Wearable textile based energy harvester designed for human motion

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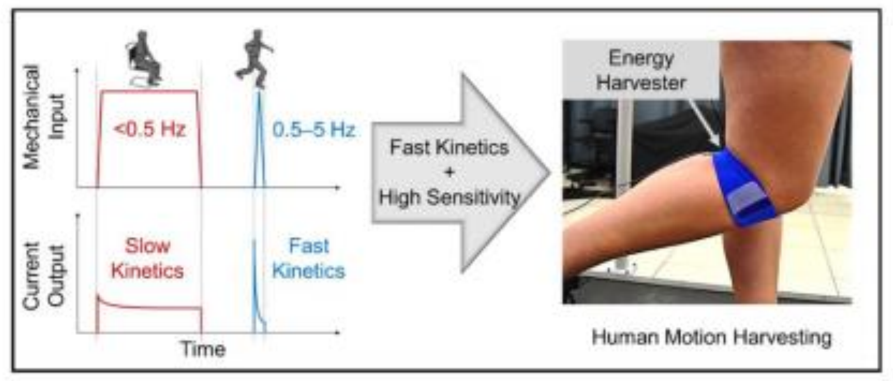
Introduction

Need for harvesters?

- Recent advances in cybernetics, artificial intelligence, and personal technology call for more energy in small or unusual form factors.
- To power these advancements - the energy of human motion
- Takes place from **0.5-5Hz**



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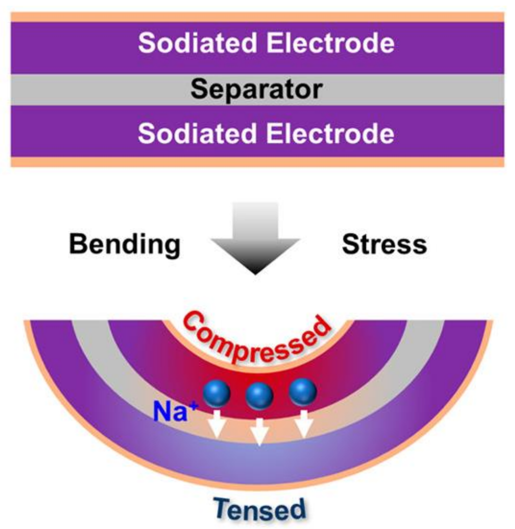
Energy Harvesters:



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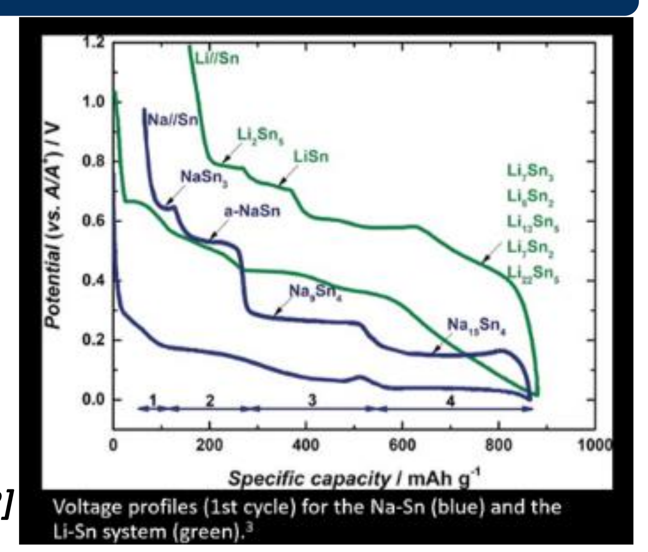
- These harvesters **convert mechanical strain** at **low frequencies** into **electrical energy**.
- Bending creates strain in lattice of active material and induces potential gradient.
- Sensitivity to strain and changes in electrolyte inspire exploration of sensing applications.

Why Tin-Sodium System?

- **Na is 1000 times more abundant** than Li in the earth's crust. Both Na and Sn are cheaper than Li.
- Tin is non-toxic and compatible with aqueous electrolyte.
- **High theoretical sodium storage capacity** of 847 $mAhg^{-1}$. [3]
- Alloys of larger ions have a higher OCV. [4]



[2] Voltage profiles (1st cycle) for the Na-Sn (blue) and the Li-Sn system (green).[2]

Plating Tin onto Textile

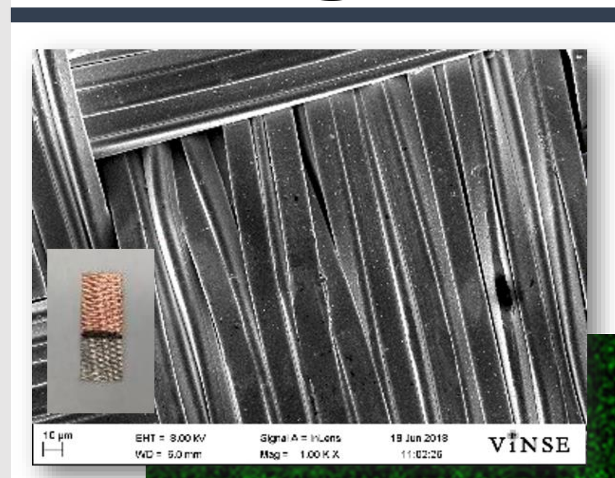


Figure 1. SEM image of plated tin on copper textile.

