# A Review Paper on Piezoelectric Energy Harvesting

*Sandeep Jain, Assistant Professor*

*Department of Electronics & Communication Engineering, Vivekananda Global University, Jaipur*

*Email Id-sandeep_jain@vgu.ac.in*

***ABSTRACT: Piezoelectric microelectromechanical systems (PiezoMEMS) make the production of self-contained microsystems of the next decade appealing. PiezoMEMS promises to remove expensive micro sensor-micro-systems assembly and have separate charging methods for batteries, while getting us closer to wireless systems and networks of battery-free sensors. A fully integrated energy harvester with a coin order of one quarter (diameter = 24.26 mm and thickness = 1.75 mm) can yield around 100 µW continuous to achieve practical application of this technology. Low-frequency environmental vibration power (below 100 Hz). This paper discusses the new state-of-the-art piezoelectric energy harvesting and summarizes key measurements such as the power density and bandwidth of recorded low-frequency input structures. This paper further outlines advances in piezoelectric materials and architectures of the resonator. In order to achieve much higher energy conversion efficiency epitaxial growth and grain texture of piezoelectric materials is being produced. The MEMS processes for these emerging materials groups are being studied for the production of lead-free, piezoelectric thin films in embedded health systems. Nonlinear resonance beams for broad bandwidth resonance are also tested, as they allow the energy harvesters to work high bandwidth and low frequency. The techniques of spraying on particles/granules are being matured to achieve meso-scale structures in a quick manner, such as aerosol deposition (AD) and granulum spray in vacuum (GSV). A power distribution circuit, which is another critical aspect of an energy harvester. To this end, the dissipation of minimum power is key to an energy harvester's small-scale power control circuit, requiring special circuit design techniques and a basic optimum power point traction. Overall, research and technological advancement took the science of energy harvesting closer in the near future to the practical applications.***

***KEYWORDS: Aerosol Deposition (AD), Energy Harvesting, Electromechanical Coupling, Granule Spray in Vacuum (GSV), MEMS, Piezoelectric.***

## INTRODUCTION

The big decreased sensors and CMOS circuits in size and power consumption has led to a concentrated investigation into internal power sources that are capable of replacing batteries or recharging them. Batteries became concerned that they had to be paid before they were used. Similarly, in distributed networks, the sensors and data acquisition elements involve centralized energy sources. In such systems, for example, battery charging, battery repair operations or geographically unavailable temperature and moisture sensors may be costly or perhaps unworkable. It can be troublesome and expensive to have to swap batteries in the large sensor network. In risky, rugged and wide terrain deployment the substitute is virtually impossible. Another example is built-in urban battlegroup sensor networks. Logically, the priority was on building on-site generators which can convert any energy in such cases (Priya and Inman 2009). Recent advancements in low power VLSI architecture have made ultra-small integrated circuits feasible, which only work 10 nW to 100's Power µW [1]–[3].

This scaling pattern opened the door to solutions for the collection of energy in the chip, removing the need for chemical batteries or complicated wires for microsensors and thus providing the basis for autonomous battery-less sensors and network systems. The use of parasites is an alternative to using a traditional battery as a power source. The orientation of applied stress relative to the polar axis influences the energy harvesting capability of piezoelectric materials for energy harvesting. The polar axis is a line that runs from north to south. Other directions at right angles to the polar axis are designated as “3” directions. The orientation of the axis is indicated by the letter "1." The direction of applied stress may be changed. Be either parallel to the polar axis, i.e. 3-direction, or perpendicular to it, i.e. 1-direction. The resultant setups are 33-mode and 31-mode, respectively. These are the two most prevalent piezoelectric energy modes. The tension that was applied and the voltage that was produced are in the same direction in 33-mode, while tension is delivered in 31-mode The voltage is acquired in a perpendicular direction, rather than in an axial direction. The piezoelectric material's open circuit voltage, Voc, is computed as follows. It is the relative dielectric constant, and d is the distance between the top and bottom electrodes.0 is the permittivity, and 0 is the constant. The method of operation has an impact on the output from a piezoelectric piezoelectric piezoelectric piezo The 33-mode produces a greater voltage output, while the 32-mode produces a lower voltage output. In terms of high current output, the 31-mode is better. Energy in the atmosphere accessible locally. Modern equipment, the movements of human beings, automobiles, buildings and environmental sources generate wasted energy, which may be an excellent outlet for limited electricity capturing without impacting the source. The fundamental theory of a piezoelectric energy harvester based on cantilevers is explained by taking into consideration the energy transfer between various realms in phases I and II. Ambient vibration injects energy into the organ at any cycle through the foundation arousal [4].

