PowerFlex: Sustainable Energy for Health Monitors

Development of a Piezoelectric Arm Sleeve to Power Continuous Glucose Monitoring Using Kinetic Energy from Elbow Flexion

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Nano 272 | Dr.Sheng Xu | 4 June 2024

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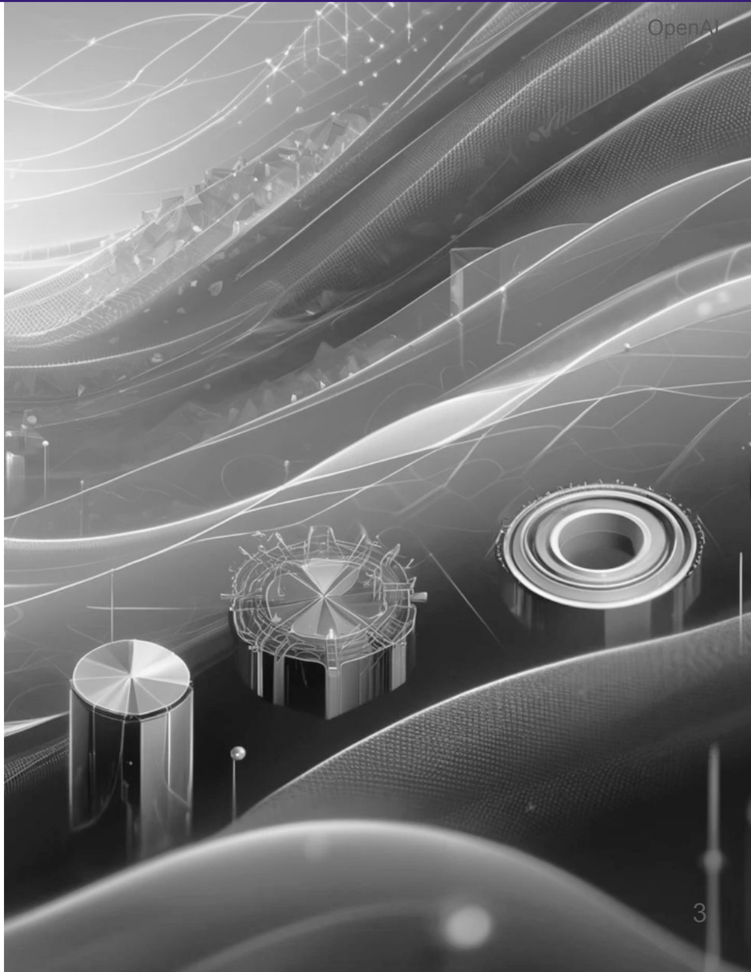

RESEARCH MOTIVATION

Societal Problem:

- Continuous Health Monitoring Needs: Traditional methods can be invasive and inconvenient.
- Dependency on Battery Power: Frequent battery replacements or recharging disrupts the use of wearable health devices.

- **133+ million Americans** live with diabetes or prediabetes.[1]
- **10+ million Americans** are treated with insulin and stand to benefit from a continuous glucose monitor (CGM).[2]

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A commercial CGM patch

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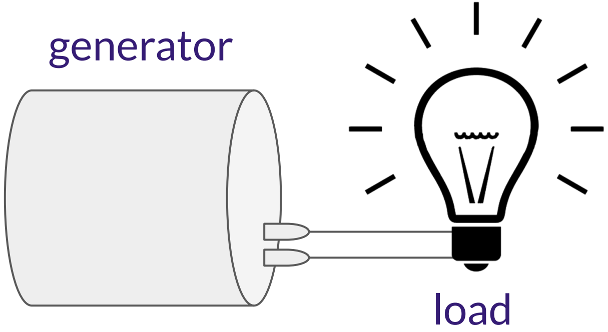
Non-invasive, passively-powered monitors?



Engineering Challenge:

- Energy Harvesting Efficiency: Efficiently convert the kinetic energy from UPPER BODY to sustain glucose monitor.

- Material and Design Optimization: Creating a flexible, durable, piezoelectric device, that maintains high energy conversion efficiency and user comfort.

EXISTING WORK: WEARABLE ENERGY HARVESTERS

Shoe-Embedded Energy Harvesters: Devices utilizing piezoelectric materials embedded in shoe soles.[3,4]

- <u>Limitation:</u> Energy captured is localized, and transferring this power to wearables on other parts of the body, like the arm, requires extensive wiring.

