Powering Locomotion of Underwater Microrobots with Piezoelectric Energy Harvesting

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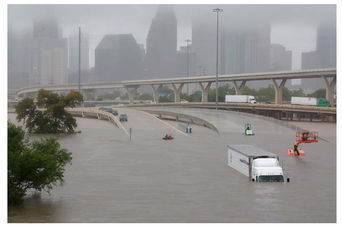
INTRODUCTION



Flood Monitoring

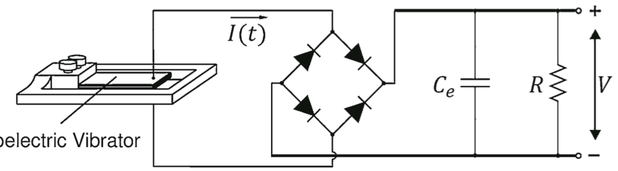
Search and Rescue

One of the major challenges of designing microrobots is finding suitable power sources for long durations of time. Piezoelectric generators have been explored as methods for harvesting energy in ocean engineering applications, and microrobots capable of underwater locomotion have been developed without a strong focus on remote power. This project synthesizes and expands on research from multiple areas of MEMS devices, aiming to utilize energy harvested from floods to propel locomotion of microrobots in water.

Summary of Achievements

1. Identified device suitable for energy harvesting from floods
2. Modeled piezoelectric bimorph to analyze voltage output
3. Use existing actuators and microrobots to determine energy requirements of device and compatibility

DEVICE DESCRIPTION



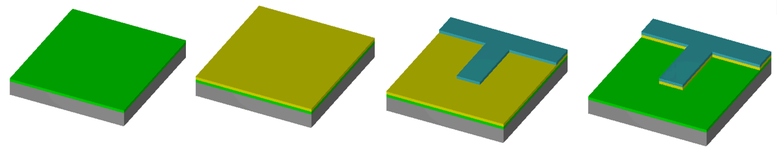
Piezoelectric Energy Harvesting Circuit

(Priya and Inman 2009)

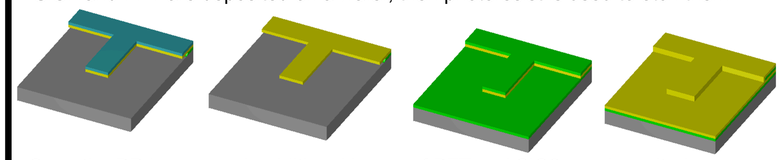
This piezoelectric bimorph device uses PZT, one of the most commonly-used piezoelectric materials. Because it has a high coupling term, it has the potential to generate more power than other piezoelectric materials; in addition, it has a high elastic modulus and relatively high tensile strength, making it suitable for electro-mechanical applications.

Multiple applications of piezoelectric generators were explored; it was determined that the application that maximized power generated and minimized power lost would be areas flooded with standing water through which vehicles, people, or other bodies passed through. In this application, power can be generated and stored when there is fluid flow, and power can be used for locomotion when there is no fluid flow to oppose it. Based on this application, the power requirements of underwater locomotive microrobots will be explored and compared to the power output of the device.

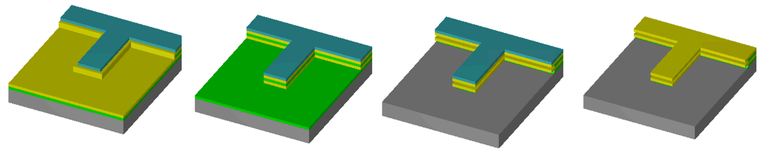
FABRICATION PROCESS



SiO2 and PZT are deposited on a wafer, then photoresist is used to etch them.

