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Modified Fermentation for Production of Bacterial Cellulose/Polyaniline as Conductive Biopolymer Material

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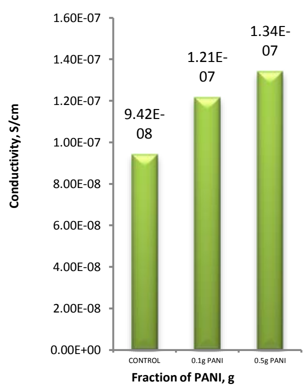
Graphical abstract



Abstract

Bacterial cellulose is a pure and highly hydrophilic material with high mechanical strength. Furthermore by adding certain substrates or by manipulating the operating conditions it is possible to change the properties of the bacterial cellulose. The objective of this research is to develop a modified method for fabrication of bacterial cellulose-polyaniline films. Polyaniline was incorporated into bacterial cellulose during fermentation by *Acetobacter xylinum* in order to produce conductive film. Bacterial cellulose/polyaniline film was synthesized with addition of polyaniline in Rotary-discs reactor during bacterial cellulose formation. The conductivity of film produced was measured and compared. The effects of polyaniline concentration were studied and the relationship between polyaniline concentration and film conductivity were determined.

Keywords: Bacterial cellulose; polyaniline; conductive film; *acetobacter xylinum*

Abstrak

Selulosa bakteria adalah bahan tulen yang sangat hidrofilik dan mempunyai kekuatan mekanikal yang tinggi. Tambahan pula, sifatnya boleh ditukar dengan menambah substrat tertentu atau dengan memanipulasi keadaan semasa fermentasi. Objektif kajian ini adalah untuk membangunkan satu kaedah yang diubahsuai untuk penyediaan filem selulosa bakteria-polyaniline. Polyaniline telah dimasukkan ke dalam selulosa bakteria semasa fermentasi oleh Acetobacter xylinum untuk menghasilkan filem konduktif. Filem selulosa bakteria/polyaniline disintesis dengan menambahkan polyaniline semasa pembentukan selulosa bakteria di dalam 'Rotary-disc reactor'. Kekonduksian filem yang dihasilkan telah diukur dan dibandingkan. Kesan kepekatan polyaniline telah dikaji dan hubungan antara kepekatan polyaniline dan kekonduksian filem telah ditentukan.

Kata kunci: Bacterial cellulose; polyaniline; conductive film; *acetobacter xylinum*

1.0 INTRODUCTION

Cellulose from bacteria has more advantages than the cellulose found in plants. These advantages provide plenty room for the use of bacterial cellulose in various fields. Compared to plant cellulose, the bacterial cellulose are highly hydrophilic with high mechanical strength. Bacterial cellulose can be produced using different methods and substrates whereby the properties can be modified based on the desired application.[1]Several researchers have shown the ability to alter the properties of the cellulose by adding certain substrates or by manipulating the operating conditions. For example, previous work were able to form a seamless cellulose glove using gas permeable mould submerged in an *Acetobacterxylinum* culture,[2] while other successfully added solid particles in the bacterial cellulose to produce new biopolymer composites.[3]

Rotary-discs reactor (RDR) is a reactor designed to increase the fermentation yield of *A. xylinum* for production of bacterial cellulose. It has simple design, higher production yield, less labour and uncomplicated to scale up. Moreover the capability of RDR to be controlled during fermentation time allows changes in the medium to be studied.

The first ever discovered conducting polymer is polyacetylene but it is environmentally unstable despite its high conductivity. This has led to the discovery of other conducting polymers such as polypyrrole, polythiophene, polyphenylene, polyphenylenevinylene and polyaniline. The electrical behaviour of these polymers and their derivatives is similar to that of polyacetylene. Moreover, they show higher stability and better processability.[4] Of all these conducting polymers, polyaniline (PANI) is establishing itself as a novel material due its potential technological applications and low cost of synthesis.[4]

PANI has been selected because of its attractiveness and functional properties from simple preparation method by oxidative polymerization techniques (chemical and electrochemical), good environmental stability (towards water and air) and low cost.

In this research, several fermentation processes were carried out in Rotary-Discs reactor under different conditions to determine the effect of PANI concentration on the conductivity of the film produced.

2.0 METHODOLOGY

2.1 Synthesis of PANI

PANI was synthesized from the oxidation reaction of 0.2 M aniline hydrochloride with 0.25 M ammonium peroxydisulfate in aqueous medium. About 2.59 gram of aniline hydrochloride was dissolved in distilled water in a volumetric flask to 50 mL of solution. 5.71 g Ammonium peroxydisulfate was dissolved in water to a final volume of 50 mL solution. Both solutions were kept for 1 hour at room temperature (~18–24°C), then mixed in a beaker, briefly stirred, and left to stand for the polymerisation process.

The following day, the PANI precipitate was collected on a filter, washed with three 100-mL portions of 0.2 M HCl, followed with acetone. Polyaniline (emeraldine) hydrochloride powder was dried in air and then in vacuum at 60 °C.

2.2 Fermentation of Bacterial Cellulose

Shigeru Yamanaka medium was used as culture medium throughout this study. It consisted of 50 g sucrose, 5 g yeast extract, 5 g ammonium sulphate, 3 g potassium dihydrogen phosphate and 0.05 g magnesium sulphate per 1 Liter distilled water:

The medium was stirred until all ingredients were dissolved. The pH of medium was adjusted with acetic acid to pH 5 before transferring it into 1 L Schott Bottle for autoclaving at 121°C for 15 min. The medium then was left at room temperature to cool before addition of 100 ml of inoculum using aseptic technique. The solution was mixed well by shaking the Schott bottle slowly.