This energy is translated into kinetic mass energy and into theoretically energy that is retained as the mechanical strain of the laser. Part of the elastic energy contained in the beam is translated into electricity as an induced load onto the piezoelectric layer that is stored on the beam. The fundamental theory of a piezoelectric energy harvester based on cantilevers is explained by taking into consideration the energy transfer between various realms in phases I and II. Ambient vibration injects energy into the organ at any cycle through the foundation arousal. This energy is translated into kinetic mass energy and into theoretically energy that is retained as the mechanical strain of the laser. Part of the elastic energy contained in the beam is translated into electricity as an induced load onto the piezoelectric layer that is stored on the beam. Piezoelectric power harvesters typically have beam systems of bimorphic or unimorphic. However, with current microfabrication methods, bimorphic cantilevers are less producible at MEMS- scale. This contributes to a broader unimorphic structure of MEMS cantilevers. The resonant frequency is generally equipped with a seismic mass at the tip of the cantilever to the usable atmospheric frequency, typically below 100 Hz.

To transform the output of AC voltage into DC, piezoelectric generators require correction. A full bride rectifier can effectively be integrated with passive diodes, but decreased front diode voltage can contribute to considerable powerloss. Active or synchronous rectifiers minimize passive diode errors. In sufficient intervals, the active corrector flips on or off MOSFET to efficiently rectify the voltage e. g. The disparity between drain and source voltage is slight at the zero-point crossing, creating an operational mistake. MEMS harvesters are usually independently tested for electrical testings after a diced wafer has been singled out. The MEMS system must be packed or temporarily connected without disruption to a special carrier wafer. Ron et al. implemented a new concept of wafer level checking before packaging and simulation. Because certain materials, such as ferroelectrics, have a crystal structure without a center of symmetry, they experience polarization changes when exposed to mechanical deformation (strain). Piezoelectric materials are active materials that produce electricity when mechanical stresses are applied to them. The kind of material used in piezoelectric energy harvesting has a big impact on how well it works. As a result, a broad variety of materials have been explored for piezoelectric energy harvesting, including inorganic, organic, and composite materials.

Large dielectric and piezoelectric coefficients, electromechanical coupling factors, and high energy conversion rates are all characteristics of piezoceramics. They are, however, very fragile and cannot withstand high stresses without being destroyed. Piezopolymers, on the other hand, have a low electromechanical coupling factor but are very flexible .Piezoelectric composites are another kind of material that combines the advantages of ceramics with the properties of polymers to meet the needs of particular applications. The crystal structure of piezoelectric materials utilized in energy harvesting is wurtzite or perovskite. The piezoelectric performance of materials having a perovskite structure is usually better than that of those with a wurtzite structure. On materials having the perovskite structure, however, an extra poling step is needed to produce piezoelectricity. Piezoelectric generators are usually made by sandwiching prepared piezoelectric materials between elastomeric substrates to provide the generator the necessary flexibility while also protecting the piezoelectric layer from external influences like dampness. The top and bottom electrodes are linked to collect and transmit the produced electric charge to the external load. The piezoelectric strain constant "d" induced polarization per unit stress applied, the voltage constant "g" induced electric field per unit stress applied, the electromechanical coupling factor k; square root of the mechanical-electrical energy conversion efficiency, and the mechanical quality factor "Q" the degree of dampedness are all important properties of piezoelectric materials for energy harvesting applications. Inorganic piezoelectric materials generally have considerably higher values of d, k, and than piezoelectric polymers. The g constants of polymers are greater because their dielectric constants are considerably lower than those of inorganic materials.

With a high charge coefficient (d33), piezoelectric voltage coefficient (g33), dielectric constant, electromechanical coupling coefficient (kp), charge sensitivity, and energy density, PZT ceramics offer excellent piezoelectric. A broad variety of soft (PZT-5H), semihard (PZT-4), and hard (PZT-8) PZT materials have been produced for various purposes by adjusting zirconia (Zr) composition and adding doping acceptor (Mn) and donor (Nb) ions. The amount of Zr in PZTs affects whether the crystal symmetry is tetragonal or rhombohedral, and PZTs produced with a composition around the MPB of these two phases have the best piezoelectric properties owing to simple dipole reorientation. Flynn and Sander placed basic constraints on PZT materials, indicating that in typical PZT materials, the mechanical stress limit is the effective restriction. For PZT-5H, they observed a mechanical stress-limited work cycle of 330 W/cm3 at 100 kHz. Various compositions of PZT-based piezoelectric materials (d33 = 300–1000 pC/N) as well as other substitute materials have been investigated in order to obtain better piezoelectric coefficients. created a high-performance piezoelectric generator based on PZTs. Bulk PZT thick films were bonded and thinned on two sides of a flexible thin beryllium bronze substrate (50 m), and a tungsten proof mass was put on the cantilever beam's tip end.

