Wave Energy Harvesting using a Variable-Area Liquid Metal-Hydrogel Capacitor

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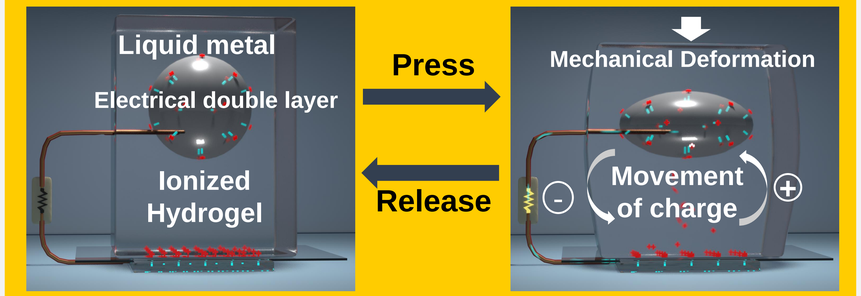
Motivation

Ocean waves provide a ubiquitous renewable energy resource exceeding 1 TW globally. But, in order to effectively harvest this complex and abundant energy source, various complimentary technologies must be simultaneously employed. Here, we provide an off-the-grid, flexible, wave mechanical energy harvester using a variable-area liquid metal-hydrogel capacitor that converts **any** form of mechanical wave energy into electrical energy

Energy Harvester Concept and Material selection

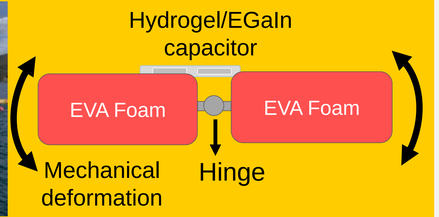


- **Eutectic gallium indium (EGaIn)** is a non-toxic liquid metal at room temperature.
- **Hydrogel** is a non-toxic, soft, and durable crosslinked polymer that is composed of mostly water.
- An ionized hydrogel/EGaIn interface creates an electrical double layer between the two materials, like a capacitor.
- Mechanically deforming this composite will result in a change in the number of charges along the interface. Once the stretchable composite returns to its original shape a **net charge is produced by the system.**
- This harvester is **able to convert any mechanical energy** including bending, stretching, compressing, and twisting into electrical energy.

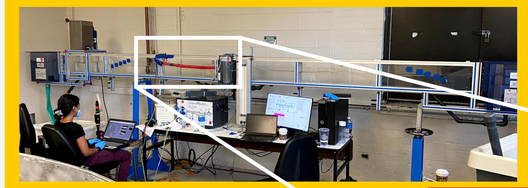
Prototype Design and Testing

Prototype Design and Fabrication:

The inspiration behind the design comes from floating attenuators, that have high degree of freedom but remain connected



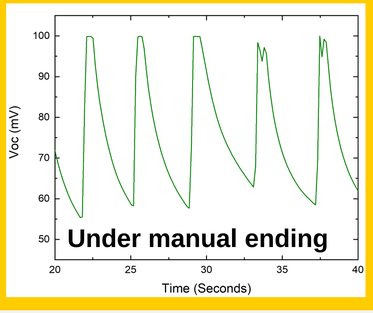
Prototype Testing:

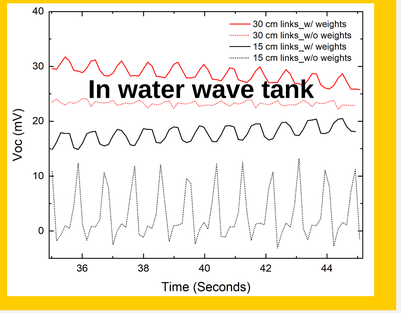


Wave generator at NC A&T University

The prototypes (of short and long links) were tested under varying wave heights and periods

Energy Harvesting Results:



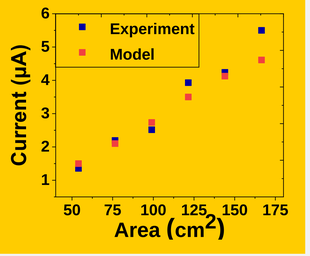


Increasing Interfacial Area

The interfacial area correlates linearly with device current output, which correlates with power squared. Therefore, **increasing the interfacial area by 10, increases the power by 100!**

$$Interfacial\ area \propto Current\ Output \propto Power^2$$

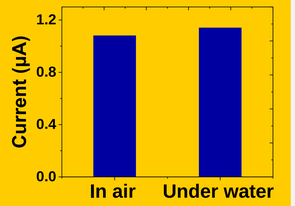
One tactic to increase interfacial area is to create a percolated network of liquid metal droplets surrounded by hydrogel.



Conclusions

Our liquid metal/hydrogel variable-area energy converter shows great promise in oceanic energy harvesting due to:

- ***Its ability to converts various types of mechanical energy to electrical energy.***
- ***It is a scalable technology (surface area)***
- ***It has also shown to be just as stable in salt water making it perfectly suitable for marine operation.***
- ***It is environmentally friendly***



Ongoing Work

- Continue work on increasing the interfacial area between the liquid metal electrode and the ionized hydrogel to optimize the power output of the energy harvester.
- Run tests of the full-scale prototype at the Coastal Studies Institute