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Comparative Analysis of Rectangular and Circular Piezoelectric Sensor for Pressure-Based Energy Generation

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Introduction

- Advances in automation have miniaturized sensors and devices, many relying on batteries for operation.
- Batteries require periodic replacement or recharging, impractical in harsh or inaccessible locations, and pose environmental risks due to toxic materials.
- Harvesting ambient mechanical energy, such as vibrations, force, stress, and pressure, provides a sustainable alternative to traditional batteries.
- Piezoelectric pressure sensors operate based on the piezoelectric effect, where certain materials generate an electrical charge when subjected to mechanical stress.
- This direct conversion of pressure to electrical signals makes them efficient for accurate measurements.
- Lead-based piezoelectric materials are efficient but environmentally hazardous but lead is toxic and hazardous to the environment.
- Lead-free alternatives like zinc oxide (ZnO) and polyvinylidene fluoride (PVDF) are ideal for pressure-based energy applications.

Objectives

- Design and study piezoelectric pressure energy harvester.
- Compare sensor output for rectangular and circular patch.
- Evaluate performance for two different materials: PVDF and ZnO.
- Identify the optimum geometry and material based on output voltage generation.

Methodology

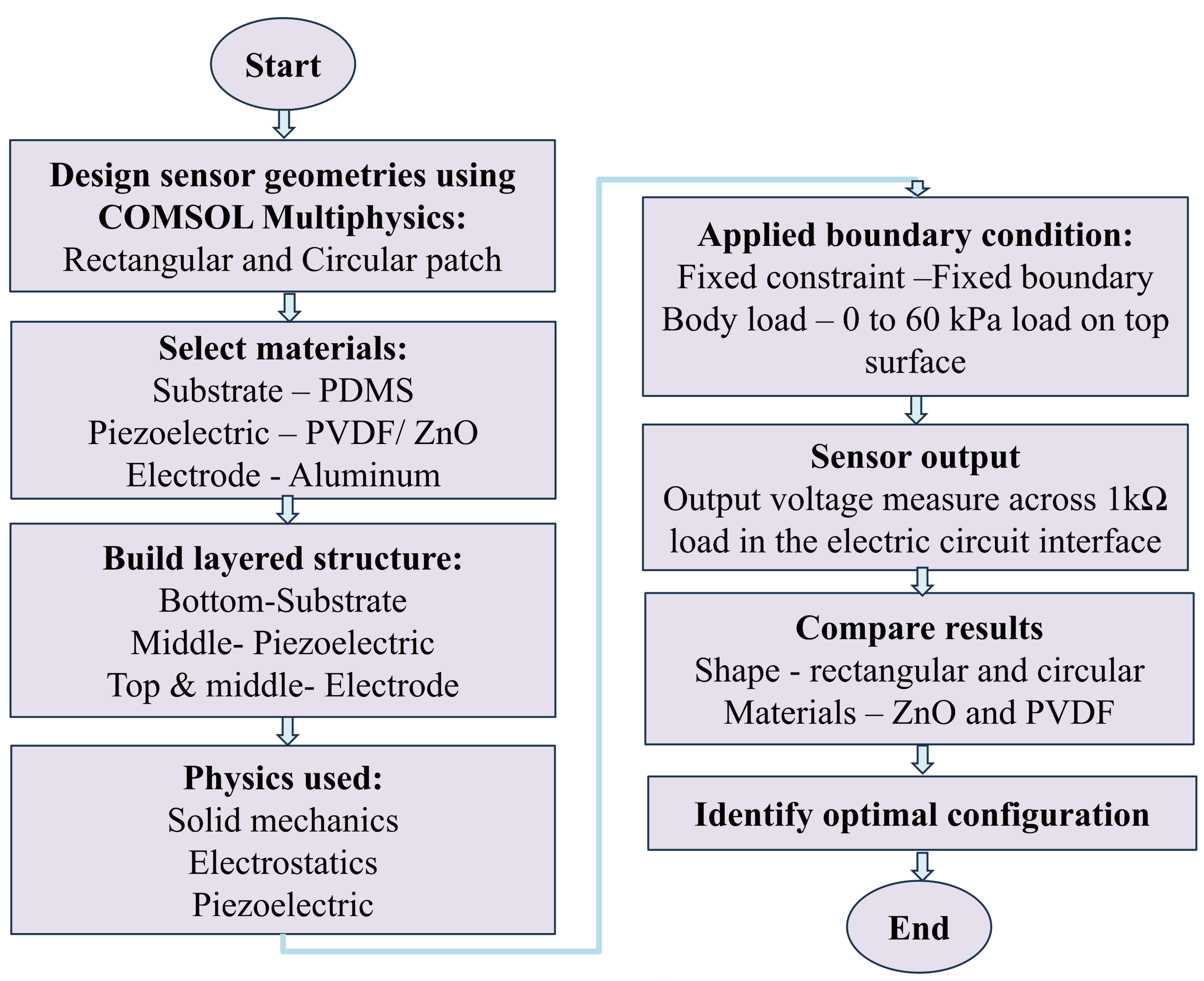


Figure 1: Flowchart of the work.

Sensor design

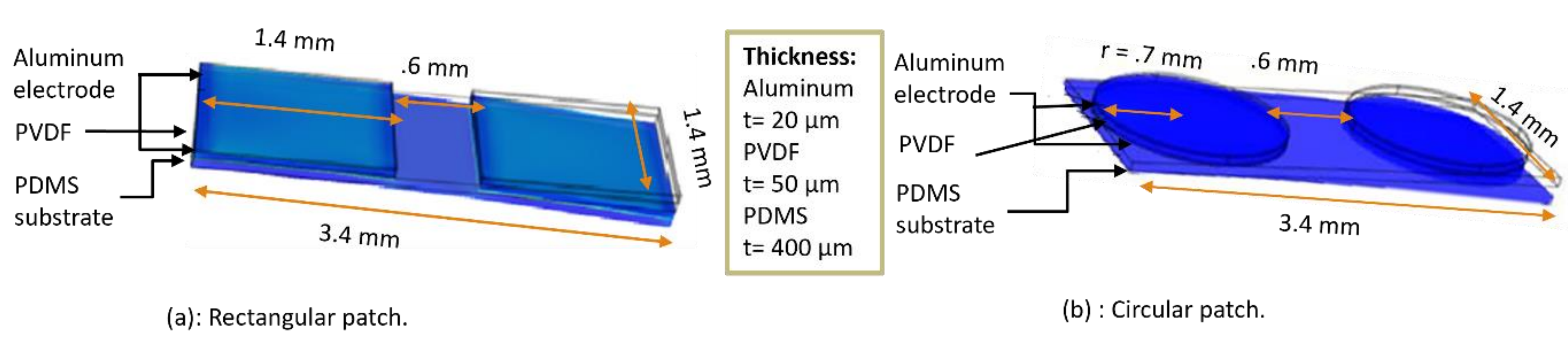
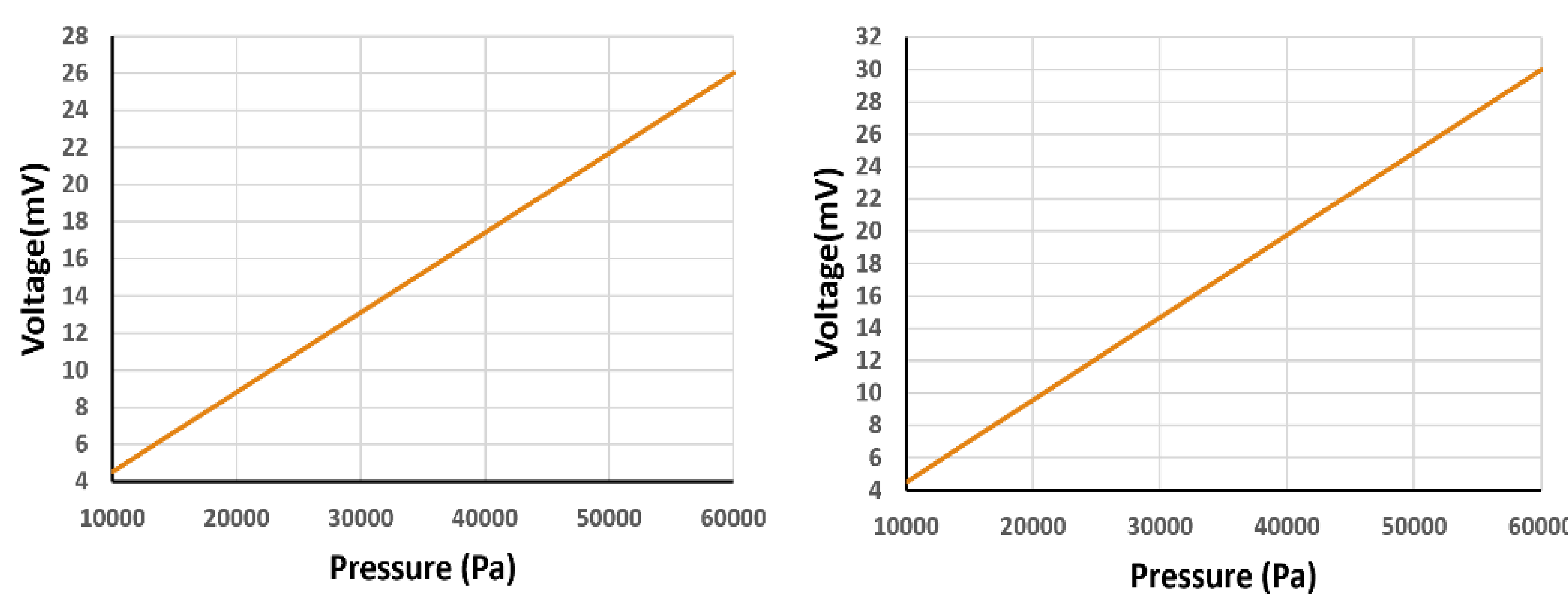


