

INTERNATIONAL CONFERENCE



The Second International Conference on
Engineering and Technology Development

2nd ICETD 2013

27, 28, 29 August 2013, Bandar Lampung, Indonesia



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2nd ICETD 2013

THE SECOND INTERNATIONAL CONFERENCE
ON ENGINEERING AND TECHNOLOGY DEVELOPMENT

28 -30 January 2013
Bandar Lampung University (UBL)
Lampung, Indonesia

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PREFACE

The Activities of the International Conference is in line and very appropriate with the vision and mission of Bandar Lampung University (UBL) to promote training and education as well as research in these areas.

On behalf of the Second International Conference on Engineering and Technology Development (2nd ICETD 2013) organizing committee, we are very pleased with the very good response especially from the keynote speaker and from the participans. It is noteworthy to point out that about 80 technical papers were received for this conference.

The participants of the conference come from many well known universities, among others : University Kebangsaan Malaysia – Malaysia, APTIKOM – Indonesia, Institut Teknologi sepuluh November – Indonesia, Surya Institute – Indonesia, International Islamic University – Malaysia, STMIK Mitra Lampung – lampung, Bandung Institut of Technology – Bandung, Lecture of The Malahayati University, B2TP – BPPT Researcher – lampung, Starch Technology Center – Lampung, Universitas Islam Indonesia – Indonesia, Politeknik Negeri Malang – Malang, University of Kitakyushu – Japan, Gadjah Mada University – Indonesia, Universitas Malahayati – Lampung, Lampung University – lampung, Starch Technology Center – Lampung, Universitas Riau – Riau, Hasanuddin University – Indonesia, Diponegoro University – Indonesia, King Abdulaziz University – Saudi Arabia, Parahyangan Catholic University – Indonesia , National Taiwan University– Taiwan, Surakarta Christian University – Indonesia, Sugijapranata Catholic University – Indonesia, Semarang University – Indonesia, University of Brawijaya – Indonesia, PPKIA Tarakanita Rahmawati – Indonesia, Kyushu University, Fukuoka – Japan, Science and Technology Beijing – China, Institut Teknologi Sepuluh Nopember – Surabaya, Researcher of Starch Technology Center, Universitas Muhammadiyah Metro – Metro, National University of Malaysia – Malaysia.

I would like to express my deepest gratitude to the International Advisory Board members, sponsor and also to all keynote speakers and all participants. I am also gratefull to all organizing committee and all of the reviewers who contribute to the high standard of the conference. Also I would like to express my deepest gratitude to the Rector of Bandar Lampung University (UBL) who give us endless support to these activities, so that the conference can be administrated on time

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Recent Advances in Biofuel Cell and Emerging Hybrid System

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Abstract-*The present paper reviews the recent development of biofuel cell. Due to its renewable nature and milder operating conditions compared to conventional fuel cell, the electrochemical system has been extensively studied. However, major problems associated with this type of electrochemical system remain an intimidating challenge, the utmost being the low power output and stability of biocatalyst being used. Various attempts have been made to overcome these problems, some are reviewed here. The authors suggest a new direction in solving these problems by using hybrid system i.e. metal biofuel cell. The new hybrid system developed is of lower cost, less complex, higher OCV and greater power output.*

Keywords: *Biofuel cell, metal biofuel cell, zinc anode, laccase*

1. Introduction

Global depletion of non-renewable energy sources has made research and development in alternative power production critical. Recently, researchers are looking into biological world for inspirations. Enzymes and microbes have been explored as catalysts for energy conversions in so called biofuel cells. Biological fuel cells (BFC) are the progeny of two parent technologies: fuel cells and biotechnology. It is capable of directly converting chemical energy to electrical energy through electrochemical reactions involving biochemical pathways (Bullen et al., 2006). Similar to conventional fuel cells, biofuel cells are made of an anode and a cathode usually separated by a selective membrane that only allows positively charged ions. However, unlike conventional fuel cells, biofuel cells utilize enzymatic catalysts, either as they

occur in microorganisms, or as isolated proteins rather than precious metals. Besides offering clean and renewable energy source, BFC is also capable of utilizing wide variety of fuel choices compared to traditional fuel cell which is limited to simple hydrogen gas, methane or methanol. Much more complex fuels can be utilized in a BFC such as ethanol, propanol, butanol, glycerol, fructose, sucrose, glucose, carbohydrate, fatty acid etc. (Moehlenbrock et al., 2009). Rather than just 2 electrons oxidation in fuel cell, BFC's are capable of doing deeper oxidation which means we can get more energy density out of the fuel.

