

# Advances in Multi-Substrate Electrochemical Sensors for Portable Analytical Applications

**Justin Platero, Research Staff**

**Advisor: Dr. Thiagarajan Soundappan**

Nano Electrochemical Analysis and Energy Storage (NEST) Laboratory  
Department of Chemistry, School of Science,  
Navajo Technical University, Crownpoint, NM.

# Outline

- Introduction to Electrochemistry Basics
- How electrochemistry can be applied to sensors
- Examples of different types of electrochemical sensors
- Data collected
- Future steps

Key Terms: Voltammetry, Oxidation, Reduction, Potential, Current, Electrodes



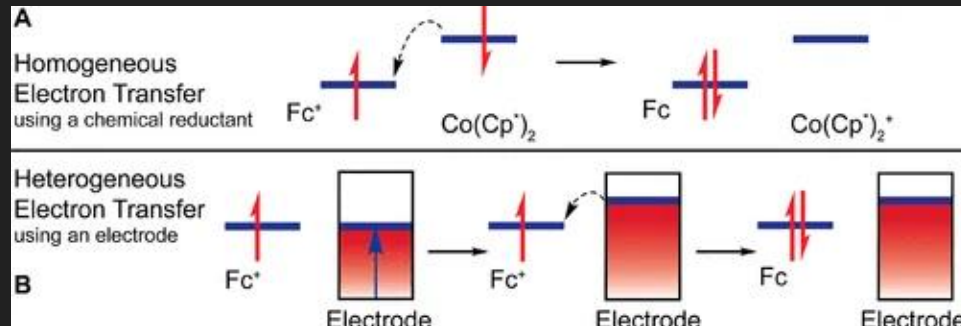
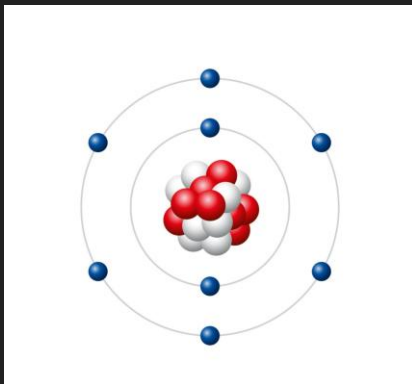
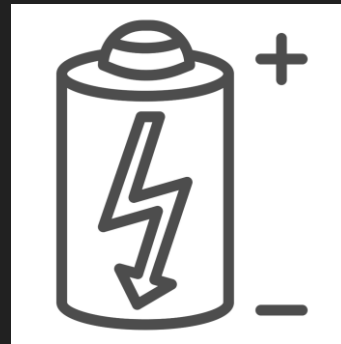
# Electrochemistry Basics

Electricity is the movement of electrons between two atoms.

Electrochemistry refers to the study of electron transfers in chemical reactions.

Oxidation refers to the loss of an electron,

Reduction refers to the addition of an electron.



Noémie Elgrishi, ACS Publications 2017

# Voltammetry

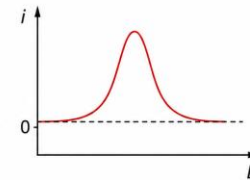
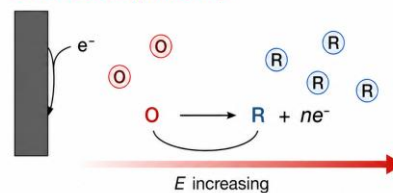
**Potential:** Voltage is the force that drives electrons through a circuit.

**Current:** Amount of charge that passes through a point on a circuit.

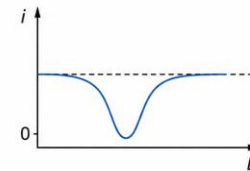
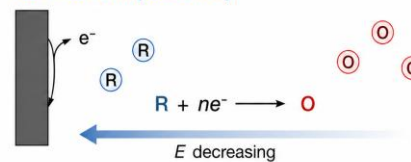
**Voltammetry:** Measures the current between two electrodes after applying a specific voltage.

B. Reversible redox couple:  $O + ne^- \rightleftharpoons R$

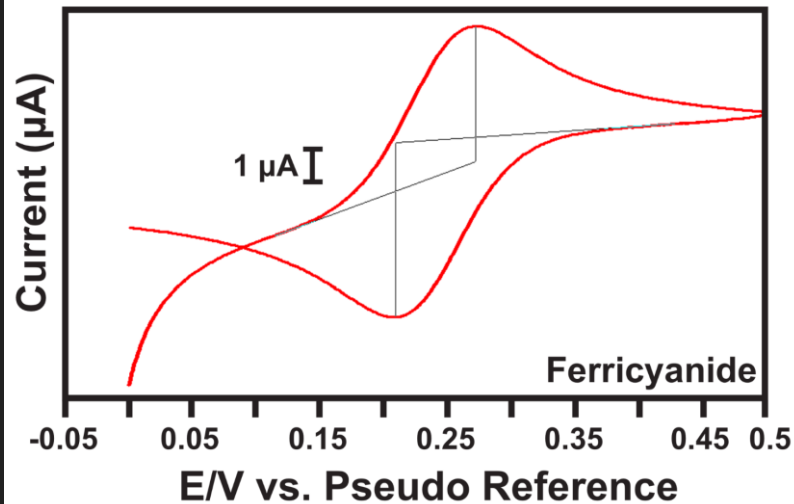
Forward scan (oxidation)



