UNIVERSITI TEKNOLOGI MARA

BIOENERGY GENERATION FROM LACCASE-GLUCOSE OXIDASE IN SINGLE AND DOUBLE CHAMBER OF ENZYMATIC FUEL CELL

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Thesis submitted in fulfillment
of the requirements for the degree of
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MSc

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CONFIRMATION BY PANEL OF EXAMINERS

I certify that a Panel of Examiners has met on 26th November 2015 to conduct the final examination of Nurrisa Binti Asrul on his Master of Science thesis entitled " Bioenergy Generation From Laccase-Glucose Oxidase In Single And Double Chamber Of Enzymatic Fuel Cell " in accordance with Universiti Teknologi MARA Act 1976 (Akta 173). The Panel of Examniners recommends that the student be awarded the relevant degree. The panel of Examiners was as follows:

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AUTHOR'S DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the results of my own work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any other academic institution or non-academic institution for any degree or qualification.

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ABSTRACT

The present work investigates a glucose oxidase-laccase enzymatic fuel cell (EFC) employing simplified system design – freely suspended enzymes and their respective substrates. The problem with conventional EFC was the complexity of the system that limits its application for e.g the immobilization procedure which was tedious and has an adverse effect on enzyme activity. EFC also had a low performance system. Single chamber (membraneless) and double chamber design are studied. The EFC comprises of a nickel mesh as the oxidative current collector (and also continuously feed oxygen into the system) and a carbon-based air electrode as the reductive current collector, enclosed in acrylic casing of 3 ml volumetric capacity. The anolyte consists of glucose oxidase enzyme (10 U), glucose substrate (200 mM) and FAD co-enzyme (3.8 mM), while the catholyte consists of laccase enzyme (10 U) and syringaldazine substrate (216 μM). Three types of anolyte/catholyte buffer electrolyte are studied – citrate/citrate, phosphate/phosphate and citrate/phosphate, in the pH range 5 – 6.5. A biocatalytic electrochemical system is highly sensitive. Consequently, any variation in the electrolyte formulation would affect the cell discharge performance. Thus, the discharge profile capacity of the EFC is utilize to elucidate the optimum electrolyte formulation. Though the approach is indirect, the observed changes are obvious, suggesting the method is viable. Despite its simple design features, the EFC demonstrated attractive performance characteristics. The single chamber design registered an OCV of 0.96 V, discharge capacity of 1 mAh (rated at 50 μA) and possessed a volumetric energy density of 286 $\mu W/cm^3$. On the other hand, the double chamber EFC design showed better discharge performance with higher operating voltage and an extended discharge duration by 12%. This could possibly be attributed to the occurrence of charge leakage phenomenon in single chamber design since the anolyte and catholyte were freely mixed. These performance characteristics are considered comparable to biocatalytic energy systems employing much more complicated design such as using immobilized enzymes and mediator, multi-walled carbon nanotubes (MWCNT), oxygenated electrolyte etc., as well as operated in controlled environment. In the EFC design, a commercial air electrode is used as the cathodic current collector which also serves as the ambient oxygen diffusion site to continuously feed oxygen into the system. Utilization of air electrode is shown to enhance the cell output by approximately 30.5 %. As the cell was characterized in an open ambient surrounding, the activity decay of both glucose oxidase and laccase were monitored continuously for 5 days. Both activity decay profiles are similar – a rapid drop in the enzyme activity in the first 20 hours (35-40%), followed by rather a steady region (25% activity decline for about 60 hours duration), and ended by a rapid drop in enzyme activity. Under exposure to uncontrolled ambient conditions, the enzymes could last for about 100 hours.

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