Development of Potentiostat for IoT Applications

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Abstract

Potentiostats are used for various electrochemical techniques and applications. Using Arduino programming and various components, a low-cost, open-source potentiostat was designed and tested as an alternative to commercial potentiostats. The potentiostat was designed to be able to run Linear Sweep Voltammetry including Chronoamperometry and Chronovoltammetery. The developed potentiostat was validated on the detection of heavy metal ions in an aqueous solution.

Background

- Potentiostats control the potential of electrodes
- Potentiostats range from $1,000-$3,000
- Possible Applications Include:
  - Heavy-Metal Detection
  - Glucose Sensing
  - Iron Detection in Blood

Figure 1. Commercial Potentiostat[1]

Heavy metal detection application:

- Heavy metals in drinking water: many toxic effects on human health
- Galvanic corrosion in household plumbing systems lead (Pb^{2+}) leaching
- Need for fast and simple detection of heavy metals
- Electrochemical sensors are considered complementary to the traditional techniques → inexpensive and portable instruments

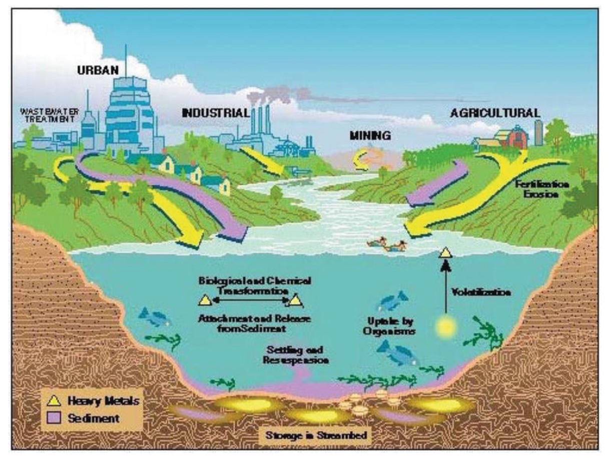
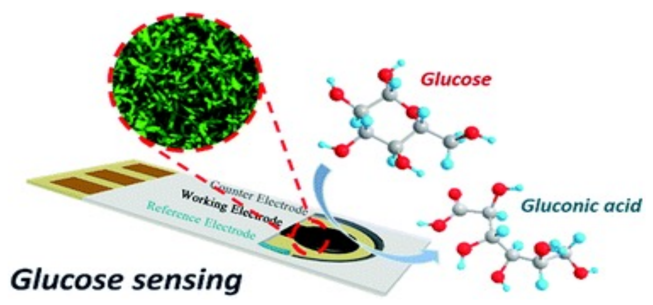


Figure 2. Heavy-Metal Sources in Water[2]

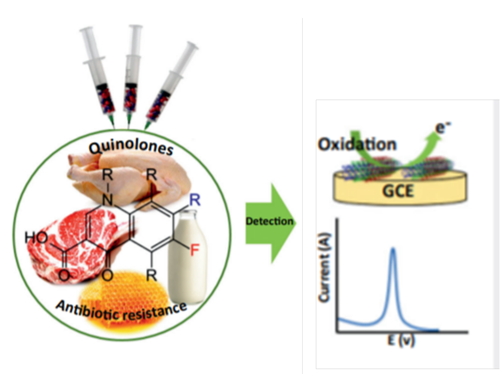
Applications

- Detection and quantitation of trace components in a wide range of applications
- Biological threat detection, quality control, and disease diagnosis.