2. Types and Applications Biofuel Cells

In general there are two types of BFC, grouped based on the catalyst being used, microbial biofuel cell (MFC) and enzymatic

biofuel cell (EFC) and each has its own advantages and disadvantages. The MFC and EFC are further divided either as direct electron transfer or mediated electron transfer (Palmore et al., 1998; Bullen et al., 2006; Palmore et al., 2011). MFC is based on the oxidation of the fuel through microbial catabolisms in the anodic compartment of a fuel cell. The current is generated by redirecting electrons from the microbe membrane respiratory chain to the anode (whole organism is utilized) (Schaetzle et al., 2009). Microbial biofuel cell is the most efficient way of utilizing complex fuels, where the oxidation process involves a series of enzyme catalysed reactions (Thurston et al., 1985). Meanwhile, EFC's use isolated enzymes as biocatalyst to convert the chemical energy of a fuel into electricity, a good substitute to the platinum catalyst used in conventional fuel cells. The capability of enzymes to oxidize various organic molecules under serene conditions, typically at ambient temperature and pressure offers advantages in fuel cell applications (Murata et al., 2009). EFCs have several positive attributes with respect to energy conversion, namely, the use of renewable catalysts, ability to operate at physiological pH and possess much higher power densities as compared to MFC. In addition, enzymes have the added advantage of catalysing specific and defined reactions (Bond and Lovley, 2005). Due to the advantage of inherent biocatalytic properties that cannot be matched by conventional fuel cell technology, biofuel cells are becoming more popular for various potential applications. Examples of current and potential applications of biofuel cells are briefly described below.

2.1 Medical devices and sensors

Biofuel cells are potential candidate for power source within the living body – in vivo power source. Compared to existing

power sources such as lithium-iodine cells (Takeuchi and Leising, 2002), biofuel cells are better alternative since the fuel source is derived from the blood stream (glucose or lactate) (Atanassov et al., 2007). This configuration is ideal for implantable power source as the need for surgical procedure to change the battery is mitigated. Biocatalyst used in biofuel cell can efficiently catalyze reactions at physiological pH and temperature as these species generally performs the best at 25-50°C. In addition, there is no tolerance issue of biocatalyst because it produces reaction products that are non-toxic to the host organism.

Other prospective medical applications of BFCs are as biosensor and power source to administer drug delivery system (Mano et al., 2003; Moore et al., 2005). For example, Katz et al. demonstrated a biosensor for glucose employing a glucose-based anode and cytochrome c cathode (Katz et al., 2001).

2.2 Bioenergy

Shukla et al., put an estimate that a car could travel 25-30 km with just a liter of concentrated carbohydrate solution (Shukla et al., 2004). So, a typical sedan car with 50 litre tank capacity should be able to go more than 1200 km. Besides that, the risk associated with transporting large amounts of volatile, flammable fuels (petrol) in the car also eliminated. Atanassov et al. laid down an interesting analogy to describe the potential in harnessing bioenergy,

“After all, there is as much energy in one jelly donut as you can find in 77 cell phone batteries. If you can get that energy out, it could have pretty, ahem, sweet consequences.”

(Atanassov et al., 2007).

Bioenergy harvested from BFCs currently is still in the microwatt range. The energy amount however is suffice to power microscale electronic sensors for monitoring air quality, plant health or the presence of biohazards. These devices require disconnected and long-term power supply. BFCs fed with ambient fuels which are derived from plants carbohydrates or animal process could be the potential power source to power such devices in the near future (Barton et al., 2004).