Reverse scan (reduction)



$\textcircled{O}$  = oxidized form       $\textcircled{R}$  = reduced form

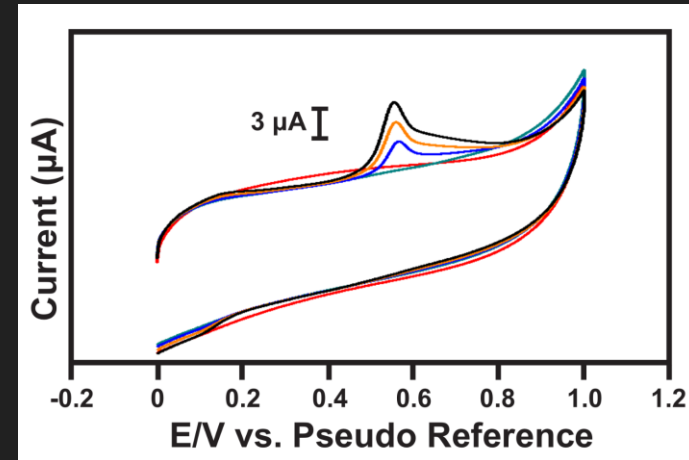
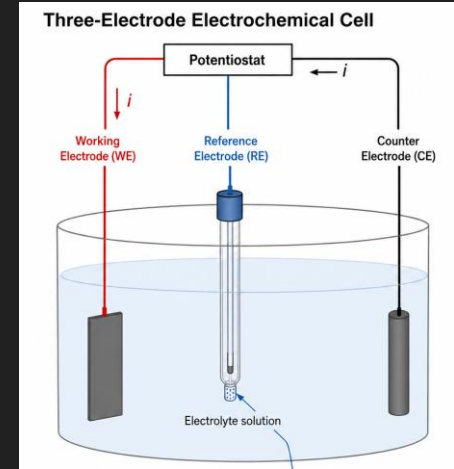
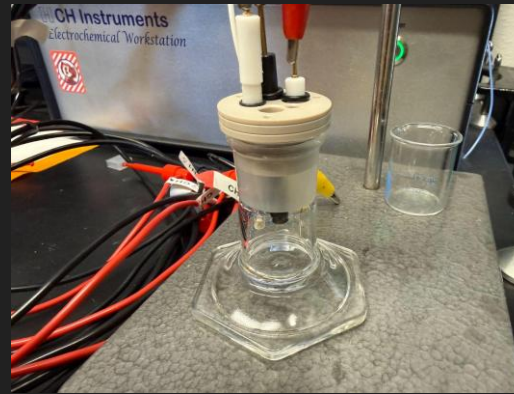


# Traditional Electrochemical Sensors

## Three Electrode Setup

Commercially available electrochemical sensors are made of conductive glassy carbon (WE), Platinum wire (CE), and Silver / Silver Chloride (RE).

Expensive materials, not very portable, impractical

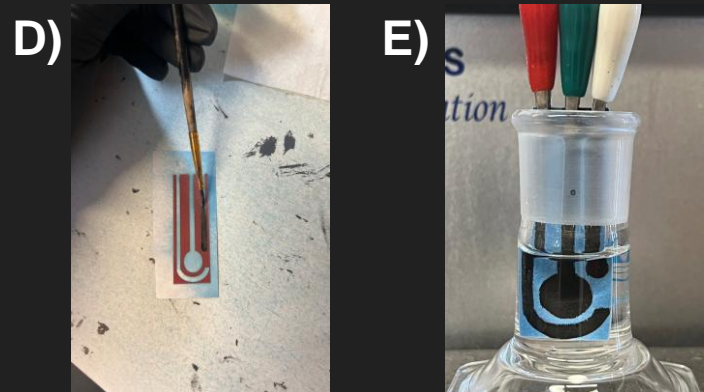
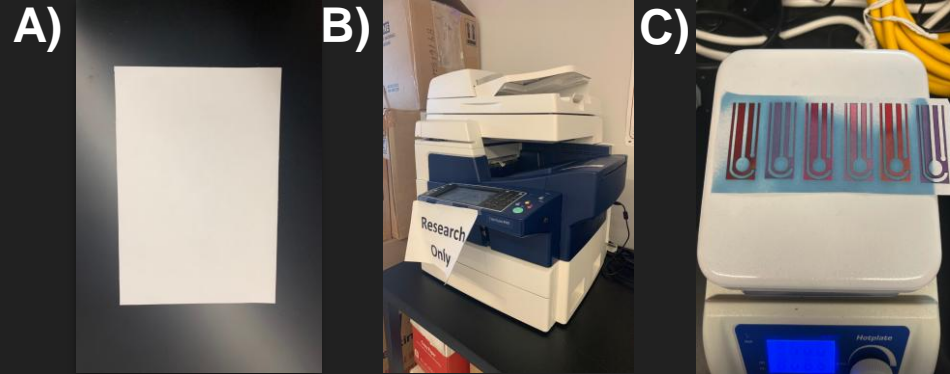


