Project number:	405511
Project name:	Healthy Aims - Intelligent Medical Implants and Ambulatory Measurement,
	Workpackage 5b **"Implantable Biofuel Cell"**
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Duration:	Dezember 2003 bis Dezember 2007
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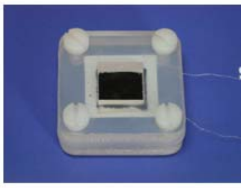
Funding through:	FP 6 of the European Union
Project partners:	DINAMIC, Universitat Rovira i Virgili,Tarragona, Spain
	Zarlink Semiconductor, Caldicote, United Kingdom
Project homepage:	http://www.healthyaims.org



Abstract

To overcome the inherently limited lifetime of batteries several alternative concepts are under consideration to realize a truly sustainable power supply system for medical implants. Within the framework of the European Union Healthy Aims project we are developing implantable biofuel cells that harvest electrical energy in the µW range from glucose and oxygen available in body fluids. Based on abiotic catalysts like platinum and activated carbon these fuel cells are promising with respect to the strict demands on implantable power supply systems, especially regarding biocompatibility and long-term stability. Together with our project partners DINAMIC and Zarlink we are currently further developing the technology and work towards an integrated energy supply system based on abiotically catalyzed glucose fuel cells.

Introduction

The limited life-time of batteries for implantable devices often necessitates surgical replacements. Abiotically catalyzed glucose fuel cells could be used as sustainable power supply for long term implants, converting the chemical energy of the body's glucose into electrical energy (Fig. 1). To facilitate the electrode reactions noble metal catalysts and activated carbon are commonly employed for glucose oxidation and oxygen reduction, respectively.

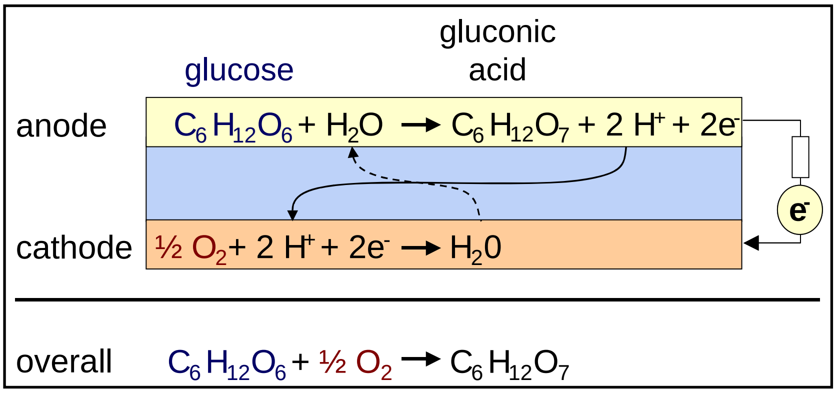


Figure 1: *Electrode reactions of an abiotically catalyzed glucose fuel cell.*

Project objectives

- Development of an implantable fuel cell demonstrator
    - further development of catalysts and matrix materials
    - optimization of the glucose oxygen profile by computer modeling
    - development of a fabrication method
- Characterization of abiotically catalyzed glucose fuel cells with respect to
    - performance in simulated physiological environment
    - in-vitro biocompatibility
- Demonstration of the fuel cell as power supply for medical implants by integrating it into a cardiac pace maker.

Fuel Cell Design

The fuel cell consists of two electrodes, anode and cathode, where glucose oxidation and oxygen reduction take place, respectively. Between the electrodes an electrically insulating polymer membrane is situated, allowing for the diffusion of ions and small molecules. A major challenge in fuel cell design is that the body fluids contain both fuel cell reactants, glucose and oxygen simultaneously. We achieve fuel separation by depletion of the feed solution from oxygen at the exterior cathode. The glucose is oxidized at an interior anode under predominantly anoxic conditions (Fig. 2).

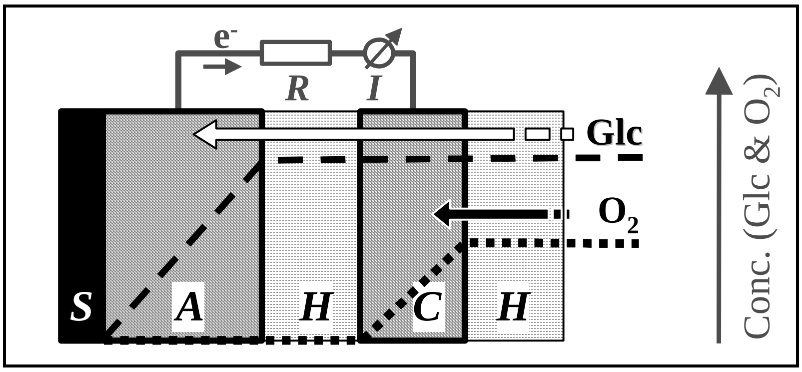


Figure 2: *Fuel cell design. Glc: Glucose; S: surface of implant, A: anode; H: hydrogel; C: cathode.*

Lab-Scale Fuel Cell Fabrication

Hydrogel membranes are casted from an aqueous solution. Electrodes are fabricated by coating a Pt screen with a catalyst paste applying a doctor blade technique. The catalyst paste consists of activated carbon supported catalyst, saturated with aqueous hydrogel solution. After thermal cross-linking, the membrane electrode assembly is mounted in a polycarbonate frame.