2.3 Inclusion of PANI during Bacterial Cellulose Formation

Medium with inoculum was poured into RDR. The RDR was covered with aluminum foil and left for five days for the fermentation process at pH 5. Different concentrations of polyaniline were added into the medium during fermentation to study the effect towards conductivity.

2.4 Voltage-Current Measurement

Voltage and Current measurement were carried out using prepared bacterial cellulose films incorporated with PANI. Keithley 6517 Electrometer was used in order to measure conductivity of the films. The conductivity and electrical sensitivity of the film were determined from the measurement. The conductivity,σ were calculated using equation 1 where L is thickness, R is resistance and A is film area.[5]

$$\sigma = L / (R.A) \quad (1)$$

3.0 RESULTS AND DISCUSSION

The effect of PANI content on the electrical conductivity of BC/PANI composite films is shown in Figure 1. Electrical conductivity also refers to ion conductivity.[6] From the results, it shows that the conductivity was highly affected by the fraction of PANI in the BC/PANI composite film which is in agreement with previous work done.[7]

It was found that the conductivity of the film increases from 9.42×10^{-8} to 1.34×10^{-7} S/cm as the PANI was increased from 0 to 0.5 g. Conductivity as high as 1.34×10^{-7} S/cm were observed when the PANI fraction was 0.5 g. This is within the range of conductivity reported in previous research in which values ranged from 6.50×10^{-8} to 1.61×10^{-4} S/cm for BC/PANI film.[5]

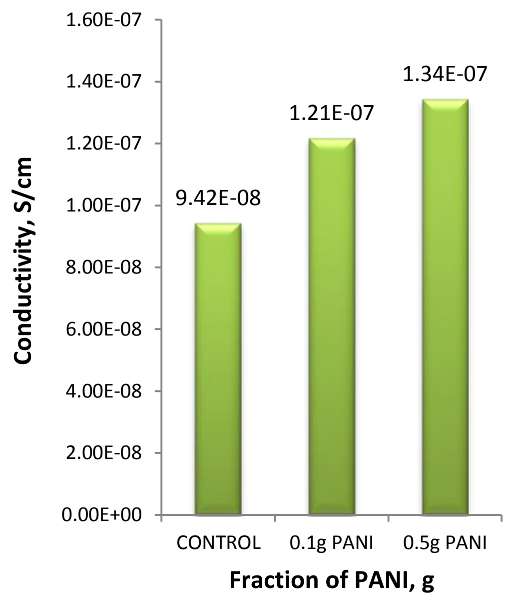


Figure 1 Conductivity of HEC/PANI at different PANI loading

A DC voltage sweep (20 V to 120 V) was applied to all BC/PANI films and the resulting current through the films was measured. The current-voltage readings were taken at different PANI loading. The data obtained from these experiments can be seen in Figure 2. From Figure 2, it can be assume that all the films showed a linear behavior from 20 V to 120 V.

The slopes of these linear regressions were compared to the respond of electrical sensitivity of the films. Thus, it appeared that BC/PANI with 0.5 g of PANI loading gave the highest sensitivity to the electrical responses. The sensitivity of the films was found to increase with increasing PANI loading.

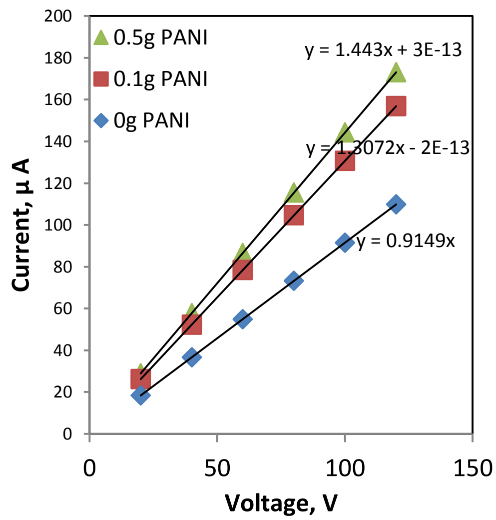


Figure 2 Current-Voltage characteristics of BC/PANI films at different PANI loading (0-0.5 g)

Figure 3 shows the relationship between the electrical sensitivity (slope) and conductivity. It can be observed that the conductivity and electrical sensitivity of the BC/PANI show a similar trend where conductivity and electrical sensitivity increased as the fraction of PANI increased from 0g to 0.5 g. Therefore, the value of electrical sensitivity is strongly dependent on the values of conductivity.

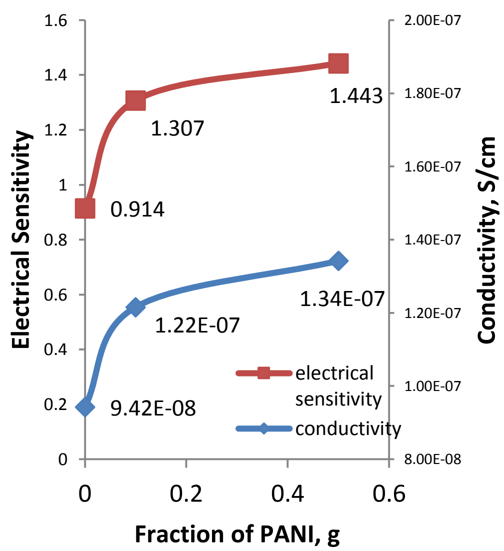


Figure 3 Relationship between conductivity and electrical sensitivity

4.0 CONCLUSION

The BC/PANI film prepared using Rotary-disc reactor showed that the conductivity of BC/PANI increased with the increase of PANI loading. The film was sensitive to electrical response which was strongly dependent on its conductivity.

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