2.3 Wastewater treatment

Waste water engineering utilizing MFCs is one of the emerging applications. Employing MFC, microorganisms' decomposition of domestic wastewater and effluent produces electricity as the by-product. Liu et al. applied a single chamber microbial fuel cell designed with eight graphite electrodes as anodes and a single air cathode. The system operated under continuous flow conditions and was capable to generate a maximum electrical power of 26 mW m^{-2} ($2.6 \text{ } \mu\text{Wcm}^{-2}$) while removing up to 80% of the COD of the wastewater (Liu et al., 2004).

3. Present Status and Challenges

Practical applications of BFCs are currently hampered by two most critical factors i.e. poor power density and short lifetime, which are related to enzyme stability, electron transfer rate, and enzyme loading (Kim et al., 2006). Power output of biofuel cells are mostly in the microwatt range which are very much lower compared to other similar technology such as the H_2/air or $\text{CH}_3\text{OH}/\text{air}$. Many practical applications require a power source with supply range of $10\text{--}100 \text{ W cm}^{-2}$. The key issue in bridging the credibility gap is to establish an effective electron transfer rate between

enzymes catalytic site and electrode. As in conventional fuel cells, the electrode design is crucial to obtain an optimum interface between current collector, fuel and catalyst. Therefore, biofuel cell electrodes should be three-dimensional, with optimum surface area, which generally means having smaller pores that increase the reactive surface area and the current generated (Minteer et al., 2007). Another approach is to employ a mediated electron transfer BFC. The electron mediator employed includes ABTS (2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid)), syringaldazine, PQQ (Pyrroloquinoline quinone), FAD (*Flavin adenine dinucleotide*), NAD^+ (*Nicotinamide adenine dinucleotide*) etc. (Palmore et al., 1998; Freire et al., 2003). In most cases, the enzyme and electron mediator are immobilized on the electrodes. Besides, since single type of enzyme only capable of partially oxidizing the fuel, a multi-enzyme system could also be employed to completely oxidize the fuel and subsequently generated more power (Atanassov et al., 2007).

Stability is another issue that hampers practical applications of BFCs. The service time of biofuel cell is determined by the stability of the biocatalysts used. Most currently developed enzymatic biofuel cells only lasts for few days (Katz et al., 1999). The state-of-the-art of present technology is capable to extend the biocatalysts lifetime in the order of months (Barton et al., 2004; Davis and Higson, 2007). However, in order to find commercial interest, the lifetime needs to be increased to at least a year.

4. Recent Advances in Enzymatic Biofuel Cells

Zebda et al. reported an innovative approach to solve the difficulty of electrical wiring of enzymes to the electrode. This

group produced a mediatorless, high power glucose biofuel cells based on compressed carbon nanotube-enzyme electrodes. Laccase and glucose oxidase were integrated in carbon nanotube disks by mechanical compression method. Cellulose film was utilised as separator. It registered an open circuit voltage (OCV) of 0.95 V and delivered a power density up to 1.3 mW cm⁻². The cell remained stable under physiological conditions storage after 30 days and still capable to deliver 1 mWcm⁻² (Zebda et al., 2011).

Researchers from University of New Mexico developed a fully enzymatic biofuel cell that operates under a continuous flow mode (Rincón et al., 2011). Their system is interesting because it operates in a continuous flow mode by employing two dehydrogenases as anode (malate dehydrogenase, MDH and alcohol dehydrogenase, ADH), against laccase as cathode via direct electron transfer (DET) method. OCV of the MDH-laccase biofuel cell was 0.584 V, while the ADH-laccase biofuel cell's was 0.618 V. Maximum volumetric power density of 20 μW cm⁻³ was reported.

Sakai and his team probably reported among the highest biofuel cell output. They utilized a mediated NAD-dependent glucose dehydrogenase (GDH)-bilirubin oxidase (BOD) biocatalytic system. The enzymes, electron transfer mediators and other components were immobilised on carbon fibre electrodes. The GDH-BOD system gave an OCV of 0.8 V and was able to produce a maximum power density of 1.45 mW cm⁻² at 0.3 V. The key features for the cell's high performance were the densely entrapped enzymes and mediator on carbon-fiber electrodes, retained enzymatic activities, optimized concentration of buffer electrolyte and cathode design structure with efficient O₂ supply (Sakai et al., 2009).

