Graphene Electrodes for Body Energy Harvesting

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Objective

- **To develop a self-sustaining thermoelectric generator using advanced material electrodes that can harvest energy from the body. In this project, we investigate the device's properties and test how much voltage can be extracted from the system**

Background

- Thermoelectric generators (TEGs) are dependent on the Seebeck effect, a phenomenon in which a temperature difference between two dissimilar electrical conductors produces a voltage.

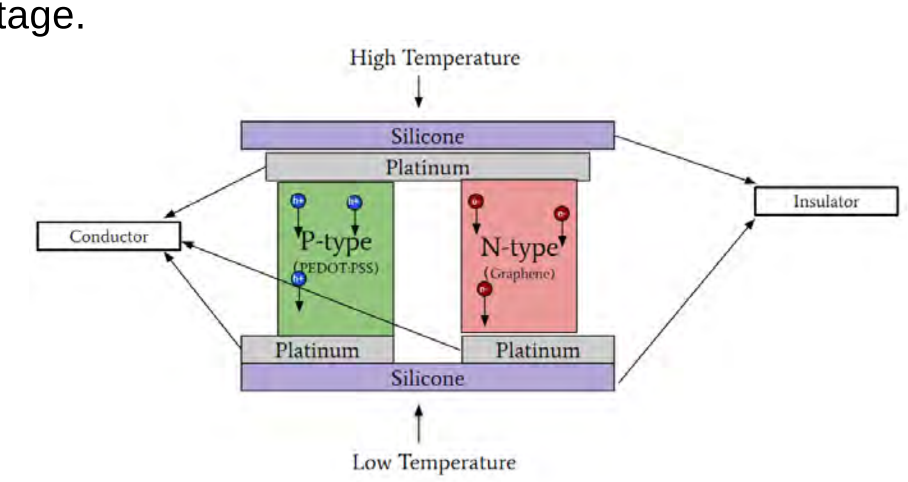

Figure 1. Schematic illustration of thermoelectric generator module.

- TEG consists of N-type material (electron charge carriers) and P-type material (hole charge carriers)

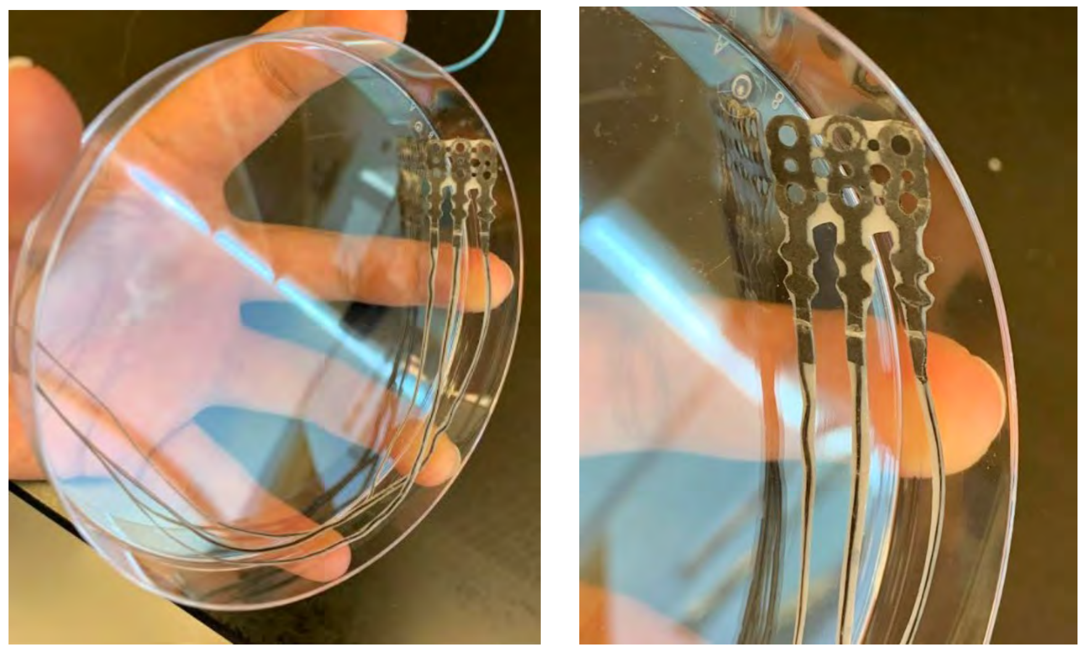

Figure 2. One of the fabricated electrodes to be used for our thermoelectric generator design showing the de-insulated side facing out. Two of the electrodes have Graphene leads (F5, F6) and the other two have Platinum + Graphene leads (P1, P2). All electrode fibers are made of Graphene and silicon insulated, and all electrodes were later coated with PEDOT:PSS on the de-insulted side of the electrode lead.

