Application of Alginate protective layers for screen printed carbon electrodes (SPCE)

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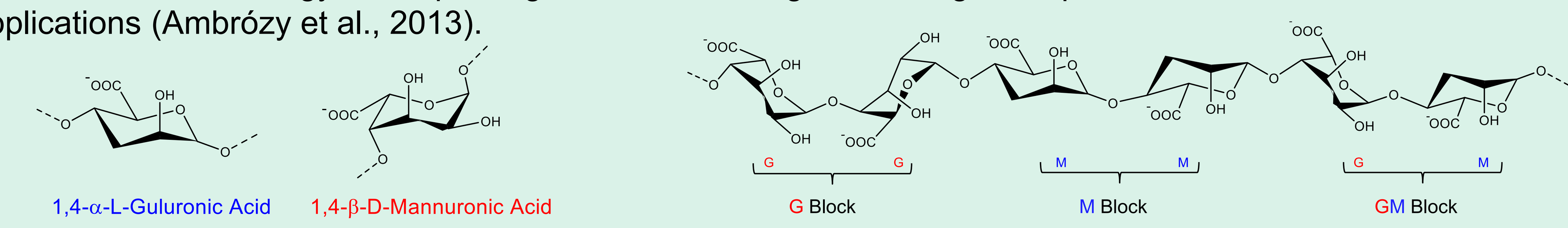
Introduction

The long-term stability and reliability of biosensors can be affected by contamination of the electrode surface during storage and use. The buildup of biological and chemical species may block active sites, decrease sensitivity, and reduce the sensor's operational lifetime. As a result, protective coatings have become an effective approach to reduce surface fouling and maintain sensor performance (Campuzano et al., 2019).Among the various coating materials, alginate is particularly attractive because of its biocompatibility, biodegradability, non-toxicity, and excellent film-forming properties. This naturally derived polysaccharide can form hydrogels and thin protective layers that serve as temporary barriers against contaminants (Kim et al., 2008; Zhang et al., 2019). An ideal protective coating should protect the electrode surface while also be removable when sensing is required, allowing the original electrochemical performance of the electrode to be recovered. The development of transient alginate-based coatings offers a simple and sustainable strategy for improving biosensor storage, handling, and performance in environmental monitoring applications (Ambrózy et al., 2013).



Aim of the study

The aim of this study was to investigate the application of alginate as a transient protective coating for screen-printed carbon electrodes (SPCEs). Alginate layers were deposited using drop-casting and electrodeposition techniques, and their influence on electrode performance was evaluated through electrochemical and spectroscopic characterization.

Particular attention was given to the ability of the alginate coating to protect the electrode surface while being easily removable under mild conditions, allowing complete recovery of the electrochemical response. The study seeks to contribute to the development of sustainable and cost-effective strategies for enhancing biosensor storage stability and minimizing biofouling without compromising sensing efficiency.

Materials and Methods

For drop-casting, 10μL of the 0.01% alginate solution was dropped on the working electrode on the SPE, using a micropipette. This was followed by addition of 5 μL of 0.005% CaCO3 solution. Electrodeposition was carried out by chronopotentiometry and applying a constant currentl of 150μA for deposition time of 300s. The functionality of the electrodes was checked after drop-casting and electrodeposition by washing the electrodes by PBS solution.

Screen-printed carbon electrodes (model C110, Metrohm) incorporating a three-electrode configuration (carbon working electrode, carbon counter electrode, and silver pseudo-reference electrode) were used as the electrochemical platform. Electrochemical characterization of the electrodes before and after each modification was performed using cyclic voltammetry. A 5 mM solution of potassium ferricyanide ($K_3[Fe(CN)_6]$) was used as the electroactive species, in 0.1 M KCl serving as the supporting electrolyte.

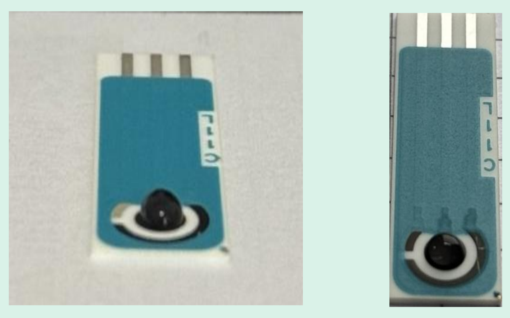


Figure 1. Drop-casting Alginate and $CaCO_3$ solutions on the SPCE.

