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Research paper

Design and analysis of energy harvester using MEMS based Cantilever with variable perforations

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Abstract

This paper represents the design and analysis of energy harvester using MEMS based cantilever with PMN-PT single crystal properties which has excellent piezoelectric properties while compared to other piezoelectric materials like PZT thick film. The design is analysed using COMSOL multi physics which is used for many MEMS operations and also problems related to physics with many mathematical calculations with better efficiency and ease to design. We designed a cantilever with PMN-PT properties which has good coupling coefficient and increased perforations in number in form of square and circular. We tested the displacement sensitivity i.e., the variation of displacement at different eigen frequencies with increase in number of perforations. We observe output voltage by designing electromechanical analysis and variation in output capacitance of 2 .41 x 10-22 Farads is observed.

1. Introduction To MEMS

Micro electro mechanical systems (MEMS) are frameworks that consolidate mechanical and electrical parts. It was made utilizing integrated circuit (IC) batch preparing procedures. Its size range is from a couple of micrometers to millimeters. These gadgets can distinguish, control and follow up on the micro scale and produce impacts at the macro scale.
The MEMS territory utilizes involvement in configuration, designing and assembling of a wide and differing scope of specialized regions that incorporate coordinated circuit creation innovation, mechanical building, materials science, electrical designing, and so on. MEMS can be found in frameworks that cover different divisions: car, restorative, electronic, correspondence and guard applications. Despite the phrasing, the coupling component of a MEMS gadget is standing out it is made. While electronic gadgets are produced utilizing IC 'PC chip' innovation, the small scale mechanical segments are fabricated by refined controls of silicon and different substrates utilizing smaller scale machining procedures, for example, surface micro mechanization and extensive volume, and in addition high-proportion micromachining. Viewpoint (HARM) specifically expel parts of the silicon or add extra auxiliary layer to shape the mechanical and electromechanical segments. While incorporated circuits are intended to abuse the electrical properties of silicon, MEMS exploits the mechanical properties of silicon or its electrical and mechanical properties.
The MEMS application has made it an empowering innovation for new biomedical applications and remote interchanges made out of optical frameworks, otherwise called micro electro mechanical frameworks, and radiofrequency (RF) MEMS.
One of the earliest applications of ambient power collected from ambient electromagnetic radiation (EMR) is the crystal radio.
The principles of energy harvesting from ambient EMR can be demonstrated with basic components are shown in Figure1.

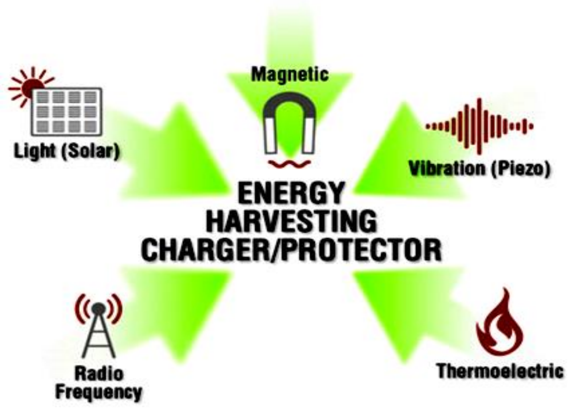

Fig. 1: Basic structure of Energy harvester

2. Literature review

G. Tang et.al, proposed a vitality reaper that low level vibration vitality is changed over into electrical vitality. The PMN-PT precious stone has a higher coupling and electromechanical coefficient. It can enhance the effectiveness of the power producing gadget and comprise of cantilevered pillar and Ni-evidence mass. UV-LIGA innovation utilized for assembling. [1].