- Graphene (N-type) is an allotrope of carbon consisting of a single layer of atoms arranged in a 2-D honeycomb lattice nanostructure that has great electron mobility
- PEDOT:PSS (P-type) is an organic conducting polymer that has a high dimensionless figure of merit ZT

Methods

- 3-channeled Graphene fiber electrodes and Platinum-coated Graphene fiber electrodes were fabricated by Dr. Gordon G. Wallace's group and used as the foundation of the TEG device.
- All electrodes are silicon insulated on one side of the leads
- Electrodes were characterized for charge storage capacity and impedance values through Electrical Impedance Spectroscopy (EIS) and Cyclic Voltammetry (CV) with Gamry Instruments equipment.
- PEDOT:PSS (P-type material) was drop-casted onto the electrode leads and electrodes were recharacterized.
- Body temperature and room temperature differences were simulated using a hot plate, ice, and temperature probes to collect voltage readings.

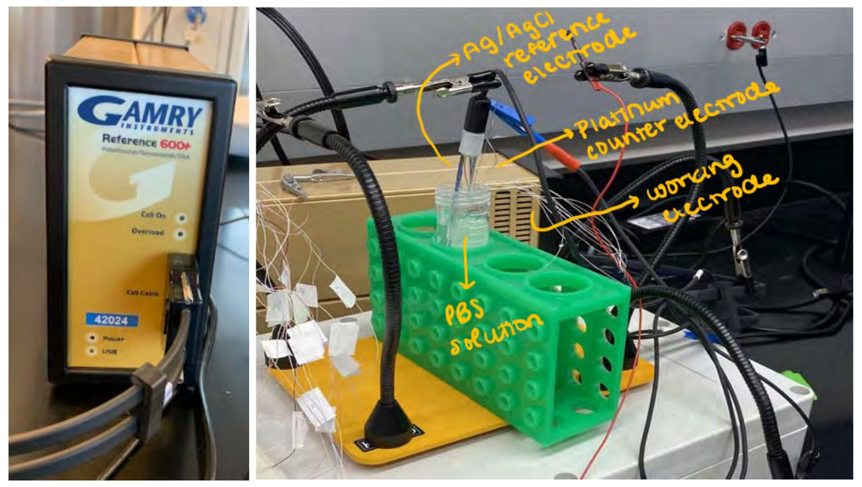

Figure 3. Characterization of electrodes through Electrical Impedance Spectroscopy (EIS) and Cyclic Voltammetry (CV).

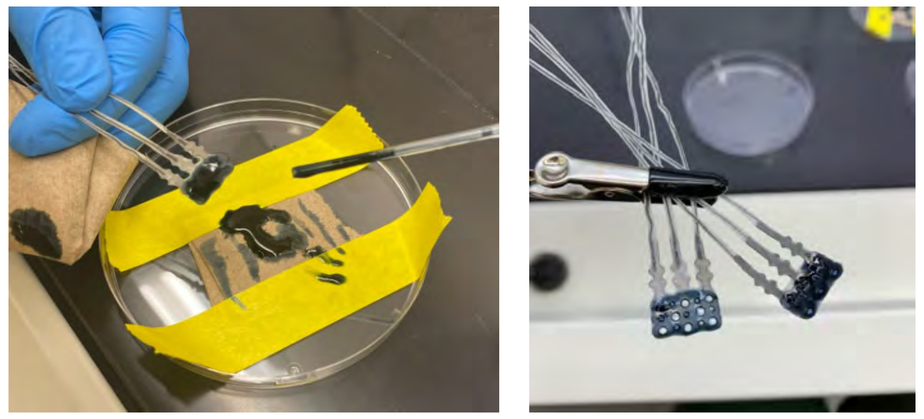

Figure 4. Drop-Casting of PEDOT:PSS onto the electrode leads.

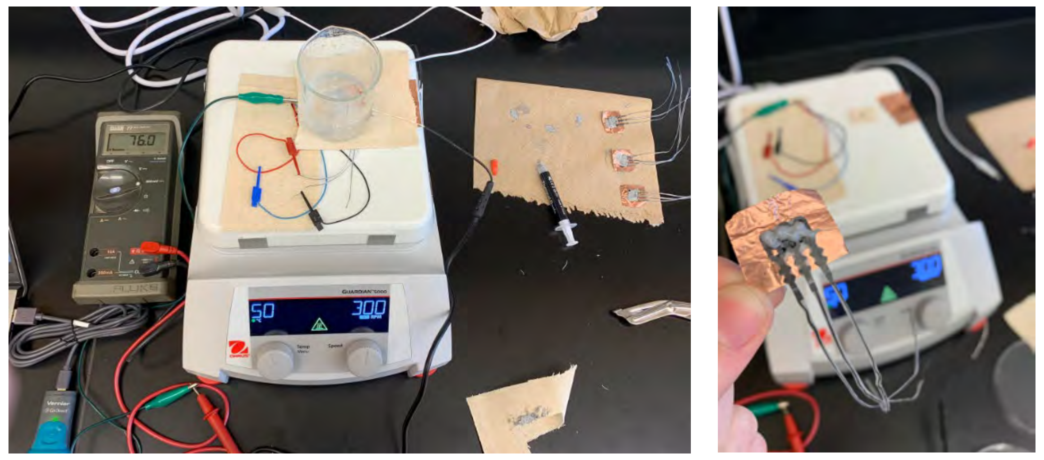

Figure 5. Hot Plate Test set-up showing the creation of a controlled temperature difference and thermal paste on the electrode leads.

