Piezoelectric Energy Harvesting System

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Abstract

The advancement of information and energy technologies has spurred an increased demand for low-power and compact electronic devices with across various fields. Developing energy harvesting technologies to capture ambient and sustainable energy offers a promising solution to complement or replace conventional batteries. The piezoelectric technique provides a solution for energy harvesting from different energy sources, and high-frequency operation in piezoelectric energy harvesting offers several advantages. These include increased power output, as more charge is generated per unit of time, which increases the current. Additionally, better alignment with the natural resonance of piezoelectric elements enhances energy conversion efficiency. Piezoelectric energy harvesters have gained significant attention in recent years due to their ability to convert ambient mechanical vibrations into electrical energy, which opens up new possibilities for environmental monitoring, asset tracking, portable technologies and powering remote "Internet of Things (IoT)" nodes and sensors. Mechanical vibrational energy, which is provided by continuous or discontinuous motion, is an infinite source of energy that may be found anywhere. The purpose of this article is to highlight developments in three independent but closely connected multidisciplinary domains, starting with the piezoelectric materials and related manufacturing technologies related to the structure and specific application; the paper presents the state of the art of materials that possess the piezoelectric property, from classic inorganics such as PZT to lead-free materials, including biodegradable and biocompatible materials. These inherent properties of flexible piezoelectric harvesters make it possible to eliminate conventional batteries for lifetime extension of implantable and wearable IoTs. This paper describes the progress of piezoelectric perovskite material-based flexible energy harvesters for self-powered IoT devices for biomedical/wearable electronics over the last decade.

Keywords: Piezoelectricity, energy harvesters, device architectures, nanostructures, piezoelectric materials synthesis, flexible electronics.

1. Introduction

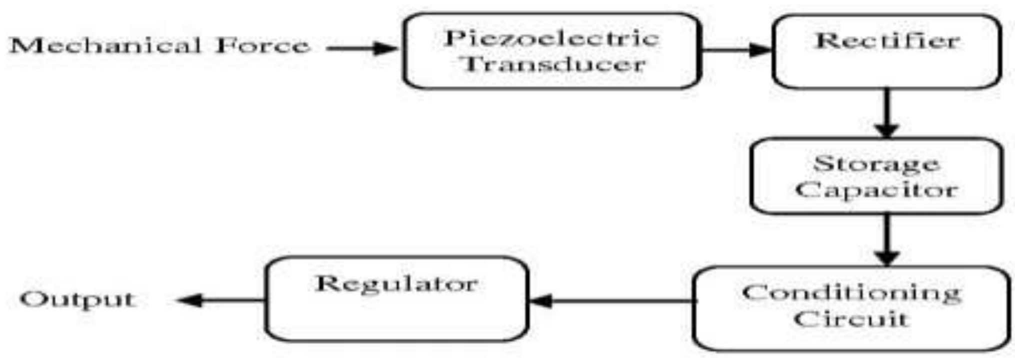
Advancement in information and energy technology has spurred growing interest in low-power and compact electronic devices, which are widely used in communication, structural health monitoring, healthcare, and positioning systems. Currently, Li-ion batteries are the dominant power source for these devices due to their availability, energy density, and effectiveness, but they have limited lifespan, require periodic replacement, and cause potential environ mental pollution. To address these limits, many research activities have been conducted to develop and apply energy harvesting technologies, advancing the utilization of ambient and sustainable energy sources, and supporting green development. Harvesting energy from various ambient sources, including wind, solar, ocean, thermal, and vibration energy, has gained significant interest as an alternative to conventional batteries for power supply. The techniques for energy harvesting are commonly classified into three categories: electromagnetic, electrostatic, and piezoelectric, and have been widely applied in various energy harvesting applications.

2.Problem Statement and Literature Review

It is the advancement of information and energy technology that has sparked interest in low power and miniaturized electronic devices that are utilized in communication, structural health monitoring, healthcare, and positioning systems. Presently, Li-ion batteries are the principal power suppliers to these devices due to their availability and efficacy energy density. however, they are associated with short life spans, require replacements and can cause environmental pollution. To counter these disadvantages, considerable evaluation has been devoted to integrating energy harvesting technologies into devices to utilize free and sustainable energy sources, thus providing a pathway for environmentally sustainable development. Of growing interest is energy harvesting from ambient sources, as a viable alternative the conventional batteries, to supply power to devices from wind, solar, ocean, thermal, and vibration energy. Methodologies for energy harvesting have been grouped into three major types and their variations; these are: electromagnetic, electrostatic and piezoelectric; their application is diverse. Therefore, the problem is to design and implement a mini piezoelectric energy harvesting system that can efficiently capture mechanical energy from sources like footsteps or vibrations and convert it into electrical energy, which can be stored and used to power small-scale electronic devices.

- **Pattipaka S. et al. (2022):** Reviews perovskite piezoelectric materials and flexible designs for wearable and implantable energy harvesters.
- **Brusa E. (2023):** Provides a broad overview of piezoelectric energy harvesting materials, device structures, and readout electronics.
- **He Q. et al. (2024):** Offers a comprehensive survey of fabrication methods, device architectures, and real-world applications of piezoelectric harvesters.
- **Xiao Y., Han Q., Wu N. (2025):** Focuses specifically on high-frequency piezoelectric energy harvesting mechanisms, structures, and performance.

