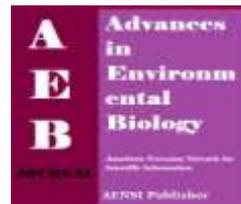




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## Electrical Properties of Chitosan-Ferredoxin Film

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### ABSTRACT

In this study, chitosan was blended with ferredoxin to further improve the electrical properties of sensing film. Chitosan powder was dissolved in 2% of acetic acid and blended with ferredoxin. The mixture was subsequently deposited on printed circuit board using electrochemical deposition technique to form films. Electrical testing of chitosan and chitosan-spinach films was done by exposing them to wet air and dry air using air exposure technique. Electrical testing results showed that the output voltage increased with the addition of ferredoxin. Scanning Electron Microscope (SEM) results showed that the surface of chitosan-ferredoxin film is smoother and more compact than chitosan film. Fourier Transform Infrared Spectroscopy (FTIR) results showed that there was N-H bonding and O-H bonding in chitosan film. Meanwhile, there was an extra peak in chitosan-ferredoxin film, which indicates the existence of [Fe-S] group.

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## INTRODUCTION

Chitosan is the only amino polysaccharide distributed in large amounts in nature which received great attention being used as a sensing material. Chitosan is a unique material that is well suited for biological micro-devices due to its ability to be selectively deposited and its high density of amine groups, which provide active bonding sites [1] and has the ability to retain its natural properties even after processed into film [2]. On the other hand, the fabrication of protein-based thin films on electrode surfaces has attracted considerable interest in the development of novel sensors. Ferredoxin is known as iron-sulphur proteins that function as electron carriers [3] in which is an important criteria for a sensor. The aim of this work is to study the electrical performance of the sensing films fabricated using chitosan and ferredoxin. It was believed that the addition of ferredoxin may improve the electrical performance of the sensing films.

## MATERIAL AND METHODS

### Material:

Chitosan powder (medium grade, 99.9% purity) and ferredoxin were purchased from Sigma Aldrich Ltd.

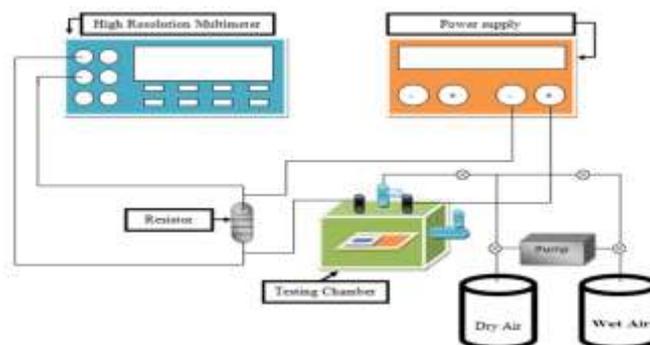
### Film Preparation:

Chitosan solution gel was prepared by dissolving chitosan powder in 2% acetic acid and stirred with rotation speed of 500 rpm for 24 hours at room temperature. Chitosan solution was blended with 5% of ferredoxin followed by electrochemical deposition process where a piece of Cu patterned PCB was dipped into the chitosan-ferredoxin solution and then subjected to the constant voltage to attract the chitosan-ferredoxin molecules to stick on the surface of copper electrode. After the deposition, the films were hard baked in a vacuum oven.

### Electrical testing:

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The electrical testing was carried out using the experimental setup as in Fig.1. The chitosan-ferredoxin film sensor was placed in a chamber and connected with power supply and multi meter with the suitable input voltage. The chitosan-ferredoxin film was exposed to both wet air and dry air respectively. The readings were taken for every 10 seconds of exposure and the exposure was repeated for five times.



**Fig. 1:** schematic diagram for electrical testing

#### Functional group analysis:

Fourier Transform Infrared Spectroscopy (FTIR) (Model: Perkin Elmer) was used to determine the existence of chitosan and ferredoxin functional group in the sample.