Results

Modification via drop-casting and electrodeposition

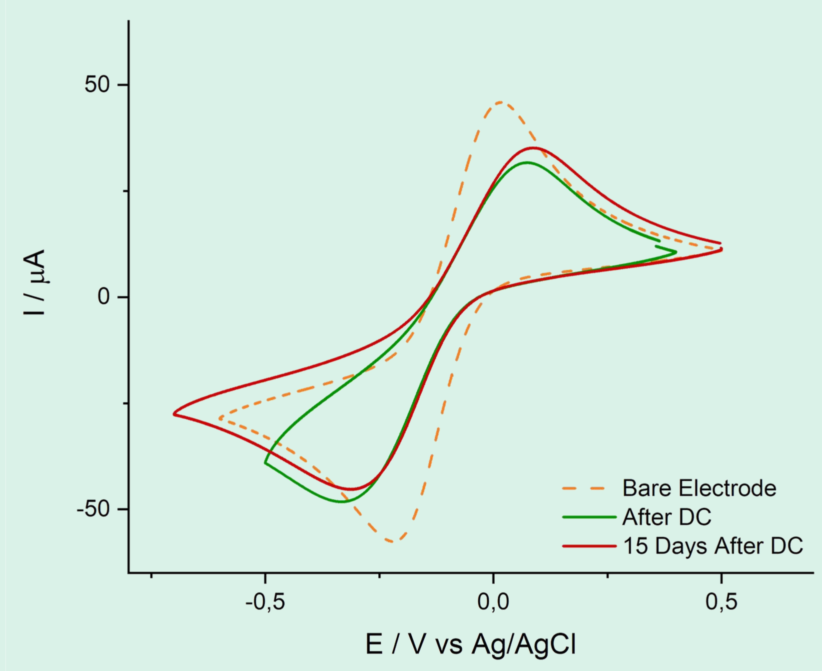


Figure 2. Cyclic voltammograms of bare SPCE and SPCE modified with 15 μL of Alginate and $CaCO_3$ solution by drop-casting, after 2hours and 15 days.

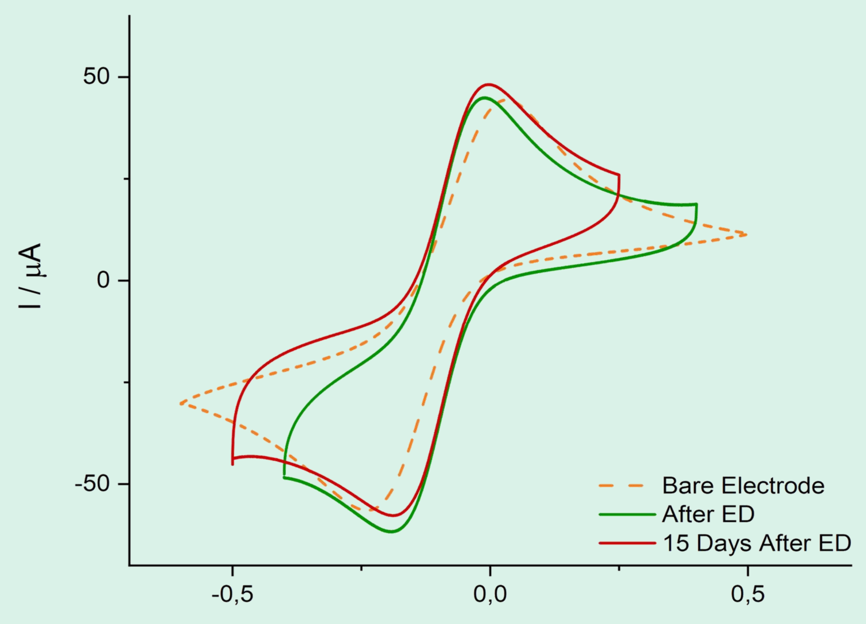


Figure 3. Cyclic voltammograms of bare SPCE and SPCE modified with electrodeposition of alginate, after 2hours and 15 days.

