Bio-functionalization of conductive textile materials with redox enzymes

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Abstract. In recent years, immobilization of oxidoreductase enzymes on electrically conductive materials has played an important role in the development of sustainable bio-technologies. Immobilization process allows the re-use of these bio-catalysts in their final applications.
In this study, different methods of immobilizing redox enzymes on conductive textile materials were used to produce bio-functionalized electrodes. These electrodes can be used for bio-processes and bio-sensing in eco-designed applications in domains such as medicine and pollution control.
However, the main challenge facing the stability and durability of these electrodes is the maintenance of the enzymatic activity after the immobilization. Hence, preventing the enzyme's denaturation and leaching is a critical factor for the success of the immobilization processes.

1. Introduction

Immobilization of oxidoreductases or redox enzymes (EC1) on conductive fibres and textiles is a method that can be used to produce small size flexible equipment for various applications replacing expensive, rigid, and big size materials. It can be used to fabricate electrodes for biosensors and biofuel cells used in many fields like medicine, environment, and energy production. These enzymes have been immobilized using different techniques like, covalent bonding, cross linking, adsorption, and mechanical compression for confinement into conductive support (1–4). A variety of conductive materials have been used to fabricate these electrodes (anode or cathode) like, multi-wall carbon nanotubes (MWCNT) and poly (3, 4-ethylenedioxythiophene (PEDOT) combination, platinum black, gold coated porous silicon with nanotubes, carbon fibers, graphite and gold (1,2,5–8).

This study focuses on the bio-functionalizing of textile based on a conductive nonwoven carbon felt by immobilizing glucose oxidase redox enzyme to produce electrodes which may be used for different applications such as biofuel cells and biosensors.

2. Materials and methods

The materials used were as follows: carbon felt from CeraMaterials. The conductive polymer poly (3, 4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT:PSS) obtained from HERAEUS. Glucose oxidase G 7141 EC (1.1.3.4) and D-glucose were obtained from Sigma-Aldrich. The glucose oxidase activity kit was purchased from Megazyme.

3. Enzyme immobilization

Commercial carbon felt (5*5 cm^2)(non-treated or PEDOT:PSS dip-coated) was placed in enzyme solution 1mg.ml^{-1} concentration (138.4 U.ml^{-1}) at pH 5.5 and temperature of 4°C for 24 hours, then washed twice with a buffer solution, and stored at 4°C until use.

The obtained bio-functionalized felts can be used as electrodes because of the enzyme's ability of catalyzing oxidation reaction of D-glucose, which releases electrons as shown in equation (1).

$$C_6H_{12}O_6 + H_2O + O_2 \xrightarrow{\text{Gox}} C_6H_{12}O_7 + 2e^- + 2H^+ + O_2 \qquad (1)$$

4. Results and discussion

The results 'Figure 1' show that at pH 7 and 25°C, electrodes obtained from physical adsorption on the carbon felt coated with PEDOT:PSS gave better enzymatic activity than the non-treated carbon felt for the first cycle of enzymatic activity essay using glucose oxidase activity kit. Furthermore, the samples with PEDOT: PSS coating maintained better activity when performing a second cycle using the same kit and same conditions. This refers to good affinity of PEDOT:PSS with the enzymes due to its composition of a mixture of cation/anion ionomers

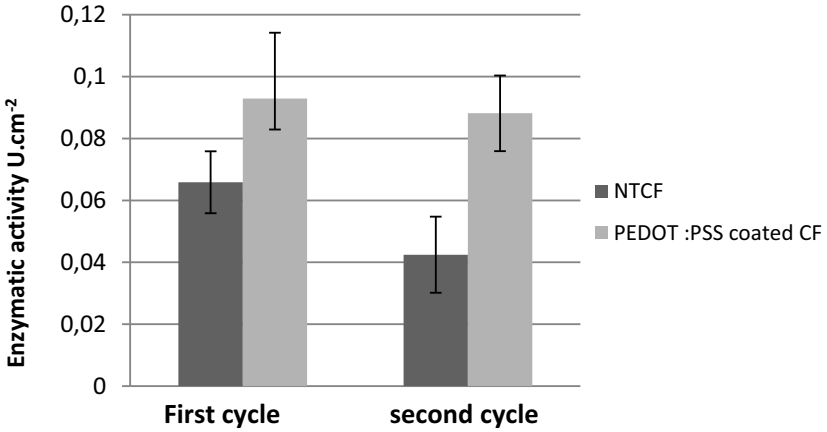

Figure 1. Enzymatic activity for glucose oxidase at pH 7 and 25 °C for non-treated carbon felt and PEDOT: PSS coated carbon felt samples.

Electrical behavior of the obtained electrodes showed to depend on glucose concentration and the scan rates used during the cyclic voltammetry tests. Regarding the substrate used, when the glucose

concentration increases, more substrate will have direct access to the active sites of the immobilized enzymes, and consequently higher electrical currents are obtained. However, when all the active sites of the immobilized enzymes are occupied for a certain moment, the increased substrate concentration does not result in any augmentation of the obtained electrical current. Furthermore, the current obtained showed to be dependent on the scan rate used in the cyclic voltammetry. Indeed, at slow scan rates, the flux towards the electrode is small compared to the faster rates because of the diffusion layer, which results according to Randles-Sevcik in smaller currents recorded.

5. Conclusion

Immobilization of the enzyme glucose oxidase on conductive carbon felt was achieved using two methods. Immobilization by adsorption on the carbon felt coated with PEDOT:PSS yielded a better enzymatic activity and reusability. These obtained electrodes aim to be used in sustainable applications related to energy and pollution control.

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