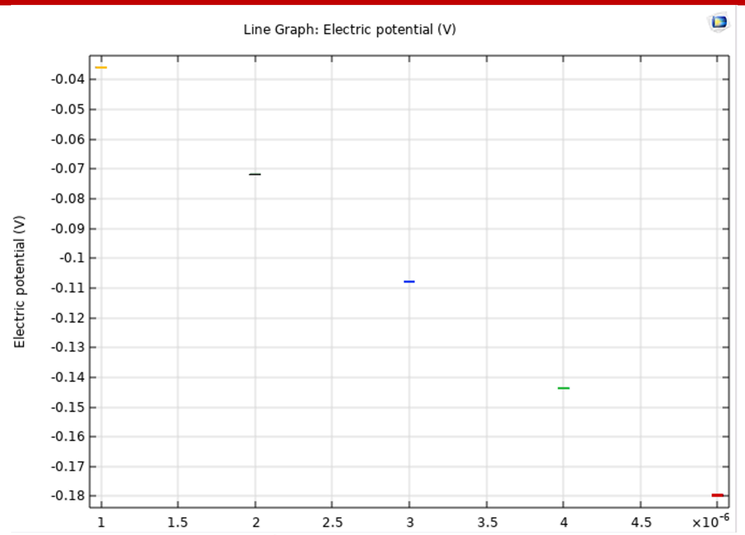


Once the PR is removed, additional layers of PZT and SiO2 are deposited.



The final layers of PZT and SiO2 are etched, and the PR is removed to reveal the released bimorph beam structure.

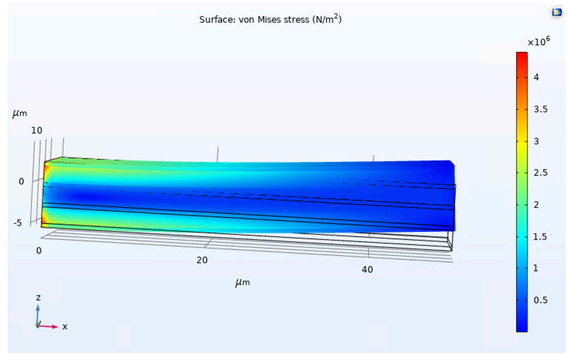
CALCULATIONS AND ANALYSIS



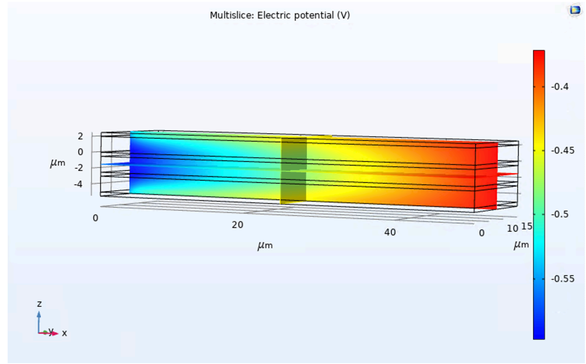
Voltage vs. Force

Here, voltage is plotted against force applied for a parametric sweep of 1E-6 to 5E-6 Newtons. At the maximum force, a voltage of 0.18V is produced.

SIMULATIONS/RESULTS



Stress on Bimorph Beam



Voltage Produced on Bimorph Beam

CONCLUSIONS

The results of my analyses so far have demonstrated the piezoelectric bimorph will output electric potential between less than 0.04V and approximately 0.18V for forces ranging from 1E-6 to 5E-6 Newtons.

Developing robots at this scale that rely on forces from an external environment poses inherent challenges; the more force or vibration a piezoelectric material can harvest energy from, the larger the barrier to or instability of a microrobot's locomotion. A challenge particularly relevant to MEMS devices is the selection of materials; because piezoelectric energy harvesting is used to replace energy sources requiring frequent maintenance, it is important to expand testing of the mechanical properties of these materials to understand fatigue life.

In the coming week, I hope to find ranges of magnitudes or models for the forces experienced by a microrobot in flood conditions to better model the energy output. Future work beyond the scope of this project would include more detailed fluid analysis and modeling based on various flood conditions, including standing water and multiple flow types.