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Eco-Technologies for Immobilizing Redox Enzymes on Conductive Textiles, for Sustainable Development ⋆

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Abstract

The objectives of this work are to investigate the use of different eco-technologies as strategies for immobilization of redox enzymes on conductive carbon-based felts, to produce bio-functionalized textiles for a future use in sustainable applications while maintaining low environmental impact. Methods using cold remote plasma, electrically conductive biocompatible coating (PEDOT:PSS) and natural crosslinker for the enzyme (genipin) were tested and showed to be efficient in the intended applications. The enzymatic activity of the used glucose oxidase was maintained for multiple number of uses, and showed potential in sustainable wastewater treatment applications in bio-Fenton and bio-electro-Fenton setups.

Keywords: Eco-technology; Glucose Oxidase Enzyme; Sustainable Wastewater Treatment; Plasma

1 Introduction

Appropriate methods for enzyme immobilization on conductive materials are necessary to improve the bio-catalytic activity of enzymes for use in applications where electrochemical response is of prime importance, such as in bioelectrodes, biosensors, or biofuel cells.

This field is getting more attention in recent years with applications used on a daily basis at different levels. Glucose biosensors for domestic use facilitate the lives of diabetes patients, while other biosensors make easy and reliable detection of cholesterol, alcohol and heavy metals,

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to improve safety and control diseases and pollution. Furthermore, power generation from bio-sourced enzyme materials is of great interest for more sustainable processes and services.

Many enzyme immobilization techniques are widely used nowadays, like immobilization on membranes and entrapment in gels or matrix. However, numerous of these methods can be improved in terms of pretreatment requirements and the use of several chemicals or energy consumption.

In this work, the main objective was to immobilize redox enzymes using eco-friendly approaches in attempt to reduce the amount of added chemical and power consumption, in addition to minimize waste production within the frame of sustainable development.

Eco-technologies and products such as plasma as dry treatment, biodegradable and biocompatible conductive polymer coatings, and low toxicity bio-based crosslinking reagent, have been used in this study to achieve the objectives. Cold remote plasma has been used to activate the surface of carbon textile for immobilization of glucose oxidase enzyme. The immobilization was carried out using either direct physical adsorption method, or bio-based naturally occurring crosslinker (Genipin), which is known for its low toxicity in comparison with conventional enzyme crosslinking agents such as glutaraldehyde. The bioactivity and bio-electro-chemical response of the immobilized enzyme were assessed primarily for a future use as bio-anode in bio/bio-electro-Fenton process, for degradation of organic pollutants. A model pollutant Remazol Blue RR reactive dye has been chosen for these treatments, since it is extensively used in textile industry worldwide, and it is known to be persistent and hard to treat. The sustainable applications mentioned show to have advantages over the traditional wastewater treatment methods in regards to environmental impact and safety in work place.

The interest of enzyme immobilization comes from the need of improving the stability and reusability of the enzymes when compared to their free state. Reusability of enzymes also contributes to the reduction of process costs [1]. In addition, the immobilization process reduces the risk of contamination of the products with the residues of the enzyme and hence, reduces the risk of allergies and other undesirable side effects [1]. Another advantage of immobilization of enzymes is the ability of extracting the enzymes from media when desired, to stop the reaction resulting in better control of the process, and less additional steps for deactivating or processing the residual enzymes in the media.

The main methods used in literature are covalent bonding, physical adsorption, cross-linking, entrapment in a matrix and encapsulation bonds [2-5].

Carbon fibers are used intensively in both research and industry nowadays in different forms (yarns, woven and nonwoven structures), to produce composite materials, and to produce electrodes and bioelectrodes for bio/electrochemical applications and reactors [6]. The use of carbon felts was more distinguished in the bio/electrochemical reactors for microbial or enzymatic fuel cells, and in wastewater treatment [7-10]. They possess high specific surface area, which helps immobilization of higher amounts of bioactive materials such as microbial populations and enzymes [11, 12].

2 Problem Formulation

The main motivation behind this work was to investigate milder and more eco-friendly methods to immobilize redox enzymes such as glucose oxidase on conductive textiles, and test their potential