7-2023

Using Alginate Beads Modified with Graphite as an Effective Electrode

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Introduction

Electrochemical sensors offer exceptional detectability, affordability, and ease of use, making them valuable in clinical, industrial, environmental, and agricultural analyses. Recently, there has been a growing exploration of developing alternative electrodes that utilize new materials and manufacturing methods, while remaining cost-effective and disposable. This study introduces an innovative electrode concept that combines graphite, a relatively abundant and inexpensive material, with alginate, a natural polymer found in brown algae. The resulting graphite-alginate beads exhibit excellent porosity and conductivity, allowing for an increased surface area and potential preconcentration of target analytes. This primary objective of this study is to characterize the graphite-alginate bead electrode. The promising results indicate that it could be applicable for detecting heavy metals in river and lake water using square wave voltammetry.

Experimental

To make the graphite-alginate beads, we first sonicated the graphite powder with a 2% alginate solution. After, we used a 10 mL syringe to drip the graphite-alginate solution dropwise into 0.1 M $CaCl_2$ and the alginate forms crosslinks with calcium. The beads stir in the solution for 15 minutes to complete the crosslinking process.

Figure 1. Bead fabrication process.

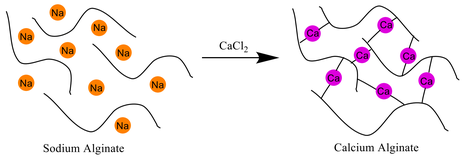

Figure 2. Alginate crosslinking with calcium to form a hydrogel

Characterization of the electrode was done using cyclic voltammetry with a 10 mM ferro/ferricyanide redox couple in 50 mM PBS solution pH 7. When amperometry was done, 0.5 V was applied to the system.

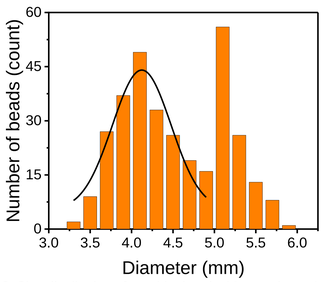

Figure 3. Size distribution of graphite beads. Mean value = 4.12 ± 0.05 mm.

Results

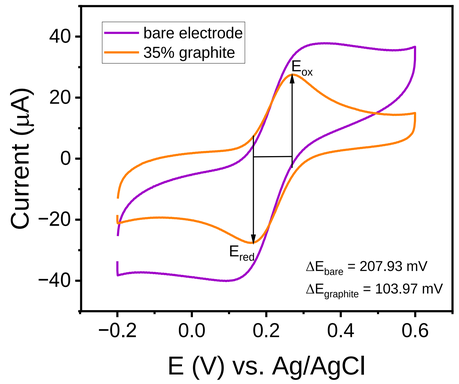

Figure 4. Cyclic voltammogram of the bare graphite electrode and the graphite bead showing the peak potential difference.

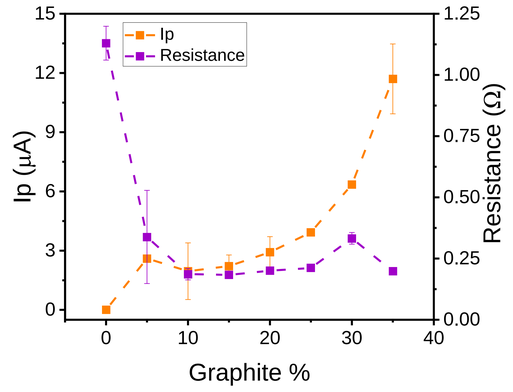

Figure 5. Peak current (µA) and resistance (Ω) of graphite-alginate beads with increasing amounts of graphite. Used a scan rate of 25 mV/s.