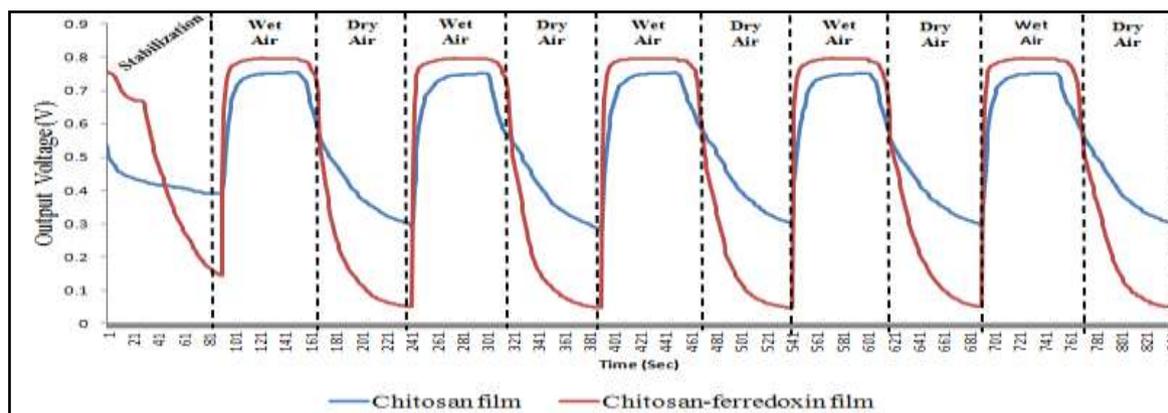
#### Morphology analysis:

Scanning Electron Microscope (SEM) was used to scan the chitosan film and chitosan-ferredoxin film. The scanning was carried out using a SEM (Model: JSM- 6460LA). In this project, the acceleration voltage of 5kV was used with scanning area of 500 $\mu$ m to obtain the best image.

## RESULT AND DISCUSSION

#### Electrical Properties:

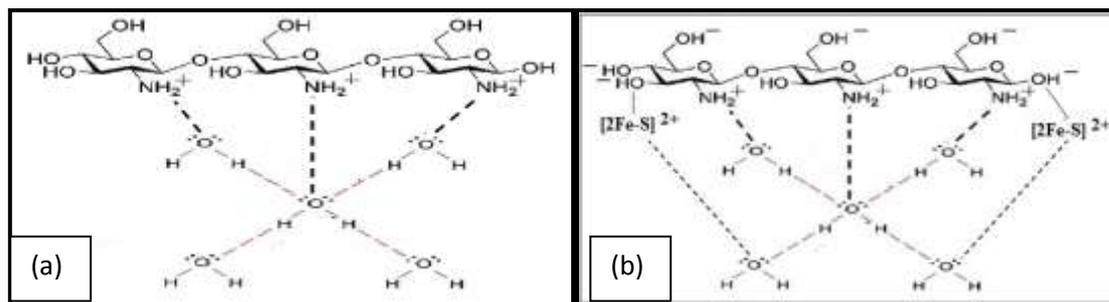
Fig.2 shows the output voltage against time for chitosan film and chitosan-ferredoxin film. The chitosan-ferredoxin film shows good response time, stability, recovery and repeatability upon exposure of wet air and dry air. It can be seen that the repeatability of the chitosan film has improved when it blend with ferredoxin. The chitosan-ferredoxin film also shows better recovery where the output voltage is able to drop to the original value when the exposure of wet air was removed. Overall, ferredoxin has improved the electrical properties of the chitosan film.



**Fig. 2:** Output voltage againsts time of chitosan film and chitosan-ferredoxin film

The sensing mechanism of chitosan towards wet air exposure can be described using electron hopping assisted by proton transfer mechanism [4]. Once wet air was exposed to the chitosan film, oxygen from water molecule will interact with the hydrogen of amine group in chitosan to form hydrogen bondings which act as pathway for electrons to move freely and cause the value of output voltage increases. Meanwhile, the presence of ferredoxin in the chitosan molecule structure create extra pathway as shown in Fig.3, therefore more electrons can move