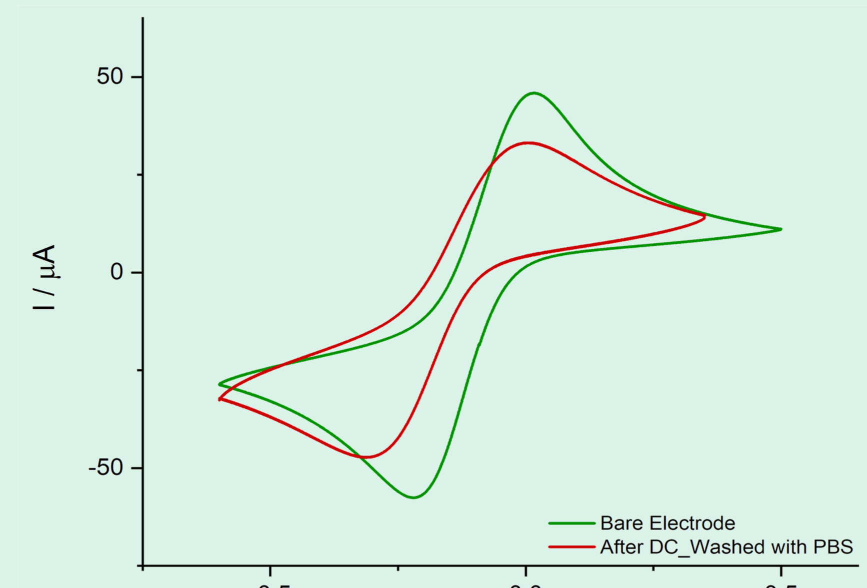


Figure 4. Cyclic voltammograms of bare SPCE and SPCE washed after drop-casting Alginate.

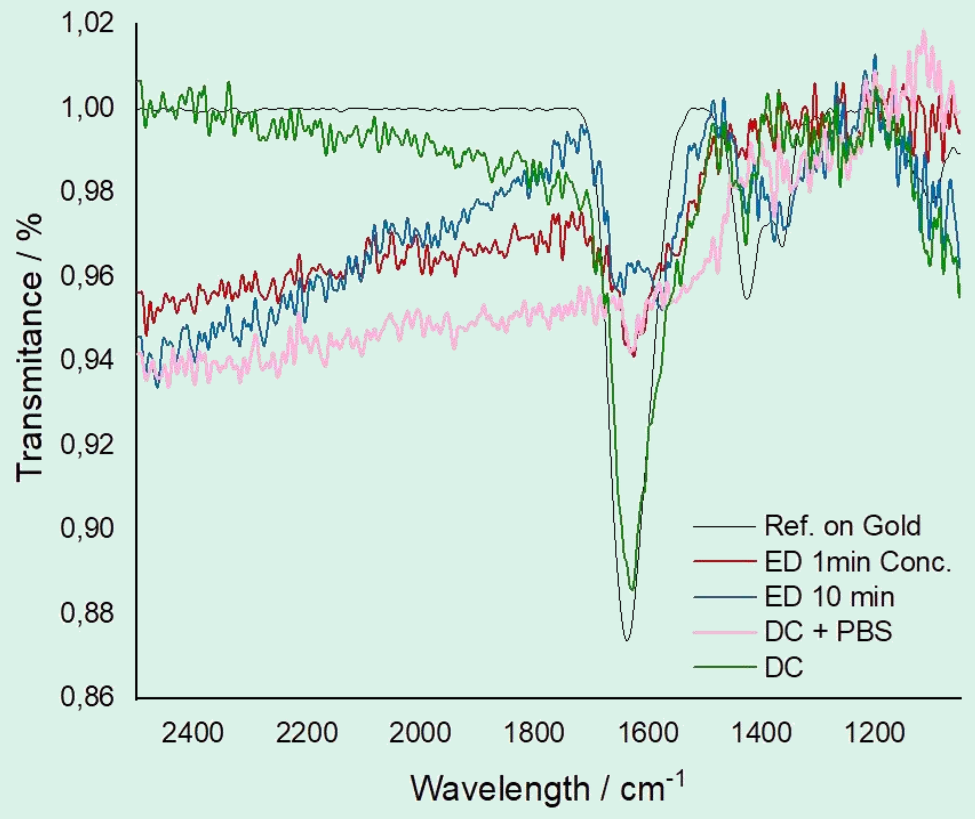


Figure 5. IRAAS plot of drop-casted Alginate on a gold Plate as a reference and alginate on gold SPEs after electrodeposition, drop-casting and also washed electrode with PBS.

