cells from other regions. In the case of suspension cells, harvesting is performed upon the infusion of fresh nutrient medium. Incorporated into the miniature culture system is a temperature-control system and gas-control loop. The inclusion of these two systems will enable the miniature culture system to be autonomous.

This work was done by Steve R. Gonda of Johnson Space Center and Stanley J. Kleis and Sandra K. Geffert of the University of Houston.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should addressed to:

Emmanuelle Schuler, Ph.D
Technology Transfer Associate
Office of Intellectual Property Management
University of Houston
316 E. Cullen
Houston, TX 77204-2015
E-mail: eschuler@uh.edu

Refer to MSC-24210-1, volume and number of this NASA Tech Briefs *issue, and the page number.*

Electrochemical Detection of Multiple Bioprocess Analytes

Key analytes can be detected using sample volumes of only 100 mL.

Lyndon B. Johnson Space Center, Houston, Texas

An apparatus that includes highly miniaturized thin-film electrochemical sensor array has been demonstrated as a prototype of instruments for simultaneous detection of multiple substances of interest (analytes) and measurement of acidity or alkalinity in bioprocess streams. Measurements of pH and of concentrations of nutrients and wastes in cell-culture media, made by use of these instruments, are to be used as feedback for optimizing the growth of cells or the production of desired substances by the cultured cells. The apparatus is designed to utilize samples of minimal volume so as to minimize any perturbation of monitored processes.

The apparatus can function in a potentiometric mode (for measuring pH), an amperometric mode (detecting analytes via oxidation/reduction reactions), or both. The sensor array is planar and includes multiple thin-film microelectrodes covered with hydrous iridium oxide. The oxide layer on each electrode serves as both a protective and electrochemical transducing layer. In its transducing role, the oxide provides electrical conductivity for amperometric measurement or pH response for potentiometric measurement. The oxide on an electrode can also serve as a matrix for one or more enzymes that render the electrode sensitive to a specific analyte. In addition to transducing electrodes, the array includes electrodes for potential control. The array can be fabricated by techniques familiar to the microelectronics industry.

The sensor array is housed in a thin-film liquid-flow cell that has a total volume of about 100 mL. The flow cell is connected to a computer-controlled subsystem that periodically draws samples from the bioprocess stream to be monitored. Before entering the cell, each 100-mL sample is subjected to tangential-flow filtration to remove particles. In the present version of the apparatus, the electrodes are operated under control by a potentiostat and are used to simultaneously measure the pH and the concentration of glucose. It is anticipated that development of procedures for trapping more enzymes into hydrous iridium oxide (and possibly into other electroactive metal oxides) and of means for imparting long-term stability to the transducer layers should make it possible to monitor concentrations of products of many enzyme reactions — for example, such key bioprocess analytes as amino acids, vitamins, lactose, and acetate.

This work was done by R. David Rauh of EIC Laboratories, Inc., for Johnson Space Center. Further information is contained in a TSP (see page 1).

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

Jeffrey L. Bursell,
Controller/Contract Administrator
EIC Laboratories, Inc.
111 Downey Street,
Norwood, MA 02062
Phone No.: (781) 769-9450

Refer to MSC-23578-1, volume and number of this NASA Tech Briefs *issue, and the page number.*

Fabrication and Modification of Nanoporous Silicon Particles

Biodegradable drug carriers allow sustained drug release for days or even weeks.

Lyndon B. Johnson Space Center, Houston, Texas

Silicon-based nanoporous particles as biodegradable drug carriers are advantageous in permeation, controlled release, and targeting. The use of biodegradable nanoporous silicon and silicon dioxide, with proper surface treatments, allows sustained drug release within the target site over a period of days, or even weeks, due to selective surface coating. A variety of surface treatment protocols are available for silicon-based particles to be stabilized, functionalized, or modified as required. Coated polyethylene glycol (PEG) chains showed the effective depression of both plasma protein adsorption and cell attachment to the modified surfaces, as well as the advantage of long circulating.