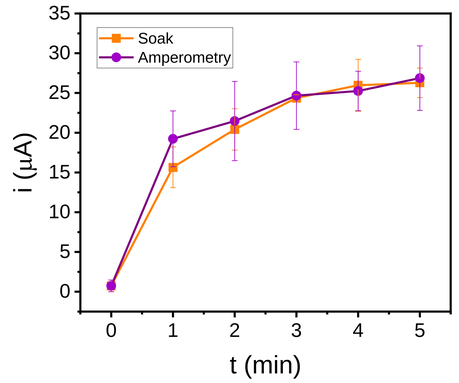

Figure 6. Comparing the peak current using amperometry versus soaking the bead in ferro/ferricyanide solution.

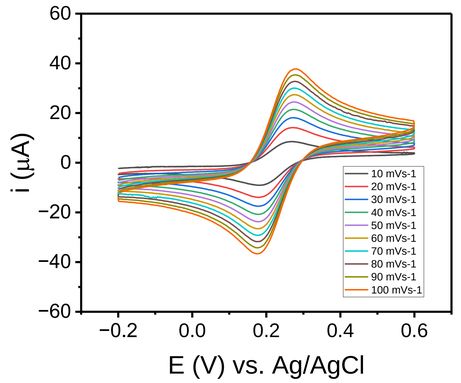

Figure 7. Cyclic voltammogram of graphite bead for sweep rate experiments.

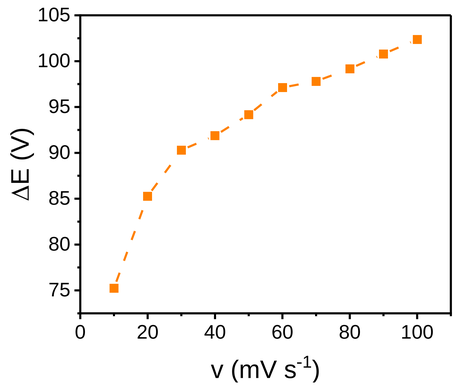

Figure 8. Peak potential difference calculated from the cyclic voltammogram from sweep rate experiments.

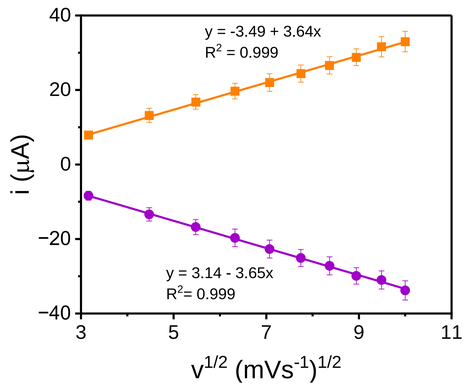

Figure 9. Peak current versus the square root of scan rate from sweep rate for anodic and cathodic peaks.

Conclusions

We successfully developed and characterized an alternative sensor that is unique, biodegradable, and low-cost using cyclic voltammetry. By measuring the resistance and activity of beads with various amounts of graphite, we determined that 35% graphite was the optimal amount for our system. To eliminate the large difference in peak currents in each cycle, we soaked the bead for 3 minutes. After doing sweep rate experiments, we determined that the anodic and cathodic processes are governed by diffusion as there is a linear relationship between the peak current and the square root of the scan rate. After collecting data and characterizing the electrode, the results are promising. There is potential for applying to detecting heavy metals and further research is needed to validate its effectiveness and optimize its performance for real-world applications.

Future Work

Future work for this project includes further characterizing the electrode and applying it for real-world applications. To characterize the electrode, scanning electron microscopy (SEM) can be used to visualize the structure of the beads and their preconcentration capability with a selected analyte. Additionally, the Randles-Sevcik equation can be employed to determine the diffusion coefficient and the electroactive area of our electrode. To apply the electrodes for detecting heavy metals in a water sample, we will conduct tests to determine the time required for preconcentration of the beads and assess their ability to detect various metals.

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Acknowledgements

Special thanks to the Garcia group at Clemson University. This work is funded by NSF – Division of Chemistry, award CHE-2050042

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