# Paper Electrode - Fabrication

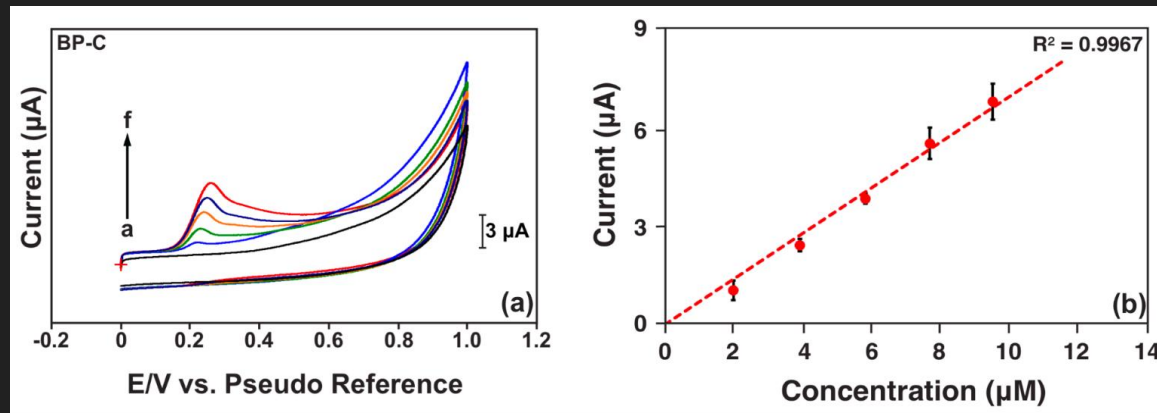
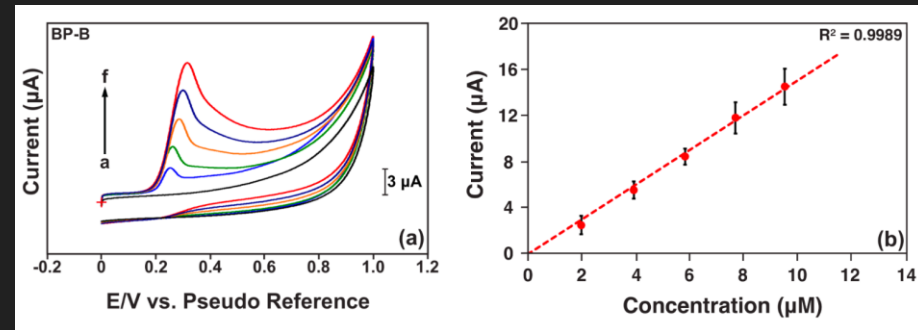
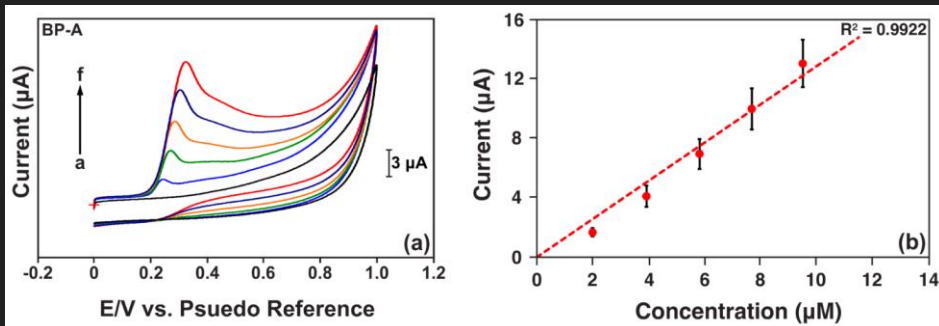
Paper is relatively cost effective, flexible, and provides a suitable substrate for sensing applications.

We use wax coating and chromatography paper to make our sensors durable.