Figure 2: The piezoelectric sensor designed (a) Rectangular patches and (b) Circular patches.

Results and Discussions

At applied pressure of 0 to 60 kPa



(a): Rectangular patch (PVDF).

(b): Circular patch (PVDF).

Figure 3: The piezoelectric output voltage obtained from the sensor (a) Rectangular patches and (b) Circular patches.

Table 1: The output voltage measured across a 1kΩ load.

Model	Output voltage(mV) For PVDF	Output voltage(mV) For ZnO
Rectangular patch	26	40
Circular patch	30	47

Conclusions

- The study highlights the importance of geometry and material selection in optimizing the performance of piezoelectric sensors.
- Comparative analysis reveals that the shape of the sensor patch significantly influences the output voltage. For PVDF as the piezoelectric material, the circular patch sensor demonstrates superior performance, generating a maximum output voltage of 30 mV compared to the 26 mV produced by the rectangular patch sensor.
- Similarly, when ZnO is used as the piezoelectric material, it exhibits higher output voltage than PVDF, with the rectangular and circular patch sensors generating 40 mV and 47 mV, respectively.
- Among all configurations, the circular patch sensor employing ZnO as the piezoelectric material achieves the highest output voltage of 47 mV, establishing it as the better design for maximizing sensor performance.

Future Scope

- Future research can focus on advanced materials, innovative geometries, and multifunctional designs to enhance sensor performance.
- Applications in wearable electronics, IoT systems, and self-powered devices offer promising directions.
- Real-world application testing for practical implementation.

References

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