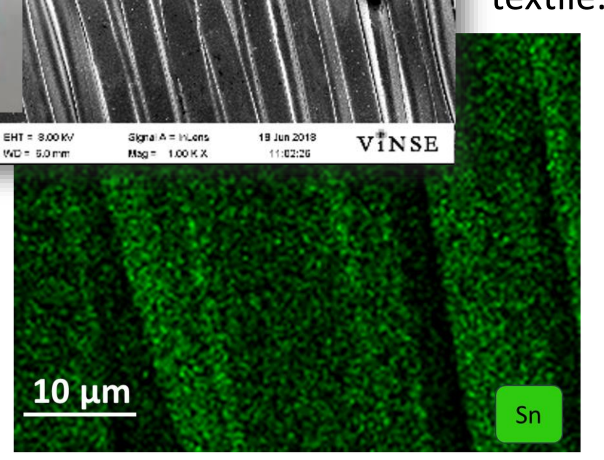


Figure 2. EDS image showing uniform distribution of tin on fibers.

Use of pulse electroplating.

Cathode: Copper textile

Anode: Pure Tin

Electrolyte: $NiCl_2$, $SnCl_2$ in H_2O with additives

Sodiation of Plated Textile

Step 1: Transform textile into energy harvester

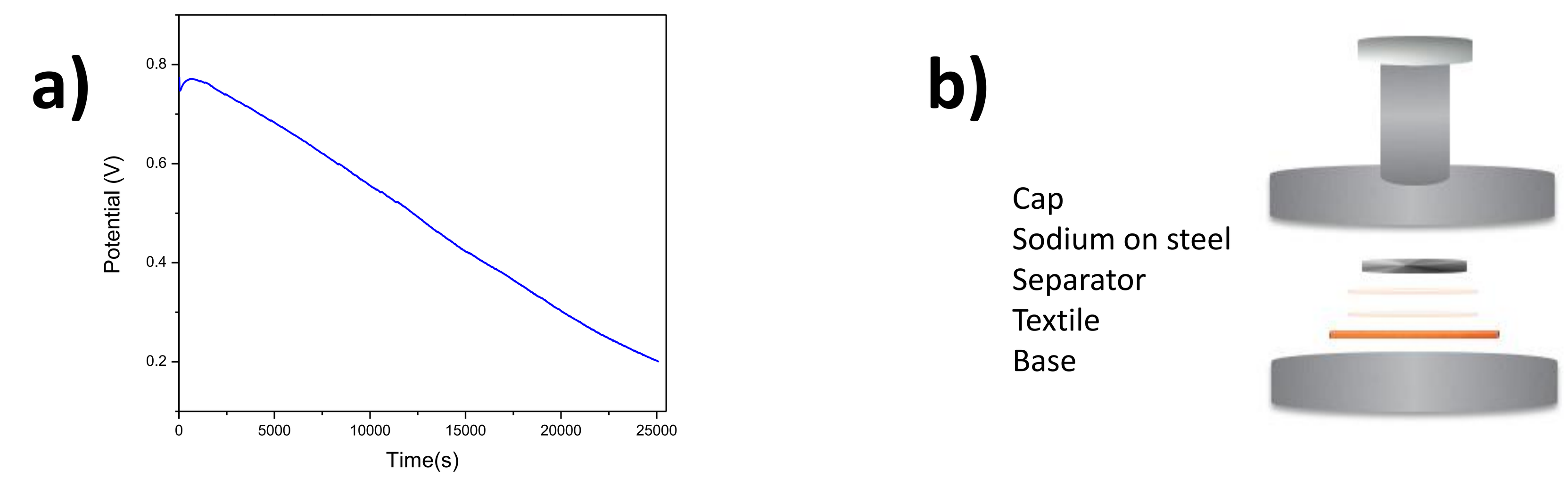


Figure 3. (a) Tin was electrochemically alloyed with sodium at constant current of 15 µA over 8.5 hours for a total sodium concentration of ~0.11 mg/cm² **(b)** Two-electrode electrochemical cell used for sodiation.

High Performance, Smart Harvesting

Step 2: Assemble harvester and test performance.

