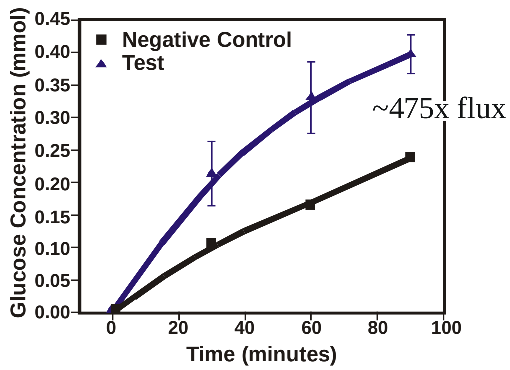
ElectroNeedles

A MINIMALLY INVASIVE PLATFORM FOR ENERGY HARVESTING AND REALTIME *IN-VIVO* ELECTROCHEMICAL IMMUNOASSAYS

Overview

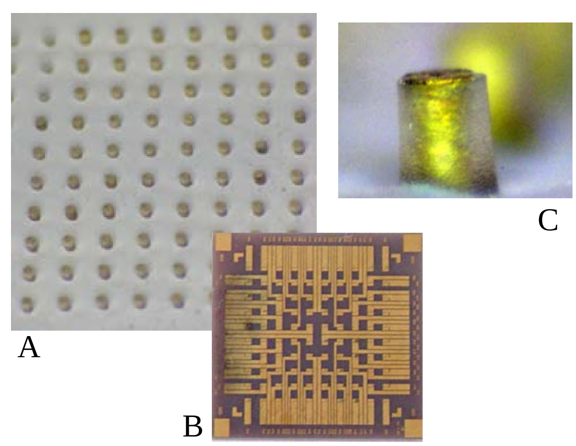
Sandia National Laboratory's BioMicroFuelCell™ (BMFC) Grand Challenge is a three-year, internally funded Laboratory Directed Research & Development Project. The long-term vision is an integrated, compact, and stable fuel cell system that can extract carbohydrate fuels from biological sources such as plants and animals. Our project goal is a miniature fuel cell, operating on pure glucose solution and delivering milliwatts of power over a period of weeks to months.

Harvesting of carbohydrate fuels, glucose, from humans involves the painless extraction of interstitial fluid (ISF) or blood. Microneedles provide an ideal platform to painlessly extract ISF. Using hollow microneedles we have been able to withdraw glucose from a donor solution (10.1 mM glucose in physiological buffer), using a Franz diffusion cell and porcine skin (Figure 1). We measured an approximate 475 times increase in glucose flux compared to the natural diffusion of glucose through porcine skin.



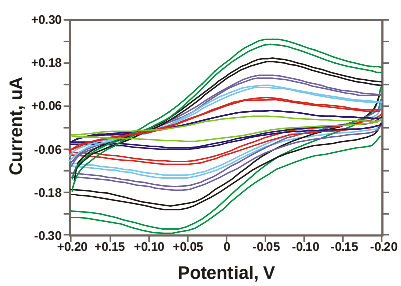
Once ISF is extracted it is transferred to an upstream fuel cell where the carbohydrate fuel is used to generate power. However, the process of removing a human's ISF is detrimental to that human, therefore, we ask, "Why extract the interstitial fluid for upstream consumption? Why not place the fuel cell inside the human and conduct the electrochemistry *in vivo*?" The conductivity of ISF is sufficient enough to allow flow of electrons to between electrodes.

We have fabricated and demonstrated the proof-of-concept for an ElectroNeedle® array, for use as a minimally invasive intracutaneous energy harvester. Photographs of the device are shown in Figure 2; an array of 10 x 10 individually addressable ElectroNeedles® (A); the back side electrical contacts (B); and an individual ElectroNeedle® (C), note the exposed gold encased in a protective dielectric sheath, leaving the electrode exposed on the very tip.

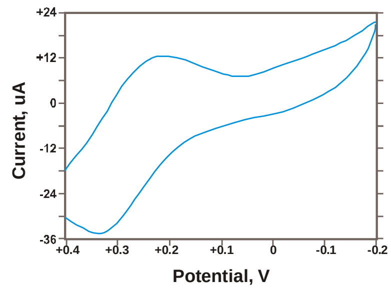


In addition to being used for energy harvesting, ElectroNeedles® may be used for *in vivo* electrochemical immunoassays. Electrochemical immunoassays utilize electrochemical methods, such as potentiometric, amperometric, and conductometric sensing, to identify the presence and concentration of biological compounds.

To demonstrate proof-of-concept for energy harvesting and electrochemical immunoassays, ElectroNeedles® were inserted into porcine skin where quinone, a neutral electrochemical probe molecule similar to Coenzyme Q, and ferrocyanide, a negatively charged electrochemical probe, were both easily detected (Figure 3). Current research efforts focus on the investigation of using ElectroNeedle® arrays for the monitoring of multiple electrochemical compounds related to general health monitoring for first responders.



Ferricyanide



Quinone

ElectroNeedle diagnostics - Sensor Versatility

Since each ElectroNeedle® is individually addressable, an array of ElectroNeedles® may be employed in the detection of multiple analytes. In the case of the electrochemical immunoassay platform shown in the Figure 1, 50 individual analytes can be simultaneously detected using the 1-cm X 1-cm ElectroNeedle® patch. Sandia has additionally fabricated a smaller ElectroNeedle® array capable of measuring up to 12 discrete analytes.

In addition, ElectroNeedles® could be tailored for interaction with specific target compounds through surface modification of the individual ElectroNeedles®. This includes antibody or enzyme immobilization on the ElectroNeedle® surface for potentiostatic measurements. For example, glucose oxidase may be immobilized onto the ElectroNeedles® to measure the glucose concentration present in the patient, or antibodies may be immobilized to measure antigens or antibodies present within the patient.   Using these techniques, the ElectroNeedles® could be used to detect a wide range of analytes including:

- Glucose
- Enzymes
- Proteins
- Antibodies
- Whole cells
- Toxins

With our integration capabilities, we are not restricted to the use of an electrochemical sensing protocol. For example, we could incorporate fiber optic connections to individual hollow needles, which would then serve as a waveguide-coupling medium for use with spectroscopic (fluorescent labeling/tagging) methods of analysis.

Media Announcements
Albuquerque Tribune article:
http://www.abqtrib.com/albq/nw_science/article/0,2668,ALBQ_21236_3969286,00.html
Sandia Lab News:
http://www.sandia.gov/LabNews/050722.html#needles
Sandia Press release, released to over 400 news agencies:
http://www.sandia.gov/news-center/news-releases/2005/all/elecneedle.html
KOB-TV Channel 4 News clip

For additional information or questions, please email us at BioNano@sandia.gov