The top PZT layer and bottom PZT layer thicknesses were decreased to 53 m and 76 m, respectively. The resulting device has an effective volume of 30.6 mm3. At an excitation force of 3.5g at a frequency of 77.2 Hz, the maximum output voltage, power, and power density of 53.1 V, 0.98 mW, and 32 mW/cm3 were obtained, respectively. At 3.0g acceleration, the generator was powerful enough to illuminate twenty-one serial LEDs at resonance. Lead, as is widely known, is a hazardous substance that may damage both the environment and the human body. As a result, governments have placed restrictions on its usage in the production of numerous goods. As a result, researchers have focused their efforts on developing high-performance lead-free piezoelectric materials, resulting in the development of a slew of new piezoceramics, the most notable of which are potassium sodium niobate and sodium bismuth titanate (Bi0.5Na0.5)TiO3, abbreviated as BNT. looked into the piezoelectric performance of lead-free (1 x) BNT–xBT ceramics sintered at 1100–1200 degrees Celsius. According to the equation E = (1/2) CV2, BT has a high dielectric permittivity and high power capability. Grain development and densification, as well as piezoelectric characteristics, were enhanced by increasing both the BT content and the sintering temperature. At x = 0.04, the (1 x)BNT–xBT ceramic had a piezoelectric voltage coefficient of 47.03 10 3 Vm/N, which was favorable.

## DISCUSSION

Piezoelectricity is the property of certain crystals to produce an electric power for mechanical stress. There are two commonly found types of phenomenon called direct and the Piezoelectric results to converse. When a piezo-electric material has a mechanical stress, an electric charge is generated proportionate to the applied stress. The direct piezoelectric effect is related to here. Instead, the strain or displacement is generated proportionally with the magnitudes of the electric field as electric field is applied to the same substance. This is known as a piezoelectric reversal reaction[5]–[10]. Piezoelectricity is the property of certain crystals to produce an electric power for mechanical stress. There are two commonly found types of phenomenon called direct and the Piezoelectric results to converse. When a piezo-electric material has a mechanical stress, an electric charge is generated proportionate to the applied stress. The direct piezoelectric effect is related to here.

Due to recent developments of portable and wearable electronics, wireless electronic 18 systems, implantable medical devices, energy-autonomous systems, monitoring systems, 19 and MEMS/NEMS-based devices, the procedure of small-scale generation of energy 20 may lead to a revolution in development of compact power technologies. 21 Figure 1 presents the output power density variation versus the actual motor power 22 for 2000 commercial electromagnetic motors. Electromagnetic motors are superior for 23 the production of power levels higher than 100 W. However, because the efficiency 24 is significantly dropped below 100 W, the piezoelectric devices with power density 25 insensitive to their size will replace battery-operated small portable electronic equipment 26 less than 50 W level. It is not logical to compare the energy harvesting systems with 27 the MW power level. Hence, it is necessary for researchers to determine their original 28 piezo-harvesting target, which should be basically the replacement of compact batteries, 29 one of the toxic wastes in the sustainable society [1]. 30 Dutoit et al. [2] provided a comparison based on the density of the output power, 31 and indicated that the power densities of the fixed-energy density sources extensively 32 drop after just 1 year of operation. So, they need maintenance and repair if possible. 33 Designing an effective power normalization scheme, strain cancelation due to multiple 34 input vibration components, optimizing the minimum vibration level required for 35 positive energy harvesting, and the prototype testing to eliminate the proof mass are 36 among the suggestions as future works.