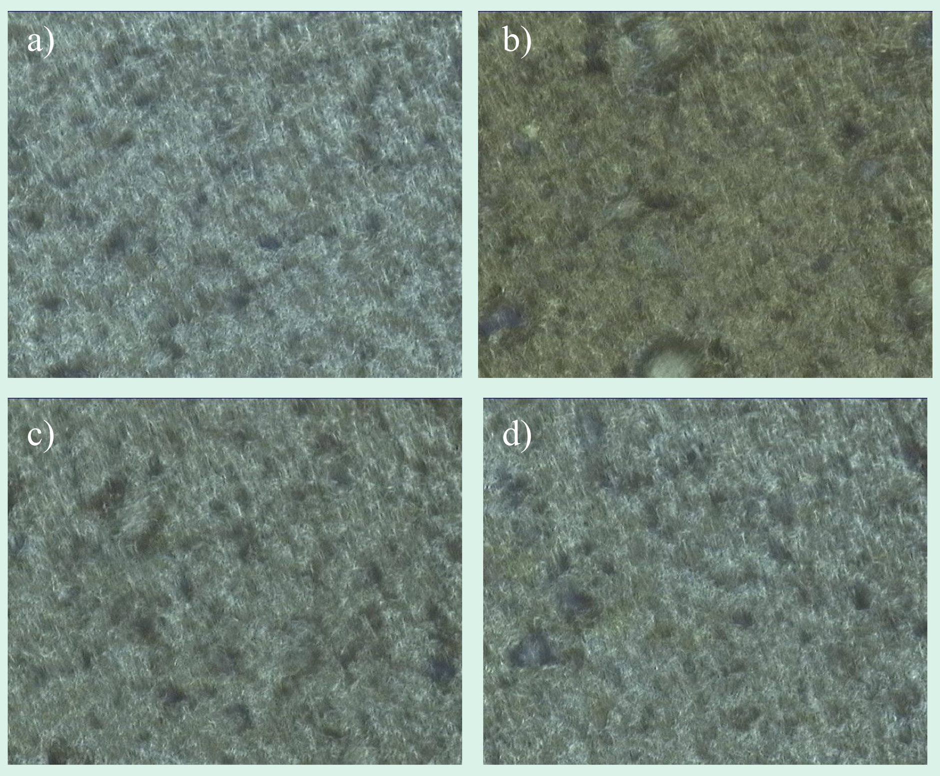


Figure 6*. Microscopic images of a) bare b) after drop-casting c) washed with PBS d) electrodeposited alginate on SPEs gold electrodes..*

Modification of the screen-printed carbon electrode surface with alginate, using both drop-casting and electrodeposition methods, resulted in appearance of more anodic peak potentials with slight drop in peak current. As shown in the cyclic voltammograms (**Figure 2**), the modified electrodes using drop-casting method would result in more peak-to-peak separation compared to the bare SPCEs.. However, by electrodeposition of alginate on the SPCEs (**Figure 3**), only slight decrease in the anodic peak current is observed and the peak to peak separation is untouched, confirming the preservation of electrode performance. **Figure 4**. demonstrates the recovery of the electrodes after drop-casting, simply by washing the electrodes with a PBS solution. IRAAS measurements (**Figure 5**), confirm the presence of alginate by both drop-casting and electrodeposition methods. It can be seen that the alginate signal disappears by washing the electrode by PBS solution.
Furthermore, microscopic images of the gold electrode confirms the findings from IRAAS measurements, illustrating the presences of alginate, as the color of the electrode changes, when alginate is present.

Conclusions

Alginate coatings were successfully applied to screen-printed electrodes using both drop-casting and electrodeposition methods. The coatings provided surface protection while causing only minor changes to the electrochemical response. Furthermore, the alginate layer could be removed by simple washing with PBS, restoring the original electrode performance. These results demonstrate the potential of alginate as a biodegradable and transient protective layer for biosensor applications.

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