An Electrochemical Lead Sensor based on a Composite Film

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Abstract

Lead is a naturally occurring toxic metal found in the Earth's crust. In this experiment, metal-bipolymer composite electrode was developed for determining the concentration of heavy metal ions, specifically lead, with the use of square wave anodic stripping voltammetry (SWASV).

The experiment was conducted using a potentiostat with a deposition time of 300 seconds, a pulse amplitude of 0.025 V, and a pulse frequency of 20 Hz in 0.1M acetate buffer at pH 4.5. The goal of this research project was to be able to create a user-friendly, low-cost, low-power sensor that is able to detect the concentration of lead in a solution in the ppm range.

Background

Lead exposure can come from multiple activities [1]:

- Fossil Fuels
- Industrial Facilities
- Pipes and Plumbing Materials
- Lead-based Paint

Lead toxicity can affect humans, animals, and other living organisms, which can lead to serious health concerns affecting important organs of the body[2].

Figure 1: Probable sources of lead contaminations.

Working Principle of SWASV

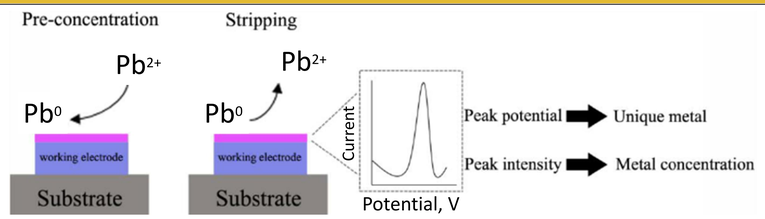

Figure 2: A schematic diagram demonstrating working principle of SWASV. [4]

- Deposition step: Fixed potential for pre-concentrating species of interest.
- Stripping step: Potential sweep to re-oxidize or strip out plated material

Experimental Process

Screen printing:

- Low cost electrode fabrication method.
- Electrode was fabricated in plastic substrate

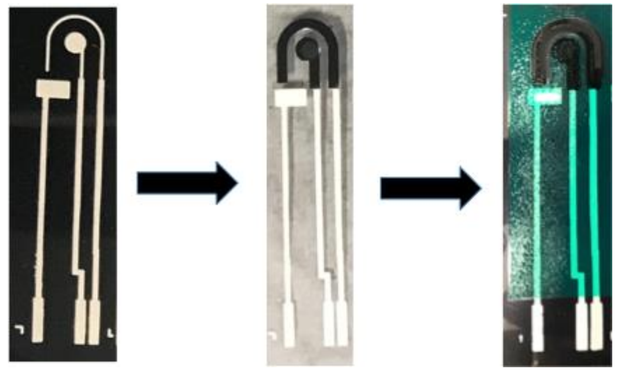

Figure 3: Photograph of screen printed electrode demonstrating different deposition steps.

Copper-chitosan co-deposition:

- Metal-chitosan composite forms stable working electrode.
- Electrolyte: copper nitrate and chitosan in acetic acid.
- Deposition current: 100 mA/cm^2
- Deposition time : 5 to 120 seconds

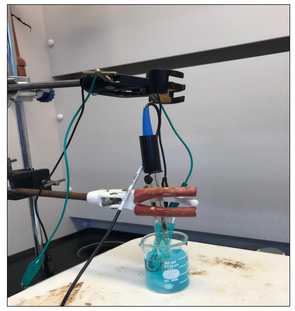

Figure 4: Photograph showing experimental setup for copper-chitosan co-deposition.

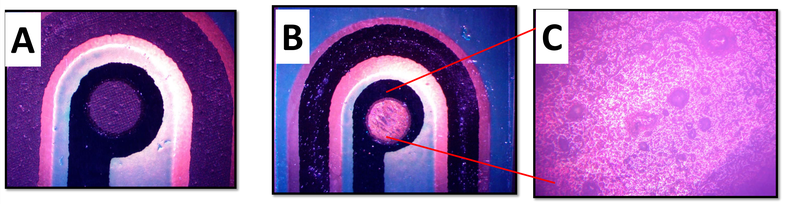

Figure 5: Optical microscope image of carbon electrode (A) and (B-C) copper-chitosan co-deposited carbon electrode.

Sensor testing:

- SWASV was used to measure lead concentration in water
- Electrolyte: 0.1M acetate buffer at pH 4.5.
- deposition time - 300 s, 2.5 mV, amplitude of 50 mV, and frequency of 20 Hz.
- Experimental setup - similar (Figure 4) as deposition process

Results

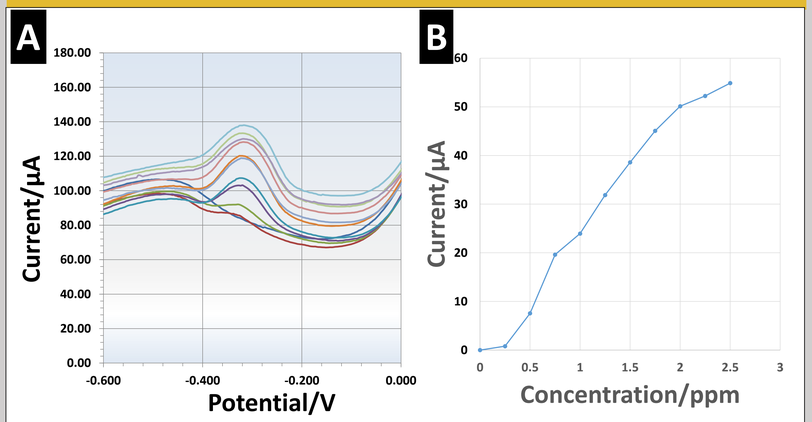

Figure 6: Differential pulse SWASV of Pb^{2+} in 0.1 M acetate buffer (pH 4.5) and corresponding calibration curve of Pb^{2+} at different concentrations.

- Peak current showed linear relation with Lead concentration.
- Saturated after 2.5 ppm
- Sensor need to optimized to enhance sensor range and detection limit

Conclusion

The copper-chitosan composite carbon electrodes were successful in the determination of lead using SWASV. The sensors were able to detect lead concentrations between 0.25 ppm to 2.5 ppm

References

[1] "Learn about Lead," *United States Environmental Protection Agency, **2018.***
[2] J. Hwang, X. Wang, S. Jung, Y. Son, H. Cho, and W. Lee, "Enhanced electrochemical detection of multi-heavy metal ions using a biopolymer-coated planar carbon electrode," *IEEE*, pp. 1-6, 2018.
[3] "US EPA, 40 CFR Part 141 Subpart I – Control of Lead and Copper" *National Primary Drinking Water Regulations, 2018.*
[4] G. March, D. Nguyen, and B. Piro, "Modified Electrodes Used for Electro-chemical Detection of Metal Ions in Environmental Analysis," Biosensors, pp. 242–275, 2015.

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