Piezo-materials can extract power directly from structural vibrations or other en45 vironmental mechanical waste energy sources in infrastructures (bridges, buildings), 46 biomedical systems, health care and medicine, and they can be used for transducers, 47 actuators, and surface acoustic wave device operation. Some disadvantages of the piezo48 harvesters are high output impedance, producing relatively high output voltages at low 49 electrical current, and rather large mechanical impedance. 50 The number of review papers on piezoelectric energy harvesting has been exten51 sively increased in the recent decade. Due to the tremendous number of published 52 review papers in this field, finding an appropriate review paper became challenging. 53 On the other hand, there are lots of overlaps, similarities, missing parts, and sometimes 54 contradictions between different reviews. Therefore, the main motivation of the present 55 paper is to present a systematic review of the review papers on piezoelectric energy 56 harvesting. We tried to summarize all deficits, advantages, and missing parts of the 57 existing review papers on piezo-energy harvesting systems. 58 An extensive search among database sources identified 91 review papers in diverse 59 applications related to the piezoelectric energy harvesting. As will be demonstrated later, 60 such papers have presented different concluding remarks for the area of usage, materials, 61 design approaches, and mathematical models. We tried to perform a very detailed 62 searching procedure with several keywords and search engines to cover all published 63 review papers, and to find the review papers without "piezo" directly mentioned in the 64 title. 65 The statistics of publications during two recent decades excluding conference 66 papers, extracted using the keyword "piezo AND energy harvesting" from SCOPUS 67 are shown in Fig. 2. The results from SCOPUS included the overall number of 4435 68 documents, containing 874 open access papers, 130 book chapters, and 36 books. The 69 national natural science foundation of China, the fundamental research funds for the 70 central universities, and the national research foundation of Korea were the most frequent 71 funding sponsors. Most common subject areas were engineering, material sciences, 72 physics and astronomy, chemistry, and energy. An extrapolation shown in the figure 73 anticipates publication of about 2500 articles per year during the coming three years.

## CONCLUSION

MEMS piezoelectric energy harvester test ~mm3 can build battery-free systems and networks of independent sensors if 10 to 100 μW of power can be consistently, robustly and cheaply collected from ambient vibration. The key features that make a good MEMS power harvester piezoelectric are its compactness, power output voltage, power output (density) bandwidth and operating frequency, amplitude, lifetime and expense. Input vibration amplitude. The two main obstacles that technology today faces include higher power density and broader resonance bandwidth. And if optical sensors are commonly used, the downside is certain. Sensitivity to outside illumination is one of the drawbacks. Another difficulty is when driving in the night or in the underground parking in the tube. For that, as the car comes out from tunnels or underground car parks, often devices always turn the wiper on. Another weakness, maybe a big one, is the comparatively small portion of the windshield in the sensing region. The device therefore only works for a small region. If raindrops are present on the driver's line, but not on the sensing field, the wiper device cannot be triggered. Non-linear resonators make harvesting electrical energy from the beam very promising that will draw nearer to autonomous battery-free systems and networks with recent developments on piezoelectric materials and harvester structural structures, whether individually or in combination. We are waiting for this coin-size harvester in the near future will harvest a continuous capacity of approximately 100μW below 100 Hz at a rate of less than 0.5 g at an inexpensive cost.

**REFERENCES**

[1] K. Uchino, “Piezoelectric Energy Harvesting Systems—Essentials to Successful Developments,” *Energy Technology*. 2018, doi: 10.1002/ente.201700785.

[2] R. Caliò *et al.*, “Piezoelectric energy harvesting solutions,” *Sensors (Switzerland)*. 2014, doi: 10.3390/s140304755.

[3] M. G. Kang, W. S. Jung, C. Y. Kang, and S. J. Yoon, “Recent progress on PZT based piezoelectric energy harvesting technologies,” *Actuators*. 2016, doi: 10.3390/act5010005.

[4] D. Grzybek and P. Micek, “Experimental investigation on the piezoelectric energy harvester as a self-powered vibration sensor,” *J. Theor. Appl. Mech.*, 2018, doi: 10.15632/jtam-pl.56.3.687.

[5] A. C. Ahn and A. J. Grodzinsky, “Relevance of collagen piezoelectricity to ‘Wolff’s Law’: A critical review,” *Medical Engineering and Physics*. 2009, doi: 10.1016/j.medengphy.2009.02.006.

[6] M. T. Ong and E. J. Reed, “Engineered piezoelectricity in graphene,” *ACS Nano*, 2012, doi: 10.1021/nn204198g.

[7] J. H. Lee *et al.*, “Reliable Piezoelectricity in Bilayer WSe2 for Piezoelectric Nanogenerators,” *Adv. Mater.*, 2017, doi: 10.1002/adma.201606667.

[8] H. Zhu *et al.*, “Observation of piezoelectricity in free-standing monolayer MoS2,” *Nat. Nanotechnol.*, 2015, doi: 10.1038/nnano.2014.309.

[9] F. Xue *et al.*, “Multidirection Piezoelectricity in Mono- and Multilayered Hexagonal α-In2Se3,” *ACS Nano*, 2018, doi: 10.1021/acsnano.8b02152.

[10] P. Yu *et al.*, “Bone-inspired spatially specific piezoelectricity induces bone regeneration,” *Theranostics*, 2017, doi: 10.7150/THNO.19748.