Fung,H et.al., Proposed a MEMS sensor The encompassing vibration vitality is changed over into piezo electric power. It additionally produced cantilever and a mass of Ni metal was conceived. In these systems, for example, sol-gel, dry synthetic drawing RIE, wet compound scratching.[2]
Lee, B.S et.al., has built up a piezoelectric MEMS, these two piezoelectric MEMS generators are cantilever write produced by a silicon procedure and can change over mechanical vitality into electric power go through PZT piezoelectric layers.[3]
LU, M.P et,al., has built up the MEMS vitality collector, the phosphorous Zno nano wires deliver positive yield voltage beats when filtered with a conductive nuclear power magnifying instrument in contact mode. The yield voltage beat happens when the tlp interacts with the streached side (positive piezo potential side) of the nano wire. The Z-type N-type link produces positive yield voltages and is filtered by the AFM tip..[4]
Marzencki, M et.al., The ecological vibration vitality is a broad framework to control remote sensor hubs. It utilizes a MEMS generator and an ASIC framework in a bundle with every one of the segments fabricated totally utilizing the miniaturized scale producing systems. The piezoelectric impact is performed by electromechanical thin movies of aluminum nitride. The outcomes revealed demonstrate the likelihood of low sufficiency signals conveyed by the generator to charge a capacity capacitor. [5]
Sun, C., et.al., The vitality reaper can be utilized as an individual vitality source to control miniaturized scale sensors and electronic items. The execution of the power trim for a cantilevered aluminum compound plate was computed with a PMN-PT gadget stuck close to the settled end and a test mass at the opposite end. The reverberation attributes and the power age limit of the gadgets were examined.[6]
Mathers, A et.al., have proposed the MEMS-based vitality collector with PMN-PT vibration-based vitality reaping. A polydimethylsiloxane-confirmation mass (PDMS) is bulbous at the tip of the composite cantilever bar and is utilized as MEMS to build up the normal recurrence. A dynamic frameworks displaying approach is utilized to investigate the reactions and execution of the consolidate plan; the power thickness forecast of the proposed outline of the join demonstrates a higher yield than that of the other piezoelectric reaper announced. [7].
S. Muensit et.al., have introduced the investigation of the execution of PMN-PT and PZN-PT monocrystals and piezo-cantilever actuators in view of PZT materials. The broke down execution alludes to the blocking power and the uprooting of the tip, and for this reason investigative constitutive articulations and FEM reproductions were utilized. [8].
Niell G Elvin et.al., They have presented a self-controlled technique for recognizing and conveying the mechanical vitality of an auxiliary framework. Vitality is created just from the transformation of mechanical voltage vitality into electrical vitality, which is then used to control a remote connect to a beneficiary and an information handling unit. [9].
Huicong Liu et.al., They have shown the plan, fabricate and portrayal of a MEMS-based piezoelectric EH gadget that works at a genuinely low reverberation recurrence with a broadband working reach. In this plan, a Si test mass is coordinated with the piezoelectric bar to play out a reverberation recurrence as low as 36 Hz [10].
L. M. Miller et.al., They have produced a minimal effort piezoelectric MEMS vitality gatherer and a thick-film electrochemical microcapacitor has been mechanically incorporated into a similar substrate by pneumatic apportioning printing. A similar printing framework is equipped for storing extra mass in the cantilever tip, giving a technique to accomplish an ease reverberation tuning [11].
Jong C. Park et.al., have exhibited a piezoelectric MEMS vitality collector that was gone for gathering vitality from low level natural vibration. It was ideally planned with multilayer cantilever structure with Si test ground to alter the reverberation recurrence and lessen the spring consistent. [12].
Robert W. Reger have worked with MEMS full amplifiers in light of piezoelectric AIN that were produced to make uninvolved acoustic channels. The piezoelectric receivers don't expect energy to work and are proposed to be utilized as a part of an almost zero power reactivation framework that consolidates the talked about gadget with low power CMOS circuits. [13].
Salem Saadon et.al., have proposed a sensor of mems with viable power, the current and the voltage of the composed reaper rely upon the arrangement of the layers of the cantilever and in addition the thickness of the help layer, gave that this thickness is more prominent than the thickness of the PZT [14].
Hyun-Cheol Song et.al., They have demonstrated the manufacture of the MEMS spiral energy harvester with ultra low frequency resonance and high power density. PZT film with a thickness of 1.8 microns was deposited on a SOI platinized wafer that exhibits a high crystalline quality and good piezoelectric properties [15].

3. Design methodology

The proposed work is done using Piezoelectric materials. it has a higher coupling coefficient and electromechanical coefficient. It converts mechanical vibration energy into electrical energy has been explored through different piezoelectric materials and structures using the platform of MEMS.
Piezoelectric MEMS energy harvester with PMN-PT cantilever has been designed using COMSOL Multiphysics. The coupling coefficient plays an crucial role in energy harvesters. In MEMS energy harvesters various piezoelectric materials has been deployed widely such as PZT thin film or thick film, AIN thin film and ZnO thin film. Our proposed work is designed using piezoelectric material PMN-PT which has excellent and outstanding piezoelectric properties when compared other piezoelectric materials.
Since it is a cantilever we fixed a constraint and after computing we observed displacement with respect to its eigen frequencies.