Inspired by the metabolic processes of living cell, Addo and co-researchers worked on rechargeable bio-batteries. In their system: ADH was immobilized into an anodic carbon composite paste with ferrocene as the mediator; prussian blue (Iron(III)hexacyanoferrate(II)) was used as the cathode; butyl-3 methylimidazolium chloride ionic liquid served as the electrolyte and Nafion 212 was used as the separator. The ability of NAD-dependent ADH to undergo reversible redox process was the key idea. Ethanol served as the fuel in the carbon paste mixture. Under discharge mode, ethanol was oxidized to acetaldehyde and when current was supplied during charging, acetaldehyde was reduced to ethanol. The cell showed a reasonable stability over a 50 discharge-charge cycles (Addo et al., 2011).

5. Noel Hybrid Biofuel Cell

In an attempt to overcome the low power density, low OCV and very complex and delicate nature of enzymes, the authors introduced a new class of biofuel cell by replacing the anodic enzyme with zinc anode (Ahmad et al., 2011; Ahmad et al., 2013). The design is adopted from a well understood and well characterised zinc-air cell. A hybrid biofuel cell, a zinc-air cell employing laccase as the oxygen reduction catalyst was explored. The bioelectrochemical system combines the well-understood zinc-air cell and an enzymatic biofuel cell - an electropositive zinc element is coupled with the biocatalytic activity of the laccase enzyme. As a result, the biofuel cell design is simplified and its cost is reduced since the anolyte components (enzyme, substrate, electron mediator and buffer solution) are replaced with cheap and abundant metallic zinc. Based on the zinc-air system, an air electrode was utilized in the cell design. The air electrode serves both as the cathodic current collector as well as to feed ambient

oxygen continuously into the system through its porous structure. A single chamber, membraneless cell design was utilized. Laccase biocatalyst was left to be freely suspended (i.e. not immobilized) in quasi-neutral potassium dihydrogen phosphate buffer (pH 6.5) electrolyte. Unlike most biofuel cells, the cell was characterized under open ambient conditions. The hybrid biofuel cell registered an average OCV of 1.2 V and could deliver a maximum power of 3.25 mW at discharge load of 8.5 mA. The highest cell capacity obtained was 7.5 mAh, rated at 0.5 mA.

6. Conclusion

Bioelectrochemical energy systems are attractive as they are clean, renewable energy source. They are popularly dubbed as the nature's solution in preserving the environment. However the energy output harvested from such systems are still low and remains as a formidable challenge. One alternative is to employ a hybrid system i.e. metal biofuel cell. The hybrid system reduces the complexity of existing BFCs while extending the energy density. The hybrid zinc-laccase biofuel cell demonstrated attractive features to be further developed.

References

Addo, P.K., Arechederra, R.L., Minteer, S.D. (2011). Towards a rechargeable alcohol biobattery. *J Power Sources* 196:3448–3451.

Ahmad, A., Othman, R., Yusuf, F., Wahab, M.F. (2011). Zinc-Laccase Biofuel Cell. *IJUM Eng. J. Special Issue on Biotechnology*, 4:153-160.

Ahmad, A., Othman, R., Yusuf, F., Wahab, M.F. (2013). A Hybrid Enzymatic Zinc-Air Fuel Cell. *Sains Malaysiana*. (Accepted for publication)

Atanassov, P., Apblett, C., Banta, S., Brozik, S., Barton, S.C., Cooney, M., Liaw, B.Y., Mukerjee, S., Minteer, S.D. (2007). Enzymatic biofuel cells. *Electrochem Soc Interface* 16:28–31.

Barton, S.C., Gallaway, J., Atanassov, P. (2004). Enzymatic Biofuel Cells for Implantable and Microscale Devices. *Chem Rev* 104:4867–4886.

Bond, D.R. and Lovley, D.R. (2005). Evidence for Involvement of an Electron Shuttle in Electricity Generation by *Geothrix fermentans*. *Appl Env Microbiol*, 71:2186–2189.