Porous silicon particles are micromachined by lithography. Compared to the synthesis route of the nanomaterials, the advantages include: (1) the capability to make different shapes, not only spherical particles but also square, rectangular, or ellipse cross sections, etc.; (2) the capability for very precise dimension control; (3) the capacity for porosity and pore profile control; and (4) allowance of complex surface modification. The particle patterns as small as 60 nm can be fabricated using the state-of-the-art photolithography. The pores in silicon can be fabricated by exposing the silicon in an HF/ethanol solution and then subjecting the pores to an electrical current. The size and shape of the pores inside silicon can be adjusted by the doping of the silicon, electrical current application, the composition of the electrolyte solution, and etching time.

The surface of the silicon particles can be modified by many means to provide targeted delivery and on-site permanence for extended release. Multiple active agents can be co-loaded into the particles. Because the surface modification of particles can be done on wafers before the mechanical release, asymmetrical surface modification is feasible.

Starting from silicon wafers, a treatment, such as KOH dipping or reactive-ion etching (RIE), may be applied to make the surface rough. This helps remove the nucleation layer. A protective layer is then deposited on the wafer. The protective layer, such as silicon nitride film or photoresist film, protects the wafer from electrochemical etching in an HF-based solution. A lithography technique is applied to pattern the particles onto the protective film. The undesired area of the protective film is removed, and the protective film on the back side of the wafer is also removed. Then the pattern is exposed to HF/surfactant solution, and a larger DC electrical current is applied to the wafers for a selected time. This step removes the nucleation layer. Then a DC current is applied to generate the nanopores. Next, a large electrical current is applied to generate a release layer. The particles are mechanically suspended in the solvent and collected by filtration or centrifuge.

This work was done by Mauro Ferrari and Xuewu Liu of the University of Texas Health Science Center for Johnson Space Center. For further information, contact the Johnson Technology Transfer Office at (281) 483-3809.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

Office of Technology Management
The University of Texas
Health and Science Center at Houston
7000 Fannin, Suite 720
Houston, TX 77030
E-mail: utsch-otm@uth.tmc.edu

Refer to MSC-24479-1, volume and number of this NASA Tech Briefs *issue, and the page number.*

High-Altitude Hydration System

Multiple methods of keeping water from freezing can be used by law enforcement personnel, skiers, and campers, and underwater by military personnel.

Lyndon B. Johnson Space Center, Houston, Texas

Three methods are being developed for keeping water from freezing during high-altitude climbs so that mountaineers can remain hydrated. Three strategies have been developed. At the time of this reporting two needed to be tested in the field and one was conceptual.

The first method is Passive Thermal Control Using Aerogels. This involves mounting the fluid reservoir of the climber's canteen to an inner layer of clothing for better heat retention. For the field test, bottles were mounted to the inner fleece layer of clothing, and then aerogel insulation was placed on the outside of the bottle, and circumferentially around the drink straw. When climbers need to drink, they can pull up the insulated straw from underneath the down suit, take a sip, and then put it back into the relative warmth of the suit. For the field test, a data logger assessed the temperatures of the water reservoir, as well as near the tip of the drink straw.

The second method is Passive Thermal Control with Copper-Shielded Drink Straw and Aerogels, also mounted to inner layers of clothing for better heat retention. Braided wire emanates from the inside of the fleece jacket layer, and continues up and around the drink straw in order to use body heat to keep the system-critical drink straw warm enough to keep water in the liquid state. For the field test, a data logger will be used to compare this with the above concept.

The third, and still conceptual, method is Active Thermal Control with Microcontroller. If the above methods do not work, microcontrollers and tape heaters have been identified that could keep the drink straw warm even under extremely cold conditions. Power requirements are not yet determined because the thermal environment inside the down suit relative to the external environment has not been established. A data logger will be used to track both the external and internal temperatures of the suit on a summit day.

This work was done by Scott E. Parazynski, Evelyne Orndoff, and Grant C. Bue of Johnson Space Center and Mark E. Schaefbauer and Kase Urban of Jacobs Technology. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center, (281) 483-1003. Refer to MSC-24490-1.