3.Working Principle



Piezoelectric Effect: The project is based on the piezoelectric effect, where certain materials generate an electric charge when subjected to mechanical stress, vibration, or pressure.

Energy Conversion: When mechanical energy is applied to the piezoelectric material, it deforms slightly.

Rectification and Storage: The generated AC voltage is usually small and fluctuating, so it passes through a rectifier circuit (diodes) to convert it into DC voltage.

Utilization of Harvested Energy: The stored energy can power low-power devices such as LEDs, sensors, or small electronic gadgets.

4. Methodology

Mechanical Force – Energy starts when pressure or vibration (like footsteps) is applied.

Piezoelectric Transducer – Converts this mechanical force into electricity (AC voltage).

Rectifier – Changes the AC voltage into DC voltage.

Storage Capacitor – Stores the generated DC energy for later use.

Conditioning Circuit – Improves and stabilizes the stored energy.

Regulator – Keeps the output voltage constant.

Output – Provides steady power to small devices like LEDs or sensors.

5. Results and Discussions

Since this is a hardware-based energy harvesting project, the simulation is usually done using software like Proteus, Multisim, or MATLAB/Simulink. The simulation aims to verify the energy conversion process from mechanical to electrical energy and the storage functionality.

Simulation Steps:

1. Piezoelectric Sensor Model:
   - Simulate the piezoelectric material as an AC voltage source that produces a small alternating voltage when mechanical stress is applied.
2. Rectifier Circuit:
   - Connect a bridge rectifier to the AC source to convert AC to DC.
   - Observe the rectified DC voltage across a load or capacitor.
3. Energy Storage:
   - Connect a capacitor or rechargeable battery in simulation to store the rectified voltage.
   - Measure voltage across the capacitor over time to see the charging behavior.
4. Load Connection:
   - Attach a small load like an LED or resistor to check if stored energy can power it.
   - Observe LED blinking or resistor current to validate output.

5. Voltage Regulation (Optional):

   o If including a voltage regulator IC (e.g., 7805), check the stable DC output suitable for powering devices.

The results confirm that even a simple piezoelectric disc can effectively convert mechanical stress into electrical energy, but the harvested power remains limited by several factors. The high internal resistance of the piezo element reduces usable current output, meaning energy extraction is most efficient when coupled with proper rectification and impedance-matching circuits. Power output was found to depend strongly on vibration intensity and frequency; low-frequency manual tapping produced high voltage but very low current, while continuous moderate vibrations produced more stable energy generation. Although insufficient for powering large loads, the system demonstrates practical potential for **self-powered sensors, intermittent electronics, and small IoT devices** when energy is accumulated over time. This highlights piezoelectric harvesting as a viable low-maintenance energy source for applications where mechanical motion is naturally available.

6. Conclusion

Energy harvesting of ambient mechanical sources and human daily movement has gained lots of attention due to the increasing development of portable microelectronics. Energy harvesters exhibit great application potential in the field of medicine, monitoring, and entertainment such as smart watches, heart-beat monitoring and walking-step monitoring. In addition, mechanical energy is an abundant and clean source of energy in our daily life, which can be harvested independent of the time and location compared to solar and in some cases thermal energy. Therefore, a range of related research has been reported to investigate techniques to enhance the performance of energy harvesters. In this review, the development progress of piezoelectric energy harvesters was summarized. Various piezoelectric materials can be utilized to harvest energy from mechanical forces by fabricating into energy harvesters. Piezoelectric energy harvesting is a candidate technological approach for generating electricity from renewable sources. Its tremendous potential has been proved in a variety of applications, ranging from energy harvesting from vibration to wearable devices. New applications like charging portable electronic devices and low-power sensors are gaining popularity quickly. These applications have the potential to significantly affect daily living and energy efficiency. Advanced piezoelectric material research has cleared the road for more efficient and lightweight electronics. This review has focused on flexible piezoelectric film and composite energy harvesters that have been developed for self-powered implantable and wearable IoT applications. The flexible piezoelectric films and composites on plastic substrates can provide energy conversion of tiny mechanical movement of the human body into an electric signal, thus enabling utilization as high-performance flexible energy source for various implantable and wearable IoT applications.

Reference

- Zhu, G.; Ren, P.; Hu, J.; Yang, J.; Jia, Y.; Chen, Z.; Ren, F.; Gao, J. Flexible and Anisotropic Strain Sensors with the Asymmetrical Cross-Conducting Network for Versatile Bio-Mechanical Signal Recognition. ACS Appl. Mater. Interfaces 2021, 13, 44925–44934.
- F. Mokhtari, Z.X. Cheng, R. Raad, J.T. Xi, J. Foroughi, Piezo fibres to smart textiles: a review on recent advances and future outlook for wearable technology, J Mater Chem A 8(19) (2020) 9496-9522.
- Viet N V, Wu N and Wang Q2017 Areview on energy harvesting from ocean waves by piezoelectric technology J. Model. Mech. Mater. 1 20160161
- Li M, Luo A, Luo Wand Wang F2022 Recent progress on mechanical optimization of MEMS electret-based electrostatic vibration energy harvesters J. Microelectromechanical Syst. 31 726–40

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