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Piezoelectric Materials for Energy Generation – A Study

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Abstract: - *Piezoelectric materials play a vital role in the field of energy generation due to their ability to convert mechanical stress into electrical energy. These materials have unique properties that make them suitable for various applications, such as sensors, actuators, and renewable energy. Additionally, they have been extensively studied for their potential in energy harvesting from vibrating systems. The basic part of the energy collector is the piezoelectric material, which, when exposed to mechanical vibrations or applied pressure, induces the displaced ions in the material and results in a net electric charge due to the dipole moment of the unit cell. This phenomenon builds an electric potential across the material. Furthermore, piezoelectric materials are also key components in the development of smart structures, with potential applications in aerospace vehicles, automobiles, micro air vehicles, sport products, and structural vibration control. The potential applications of piezoelectric materials for energy generation are vast and diverse, ranging from health monitoring to energy harvesting. The use of piezoelectric materials for energy generation has gained significant attention in recent years. This systematic review aims to analyse and evaluate the different piezoelectric materials and their potential for energy generation.*

Keywords: *Piezoelectric materials, Energy harvesting, Dipole movement, Energy generation.*

1. Introduction

The demand of electric power is increasing day to day. Different type of power generation methods is existing in our society. Main objective of current technologies is trying to invent and provide a pollutants loose approach of electricity generation [1]. The power generated by footstep is converted to electrical energy through piezoelectric sensor. When a person walks, he loss energy to the floor and that mechanical energy will convert into the electrical energy by the help of the piezoelectric sensor. Piezoelectric generators are typically small and lightweight, making them suitable for applications where size and weight are critical factors. These have a fast response time, allowing them to quickly convert mechanical energy into electrical energy. Piezoelectric generators are considered environmentally friendly because they do not produce harmful emissions or pollutants during operation. Piezoelectric generators do not require external power sources or batteries to operate. Once set up, they can generate electricity without the need for ongoing maintenance [2].

This System is used to generate voltage by using foot step force. The system works as a medium to generate power using pressure, force. This task could be very beneficially in public places like bus stands, theaters, railway stations, buying shops, sports arena and soon Then these systems can also generate voltage on each by each step of a foot. Whenever force is applied on piezoelectric sensor, then the force is converted into electrical energy. In that movement, the output voltage is stored in the battery. The output voltage which is generated from the sensor is used to drive DC loads [3]. This sensor converts the pressure on it to a voltage. By using this energy saving method, foot step power generation system we are generating power. A piezoelectric sensor is a device that uses the piezoelectric effect, to measure changes in pressure, acceleration, temperature, strain, or force by converting them to an electrical charge.

Electricity from footsteps, SS Taliyan, BB Biswas, RK Patil, GP Srivastava, TK Basu, 2010 [4]. This paper discusses the basic engineering and operational mechanism of piezo crystal, engineering analysis of the model, working of piezo crystal and energy generation through footsteps. Potentials of piezoelectric and thermoelectric technologies for harvesting energy from pavements, Lukai Guo, Quing Lu, 2017 [5]. This paper discusses the cost effectiveness analysis of energy harvesting pavement technologies. It estimates electrical energy generation from a pavement network by two technologies cost calculation and estimating needs. Cost analysis and estimation of energy production based on piezoelectric technology. Floor tile energy harvester for self-powered wireless occupancy sensing, Nathan Sharpes, Dušan Vučković and Shashank Priya, 2016 [6]. This paper presents details about designing and optimum structure of the piezoelectric product. Also proposed a suitable structure for product design for commercialization and design of outer shell circuit design and structure.

2. Methodology

The working principle of piezoelectric materials is based on their asymmetric crystal structure. This structure creates a dipole moment within the material, which makes it sensitive to both mechanical stress and electric fields. When mechanical stress is applied to a piezoelectric material, such as through vibrations or pressure, it causes the crystal lattice to deform. This deformation generates electric charges on the electrodes of the material, known as the direct piezoelectric effect. These electric charges can then be collected and used as an electrical output. This phenomenon can be explained by the alignment of electric dipoles within the material. In the absence of mechanical stress, the electric dipoles in the piezoelectric material have random orientations (Wang & Li, 2022)[7]. However, when mechanical stress is applied, it aligns the dipoles in a specific direction, resulting in the generation of electric charges. This direct piezoelectric effect can be utilized in various applications, including the generation of electricity. By utilizing the piezoelectric effect, piezoelectric materials can be used to harvest mechanical energy and convert it into electrical energy. It involves the utilization of a piezoelectric material that undergoes mechanical deformation when subjected to external forces or vibrations. This mechanical deformation causes a redistribution of the charges within the material, generating an electric field and subsequently producing electricity. To enhance the efficiency of electricity generation, a current source in parallel with a capacitor can be used to model the electrical behaviour of a piezoelectric transducer. This methodology is explained in figure 1.