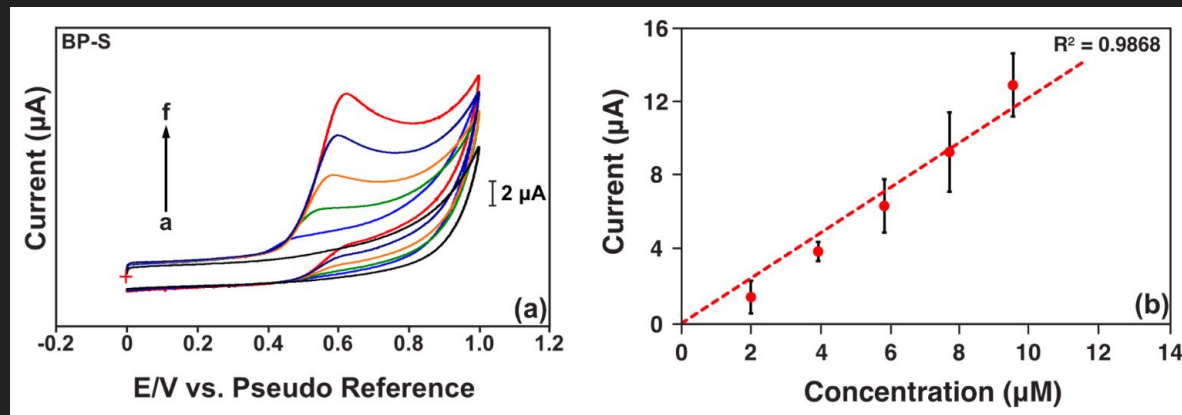
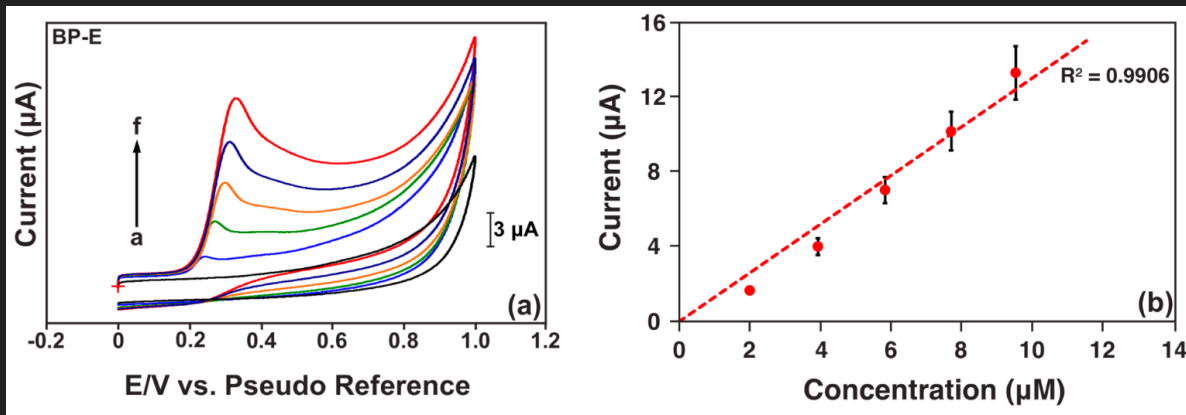
Then we manually coat the conductive carbon ink into the three electrode channels.



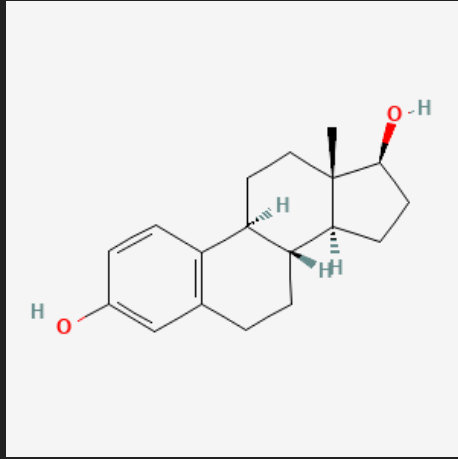
# Paper Electrode - Results (Bisphenol Compounds)



