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14. ABSTRACT This grant was for instrumentation to advance the electrochemical and biochemical monitoring and control of bioelectrochemical systems (BESs). Emerging applications of this technology include energy-neutral or -generating wastewater treatment, biomass conversion to alternate energy carriers, power delivery to remote monitoring devices, and enhanced bioremediation, all of which are expressed areas of interest to the DoD. The equipment included a system of two components, a Biologics 16-channel potentiostat/galvanostat equipped with individual channel electrochemical impedance spectroscopy (EIS) capabilities and a Columbus Instruments 20					
15. SUBJECT TERMS bioelectrochemical system monitoring, potentiostat, real-time gas monitoring					
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Report Title

Final Report for DURIP: Multichannel Microbial Fuel Cell Station for Simultaneous Electrochemical and Biochemical Monitoring and Control

ABSTRACT

This grant was for instrumentation to advance the electrochemical and biochemical monitoring and control of bioelectrochemical systems (BESs). Emerging applications of this technology include energy-neutral or -generating wastewater treatment, biomass conversion to alternate energy carriers, power delivery to remote monitoring devices, and enhanced bioremediation, all of which are expressed areas of interest to the DoD. The equipment included a system of two components, a Biologics 16-channel potentiostat/galvanostat equipped with individual-channel electrochemical impedance spectroscopy (EIS) capabilities and a Columbus Instruments 20-channel gas production and composition monitor. Combined, this system allows continuous monitoring of parallel BES systems under strict and well characterized operational control. We have already used the system for many studies, including the demonstration of exoelectrotrophic activity of *Clostridium acetobutylicum*, the comparative examination of anodic communities that develop on potentiostatic versus dynamic anodes, the use of a rumen-derived inoculum that led to enhanced cathode performance, bioprospecting for novel acidotolerant exoelectrogens and exoelectrotrophs from acid mine drainage, the testing of nitrate and anode potential effects on facultative exoelectrogenic metabolisms, and the use of heliox to test oxygen diffusion constraints in air-cathode systems. All of these projects are completed and manuscripts are in preparation.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Received Paper

TOTAL:

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received Paper

TOTAL:

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Papers in Preparation for 2013 submission:

Zhao, Y., M.M. Mench, J.M. Regan (In preparation). Discrimination of Air-Cathode Performance and Impedance Constraints Using Heliox Substitution.

Yan, H., J.M. Regan (In preparation). Microbial Community Development in Potentiostatic and Dynamic Anodes Conditions.

Vargas, I.T., I.U. Albert, J.M. Regan (In preparation). Rumen-Derived Bacteria Catalyze Cathode Oxidation in Air-Cathode Microbial Fuel Cells.

Vargas, I.T., C. Rojas, M.A. Bruns, J.M. Regan (In preparation). Biocathode Development Using Acid Mine Drainage Inoculum.

Kashima, H, J.M. Regan (In preparation). Facultative Anode Reduction and Nitrate Reduction: Nitrate Concentration and Anode Potential Effects.

Yan, H., J.M. Regan (In preparation). Exoelectrotrophic Activity of *Clostridium acetobutylicum* and Effects of Cathode-Delivered Electrons on Fermentation Product Distribution.

Presentations:

Zhao, Y., H. Kashima, J.M. Regan (2012) Study of Baseline Current in Microbial Electrolysis Cells. Poster presentation at the 15th Annual Environmental Chemistry Student Symposium, March 30, University Park, PA.

Zhao, Y., H. Kashima, J.M. Regan (2012) Study of Baseline Current in Microbial Electrolysis Cells. Poster presentation at the North American International Society of Microbial Electrochemical Technologies meeting, October 9, Ithaca, NY.

Vargas, I.T., J.M. Regan (2012) Biocathode Development Using Acid Mine Drainage Inoculum. Poster presentation at the North American International Society of Microbial Electrochemical Technologies meeting, October 9, Ithaca, NY.

