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Biofuel Cells, an Alternative to Conventional Fuel Cells

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Imagine running your cellphone and mp3 player on alcohol, sounds surprising? Biofuel cells will make it a reality in the near future. Here we explore the tremendous possibilities of biofuel cells.

In October 2008, Japanese scientists from the Sony Corporation developed a bio-battery that generates electricity from glucose using enzymes as catalysts. When the researchers stacked four of the cells together, they achieved a power output of 100 milliwatts, enough to run an mp3 player or a remote controlled car.

Biological fuel cells (biofuel cells) use biocatalysts, which include bio-molecules such as enzymes or even whole living organisms (microbes) to catalyze oxidation of biomass-based materials for generating electrical energy. A typical biofuel cell consists of an anode and a cathode separated by a proton-conducting membrane. A renewable fuel, such as a sugar, is oxidized by microorganisms at the anode, generating electrons and protons. The protons migrate through a membrane to the cathode while the electrons are transferred to the cathode by an external circuit. The electrons and protons combine with oxygen at the cathode to form water.

Biofuel cells are highly renewable and capable of using naturally available biomass as fuel, as a result, they are an excellent alternative to conventional fuel cells (and batteries) that are plagued by non-renewability, non-implantability, size/weight, operating conditions (high temperature, acidity and toxicity), waste issues, and logistics. They are able to operate at a low substrate concentration which can be even at the micromolar level.

Types of biofuel cells

There are a number of biologically-based fuel cell formats:

Cells which use a primary fuel (usually an organic waste such as corn husks) and generate a material such as hydrogen, which is then used as a secondary fuel within a conventional hydrogen/oxygen fuel cell. It is to be noted that there is no direct generation of power by biological means here.

Cells which generate electricity directly from an organic fuel such as glucose, using either enzymes or complete microorganisms.

Cells which combine the utilization of photochemically active systems and biological moieties to harvest the energy from sunlight and convert it into electrical energy.

Biofuel cells which directly convert fuel to electricity utilize biological moieties such as enzymes or living cells to directly generate power from the chemical energy contained within various organic or inorganic species. A typical fuel cell of this format has two electrodes separated by a semi-permeable membrane placed in a solution. A biological species such as a microbial cell (E.coli) or enzyme (glucose oxidase) can either be in solution (or as a suspension) within the anodic compartment of the cell—or alternatively be immobilized at the electrode. Once a suitable fuel is introduced, it becomes either partially or totally oxidized at the anode and the electrons released by this process are used to reduce oxygen at the cathode. The presence of mediator compounds such as methylene blue increase the efficiency of the cell. Enzyme-based fuel cells remain as a focus for research due to the high turnover rate and high biocatalysis rate associated with enzymes.

The progress in the immobilization of enzymes at electrode surfaces has facilitated efficient electron transfer between the enzyme and the electrode, this indicates that the presence of oxygen in the anodic environment would not affect the bioelectrocatalytic activity of the enzyme and the enzyme-based electrodes could match the performance attainable at platinum electrodes.

Photochemical biofuel cells use respiratory fuel as it makes use microbes. For instance, a cell containing biological moieties in both the anode (cyanobacteria) and cathode (bilirubin oxidase) compartments, the cyanobacteria catalyze the photooxidation of water with the production of electrons that are passed to the carbon felt anode and are thereby made available for the reduction of oxygen at the cathode.

Future

Although there is a huge potential for further improvement, the development of biofuel cells for practical applications is still in its infancy. However, based on their utility, here are some of the areas in which they could find an application.

Transport and energy generation: At present fossil fuels are driving the world’s power needs but they pose environmental hazards and also cannot be used indefinitely. The utilization of biofuel cells with carbohydrates as a power source would, if they could be developed, help to mitigate at least some of these problems. It has been calculated that a liter of concentrated carbohydrate solution could power a car for 25–30 km. If a car running on concentrated carbohydrate solution is fitted with a 50 liter tank, it could travel over 1,000 km without refueling.

Implantable power sources: Biofuel cells can potentially be run in living systems, since the oxygen and fuel required for their operation can be taken from their immediate environment and this offers great potential as power sources for implantable medical devices. For example, a biosensor for glucose has been developed to give a measurement of the glucose concentration in the range of 1–80 mM. A similar sensor for lactate has also been developed. Biofuel cells can be used in pacemakers, catheters, defibrillators, active delivery devices (insulin pumps etc.), drug delivery systems, middle ear hearing devices, and more. Ideally an implanted biofuel cell would use a biological metabolite fuel source such as glucose or lactate, both of which are readily available in physiological fluids such as blood.

Wastewater treatment

Numerous fuel cells have been shown to generate power by oxidation of compounds found in wastewater streams. This could help in the removal of organic compounds from the waste stream for the generation of electrical power.

The most relevant application involves the use of a biofuel cell to trickle-charge lithium-ion batteries used in consumer electronics such as cell phones, laptops and PDAs. They could be used as power sources for environmental sensors, pollution monitors, wildlife tracking sensors, crop quality control sensors etc. Biofuel cell will also enhances power supplies in remote areas as readily available fuel sources such as plant saps with high levels of sugars could be used as a fuel.

Although some specialist devices like short lifetime implantable power devices could now be considered feasible. There is a need for a continuous research effort to see large scale use of biofuel cells.

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