Thermoelectric Generators for Body Heat: Convert body heat to electricity.[5]

- <u>Limitation:</u> The energy output is often insufficient for devices requiring higher power, like continuous glucose monitors.

Kinetic Energy Harvesters in Wearables: Various wearables have integrated kinetic energy harvesters.[6]

- <u>Limitation:</u> Many such systems provide inconsistent energy outputs, especially in less active individuals or in those whose movements do not align well with the harvester's operational mechanics

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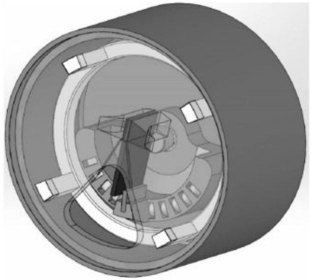

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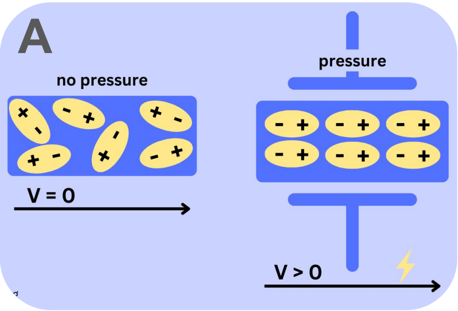
TECHNICAL BACKGROUND

Piezoelectrics: Generate an electric charge in response to mechanical stress.[7] Piezoelectricity occurs when a material's structure deforms, leading to a change in dipole moment, generating an electric potential. [8]

Polyvinylidene Fluoride (PVDF): A highly non-reactive and pure thermoplastic fluoropolymer with exceptional piezoelectric properties. It is common in wearables due to flexibility and biocompatibility.[10]

Cantilever Piezoelectrics: Are particularly effective for wearable applications due to their ability to be tuned to specific frequencies corresponding to human movement, making them ideal for energy harvesting.[9]

Piezoelectric Effect



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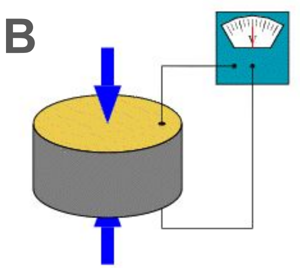
Button-Type



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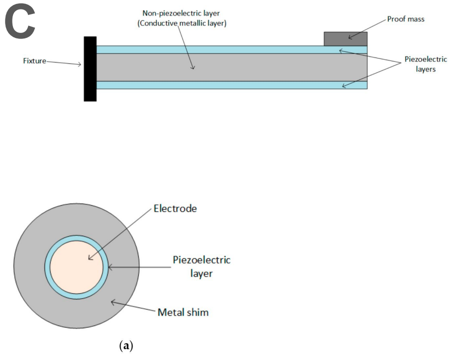
Cantilever-Type



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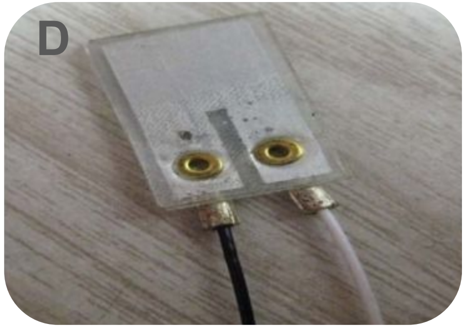
Flexible Cantilever-Type Device



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PROJECT OVERVIEW

Research Hypothesis: Integrating a cantilever beam transducer made from Polyvinylidene Fluoride (PVDF) into an arm sleeve will efficiently harness kinetic energy from natural arm movements, providing a continuous and sustainable power source to operate a built-in glucose monitor, thereby enhancing the convenience and efficacy of diabetes management without the need for external power sources.

Through meticulous design optimization, this approach endeavors to transcend the constraints of existing energy harvesters, demonstrating that an arm sleeve could offer enhanced capabilities for powering upper body wearable devices, with a minimally invasive design and absence of wiring and bulky hardware.