Bullen, R.A., Arnot, T.C., Lakeman, J.B., Walsh, F.C. (2006). Biofuel cells and their development. *Biosens Bioelectron*, 21:2015–2045.

Davis, F., Higson, S.P.J. (2007). Biofuel cells—Recent advances and applications. *Biosens Bioelectron*, 22:1224–1235.

Freire, R.S., Pessoa, C.A., Mello, L.D., Kubota, L.T. (2003). Direct electron transfer: an approach for electrochemical biosensors with higher selectivity and sensitivity. *J Braz Chem Soc*, 14:230–243.

Katz, E., Bückmann, A.F., Willner, I. (2001). Self-Powered Enzyme-Based Biosensors. *J Am Chem Soc*, 123:10752–10753.

Katz, E., Filanovsky, B., Willner, I. (1999). A biofuel cell based on two immiscible

solvents and glucose oxidase and microperoxidase-11 monolayer-functionalized electrodes. *New J Chem*, 23:481–487.

Kim, J., Jia, H., Wang, P. (2006). Challenges in biocatalysis for enzyme-based biofuel cells. *Biotechnol Adv*, 24:296–308.

Liu, H., Ramnarayanan, R., Logan, B.E. (2004). Production of Electricity during Wastewater Treatment Using a Single Chamber Microbial Fuel Cell. *Environ Sci Technol*, 38:2281–2285.

Mano, N., Mao, F., Heller, A. (2003). Characteristics of a miniature compartment-less glucose-O₂ biofuel cell and its operation in a living plant. *J Am Chem Soc*, 125:6588–6594.

Minteer, S.D., Liaw, B.Y., Cooney, M.J. (2007). Enzyme-based biofuel cells. *Curr Opin Biotechnol*, 18:228–234.

Moehlenbrock, M.J., Arechederra, R.L., Sjöholm, K.H., Minteer, S.D. (2009). Analytical Techniques for Characterizing Enzymatic Biofuel Cells. *Anal Chem*, 81:9538–9545.

Moore, C.M., Minteer, S.D., Martin, R.S. (2005). Microchip-based ethanol/oxygen biofuel cell. *Lab Chip* 5:218–225.

Murata, K., Kajiya, K., Nakamura, N., Ohno, H. (2009). Direct electrochemistry of bilirubin oxidase on three-dimensional gold nanoparticle electrodes and its application in a biofuel cell. *Energy Environ Sci*, 2:1280–1285.

Palmore, G.T. R., Whitesides, G. M. (2011). Microbial and Enzymatic Biofuel Cells. *Enzym. Convers. Biomass Fuels Prod.* American Chemical Society, 271–290.

Palmore, G.T.R., Bertschy, H., Bergens, S.H., Whitesides, G.M. (1998). A methanol/dioxygen biofuel cell that uses NAD⁺-dependent dehydrogenases as catalysts: application of an electro-enzymatic method to regenerate nicotinamide adenine dinucleotide at low overpotentials. *J Electroanal Chem*, 443:155–161.

Rincón, R.A., Lau, C., Luckarift, H.R., et al. (2011). Enzymatic fuel cells: Integrating flow-through anode and air-breathing cathode into a membrane-less biofuel cell design. *Biosens Bioelectron*, 27:132–136.

Sakai, H., Nakagawa, T., Tokita, Y., (2009). A high-power glucose/oxygen biofuel cell operating under quiescent conditions. *Energy Environ Sci*, 2:133–138.

Schaetzle, O., Barrière, F., Schröder, U. (2009). An improved microbial fuel cell with laccase as the oxygen reduction catalyst. *Energy Environ Sci*, 2:96–99.