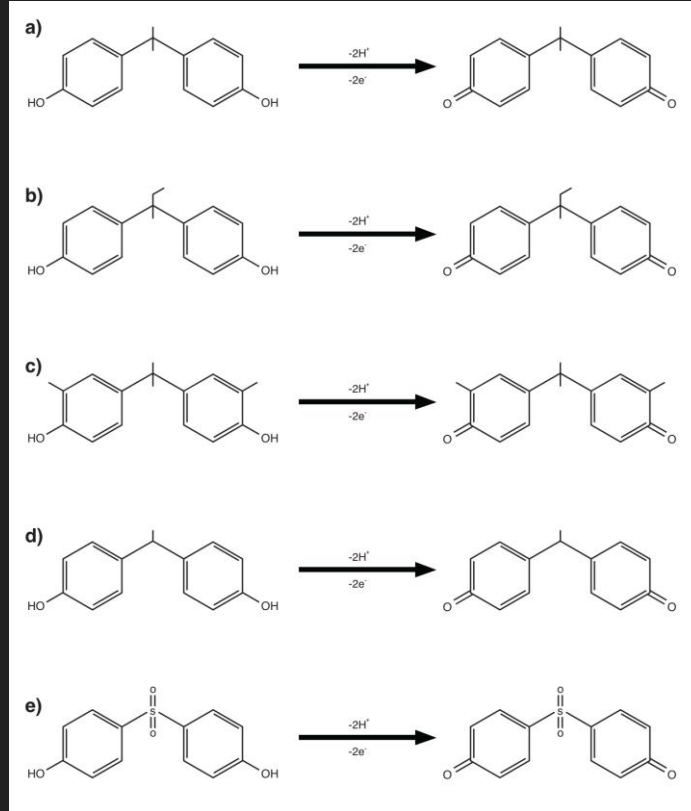
# Paper Electrode - Results



# Paper Electrode - Results



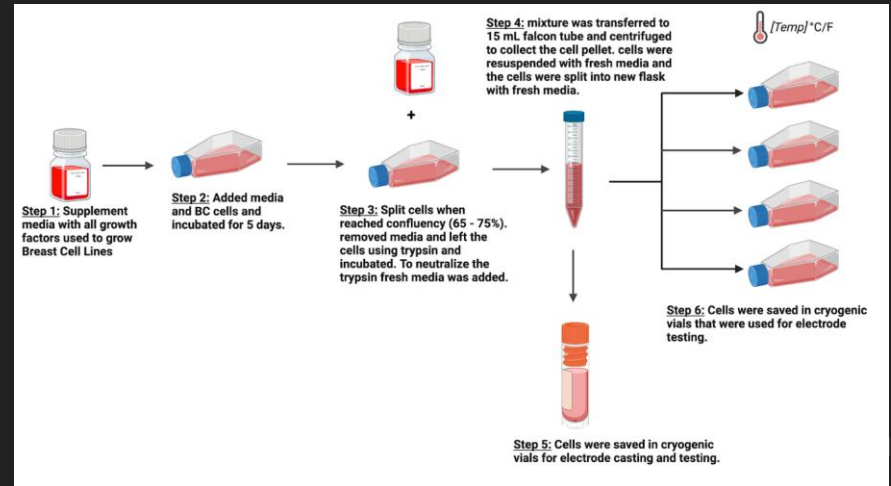
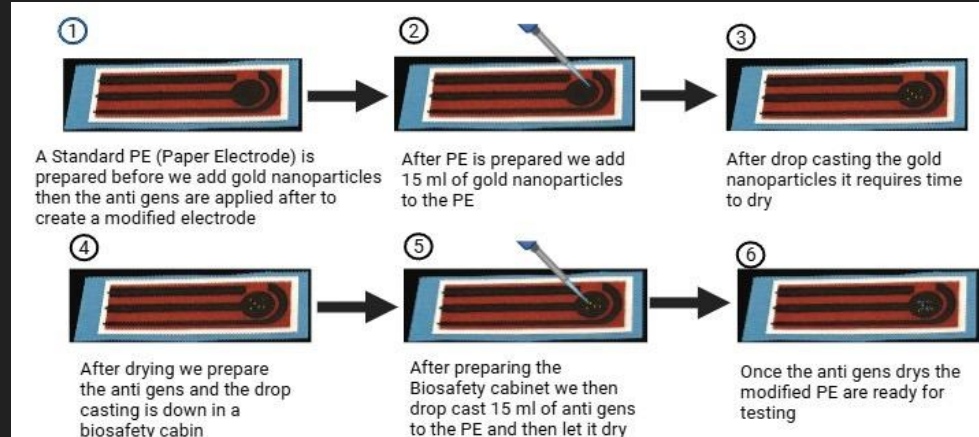
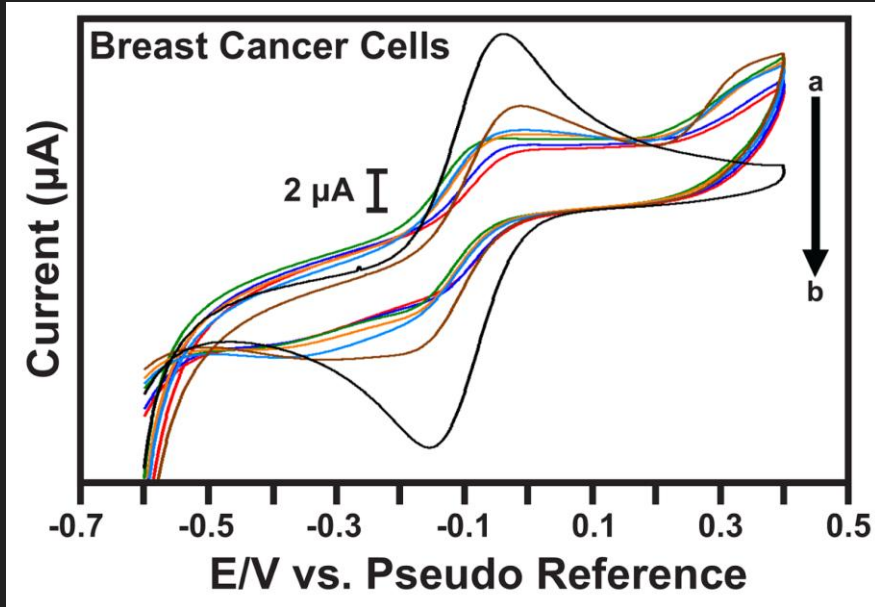
Estradiol ~  
Pubmed