Specific Aim 1

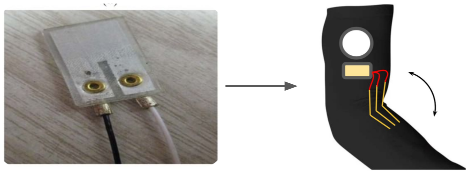
Design and Fabrication of Arm Sleeve with Transducers

Specific Aim 2

Optimization of Energy Harvesting and Storage

Specific Aim 3

Validation and Testing of the Glucose Monitoring System



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SPECIFIC AIMS

Specific Aim 1	Specific Aim 2	Specific Aim 3
Design and Fabrication	Optimization	Validation

Prototype Development and Material Selection

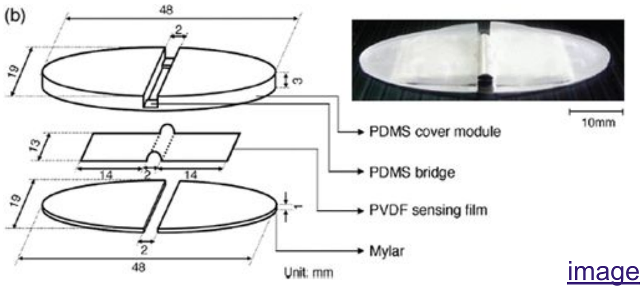
A prototype arm sleeve will be developed using Polyvinylidene Fluoride (PVDF) as the primary piezoelectric material in cantilever beam transducers.

Design Optimization and Computational Modeling:

Cantilever beams will be optimized using computational modeling in COMSOL Multiphysics.[11]

Fabrication Techniques and Assembly:

Thin-film deposition and laser cutting techniques will be employed to construct the beams. These will be integrated onto a flexible fabric, which will then be assembled with electronic components such as wiring and an energy storage system.[12,13]



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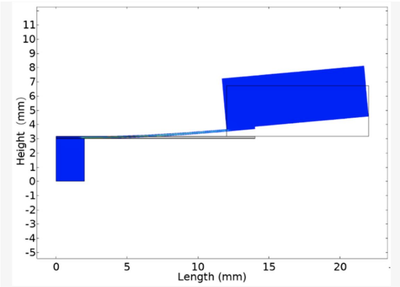
PVDF used in a device for sensing



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COMSOL Simulation of Piezoelectric Cantilever Beam

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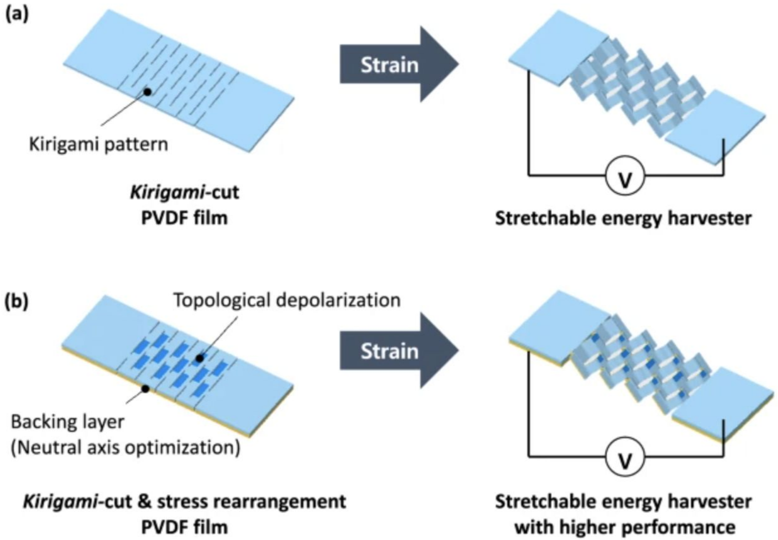