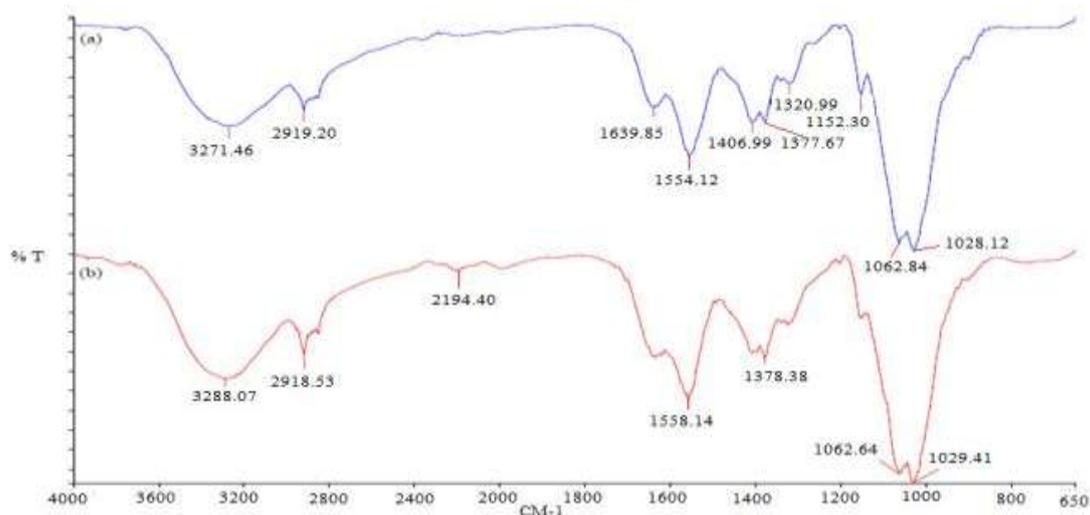
freely from valance band to conduction band. Thus,ferredoxinimproves the electrical performance of chitosan film.



**Fig. 3:** Electron hopping assisted by proton transfer mechanism of : (a) chitosan and water molecules, (b): chitosan-ferredoxin compound and water molecules

#### FT-IR result:

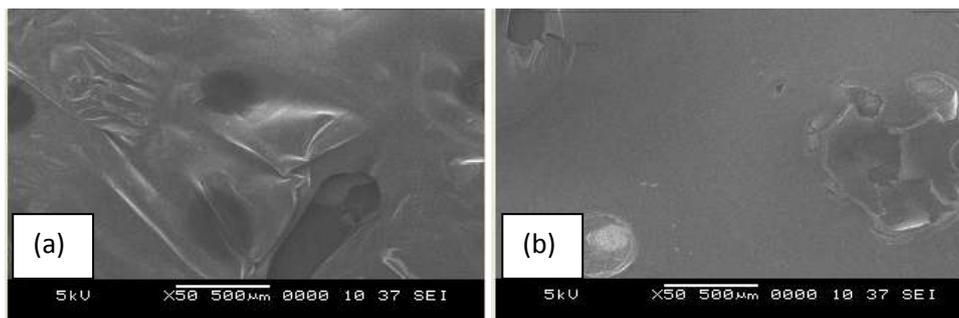
FTIR spectra were obtained by scanning the chitosan film and chitosan-spinach film using spectrometer (Perkin Elmer). The result was reported as in Fig. 4. The absorption peak at  $3271.46\text{ cm}^{-1}$  and  $2919.20\text{ cm}^{-1}$  are due to overlapping of  $\text{NH}_2$  and  $\text{OH}$  [5]. N-H group can be seen at the spectrum of  $1554.12\text{ cm}^{-1}$ . Meanwhile, the absorption peak at  $1406.99\text{ cm}^{-1}$  indicates the existence of  $\text{OH}$  group in chitosan film [5]. As for the chitosan-ferredoxin film, there is an extra peak appear at  $1999\text{ cm}^{-1}$  to  $2194\text{ cm}^{-1}$  indicating the existence of  $[\text{Fe-s}]$  [6].



**Fig. 4:** (a) Chitosan film, (b) Chitosan-ferredoxin film

#### Morphology analysis:

The SEM micrographs obtained from chitosan film and chitosan-spinach films are presented in Fig. 5. Chitosan film as in Fig 5(a) has poor film surface indicating that the chitosan film is not well deposit on the PCB. This will limit the flow of electrons. In contrast, it can be seen in the chitosan-ferredoxin film image 5(b), the surface is smoother compare to chitosan film surface. The surface of the chitosan-ferredoxin film is more compact which allow the flow of the electron becomes easier.



**Fig. 5:** (a) image of chitosan film (b) image of chitosan-ferredoxin film

*Conclusion:*

Chitosan-ferredoxin film is a new material that it is potential to be used as a sensing material. The presence of ferredoxin in the chitosan molecule structure creates an extra pathway for electron movement. The surface morphology of chitosan-ferredoxin film is smoother and more compact compared to the chitosan film where the smoother and more compact surface allow the electron flow easier. Thus, the electrical performance of the sensing film was improved by mixing ferredoxin in chitosan.

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