Bisphenol Analogues

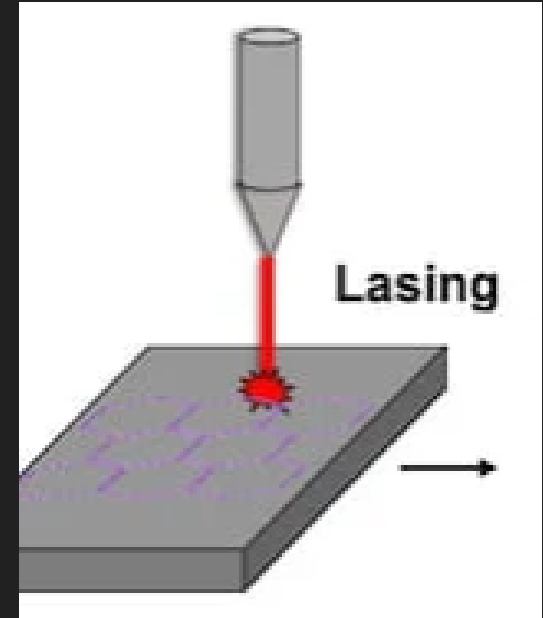


# Modified Paper Electrode - Results



# Laser Induced Graphene Electrodes - Intro

- Paper electrodes are great electrochemical sensors, however they degrade in aqueous solutions overtime.
- Our Laser Induced Graphene (LIG) sensors are more durable and can be scaled to smaller sizes.
- We convert polyimide kapton film into conductive graphene



Jacob L. Beckam *ACS Publications* 2021

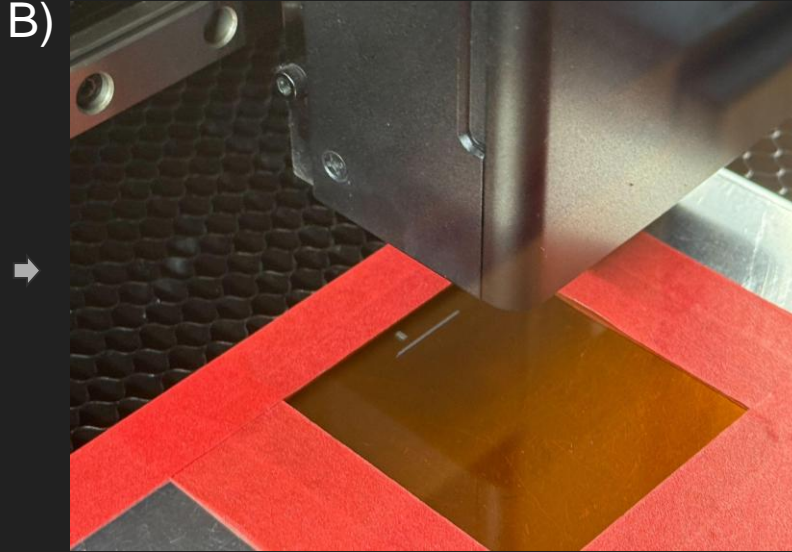


# Laser Induced Graphene Electrodes - Fabrication

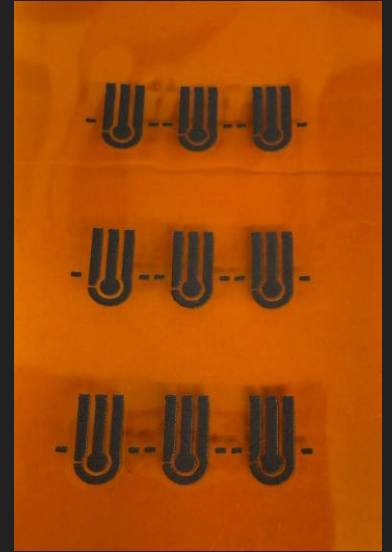
A)