Stretchable energy harvester using kirigami pattern nature

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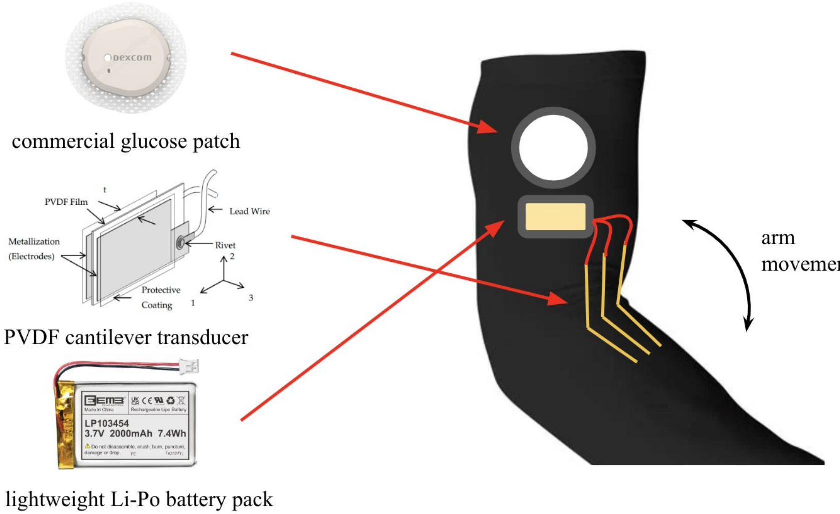

Figure: Schematic of proposed system, adapted from Dung et. al (2016)

SPECIFIC AIMS

Specific Aim 1	Specific Aim 2	Specific Aim 3
Design and Fabrication	Optimization	Validation

Energy Harvesting Optimization:

Adjust the number, arrangement, and adaptation of transducers.[14]

Experimental Testing and Validation:

data analysis

A robotic arm will simulate natural human arm movements to test the performance of the piezoelectric transducer and sleeve system.[15,16,17]

Energy Storage Integration:

A micro-energy storage system using thin-film or Li-Po batteries, will be integrated, ensuring sufficient harvested energy for continuous operation during typical daily activities.[18]

A Elbow Range of Motion

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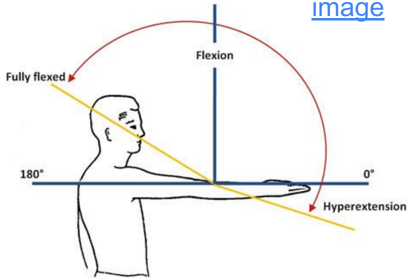

B KUKA Robotic Arm

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SPECIFIC AIMS

Specific Aim 1	Specific Aim 2	Specific Aim 3
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Sensor Integration and Initial Testing:

- Ensuring stable placement and functionality with piezoelectric power.

Clinical Trials and Data Analysis:

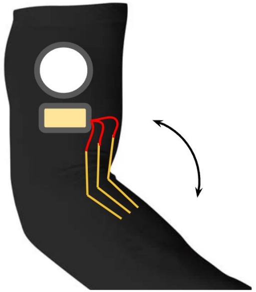
- Simulate various everyday activities to assess the glucose monitoring system's effectiveness and user comfort.

Durability and Usability Testing:

- Long-term wear and degradation analysis through accelerated life testing, to ensure it remains comfortable and durable

[OpenAI]

PROJECT SUMMARY

Specific Aim 1	Specific Aim 2	Specific Aim 3
Design and Fabrication of Arm Sleeve with Transducers	Optimization of Energy Harvesting and Storage	Validation and Testing of the Glucose Monitoring System
	 [image]	
Time: 1 Year	Time: 6 months	Time: 6 months
Cost: $15,000	Cost: $1000	Cost: $1000

IMPACT, DELIVERABLES, LIMITATIONS

Deliverables:

1. Self-Powered Glucose Monitoring System:
   - Development of a wearable arm sleeve.
2. Enhanced Device Performance:
   - Improving diabetes management by providing real-time glucose level data without frequent recharging.
3. Prototype and Testing Results:
   - Comprehensive testing data for efficiency, stability, and comfort.

Future Impact:

- Expansion to Other Medical Devices
- Reduction in Healthcare Costs
- Contribution to Sustainable Practices

Limitations:

- Dependence on Arm Movement
- Energy Conversion Efficiency
- Device Durability

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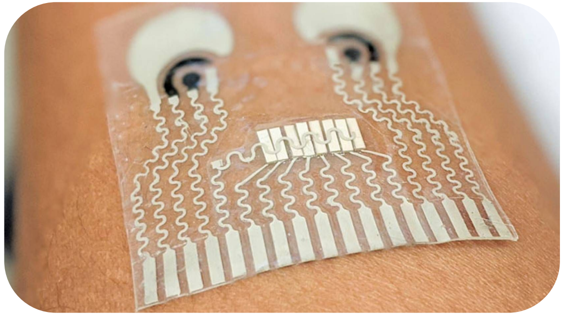

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THANK YOU

Questions?