources to satisfy growing needs of energy consumption.

3.1 Piezoelectric material in Roads

Innowattech Energy Harness System, an Israel based company, is continuously working on researches and experimentations for developing of piezoelectric generators that can harvest mechanical energy imparted on roads from passing vehicle and a storage system that can store the energy produced, which can later be used for lighting up the street light, toll light and other electrical requirement on the road. Innowattech has conducted several trials with IPEG (Innowattech Piezoelectric Generator) at Technion Institute of Technology in Haifa. The result of these trials showed that the system can produce significant amount of electric power of about 400 KWh from 1km stretch (assuming 600 vehicles moving on road per hour). They further concluded that this system can also be very well used on railway lines and airline runways [9, 13].

3.2 Energy from foot steps

On 12th December 2008, experimentation was started at two of the Japan's busiest stations, with intent to harness energy produced by walking. This experiment consisted of the installing of special

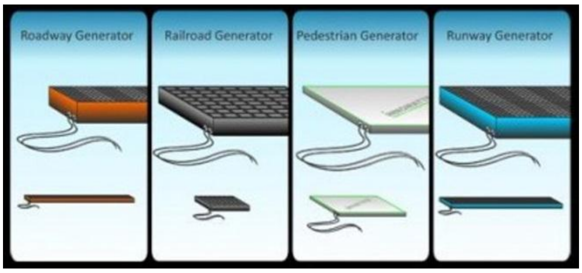

Figure4: Innowattech Energy harvesting systems

piezoelectric flooring tiles in front of the ticket turnstyle that would take step of every person passing over it. With every step a person makes on it a small vibration was triggered with was then converted and stored as electrical energy [11].

In India a group from "Mar Athanasius College of Engineering, Kothamangalam" did a research and produced piezo-electric tiles that can produce electricity by harnessing power from the footstep movement over them. They checked various piezoelectric material and concluded PZT showed better results.

Their results concluded that voltage of 40 volt is generated across the tile when the weight of 75 kg is applied [12].

4. Conclusion

Piezoelectric energy is versatile, sustainable and upcoming source for fulfilling the rapid increasing power need of today's era. It can be utilized in the roads and highways where the movement of traffic is higher or can be used at railway stations, airport etc., or in crowded places where the movement of people is more. Concentrating and working on its application and utilizing it can produce miraculous results. Power generated from these will be eco-friendly and no waste is produced during electric generation which can harm the environment.

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