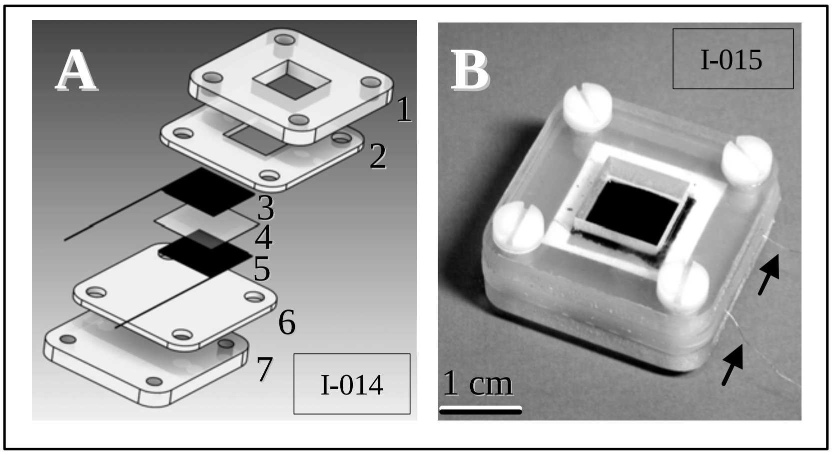


Figure 3*: Device for the rapid assembly of various biofuel cell designs. A: Components. B: Assembled biofuel cell.*

Electrochemical Testing Unit

Our test setup consists of a multi-channel galvanostat for measurement of the electrode potentials at different current densities. A biostat incubates the fuel cell at 37°C in air saturated physiological phosphate buffer containing 0.1 wt % glucose.

Power Output

Our current demonstrator achieves maximum power density of 3.5 µW cm^{-2} at a current density of 20 µA cm^{-2} (Fig. 4).

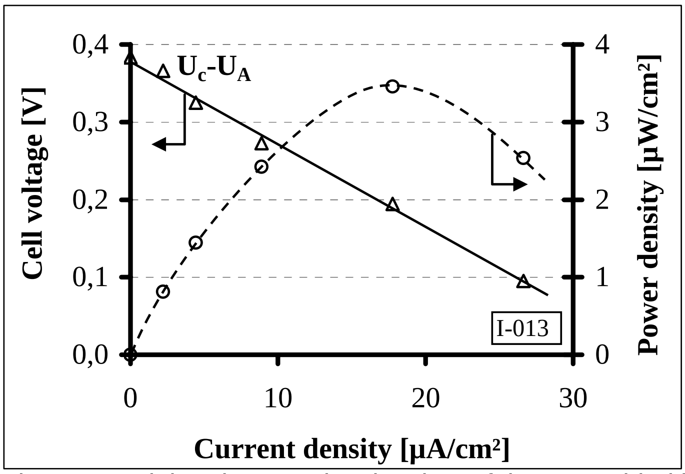


Figure 4: *Current density – potential and power density plots of the assembled biofuel cell.*

Outlook

Expected end result of the project is a demonstrator of an implantable direct glucose fuel cell with a power output in the range of 5 to 20 µW cm^{-2}. Fabrication of the fuel cell with an automated method such as screen printing will be demonstrated. The fuel cell will be tested with respect to cytotoxicity (in-vitro-biocompatibility), and its chemical and mechanical stability. The integration of the fuel cell into a cardiac pacemaker will demonstrate its use as power supply for low power medical implants.

Publications

1. von Stetten, F., Kerzenmacher, S., Sumbharaju, R., Zengerle, R., and Ducree, J. (2006) ***Biofuel Cells as Micro Power Generators for Implantable Devices***. *Proc. Eurosensors XX,* pp. M2C-KN.
2. von Stetten, F., Kerzenmacher, S. Lorenz, A., Chokkalingam, V., Miyakawa, N., Zengerle, R., and Ducrée, J. (2006) **A one-compartment, direct glucose fuel cell for powering long-term medical implants.** *Proc. IEEE MEMS,* pp. 934-937.
3. Woias, P., Manoli, Y., Nann, T., and von Stetten, F. (2005) **Energy Harvesting for Autonomous Microsystems.** *mst news* 4: 42-45.

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