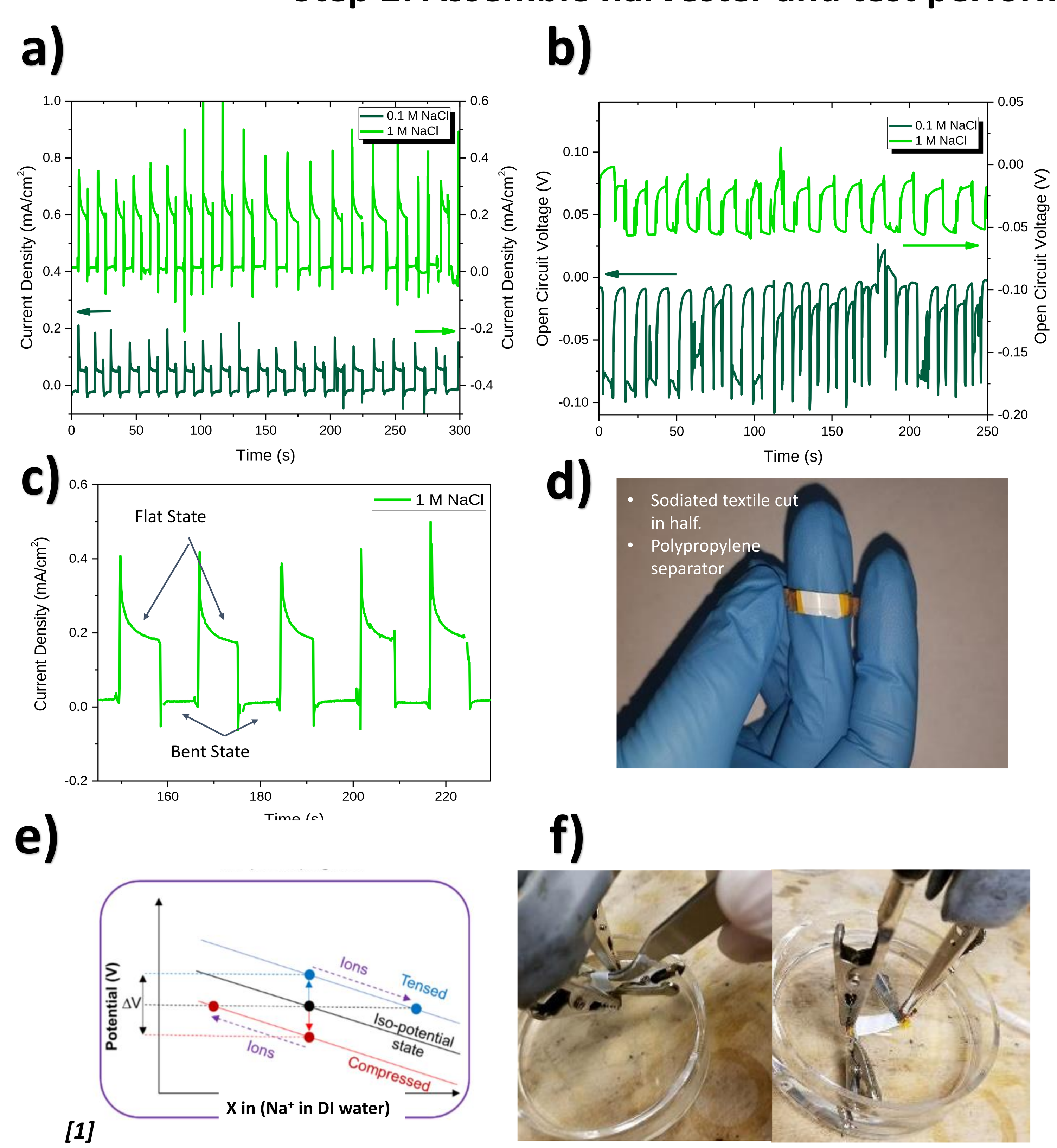


Figure 4. (a) Short circuit current (SCC) response and **(b)** open circuit voltage (OCV) of harvester in 1M and 0.1M NaCl solutions. **(c)** Subset of SCC plot for 1M electrolyte showing nature of response in bent and unbent states. **(d)** Photograph of assembled device. **(e)** Schematic representation of the operation of an electrochemical energy harvester. **(f)** Photograph showing bend tests on energy harvester.