Results

Electrode	Before PEDOT:PSS	After PEDOT:PSS
Graphene F5	775.27 Ω	674.37 Ω
Graphene F6	1109.3 Ω	1084.3 Ω
Platinum P1	557.67 Ω	489.30 Ω
Platinum P2	578.00 Ω	541.30 Ω

Table 1. Impedance for all electrodes pre- and post-PEDOT:PSS measured from EIS curves.

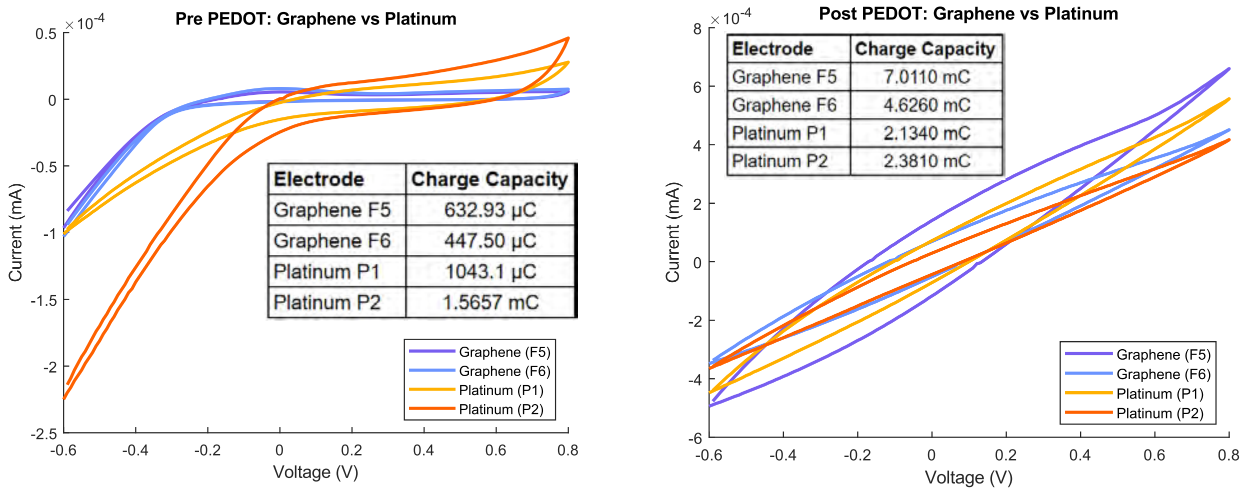

Figure 6. (A) Cyclic voltammetry graphs and charge capacity of electrodes before PEDOT:PSS coating. (B) Cyclic voltammetry graphs and charge capacity of electrodes after PEDOT:PSS coating.

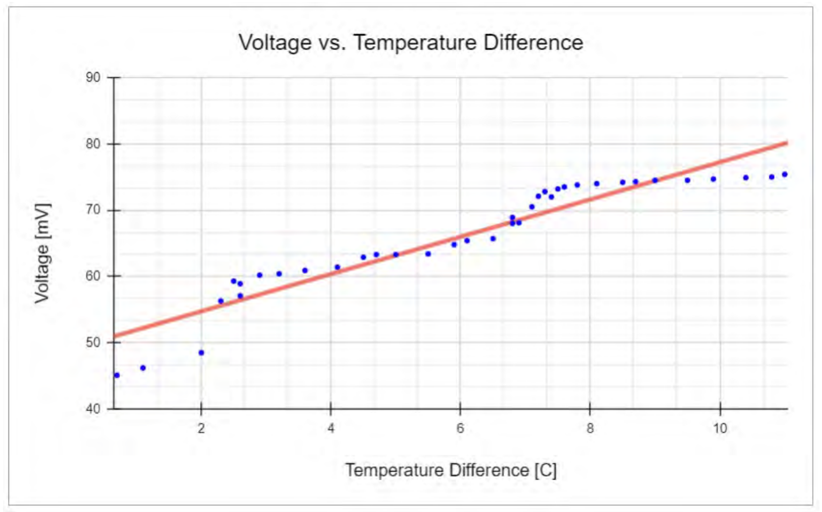

Figure 7. Plot showing the increase in voltage as the temperature differential increases on the hot plate for the F6 graphene electrode.

Electrode	Voltage Measurement [mV]	Hot Temperature [C]	Cold Temperature [C]	Temperature Difference [C]
P1 (Pt)	0.5	31.5	20.8	10.7
P2 (Pt)	0.43	33.4	17.8	15.6
F5	9.6	30.9	18.5	12.4
F6	77	39.7	26.2	13.5

Table 2. Voltage readings from the hot plate test for all four electrodes with a temperature difference maintained between 10 – 15 C.

Conclusions

- **The graphene electrodes showed high voltage readings consistent with previously developed work and known theory. This work can be improved in the future by making the electrodes less delicate/ susceptible to damage, applying a more consistent, even layer of PEDOT:PSS, increasing the amount of graphene in the electrode leads, and increasing the electrode lead surface area.**

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