Kashima, H., J.M. Regan (2013). Critical Conditions Controlling Facultative Metabolic Processes, Anode Reduction and Nitrate Reduction, of Anode Biofilms in Microbial Electrolysis Cells. Poster presentation at PSU's 16th Annual Environmental Chemistry and Microbiology Student Symposium, March 15th, University Park, PA.

Kashima, H., J.M. Regan (2012). Facultative Nitrate Reduction by an Exoelectrogenic denitrifier, *Geobacter metallireducens*, as a Competitive Reaction to Anode Reduction in Microbial Electrolysis Cells. Presentation at the North American Meeting of the International Society for Microbial Electrochemistry and Technology, October 9, Ithaca, NY.

Yan, H., J.M. Regan (2012). Cathode-Influenced Metabolic Flux Distribution in Exoelectrotrophic Clostridia. Presentation at the North American Meeting of the International Society for Microbial Electrochemistry and Technology, October 9, Ithaca, NY.

Regan, J.M. (2013). Anode and Cathode Biofilms in Bioelectrochemical Systems. Keynote presentation at the 15th Annual Environmental Chemistry Student Symposium, March 30, University Park, PA.

Regan, J.M., H. Yan, I.T. Vargas (2012). Opportunities to Tailor Air-Cathode Biofilms in Bioelectrochemical Systems. Invited presentation at the 59th American Vacuum Society Meeting, November 1, Tampa, FL.

Regan, J.M., H. Yan, I.T. Vargas (2012). Opportunities to Tailor Air-Cathode Biofilms in Bioelectrochemical Systems. Invited presentation at the American Society for Microbiology Biofilms Specialty Conference, October 2, Miami, FL.

Number of Presentations: 9.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received Paper

TOTAL:

Number of Manuscripts:

Books

Received Book

TOTAL:

Received

Book Chapter

TOTAL:

Patents Submitted

Patents Awarded

Awards

None

Graduate Students

<u>NAME</u>	<u>PERCENT SUPPORTED</u>
FTE Equivalent:	
Total Number:	

Names of Post Doctorates

<u>NAME</u>	<u>PERCENT SUPPORTED</u>
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

<u>NAME</u>	<u>PERCENT SUPPORTED</u>
FTE Equivalent:	
Total Number:	

Names of Under Graduate students supported

<u>NAME</u>	<u>PERCENT SUPPORTED</u>
FTE Equivalent:	
Total Number:	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 0.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:..... 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):..... 0.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:..... 0.00

Names of Personnel receiving masters degrees

NAME

Total Number:

Names of personnel receiving PHDs

NAME

Total Number:

Names of other research staff

NAME

PERCENT SUPPORTED

FTE Equivalent:

Total Number:

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

The equipment station supported through this award has greatly increased the quantity and quality of advancements made in the Regan lab, as compared to the previous single-channel potentiostat with manual gas collection and analysis. We are now able to operate up to 16 systems simultaneously under potentiostatic conditions. With this system, we have systematically tested the effect of anode potential on denitrification by facultative exoelectrogens in BESs. We have found that denitrification is favored at all anode potentials, but the ability of a biofilm to concurrently denitrify and produce current is a function of the biofilm thickness, indicating it is a diffusion-limited control. We also monitored the current induced by cathodic growth of *Clostridium acetobutylicum*. This species had previously been demonstrated to be capable of anode reduction, but this is the first demonstration of cathode oxidation without the addition of a mediator. The fermentation products were altered under closed-circuit conditions relative to open-circuit controls. We are also nearing completion on a study of oxygen diffusion constraints in air cathodes under low- and high-current conditions, using heliox to increase the oxygen diffusivity. In this study, we have pinned down the maximum oxygen transfer rate to show when it becomes limiting. Finally, we have retrieved an acidotolerant (possibly acidophilic) cathode oxidizing consortium derived from acid mine drainage, and demonstrated the absence of current following gamma irradiation of the biofilm. We are currently doing pyrosequencing of the community to suggest which bacteria might be involved in this biocathodic activity.

Technology Transfer