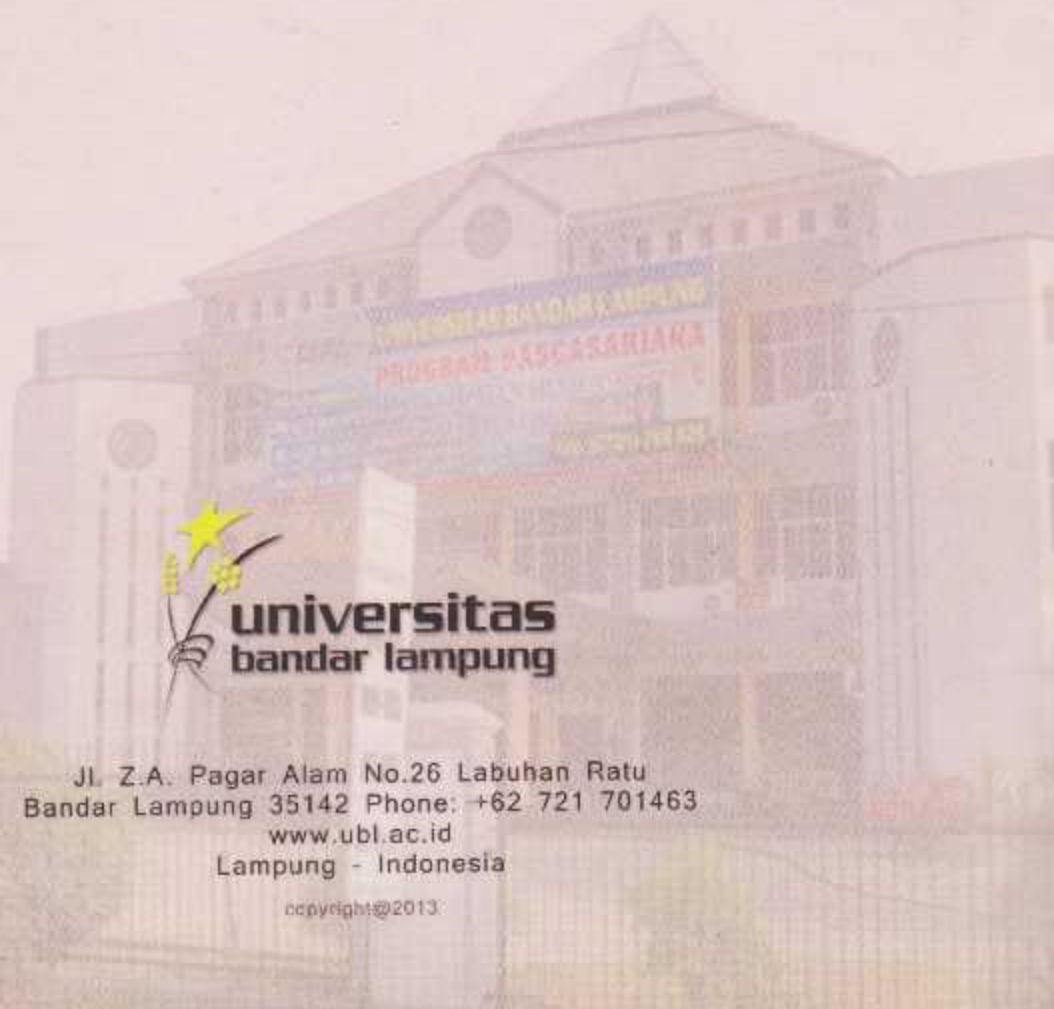
Shukla, A., Suresh, P., Berchmans, S., Rajendran, A. (2004). Biological fuel cells and their applications. *Curr Sci*, 87:455–468.

Takeuchi, E.S., Leising, R.A. (2002). Lithium Batteries for Biomedical Applications. *MRS Bull* 27:624–627.

Thurston, C.F., Bennetto, H.P., Delaney, G.M. (1985). Glucose Metabolism in a Microbial Fuel Cell. *Stoichiometry of*

Product Formation in a Thionine-mediated Proteus vulgaris Fuel Cell and its Relation to Coulombic Yields. J Gen Microbiol, 131:1393 –1401.

Zebda, A., Gondran, C., Le Goff A., Cosnier, S. (2011). Mediatorless high-power glucose biofuel cells based on compressed carbon nanotube-enzyme electrodes. Nat Commun 2:370.



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