Glucose sensing using potentiostat[3]

Glucose Testing[4]



Food quality control[5]

Blood Testing for Iron[6]

Figure 3. Applications of the potentiostat as electrochemical sensor

Experimental Procedure

Potentiostat Testing:

1. Input desired parameters
2. Connect working electrode to one terminal of resistor and reference and counter electrodes to opposite terminal.
   - 10KOhm resistor used in testing
3. Run LSV for Current vs. Potential

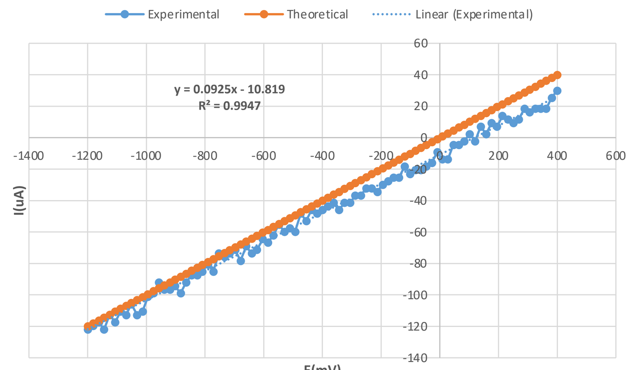


Figure 4. Experimental vs. Theoretical Current

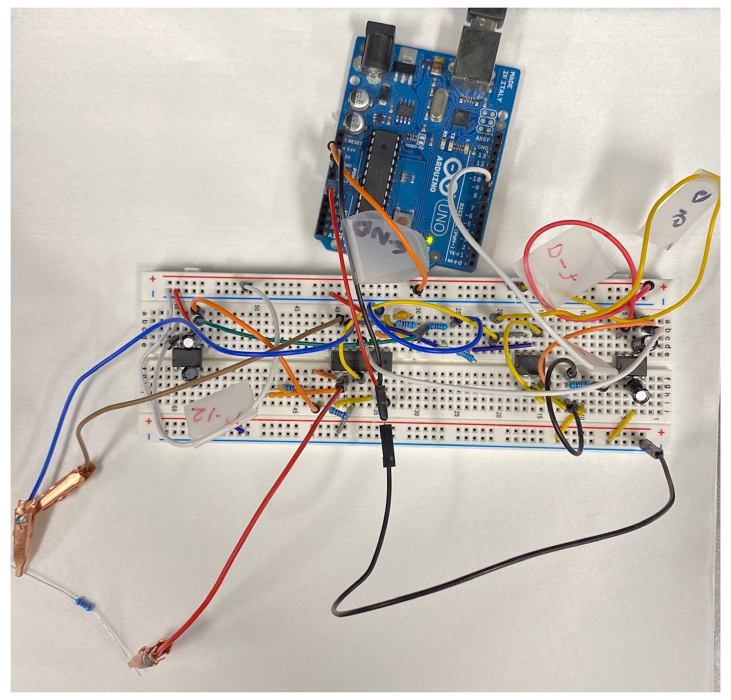


Figure 5. Linear Sweep Voltammetry testing

Sensor Fabrication:

- Sensors screen-printed on the flexible substrate
- Silver as the conductive line
- Carbon as the electrode
- Polymer as the insulation layer

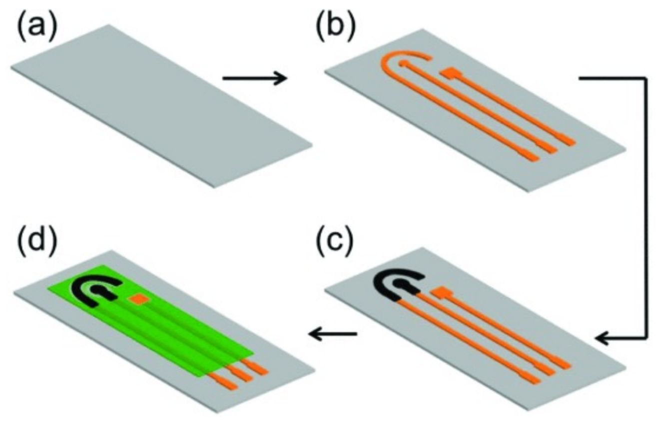


Figure 6. Sensor fabrication process[7]

Sensor Testing:

1. Connect potentiostat to sensor
2. Dip sensor in solution
3. 1 PPM of Pb. Stir
4. Run the Potentiostat LSV
5. PLX-DAQ outputs Current vs. Potential