Sweat activated harvester

1. High Performance: ***Peak power: 36.4 µW/cm²*** ***Energy: 131.1 µJ/cm²***

2. Non-Toxic: Utilizes an aqueous electrolyte (NaCl) which simulates human sweat.

3. Safe: Iso-potential state, low risk of electrolyte fire.

4. Ideal for human motion: Bent at .1Hz

5. Smart functionality: capable of sensing change in sodium concentration.

Conclusions

- **Device successful at converting strain at low frequencies into record-breaking quantities of power and energy.**
- **Textile-based harvester is activated by human SWEAT.**

Testing Method	Operational Frequency (Hz)	Bending Radius (mm)	Peak Power (µW/cm²)	Energy Harvested (mJ/cm²)	Response Time (s)	Concentration NaCl (M)
Bending	.1	1.4	36.4	.1311	10	1
	.1	1.4	14.0	.0252	10	.1

Figure 5. Performance of the Sodium-Tin energy harvester described in this work

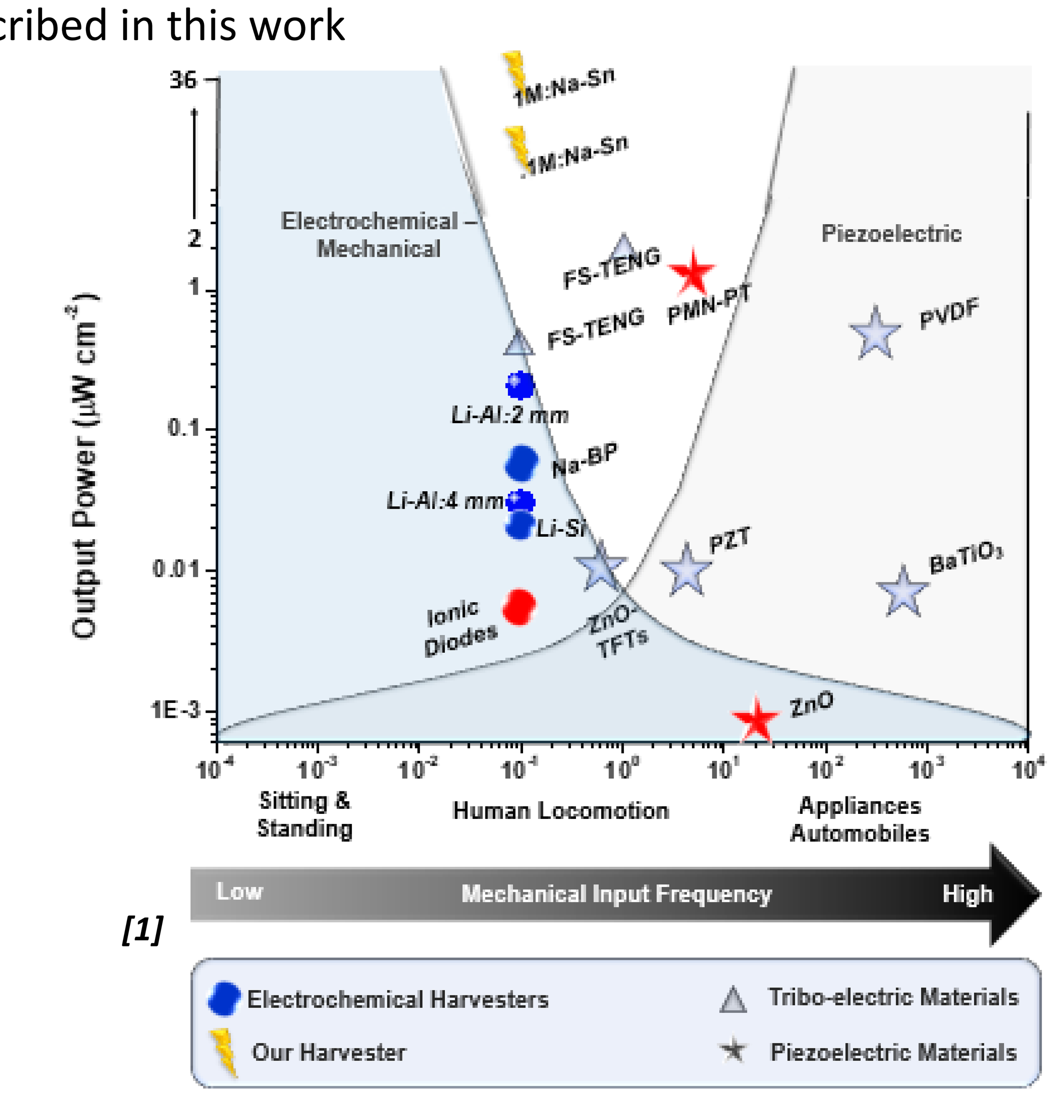


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Figure 6. Plot of measured performance from energy harvesting textiles versus state-of-the-art in the literature. **Our devices show highest performance measured to date.**

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Future Work

- **Further analysis of hydration monitoring capability and additional sensing opportunities**
- **Identify optimal packaging method**
- **Human motion testing**
- **Further testing using different weaves of fabric**

References

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