4. Results and discussions

Figure 2 shows the cantilever with material PMN-PT.
To increase the sensitivity of the cantilever some perforations of square and circle are made at the movable end of the cantilever and Eigen frequency versus displacement analysis is done as shown in figure 3(a) Square perforations on cantilever at free end and 3(b). Circular perforations. To get the more sensitivity the number of perforation are increased and Eigen frequency versus displacement analysis is done as shown in figure 4(a), 4(b) and 5(a) , 5(b).

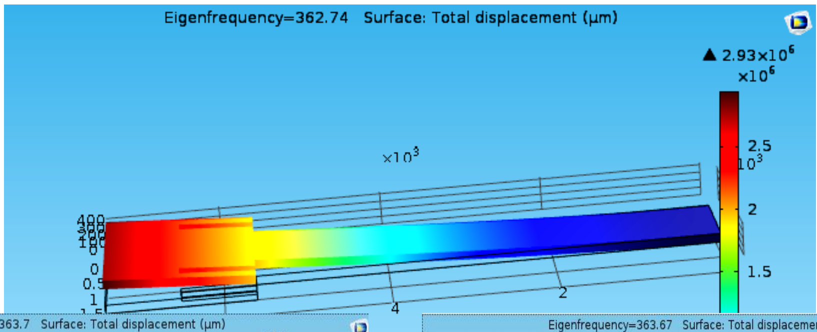

Fig. 2: Cantilever with material PMN-PT

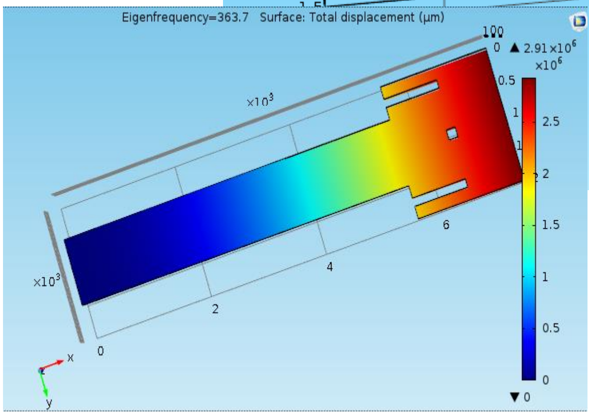

Fig. 3(a): Square perforations on cantilever at free end

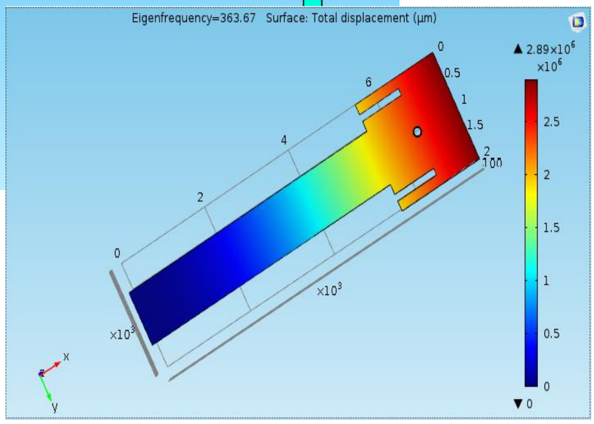

Fig.3(b): circular perforations on cantilever at free end

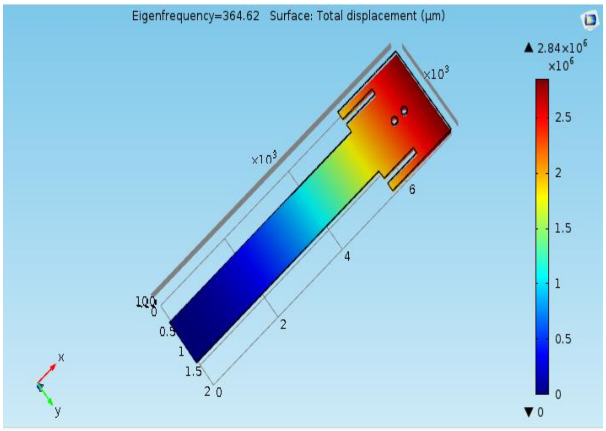

Fig. 4(a): Two Square perforations on cantilever at free end

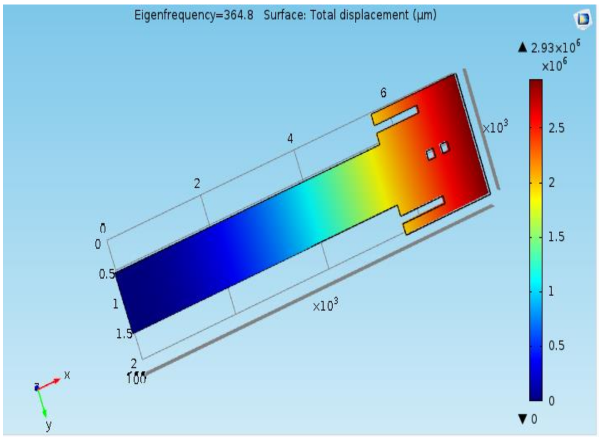

Fig.4(b): Two circular perforations on cantilever at free end

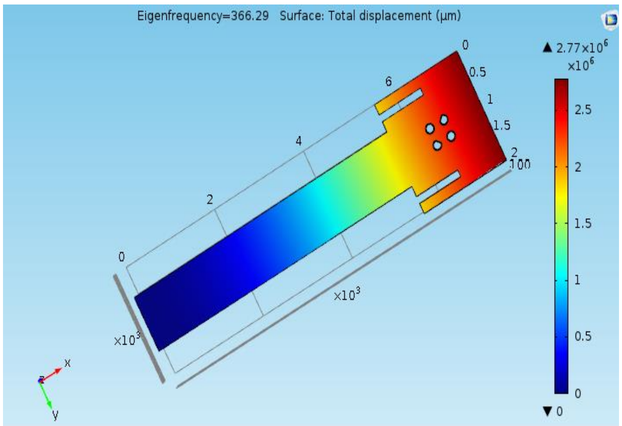

Fig. 5(a): Four Square perforations on cantilever at free end

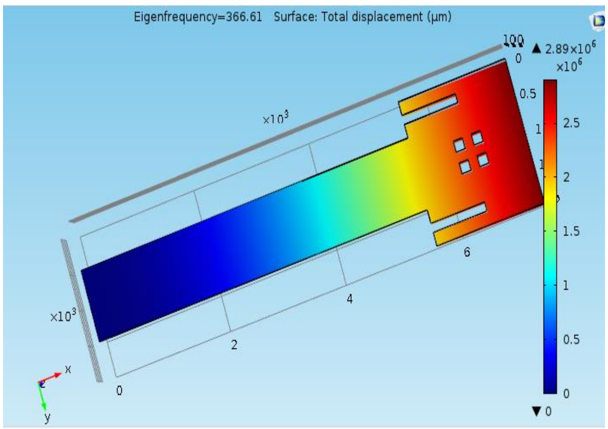

Fig.5(b): Four circular perforations on cantilever at free end