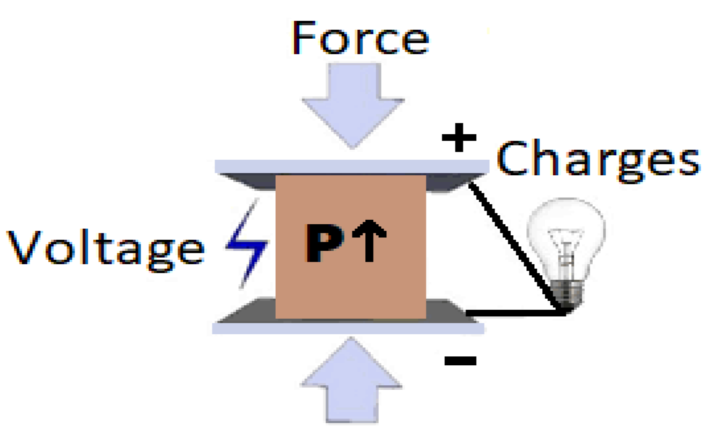

Figure 1:- Working principle of piezoelectric effect.

2.1. Working model of electricity generation from piezoelectric material

It involves the utilization of a piezoelectric material that undergoes mechanical deformation when subjected to external forces or vibrations. This mechanical deformation causes a redistribution of the charges within the material, generating an electric field and subsequently producing electricity. To enhance the efficiency of electricity generation, a current source in parallel with a capacitor can be used to model the electrical behaviour of a piezoelectric transducer.

The generated electricity from the piezoelectric material typically has characteristics such as high voltage, low current, and high impedance by focusing on power optimization and the design of an electrical interface circuit, it is possible to overcome the poor characteristics typically associated with power generated from piezoelectric materials, such as high voltage, low current, and high impedance.

3. Working and Discussion

One important area of research is focused on improving the characteristics of power generation from piezoelectric materials. This includes finding ways to increase the current output, decrease the impedance, and optimize the overall power generation efficiency. Additionally, researchers are also exploring new techniques for integrating piezoelectric materials into electrical interface circuits to ensure a smooth and efficient transfer of power. This research aims to overcome the limitations of piezoelectric power generation, such as high voltage and low current, by developing innovative solutions for power optimization and electrical interface circuit design. Use the following sources if appropriate. Currently, different materials are found with piezoelectric characteristics. Nonetheless, the application of piezoelectric materials for electric power generation often requires careful consideration of specific material properties. For example, ceramic materials like PZT, PMN-PT, and ZnO are commonly used as bulk materials due to their excellent properties such as high piezoelectric coefficients, good mechanical stability, and high dielectric constant. In conclusion, electricity generation from piezoelectric materials presents both challenges and opportunities. However, power generated from a piezoelectric material usually comes with poor characteristics such as high voltage, low current and high impedance. Many people focus on the characteristic of power generation of piezoelectric material, while others are dedicated to power optimization and the design of electrical interface circuits.

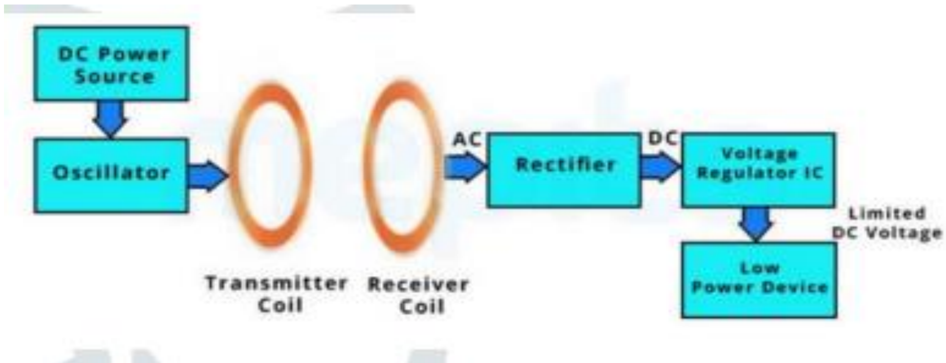

Figure 2:- The design of electrical interface circuits of piezoelectric effect

3.1. Applications of piezoelectric materials

Piezoelectric materials have gained significant attention and are being widely explored in various applications due to their unique properties. Some of the applications of piezoelectric materials include:

- Ultrasonic transducers: Piezoelectric materials are commonly used in ultrasonic transducers for applications such as medical imaging, non-destructive testing, and industrial inspection.
- Sensors: Piezoelectric materials can be used as sensors for various purposes such as pressure sensing, force sensing, and vibration sensing (Guan et al., 2022).
- Actuators: Piezoelectric materials are used as actuators in applications like precision positioning, robotics, and microfluidics.
- Energy harvesting: Piezoelectric materials can convert mechanical energy into electrical energy, making them suitable for energy harvesting applications such as self-powered sensors and wireless charging of electronic devices.
- High power piezoelectric actuators: Piezoelectric materials can be used to create high power actuators that can generate large forces and displacements, making them useful in applications such as robotics and haptic feedback systems.
- Intelligent structures: Piezoelectric materials are being incorporated into smart or intelligent structures to enhance their functionality and performance. These structures can adapt and respond

to external stimuli, making them suitable for applications such as structural health monitoring, vibration control, and shape-changing devices.

- Smart materials: Piezoelectric materials are a key component in the development of smart materials.

3.2. Challenges in Harnessing Electricity from Piezoelectric Materials

Some of the challenges in harnessing electricity from piezoelectric materials include optimizing the efficiency of energy conversion, ensuring long-term durability of the material under harsh environmental conditions, and developing scalable and cost-effective manufacturing processes for large-scale implementation. Advances in Piezoelectric Material Technology Recent advances in piezoelectric material technology have shown promise in addressing these challenges. These include the development of new piezoelectric materials with enhanced performance characteristics, such as higher piezoelectric coefficients and improved stability, as well as the integration of smart materials and advanced sensing technologies to improve energy harvesting efficiency. Furthermore, researchers are exploring innovative techniques for enhancing the power output of piezoelectric materials, such as utilizing multi-layer or composite structures and incorporating nanostructured materials. Additionally, researchers are also investigating the potential of integrating piezoelectric materials into existing infrastructure, such as roads and buildings, to maximize energy harvesting opportunities and create a more sustainable energy landscape. Furthermore, researchers are also exploring the integration of piezoelectric materials with other renewable energy technologies, such as solar panels and wind turbines, to create hybrid energy systems that can generate electricity from multiple sources. Ultimately, these advancements in piezoelectric material technology hold great potential for revolutionizing the field of electricity generation, offering a sustainable and renewable energy solution.

3.3. Future Outlook

Piezoelectric energy generation is a promising renewable energy technology that harnesses the mechanical energy from vibrations and movements to generate electricity (Ellabban et al., 2014). With advancements in material science and engineering, piezoelectric energy generation has the potential to become a major player in the renewable energy sector. It offers several advantages, such as being highly efficient, scalable, and environmentally friendly. However, there are still some challenges that need to be addressed for the widespread adoption of piezoelectric energy generation. These challenges include improving the energy conversion efficiency, developing cost-effective and durable piezoelectric materials, and optimizing the design and integration of piezoelectric devices into various applications. Furthermore, research and development efforts should focus on exploring new applications and markets for piezoelectric energy generation, such as smart cities, wearable technology, and self-powered sensors. The future of piezoelectric energy generation looks promising, with ongoing advancements in technology and research. Overall, the road ahead for piezoelectric energy generation is filled with potential and opportunities. In particular, the use of piezoelectric materials in building infrastructure, such as roads and bridges, could potentially generate electricity from the vibrations caused by traffic, making it a sustainable and decentralized energy source. In conclusion, while there are still challenges to overcome, the future of piezoelectric energy generation is bright.

4. Conclusion

Piezoelectric materials have gained significant attention and are being widely explored in various applications due to their unique properties. Some of the applications of piezoelectric materials include: Ultrasonic transducers: Piezoelectric materials are commonly used in ultrasonic transducers for applications such as medical imaging, non-destructive testing, and industrial inspection. Piezoelectric materials can be used as sensors for various purposes such as pressure sensing, force sensing, and vibration sensing. Piezoelectric materials are used as actuators in applications like precision positioning, robotics, and microfluidics. Some of the challenges in harnessing electricity from piezoelectric materials include optimizing the efficiency of energy conversion, ensuring long-term durability of the material under harsh environmental conditions, and developing scalable and cost-effective manufacturing processes for large-scale implementation. Piezoelectric energy generation is a promising renewable energy technology that harnesses the mechanical energy from vibrations and movements to generate electricity. With advancements in material science and engineering, piezoelectric energy generation has the potential to become a major player in the renewable energy sector. It offers several advantages, such as being highly efficient, scalable, and environmentally friendly.

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