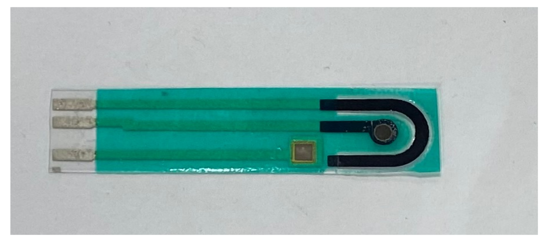


Figure 7. Fabricated electrochemical sensor

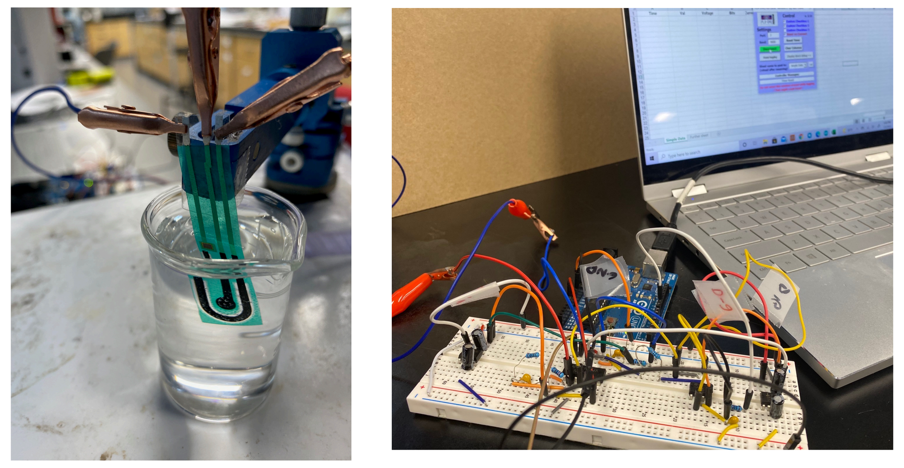


Figure 8. Electrochemical Sensor test setup

Results

Potentiostat Development:

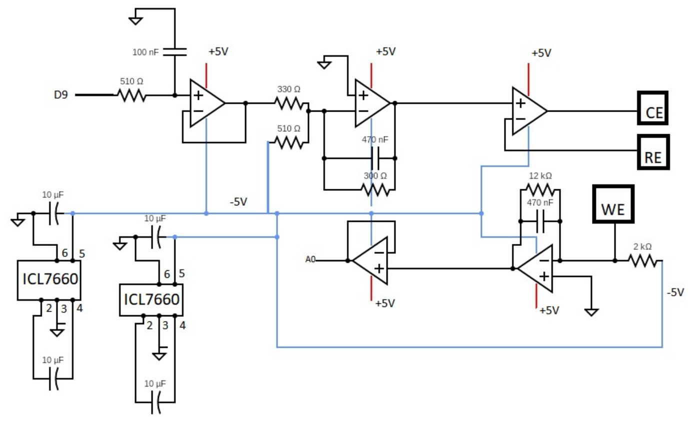


Figure 9. Circuit schematic for potentiostat

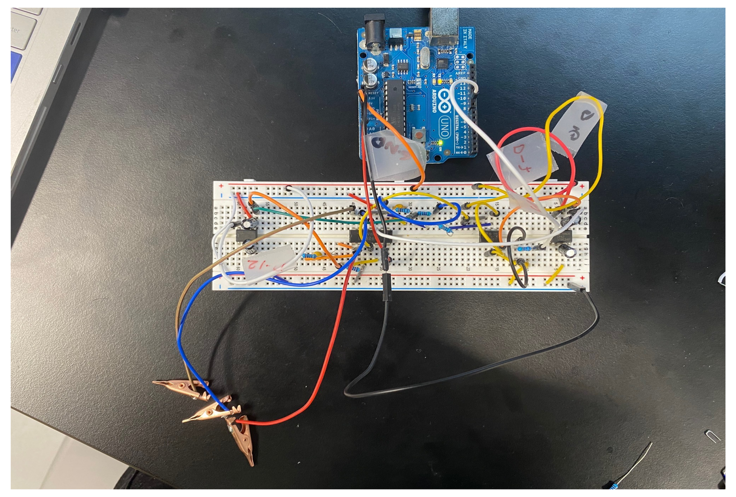


Figure 10. Breadboard setup of potentiostat

Results (cont.)