Table 1: shows the variation of Displacement with variation in Eigen Frequency for different types of perforationsand their displacement sensitivities(In table A- Eigen Frequency and B- Displacement)

Type of Perforation	No Perforations		1 Perforation		2 Perforation		4 Perforation	
	A	B	A	B	A	B	A	B
Square Perforation	362.74	2.93 X106	363.7	2.91 X106	364.8	2.93 X106	366.61	2.89 X106
	2658.7	2.87 X106	2659.1	2.86 X106	2661.3	2.86 X106	2660.2	2.86 X106
	3197.1	4.16 X106	3196.1	4.15 X106	3195.8	4.19 X106	3194.8	4.16 X106
	3215.4	2.94 X106	3223.6	2.92 X106	3233.1	2.94 X106	3248.7	2.9 X106
	7542.5	3.66 X106	7534.3	3.69 X106	7534.5	3.68 X106	7507.6	3.76 X106
	13831	7.01 X106	13792	7.04 X106	13777	7 X106	13670	7.09 X106
Circular Perforation	362.74	2.93 X106	363.67	2.89 X106	364.62	2.84 X106	366.29	2.77 X106
	2658.7	2.87 X106	2659.1	2.89 X106	2661.1	2.9 X106	2660.2	2.96 X106
	3197.1	4.16 X106	3196	4.2 X106	3195.9	4.3 X106	3195.2	4.36 X106
	3215.4	2.94 X106	3223.4	2.9 X106	3231.6	2.85 X106	3246.1	2.78 X106
	7542.5	3.66 X106	7534.3	3.73 X106	7534.9	3.77 X106	7511	3.94 X106
	13831	7.01 X106	13784	7.14 X106	13778	7.24 X106	13680	7.42 X106

Figure 6 shows the variation of Displacement with variation in Eigen Frequency for different types of perforations.