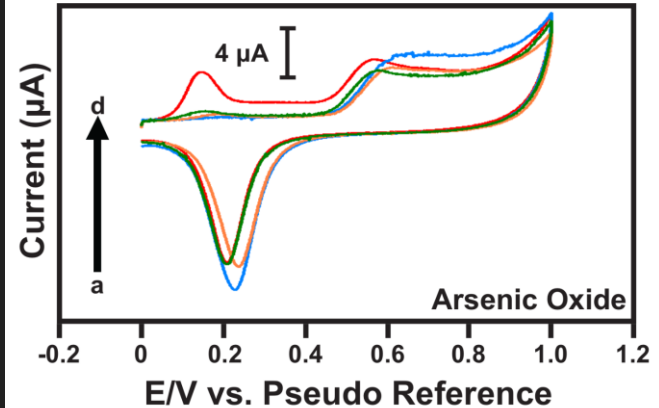
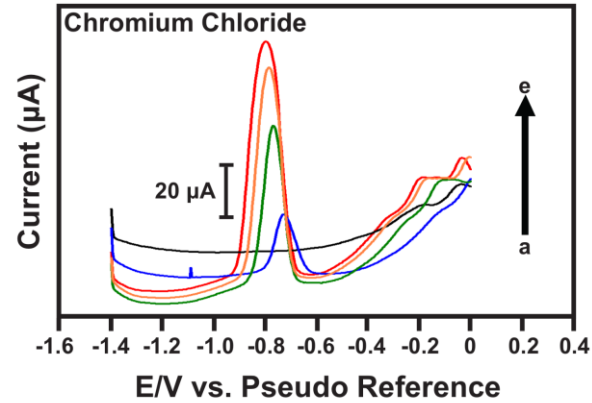
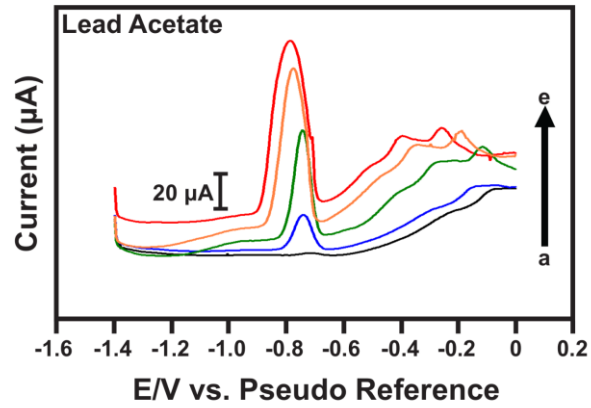
B)



C)