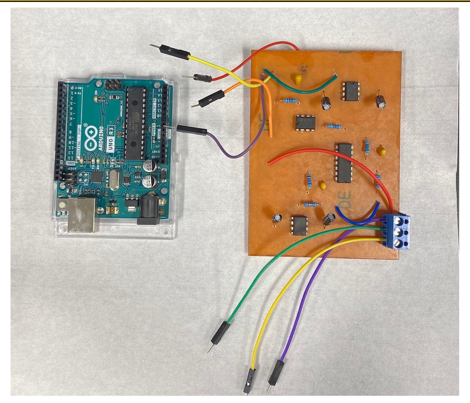


Figure 11. PCB printing of potentiostat

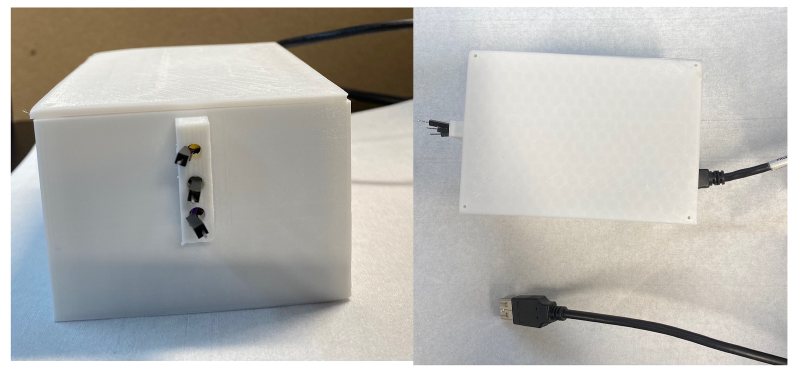
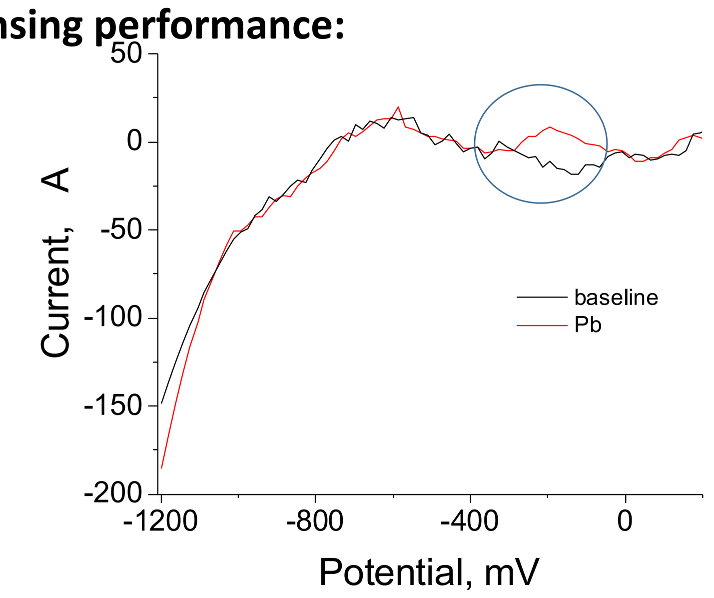


Figure 12. Potentiostat device casing

Sensing performance:



Deposition potential: -1.2 V
Deposition time: 300 s

Figure 13. Lead ion detection using Linear Sweep Voltammetry

Conclusions and Future Work

- Built a potentiostat using breadboard and transferred to PCB for compactness
- Developed potentiostat can be used to perform electrochemical measurements using Linear Sweep Voltammetry, Chronoamperometry, and Chronovoltammetry
- Developed Arduino script to allow user to change potential window, scan rate, cycle number, and electrochemical technique
- Lead ion peak is observed at ~ -350 mV using fabricated electrochemical sensor
- Planned future work includes:
  - App development for UI
  - Allow for greater potential window

References

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