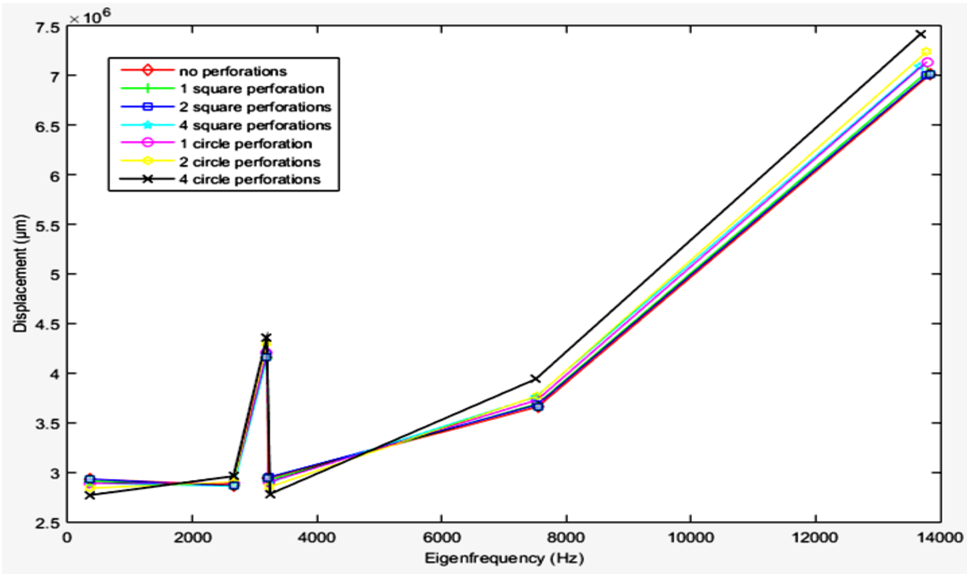

Fig. 6: variation of Displacement with variation in Eigen Frequency for different types of perforations.

From the graph it is clear that the cantilever with four perforations of circular shape shows more displacement sensitivity than all the proposed structures.

To observe the output voltage the structure is applied a electromechanical analysis and the variations in the output capacitance of 2.41 x 10-22 Farads is shown in Figure7.

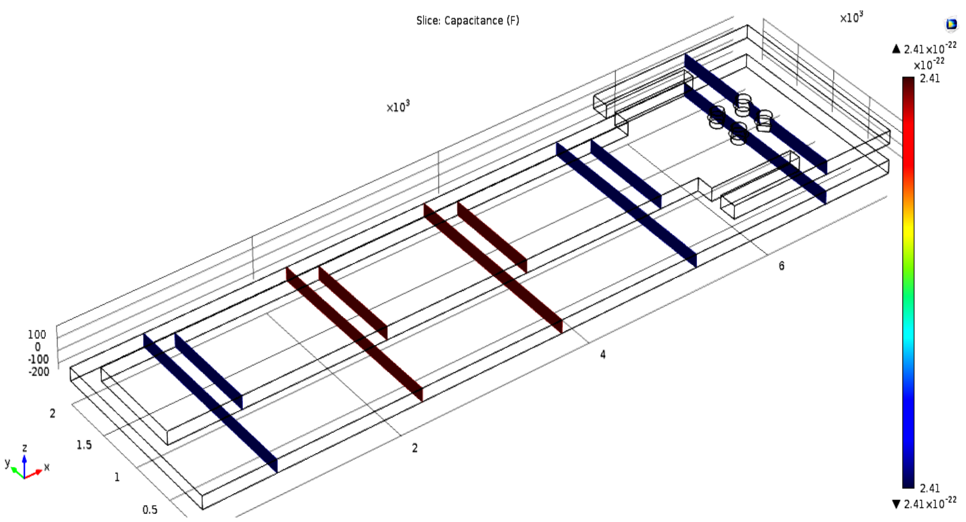

Fig. 7: Output capacitance 2.41 x 10-22 Farads

5. Conclusion

In this work a new and more sensitive model of cantilever based energy harvester is proposed in which the number of perforations is increased with a shape of circular and square. from the results the circular perforations shows more displacement sensitivity than the square type of perforations. On application of voltage a capacitance of 2,41 x 10-22 Farads is obtained.

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