# Laser Induced Graphene Electrode Sensors - Data

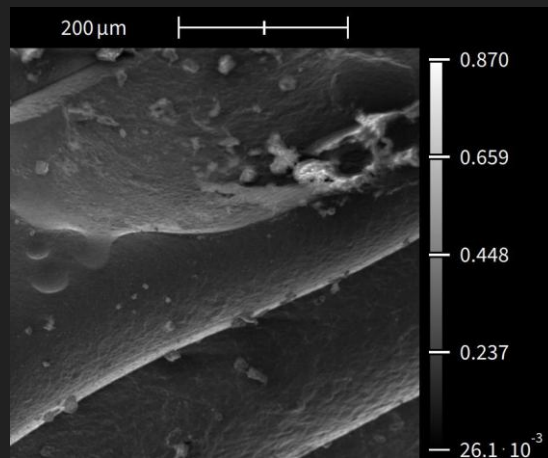


# 3D Printed Electrodes - Intro & Fabrication

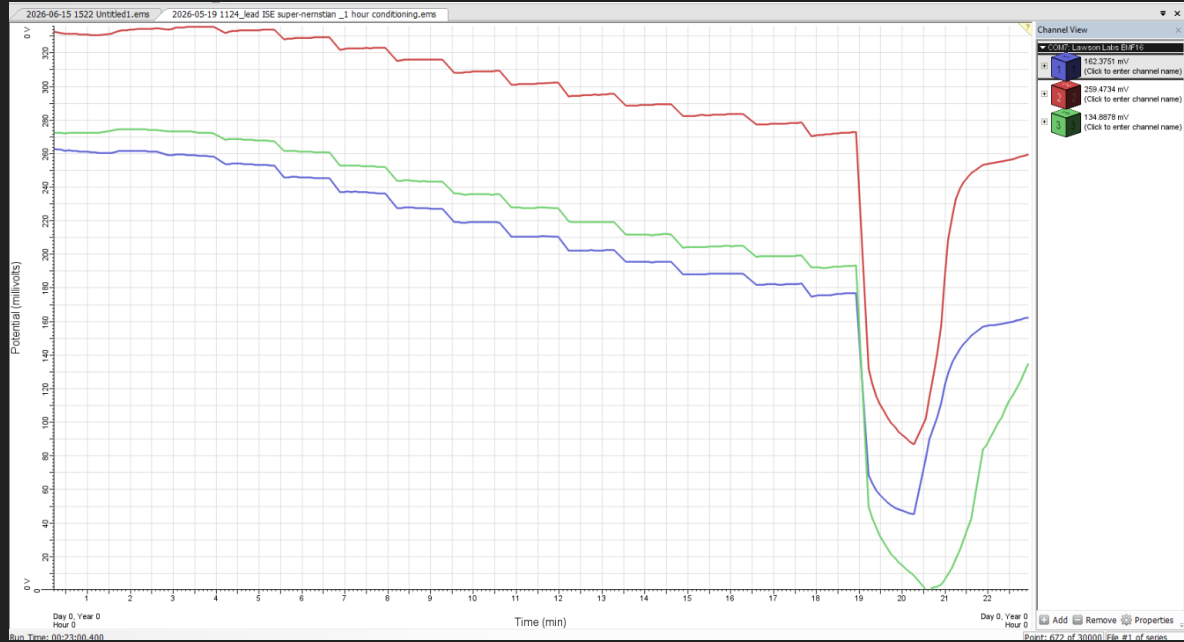
Another emerging research area is 3-D printed electrodes.

Using conductive PLA Filament, we can print conductive electrodes.

Novel sensor shapes can be incorporated into more devices for environmental monitoring and healthcare.



# 3D Printed Electrodes - Data

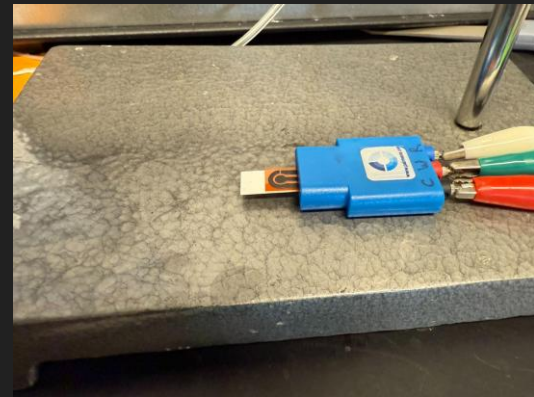


# Future Works

Find new target analytes for our sensors.

Test real world samples:  
Groundwater, soil, sweat etc.

Attach sensors to 3D Printed boat for  
environmental monitoring.



# Acknowledgements

- NTU: Dr. Thiagarajan Soundappan (PI)
- Washington State University, Vancouver



*Dr. Soundappan (NTU)*



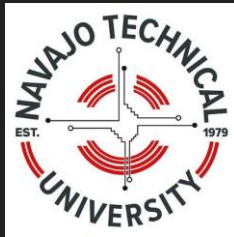
*Dr. Praveen (WSU)*

Dr. Praveen Sekhar

- Harvard University: Dr. Khaled Abdelazim
- N.E.S.T Team students and Staff



*Dr. Khaled (Harvard)*



# NEST TEAM Members



# References

Difference between Voltage and Current Explained, [spikeelectric.com/what-is-difference-between-voltage-current/](https://spikeelectric.com/what-is-difference-between-voltage-current/). Accessed 18 June 2026.

Electricity Explained - U.S. Energy Information Administration (EIA), [www.eia.gov/energyexplained/electricity/](https://www.eia.gov/energyexplained/electricity/). Accessed 18 June 2026.

Elgrishi, Noémie, et al. “A practical beginner’s Guide to cyclic voltammetry.” *Journal of Chemical Education*, vol. 95, no. 2, 3 Nov. 2017, pp. 197–206, <https://doi.org/10.1021/acs.jchemed.7b00361>.

Subramani, Indra Gandhi, et al. “Flexible laser-induced graphene electrodes on polyimide film: Hybrid nanoflower-modified dielectric microjunctions for non-faradaic analysis.” *Biochemical Engineering Journal*, vol. 208, Aug. 2024, p. 109339, <https://doi.org/10.1016/j.bej.2024.109339>.

Sakthivel, Kogularasu, et al. “Editors’ choice—review—advances in electrochemical sensors: Improving Food Safety, quality, and traceability.” *ECS Sensors Plus*, vol. 3, no. 2, 3 June 2024, p. 020605, <https://doi.org/10.1149/2754-2726/ad5455>.

